April 7th, 2011

UNIT 3:
LIGHTING/ELECTRICAL REPORT

KGB Maser
Management. Engineering. Consulting.

IPD/BIM TEAM #3

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EXECUTIVE SUMMARY

The following unit of KGB Maser's report includes lighting- and electrical-specific requirements for Architectural Engineering senior capstone thesis. The subject building is scheduled for completion in the summer of 2011. The Millennium Science Complex will be both a signature building and house state-of-the-art research facilities to further Penn State's reputation for science excellence. The existing power system is a double-ended, main-tie-main configuration being supplied by Penn State campus power. Within the building, there are two distribution voltages – 480Y/277V for lighting and mechanical equipment and 208Y120V for receptacle and small loads. Lighting delivery consists of recessed lay-in-grid luminaires. Portions of the perimeter spaces are controlled using daylight sensors and the Lutron EcoSystem digitally addressable lighting interface. There will be three spaces considered for lighting and power system redesign.

The first space in the redesign exercise is a third floor perimeter student study area. The lighting redesign includes reducing the number of fixtures per row of luminaires, creating a pseudo ceiling by suspending luminaires, adding task lighting for the desks, and integrating automatic shading with a larger overhang applied to glazing. The cost changes can be seen in Unit 1 of KGB Maser's report. The operating cost is estimated to save $46.48 for the third floor of the Millennium Science Complex. Following lighting delivery redesign, the panelboard feeding the space will be resized according to the National Electrical Code.

The second space in the redesign exercise is a third floor office for distinguished personnel. The lighting redesign for this space includes an aesthetic change in luminaire delivery to accommodate the visual environment created by chilled beam application. There are three applications of lighting design in this space – wall washing, overhead lighting, and grazing. Fixtures with aesthetics similar to chilled beams have been applied to the overhead lighting, chalkboard-type fixtures graze shelving in a recessed alcove, and linear T5 wall washers balance luminance on the interior wall with surfaces near the large glazing. Additionally, as with the previous space, the controls and panelboards will be designed to accommodate the new lighting application.

The final redesign space is KGB Maser's signature design for the Millennium Science Complex – the cantilever courtyard and steel sculpture. The ironic nature of this space makes it unique for lighting design. It is located at the main entrances of the building wings, yet foot traffic over its center trespasses upon the vibration requirements of the nanotechnology laboratories below. Utilizing mostly floodlighting, the courtyard will be emanating its grand nature through a soft glow. Two main applications of lighting will be used in this space – grazing the support members of the structure and floodlighting the soffit and light well of the cantilever. The control of this space is achieved through state-of-the-art lighting control panels.

In addition to the aforementioned lighting redesign, two electrical-specific depth topics will be examined. Through mechanical redesign, water pumps will be consolidated into a motor control center. This distribution center will then be located within the Millennium Science Complex in an appropriate space, given what space is available for reconfiguration. The second topic includes a short circuit analysis in SKM Power Tools for Windows of major equipment supplying the third floor of the complex.

TABLE OF CONTENTS

LIGHTING OVERVIEW

The following section presents lighting requirements for AE482. There are three spaces to be redesigned along with integration between daylighting, shading, and the mechanical system design. The three spaces include a third floor student study area, third floor office for distinguished personnel, and architectural lighting for the structural redesign of the cantilever courtyard.

Student study areas appear around the perimeter of the second and third floor of the Millennium Science Complex. The existing lighting delivery utilizes linear sets of 1x4 recessed luminaires over the aisles of each set of workstations. These rows of luminaires are currently dimmable and will continue to be dimmable in redesign. The corridor utilizes the same linear recessed fixture, but is only controlled by periodic occupancy sensors and is non-dimming. All luminaires in both the corridor and the student study area perform with T8 lamps. The redesign will be governed by the following goals:

a. Visual separation of corridor and study area through luminaire applications
b. Daylight integration in both dimming and automatic shading
c. Energy responsibility by complying with appropriate energy codes

Offices appear throughout the Millennium Science Complex around the perimeter of each wing. The specific office being examined for redesign is a “Distinguished Office” on the third floor located on the south side of the Material Science wing. The existing lighting delivery system is the same as the student study areas – 1x4 recessed luminaires through the center of the room. The redesign was originally intended to utilize integrated chilled beam lamping, but was abandoned when lighting integrated chilled beams were found to be non-ideal for KGB Maser’s mechanical system design goals. The redesign now involves new recessed fixtures to blend with chilled beam aesthetics. Secondary to overhead lighting is the addition of washing luminance balance between the window wall and corridor wall and book shelf task lighting delivery.

The final space that will be redesigned for lighting has two major purposes for the Millennium Science Complex – an architectural statement and pedestrian control. The over 150-foot cantilever provides a unique architectural interest and is designed to help isolate the nanotechnology labs below from the building vibrations. To achieve the latter design goal, the structure of the building had to be oversized three-fold to absorb vibrations. The structural redesign involves adding support to the cantilever and wrapping the structure in a steel sculpture. By boxing out the cantilever light well, the courtyard landscape becomes inaccessible to pedestrians and protects the nano-technology labs below. The lighting redesign for this space has been limited to the steel sculpture and pathways outside the entrance canopies that fall in the building footprint. To emphasize the grand nature of the sculpture, recessed lighting along the perimeter of the sculpture will both graze the steel and wash the underside of the cantilever.

Each design section hereafter will include applicable design criteria, space properties, a discussion of lighting gear used, and a discussion on the space’s ultimate performance in the redesign.

EXISTING CONDITIONS REVIEW

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.

Perimeter study areas are controlled by EcoSystem ballasts, daylight sensors, and occupancy sensors. There is currently no task lighting within these spaces. The rows of computer desks are open to the corridor and all overhead lighting is recessed 1x4 fluorescent luminaires.

Offices contain the same recessed 1x4 luminaires as the corridors and student study areas, but are not connected to a smart dimming system. With the exception of few “distinguished” offices, additional task lighting will be up to the end user to provide.

The space beneath the cantilever houses a serpentine pathway that is lighted by various heights and styles of landscape and area lighting. The luminaires include the Penn State campus standard Louis Poulsen Kipp Post design for surrounding pathways. All existing light delivery within this space is high intensity discharge metal halide lamping ranging from 39W to 100W depending upon mounting height within the cantilever soffit.

SPACE 1: STUDENT STUDY AREA

Study areas are located throughout the perimeter of each floor in the Millennium Science Complex. These areas are workstations for occupants of the building and can be accessed directly from perimeter corridors. Primary tasks in these areas include computer usage, reading, and writing tasks. Additionally, study areas interact with large windows perpendicular to workstations. Sunlight penetration is both beneficial and detrimental to occupants. Psychological benefits and reduced energy usage are available; however, too much daylight will cause occupants to become uncomfortable within the space.

Located in the study area are five rows of computer work stations. The stations are divided by partitions that have been redesigned to reach 4’-0” above finished floor to allow for less shading between rows of computers. As part of KGB Maser’s IPD/BIM initiative, plans shown will be from the team central modeling file.

FLOOR PLAN

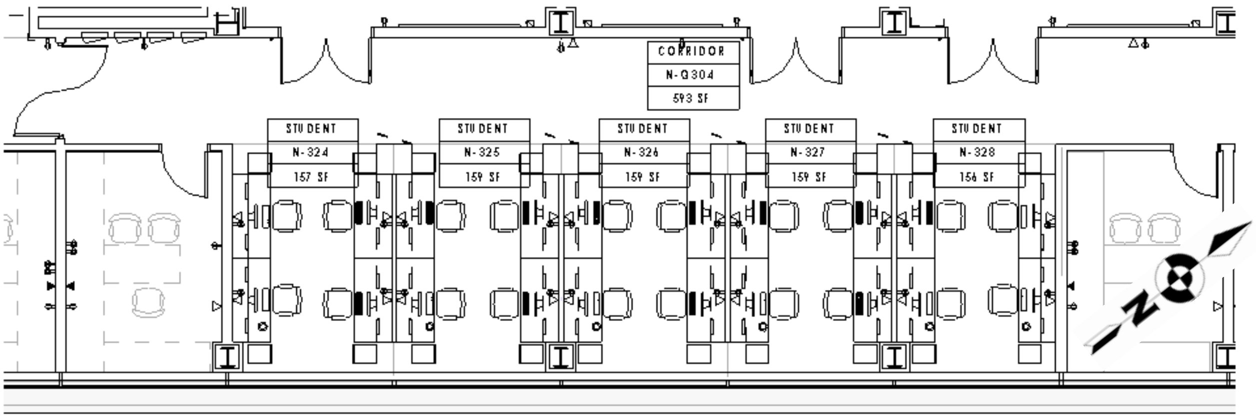


Figure 3.1: Student Study Area Floor Plan, NTS, from KGB Maser Central Revit model

ROOM SURFACE MATERIALS

The table below lists the various reflectances in use in this space.

Surface	Material Description	Reflectance	Specification
East Wall	Painted GWB – Benjamin Moore OC-26 Silver Satin, eggshell	0.76	09900
West Wall	Painted GWB – Benjamin Moore OC-26 Silver Satin, eggshell	0.76	09900
North Wall	Painted GWB – Benjamin Moore 2111-60 Barren Plain, eggshell (Corridor)	0.60	09900
South Wall	Painted GWB – Benjamin Moore OC-26 Silver Satin, eggshell	0.76	09900
Ceiling	Armstrong ACT Ultima HRC Beveled Tegular	0.74	09500
Floor	Mannington Solidpoint VCT 12"x12" in 341 Cameo White (Corridor) J&J Commercial/Invision Altered Elements Weathered Steel Modular 333 Iron Carpet (Student Study)	0.70 0.16	09685
Glazing Redesign	Viracon VNE 13-63 insulating laminated glass with low-e coating on surface #2 VLT = 0.66 Uwinter= 0.29 UVT < 0.01 Usummer= 0.26 SHGC = 0.29 SC = 0.33 LSG = 2.24	0.10	N/A
Desk Partitions	Painted GWB – Benjamin Moore OC-26 Silver Satin, eggshell	0.76	09900
Desk Surfaces	Oak table – assumed	0.22	N/A

FURNITURE DESCRIPTION

The furniture in the student study area is comprised of various elements producing a two-shelf system to support computer stations. Figures 3.2 and 3.3 below illustrate the geometry of the workstations.

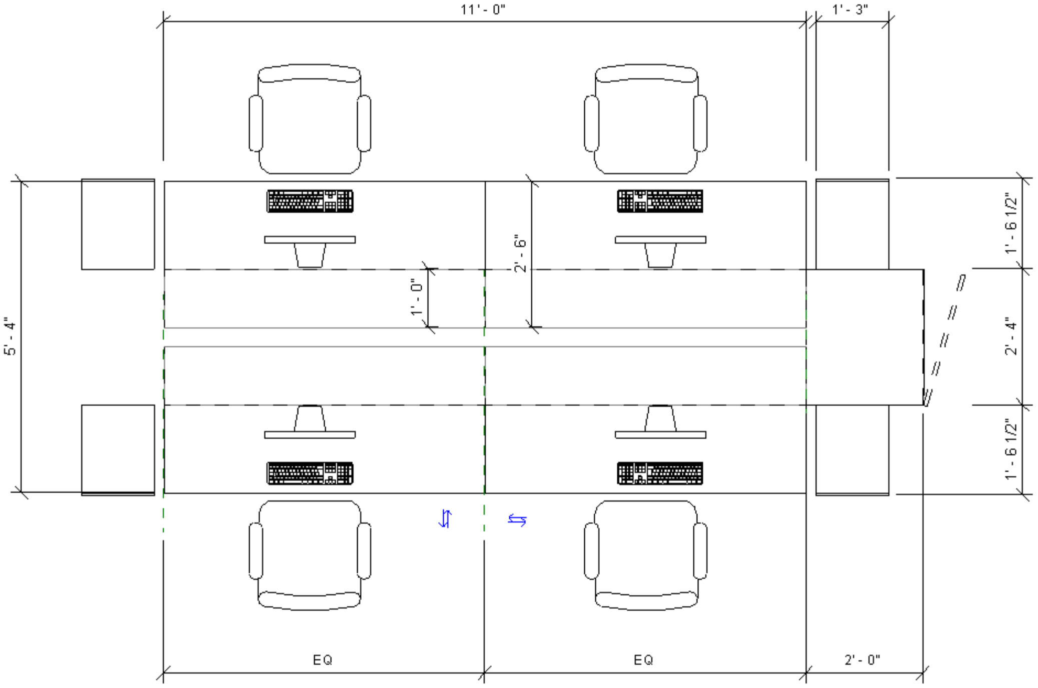


Figure 3.2: Typical Workstation in Plan View, NTS, from KGB Maser Revit Desk Family

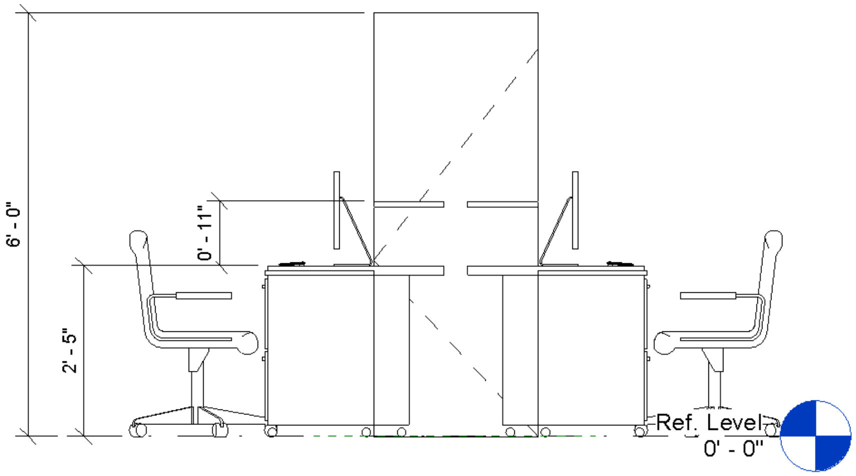


Figure 3.3: Typical Workstation in Elevation View, NTS, from KGB Maser Revit Desk Family

TASKS AND ACTIVITIES

This particular area of the Millennium Science Complex is unique in that there are two distinct areas that share a "wall," but there is no physical barrier. 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. Though this space is mostly computer work, the latter activity must be addressed due to the absence of a physical barrier between the two spaces.

DESIGN CRITERIA

Corridors and study areas individually are relatively straight forward to design, but when they are coupled without a barrier, the design is more complicated. Corridor spaces only require five footcandles of illuminance, yet in this application they are adjacent to study spaces requiring thirty to fifty footcandles for various tasks. Light falling on the corridor from the study areas will easily meet this illuminance. Design criteria in this section have been researched in the IESNA Lighting Handbook.

Corridor Design Criteria

Shadow Avoidance 5fc horizontal illuminance

Navigating corridors is a simple task. Occupants only need to know if they will come into contact with any obstructions in their path. Visually, shadows cast across the floor – in this case from workstations and cabinetry – will cause pedestrians to take notice of the lighting in the space. To be considered successful, a lighting design must be uniform.

Study Area Design Criteria

Reading Tasks 30-50fc horizontal illuminance

Reading tasks in the study area vary depending on the task medium. Users may be reading from notes written in #2 pencils, pens, or printed on a variety of colored papers. Higher illuminance values allow for faster and more accurate deciphering of reading material. Increased illuminance values may be provided by a task-ambient design in which overhead lighting provides minimum light to the task plane while task-specific lighting boosts illuminance on the task surface.

Lobbies, Lounges, and Reception Areas 10fc horizontal illuminance

In the office section of the IESNA Lighting Handbook design guide, a specific line is devoted to lounges. The largest concern in these types of spaces is the appearance of the space and the luminaires. The design should be uniform, even a repeating pattern, so as to not distract users of the space.

Visual Display Terminals (VDT) 3fc horizontal illuminance

In older interpretations of design criteria, direct and reflected glare are large concerns when dealing with computer screens. With the advent of flat screen monitors – usually with plasma or liquid crystal display – glare is no longer a large concern.

Luminance Ratios

Paper to VDT:	3:1 / 1:3
Task to Adjacent Surroundings:	3:1 / 1:3
Task to Remote Surfaces:	10:1 / 1:10

REDESIGN PLANS, SECTIONS, ELEVATIONS

For the following plans, sections, and elevations, see Appendix 3.B:

A101 – Student Area Floor Plan and Section

LE101 – Student Area Lighting Layout and Section

LUMINAIRE SCHEDULE

For luminaire, lamps, and ballast manufacturer cut sheets, see Appendix 3.C.

Student Study Area and Corridor Luminaire Schedule

Tag	Image	Manufac.	Product	Catalog No.	Description	Lamp	Input Watts	Voltage	Ballast
C-1		Lithonia Lighting	ES8	ES8P-132-277-(Ballast)-L841HT8	Recessed linear fluorescent troffer luminaire with specular baffles; sized to fit within 1'x4' acoustical ceiling grid	(1) FO32/841/XP/ECO Osram Sylvania	32	277	VEL-1P32-SC Philips Advance
S-1		LiteControl	SD^{X}	P-S/D-1824T8-BW-CWM-(Ballast)-277	Semi-direct pendant fixture mounted 2'-0" below ceiling surface; matte white finish with baffles; total linear system 8'-0" nominal; additional end cap to allow for occupancy sensor mount	(2) FO32/841/XP/ECO Osram Sylvania	65.7	277	H3D-T832-C-U-2-10 Lutron
T-1		Philips Alkco	Aris	ARIS-11-40-120-PRL-DWC	Low profile LED surface mounted luminaire; integral switch; 4000K; mounting under top shelf of desk	4000K LED integral to fixture	6	120	N/A

CONTROL EQUIPMENT SCHEDULE

For control equipment cut sheets, see Appendix 3.C. For wiring diagrams, see "Dimming and Wiring Diagrams" in the electrical portion of this document. The Lutron EcoSystem lighting control option allows for integration of both daylight and occupancy sensors. The existing perimeter spaces utilize this system and the redesign would most benefit from using the system also. The corridor lighting will be connected to the existing sensors.

Study Area and Corridor Control Equipment Schedule

Tag	Image	Manufac.	Product	Catalog No.	Description
DS		Lutron	Wired Daylight Sensor	C-SR-M1-WH	Wired daylight sensor compatible with Lutron Ecosystem; ceiling mounted between rows of pendant luminaires
ES		Lutron	EcoSystem EnergiSavr Node	QSN-4S16-S	Addressable lighting control unit to setup at least three lighting zones, three occupancy/vacancy sensors, and two daylight sensors; 277V control operating capability

Study Area and Corridor Control Equipment Schedule (Continued)

Tag	Image	Manufac.	Product	Catalog No.	Description
LOSH		Lutron	Infrared Wall-Mount Occupancy Sensor	LOS-WIR-WH	Wall-mounted passive infrared occupancy/vacancy sensor with 90-110° coverage mounted to view into the study area; apply enough sensors to control entire study area pendant fixtures at 277V
LOSL		Lutron	Infrared Wall-Mount Occupancy Sensor	LOS-WIR-WH	Wall-mounted passive infrared occupancy/vacancy sensor with 90-110° coverage mounted to view into the study area from back of cabinets; apply enough sensors to cover study area for switching task lighting at 120V
PPH		Lutron	PP Series Power Pack	PP-277H	24V power pack to power occupancy sensors at 277V
PPL		Lutron	PP Series Power Pack	PP-120H	24V power pack to power occupancy sensors at 120V
SM		Lutron	QS Sensor Module	QSMX-4W-C	EcoSystem compatible sensor module; non-radio frequency

The coverage areas of the occupancy sensors can be seen in the figures below:

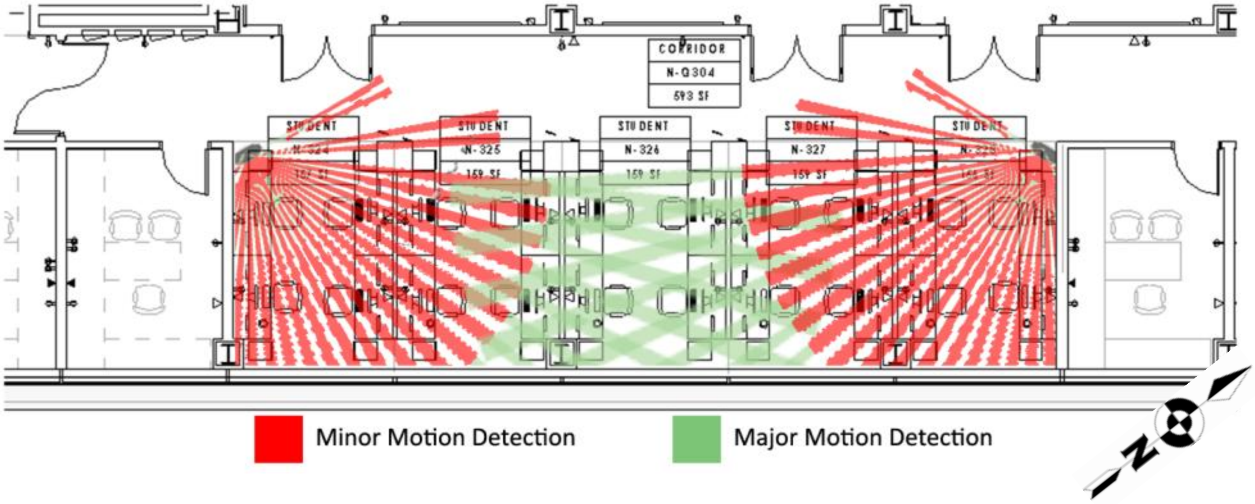


Figure 3.4: Study Area Overhead Lighting Occupancy Sensor Coverage, NTS

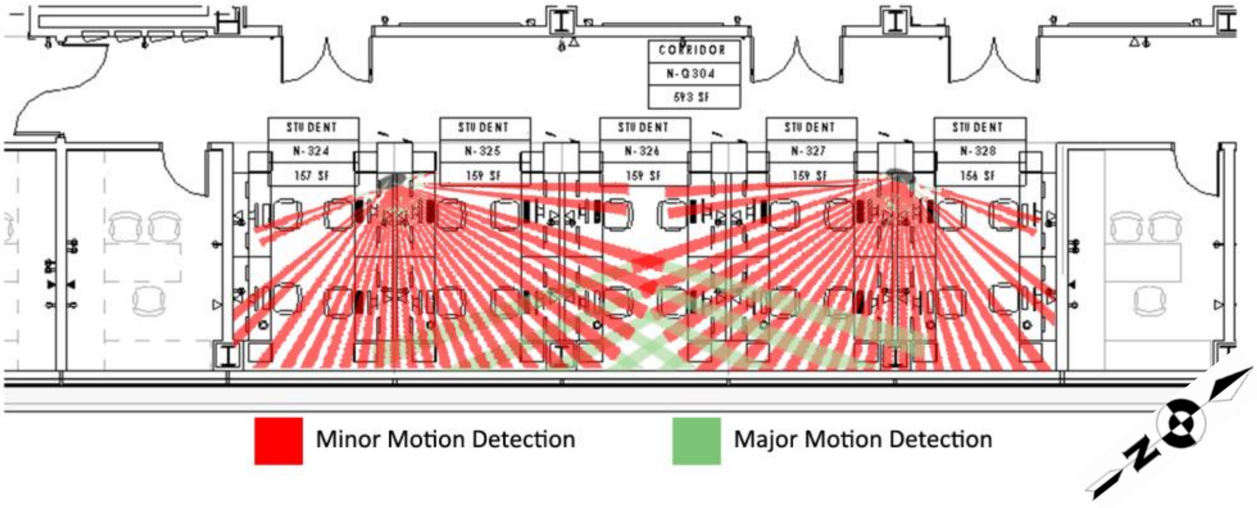


Figure 3.5: Study Area Task Light Occupancy Sensor Coverage, NTS

For a detailed discussion on how the presented control equipment will operate within the space, see the "Control Descriptions" section of the electrical portion of this document.

SHADING DEVICES AND DELIVERY

For a more in-depth description of the overhang selection, see Unit 1 of this document. Normally, roller shades are operated in a top-down configuration. As discussed in said section of this document, bottom-up roller shades allow for more ambient light and ground reflectance to enter the space. With an appropriate openness factor and interior shade color, occupants are able to see out of the space without blinding sunlight entering the space.

Study Area Shading Equipment Schedule

Tag	Manufac.	Product	Catalog No.	Description
MS	MechoShade	FTS Electro Bottom-Up Shade	Unavailable	Bottom-up, sill-mounted shading system; 11'-0" nominal length of units; two motors; modified guide cable to allow for two shade roller mounts; top pulley recessed into ceiling cavity; two hembar attachments; second shade mounting half distance to ceiling with non-motor return roll; 10% openness factor shade cloth; light gray color
SSC	MechoShade	SolarTrac Automation System	Unavailable	Integrated roof-mounted radiometers to override shade position when in absence of daylight; minimum 5 shade positions; programmable computer simulation program and interface

The overall goal of the shading delivery is to block direct sunlight in both upper glazing and lower glazing. To accomplish this goal, the overhang delivery discussed in Unit 1 of this document must bisect the exterior glazing. By dividing the glazing in two sections with the same height, only one motor is needed to control two levels of shades. Each section then has the same path distance to cover the same profile angle penetrations. As specified in the table above, the shading automation system will be programmed to handle ranges of profile angles according to the façade orientation. The associated profile angles by façade can be seen in Figure 3.6 below. The MechoShade SolarTrac system can be programmed to account for each façade individually with sensor override for overcast conditions. In cloudy scenarios, the shades will be returned to the "off" position. When the sensor is active, then each façade can be programmed to the appropriate shade height according to the computer.

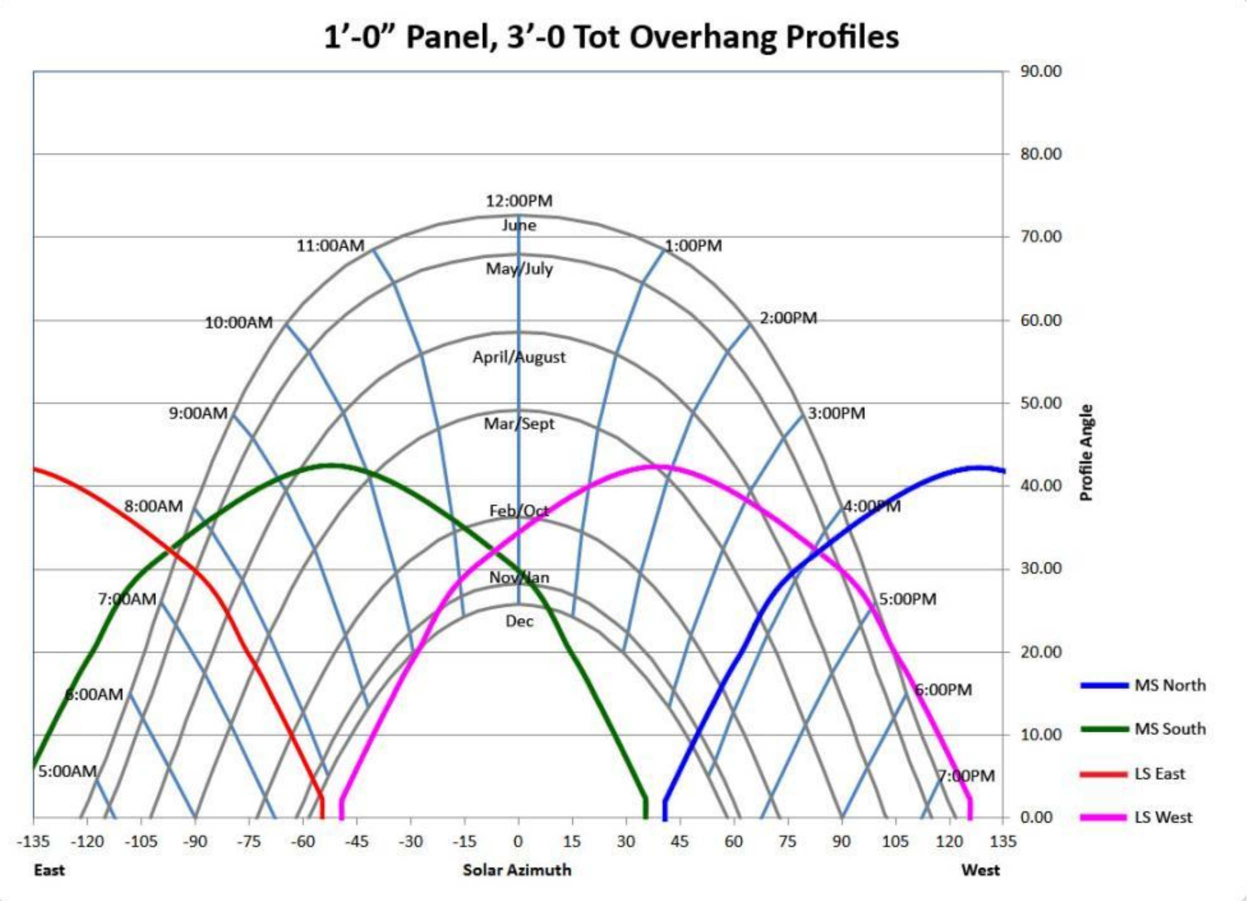


Figure 3.6: Profile Angles by Façade

PERFORMANCE DATA

The table below summarizes light loss factors used in illuminance calculations for the student study area. The Millennium Science Complex is assumed to be a clean environment, yet luminaires will not be actively cleaned very often (maximum allowable by IES standards).

Student Area Light Loss Factors				
Mark	Ballast Factor	Lamp Lumen Depreciation	Luminaire Dirt Depreciation	Total Light Loss Factor
C-1	0.92	0.95	0.88	0.77
S-1	1.0	0.95	0.88	0.84
T-1	1.0	1.0	0.88	0.88

The following figures illustrate light distribution compliance for student area design criteria discussed previously. Models for analysis were exported from AutoDesk Revit Architecture in drawing formats associated with acceptable geometry import into AGI32. For a further discussion on the BIM related model sharing, see Unit 1 of this document.

Figure 3.7: Student Area Rendering (top) and Exterior Render into Study Area (bottom)

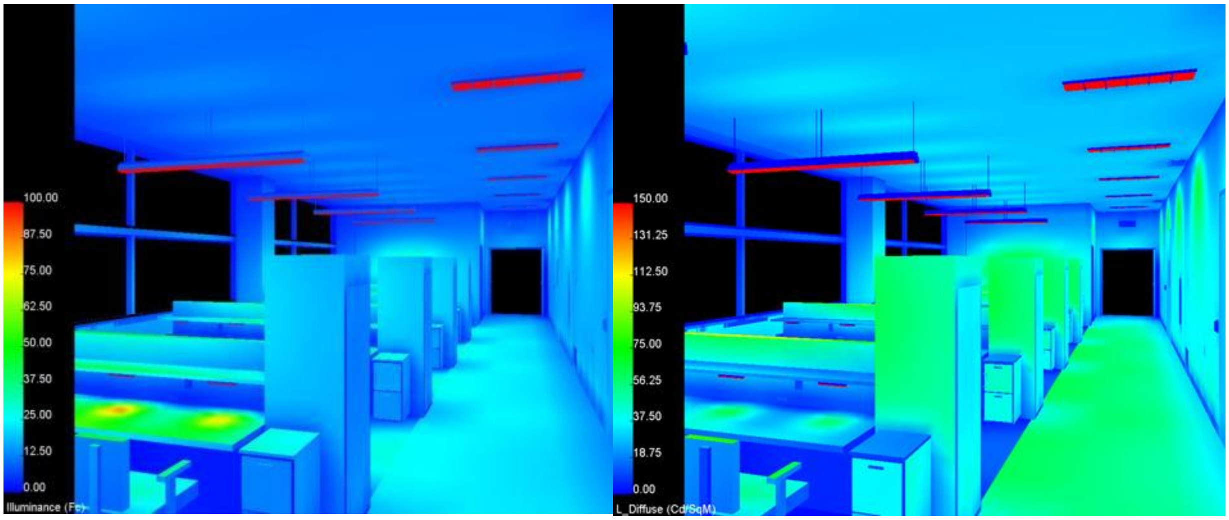


Figure 3.8: Illuminance, fc, Pseudo Color Image (left) and Luminance, cd/m^2, Pseudo Color Image (right)

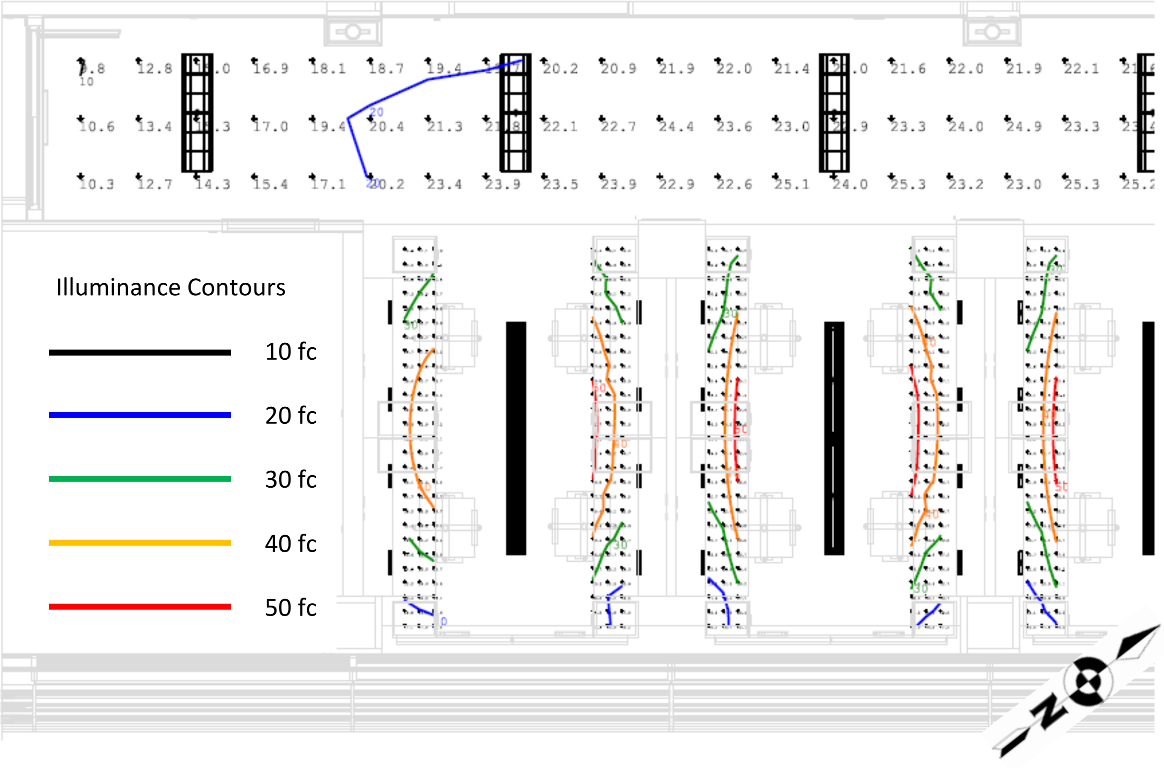


Figure 3.9: West Portion of Student Study Area Illuminance Contours (fc), plan NTS

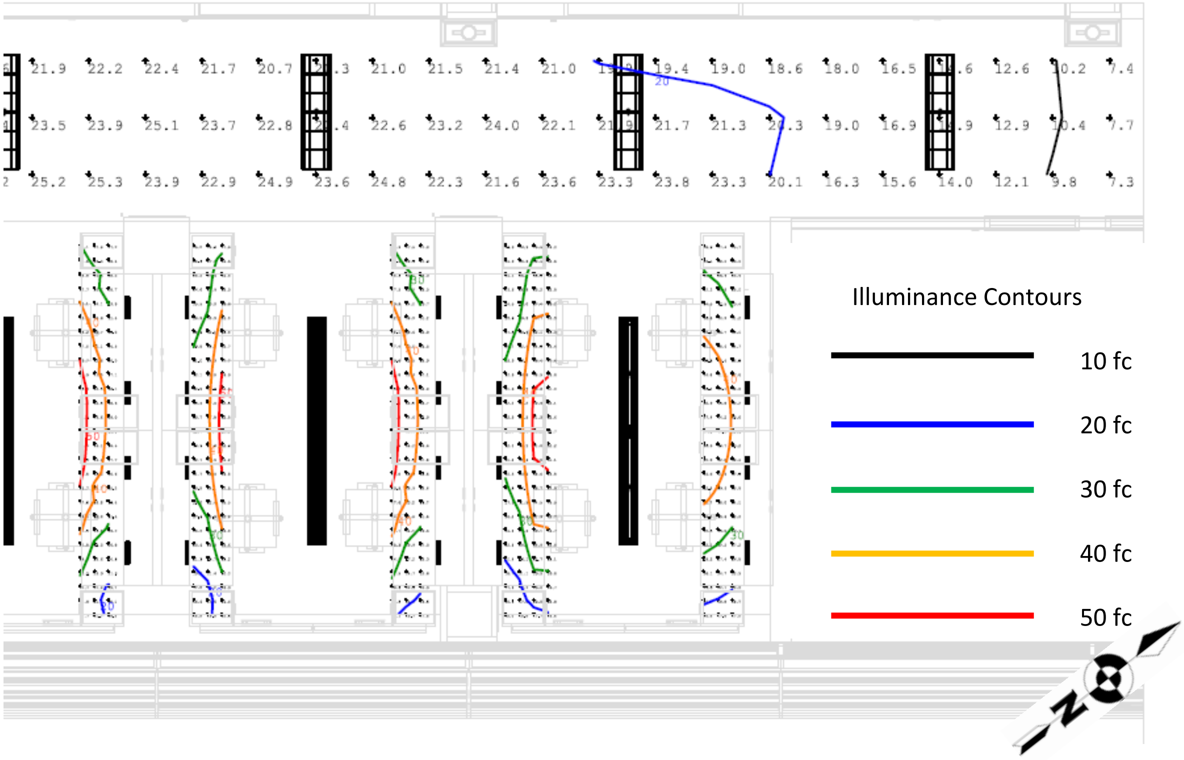


Figure 3.10: East Portion of Student Area Illuminance Contours (fc), plan NTS

ASHRAE Standard 90.1 Compliance

Space	Area (ft^2)	Allowable LPD (W/ft^2)	Allowable Power (W)	Total Power Used (W)	Actual LPD (W/ft^2)
Study Area	825.0	1.2	990.0	657.0	0.796
Corridor	657.9	0.5	329.0	224.0	0.681*

Illuminance Summary Table

Study Area Illuminance Summary						
Space	Illuminance (fc)			Max./Min.	Coeff. Of Variation	Uniformity Gradient
	Min.	Avg.	Max.			
Study Area Only	9.0	36.5	106.0*	11.73	0.47	2.47
Corridor Only	4.5	9.36	10.8	2.40	0.15	1.31
Student Area Combined	15.0	34.3	55.0	3.67	0.27	1.42
Corridor Combined	7.3	20.0	25.3	3.47	0.23	1.38

General ambient light for the tasks in both the student study area and the corridor are provided by the overhead luminaires. Examining each of the aforementioned design criteria and Figures 3.7 and 3.8 above, the performance of the design can be qualitatively and quantitatively judged:

Corridor Area

Shadow Avoidance

The linear recessed corridor lights in conjunction with the pendant luminaires in the study area diminish shadowing from tall cabinets. There is only a few footcandles difference in illuminance between the center of the hallway and at the cabinet's base.

Student Study Areas

Reading Tasks

All tasks related to paper and pencil are most likely to be occurring at the desk plane. The combination of pendant fixtures and under-shelf task lights provides between 15 and 55 footcandles of illuminance. The former value may be dismissed as it is beyond the usable area under the upper shelf of the workstations. The design criteria called for 30 to 50 footcandles and with an average of 34.3 footcandles on the desk plane, this application can be considered a success.

Lobbies, Lounges and Reception Areas

The illuminance value in this design criteria section applies to only lobbies, lounges, and reception areas. Of the most importance with respect to this section of design criteria is the appearance of the space and luminaires. The redesign achieves this goal on two levels – it separates to different open spaces with an imagined ceiling and keeps uniform layout and illuminance between rows of workstations. By suspending study area luminaires 2'-0" from the ceiling finish, a second "ceiling" is created in the visual environment. Occupants walking by the student area can see from down the hall that a peripheral, lower zone is in the area. The redesign achieves appropriate appearance of luminaires by keeping uniform spacing and alignment of luminaires between the corridor and study area. Though mounted below the ceiling height, the study area luminaires appear on the same sight line as corridor lights as viewed from the exterior of the building.

Visual Display Terminals (VDT)

As discussed in the design criteria section of this space, computer screens have advanced to be a non-issue with respect to light interaction. The user is able to tilt screens that may experience blurring of screen images due to overhead lighting. Given the nature of screen materials themselves, VDTs are of no concern in the redesign.

Luminance Ratios

The luminance pseudo color image in Figure 3.5 illustrates brightness that users will experience within the redesigned space. Task areas beneath shelving – illuminated by the LED strip luminaires – is approximately 50 to 70 candelas per square meter. Near surfaces such as cabinet tops and upper shelves are in the 15 to 20 candelas per square meter range. The remote surfaces within the space that are visible to occupants, such as far walls, are near or below 10 candelas per square meter. These scenarios satisfy the initial design criteria presented.

In conclusion, this space has achieved its design goals. Automatic shading in perimeter public spaces, such as the student area, provides daylight control without user interference. The automatic shading system in combination with dimming control systems allows for decreased energy usage. Task and ambient applications give users flexibility with light levels at the desk plane. The space is noticeably separated from the corridor due to the application of suspended luminaires over the student area, thus showing occupants that there are two distinct spaces present.

SPACE 2: DISTINGUISHED PERSONNEL OFFICE

Also located throughout the perimeter of the Millennium Science Complex, the offices provide occupants with a connection to the exterior environment through daylighting. Primary tasks in these areas include computer usage, reading, and writing tasks. As with study areas, the offices interact with large windows, but the orientation of the room puts the windows at the back of the occupant. This orientation may be a nuisance when working with computers. Sunlight penetration is both beneficial and detrimental to occupants. Psychological benefits and reduced energy usage are available; however, too much daylight will cause occupants to become uncomfortable within the space. The shading delivery will be user-controlled to allow for occupant-specific daylighting.

Also located within the perimeter offices are desks, tables, and shelves. The shelves will be lighted to accommodate reading tasks in the vertical plane. With the available daylight, the wall opposite the windows may need to be washed to balance luminance levels of surfaces in the room. As part of KGB Maser's IPD/BIM initiative, plans shown will be from the team central modeling file.

FLOOR PLAN

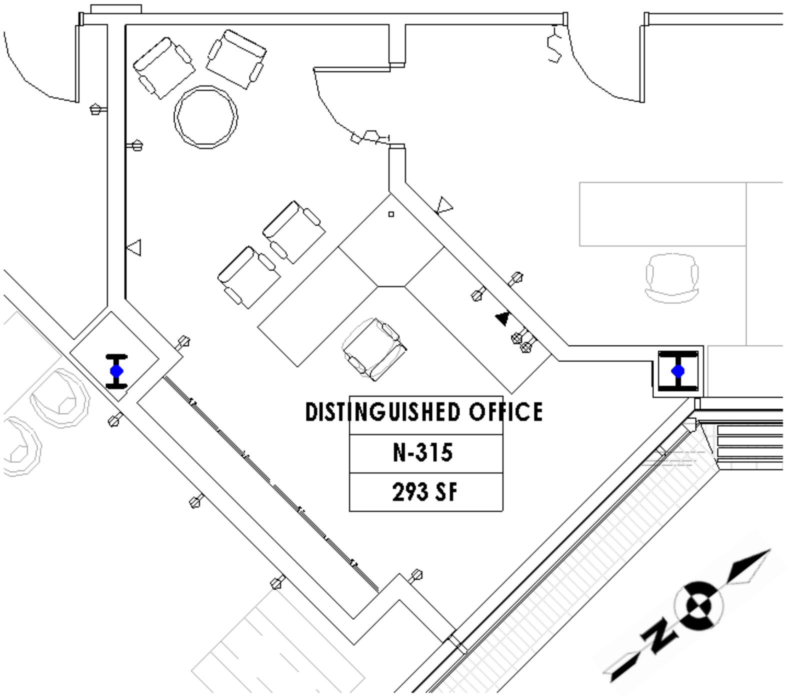


Figure 3.11: Distinguished Office Floor Plan, NTS, from KGB Maser Central Revit Model

ROOM SURFACE MATERIALS

The table below lists the various reflectances in use in this space.

Surface	Material Description	Reflectance	Specification
East Wall	Painted GWB – Benjamin Moore OC-26 Silver Satin, eggshell	0.76	09900
West Wall	Painted GWB – Benjamin Moore OC-26 Silver Satin, eggshell	0.76	09900
North Wall	Painted GWB – Benjamin Moore OC-26 Silver Satin, eggshell	0.76	09900
South Wall	Painted GWB – Benjamin Moore OC-26 Silver Satin, eggshell	0.76	09900
Ceiling	Armstrong ACT Ultima HRC Beveled Tegular	0.74	09500
Floor	J&J Commercial/Invision Altered Elements Weathered Steel Modular 337 Ore Carpet	0.35	09685
Glazing Redesign	Viracon VNE 13-63 insulating laminated glass with low-e coating on surface #2 VLT = 0.66 Uwinter= 0.29 UVT < 0.01 Usummer= 0.26 SHGC = 0.29 SC = 0.33 LSG = 2.24	0.10	N/A
Cove Base	Johnsonite 4" vinyl base color 179 steel	0.75	09900
Desk Surfaces	Oak table – assumed	0.22	N/A
Shelving	Oak finish – assumed	0.22	N/A

FURNITURE DESCRIPTION

Furniture within the space includes a large cornered desk that orients the occupant with his or her back to the large window wall. There may be up to five office chairs within the space – one for the room "owner," two for meetings with the owner, and two for users waiting around the small table in the corner. Located within a wall nook is a set of shelves and cabinets. Books, binders, and objects may be stored on these shelves at any time. Overall, the furniture layout and use is very simple, thus the lighting will be simple to address the tasks within the space.

TASKS AND ACTIVITIES

The tasks and activities within the offices are very straight forward. Occupants will be reading, writing, and using computers to communicate their research. Since this is a graduate level research building, there may be professors grading assignments, lab notebooks, and exams within their offices. Other than these reading specific tasks and activities, offices may be used for meetings with students. The professors within the office must be able to see their guests with appropriate facial coloring and with little shadowing of facial features.

DESIGN CRITERIA

General Office Criteria

Filing 10 fc vertical

Filing activities in the office will be confined mostly to the recessed shelving area. The occupant will be storing books, binders, and other reading material on shelving above cabinets in this area. There are no cabinet tops that would benefit from higher light levels for reading tasks. The vertical task plane is at the face of the shelving. The user must be able to discern which material he or she is looking for before pulling it out to read. Thus the vertical face of the shelving will need to be at the suggested 10 fc illuminance.

Private Offices 30-50 fc horizontal, 5 fc vertical

Of utmost importance within the office is the ability to integrate and control the room light in reaction to daylight. The personnel in the distinguished office have the most interaction with daylight due to the room's location on the perimeter. As these offices are private in nature, an automatic shading and dimming system may not be the best solution since different people tolerate different levels of daylight. The second concern is of glare. Although the use of flat screen monitors has diminished the worry of glare on screens, the large window wall may cause screens to be washed out if too much light falls on the screen. The user will need to be able to control both the electric lighting and daylight delivery to account for the possibility of the screen being washed by too much light. This control aspect also plays into the importance of luminance on various room surfaces. As in the description above, wall washing or grazing will be applied to the wall opposite the window wall. This will balance luminance levels within the space and to keep the occupant's eyes from being drawn away from the task at hand.

Reading Tasks

Paper Tasks 30-50fc horizontal illuminance

Reading tasks in the study area vary depending on the task medium. Users may be reading from notes written in #2 pencils, pens, or printed on a variety of colored papers. Higher illuminance values allow for faster and more accurate deciphering of reading material. Increased illuminance values may be provided by a task-ambient design in which overhead lighting provides minimum light to the task plane while task-specific lighting boosts illuminance on the task surface.

Visual Display Terminals (VDT) 3fc horizontal illuminance

In older interpretations of design criteria, direct and reflected glare are large concerns when dealing with computer screens. With the advent of flat screen monitors – usually with plasma or liquid crystal display – glare is no longer a large concern.

Luminance Ratios

Paper to VDT:	3:1 / 1:3
Task to Adjacent Surroundings:	3:1 / 1:3
Task to Remote Surfaces:	10:1 / 1:10

REDESIGN PLANS, SECTIONS, AND ELEVATIONS

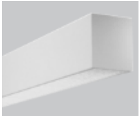
For the following plans, sections, and elevations, see Appendix 3.B:

A102 – Office Area Floor Plan and Section
LE102 – Office Area Lighting Layout Plan and Section

LUMINAIRE SCHEDULE

For luminaire, lamps, and ballast manufacturer cut sheets, see Appendix 3.C.

Office Luminaire Schedule

Tag	Image	Manufac.	Product	Catalog No.	Description	Lamp	Input Watts	Voltage	Ballast
O-1		LiteControl	Mod-66	LG-D-66N-2-4-T8-FP-CWM-IND-ECO/ELB-277	Lay-in grid recessed luminaire to be combined with custom edges to mimic chilled beams; manual dimming capabilities; total assembly to occupy one 1x4 section of ACT grid	(2) F032/841/XP/ECO Osram Sylvania	65.7	277	H3D T832 C U 2 10 Lutron
OS-1		LiteControl	Mod-66 Chalkboard	W-ADW-66N-1-8-T8-6044-CWM - -ELB--277	Chalkboard luminaire mounted on interior of shelf nook bulkhead; mounted to throw light on shelves; space evenly on bulkhead	(1) F096/841/XP/ECO Osram Sylvania	70	277	VEL-2P59-SC Philips Advance
WW-1		LiteControl	Mod^2 Recessed Wall Wash	LG-WWD-44-1-8-T5HO--CWM-IND-LP/ELB-277	Linear recessed wall wash luminaire; mounted 3’-0” from face of wall	(1) FP54/841/HO/ECO Osram Sylvania	62	277	ICN4S5490C2LS@277 Philips Advance

CONTROL EQUIPMENT

For control equipment cut sheets, see Appendix 3.C. For wiring diagrams, see “Dimming and Wiring Diagrams” in the electrical portion of this document.

Office Control Equipment Schedule

Tag	Image	Manufac.	Product	Catalog No.	Description
ODS		Lutron	Skylark dimmer switch	SF-12P-277-3-GR	Three-way combination on/off/dim switch; located near office desk for occupant to dim lighting while at desk; gray finish to match OOS switch; mounted 3’-6” AFF
OOS		Watt Stopper	DW-200 Wall Switch Sensor	DW-200-G	Multi-load wall box mounted combination PIR and ultrasonic vacancy sensor with two-level switching; must be able to switch two loads – overhead lighting and shelf lighting; located at 4’-0” AFF at office entry door

For a detailed discussion on how the presented control equipment will operate within the space, see the “Control Descriptions” section of the electrical portion of this document.

Occupancy passive infrared sensor coverage can be seen in the figures below:

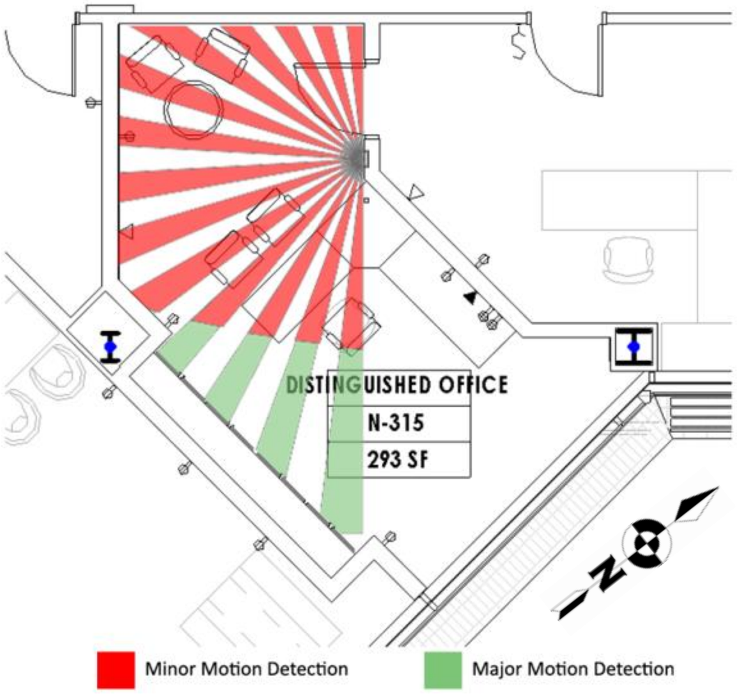


Figure 3.12: Office Lighting Occupancy Sensor Coverage

SHADING DEVICES

The shading devices for office areas throughout the Millennium Science Complex utilize the same equipment as seen in “Space 1: Student Study Area” of this unit. There is one change to the design – the office shading system will be controlled by the occupant. The change in equipment can be seen in the table below:

Office Shading Equipment Schedule

Tag	Manufac.	Product	Catalog No.	Description
MS	MechoShade	FTS Electro Bottom-Up Shade	Unavailable	Bottom-up, sill-mounted shading system; 11’-0” nominal length of units; two motors; modified guide cable to allow for two shade roller mounts; top pulley recessed into ceiling cavity; two hembar attachments; second shade mounting half distance to ceiling with non-motor return roll; 10% openness factor shade cloth; light gray color
MC	Unknown	Unknown	Unavailable	Wall-mounted switch hard-wired to the shade motor; controls include “up,” “center off,” and “down”; mounted within 5’-0” laterally from exterior window and 3’-6” AFF

PERFORMANCE DATA

The table below summarizes light loss factors used in illuminance calculations for the offices. The Millennium Science Complex is assumed to be a clean environment, yet luminaires will not be actively cleaned very often (maximum allowable by IES standards).

Office Light Loss Factors

Mark	Ballast Factor	Lamp Lumen Depreciation	Luminaire Dirt Depreciation	Total Light Loss Factor
O-1	1.0	0.95	0.88	0.84
OS-1	1.10	0.95	0.88	0.74
WW-1L(R)	0.99	0.93	0.88	0.81

The following figures illustrate light distribution compliance for office design criteria discussed previously. Models for analysis were exported from AutoDesk Revit Architecture in drawing formats associated with acceptable geometry import into AGI32. The renderings were completed using file sharing between AutoDesk Revit Architecture and AutoDesk 3D Studio Max Design as discussed in “Model Sharing Between Revit and 3D Studio Max” of Unit 1 of this document.

Figure 3.13: Office Rendering from Revit Architecture (left) and AGI32 (right)

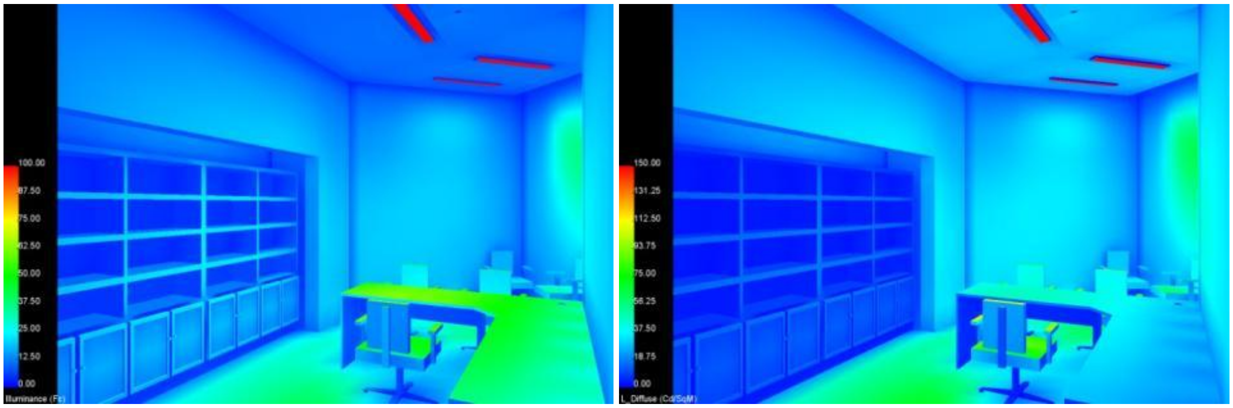


Figure 3.14: Office Illuminance, fc, Pseudo Color Image (left) and Luminance, cd/m2, Pseudo Color Image (right)

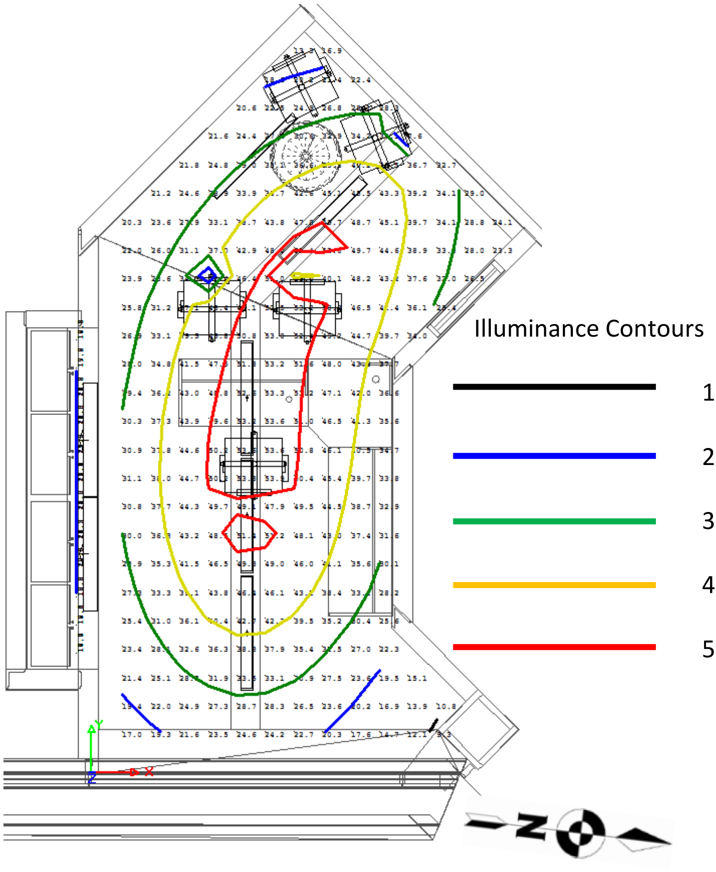


Figure 3.15: Office Plan Illuminance Contours, plan NTS

ASHRAE Standard 90.1 Compliance

Lighting Type	Area (ft^2)	Allowable LPD (W/ft^2)	Allowable Power (W)	Total Power Used (W)	Actual LPD (W/ft^2)
Office General	262.38	1.1	288.61	262.8	1.00
Decorative	262.38	1.0	262.38	132	0.50

Illuminance Summary Table

Office Illuminance Summary						
Calculation Grid	Illuminance (fc)			Max./Min.	Coeff. Of Variation	Uniformity Gradient
	Min.	Avg.	Max.			
Horizontal Task	7.60	35.75	53.90	7.09	0.31	4.83
Vertical at Shelves	14.9	19.36	22.10	1.48	0.10	1.17

General ambient light for the desk tasks is provided by the lay-in-grid overhead luminaires. Examining each of the aforementioned design criteria and Figures 3.13, 3.14 and 3.15 above, the performance of the design can be qualitatively and quantitatively judged:

General Office Criteria

Filing	10 fc vertical

Filing activities receive plenty of light from the “chalkboard” luminaire – 19.36 fc average. This illuminance level is plenty to perform the simple tasks associated with the shelving. With the shelf illuminance up to its current level and the load being considered decorative lighting by ASHRAE Standard 90.1, the application of the chalkboard luminaire for grazing the shelving is considered a successful design.

Private Offices	30-50 fc horizontal, 5 fc vertical

As mentioned previously, high importance within the office is placed on the ability to integrate and control the room light in reaction to daylight. For a more in-depth description on the lighting and daylight controls in the office, see the “Control Descriptions” section of the electrical section in this unit. The wall washing that has been applied to the wall opposite the window wall has proven to be both uniform and sufficient in the 20 fc range as seen in Figure 3.15. This has balanced luminance levels within the space well, seen in Figure 3.14. The private office design can be considered successful.

Reading Tasks

Paper Tasks	30-50fc horizontal illuminance

The paper-related tasks will be occurring at the professor’s desk. The recessed overhead luminaires supply between 7 and 54 footcandles of illuminance. Looking closer at the illuminance spread for the horizontal task plane, the bulk of the usable calculation points are between 30 and 54 footcandles. The lower values occur around the perimeter and corners of the space. The design criteria called for 30 to 50 footcandles and with an average of 35.75 footcandles on the desk plane, this application can be considered a success.

Visual Display Terminals (VDT)	3fc horizontal illuminance

As discussed in the design criteria section of this space, computer screens have advanced to be a non-issue with respect to light interaction. The user is able to tilt screens that may experience blurring of screen images due to overhead lighting. Given the nature of screen materials themselves, VDTs are of no concern in the redesign.

In conclusion, the office lighting design has passed all design criteria tests presented. The overhead lights provide sufficient and uniform light to the desk task plane, the wall washing application balances luminance on the blank wall opposite the window wall, and the chalkboard luminaire provides ample visibility for the shelving unit. The control of electric light and daylight delivery, which will be seen in the electrical portion of this unit, will provide control to suit the occupant’s need.

SPACE 3: CANTILEVER COURTYARD

A very large and important feature of the Millennium Science Complex is the 150-foot-plus cantilever that combines the Material Science and Life Science wings. In both the existing design and KGB Maser's redesign, the cantilever courtyard area is a focal point for pedestrians and for a statement of the building's architecture. The primary focus will be the newly designed steel support and sculpture that rises into the light well of the cantilever. The lobby and entry lighting will remain as existing design.

The structural redesign holds three purposes – to keep foot traffic off of the vibration-sensitive laboratories below, reduce the need of very oversized members in the wings, and to add an artistic interest to the exterior of the building. The lighting design for this space is intended to highlight the courtyard for user navigation and display the steel sculpture as a piece of art, not just as support structure.

The primary tasks in this area are very simple. Occupants of this space will be entering and exiting the Millennium Science Complex through the main lobby doors, passing by on the way to class, or viewing the structural sculpture. Illuminance levels need not be very high as outdoor navigation is the main concern and problem times of the day will be after operating hours most of the year. No outdoor furniture will be located within this area of the grounds because of the nature of spaces below grade. The original courtyard design was a serpentine of paths that led visitors in no aimed direction. This was done to deter mass quantities of people from sending unwanted vibrations into the nanotechnology labs below. In continuing the importance of vibration control, pedestrians will not have the opportunity to enter the courtyard area – small walls, shrubbery, and lack of paths will restrain pedestrians from passing over the nanotechnology labs.

The lighting design goal in this space is to combine bottom-up grazing of the steel structure with floodlighting of the underside of the building. Having a soft glow on the red-orange panels beneath the cantilever will create an illusion of a graceful engine keeping the building afloat. Grazing the structure will cause extreme high and low luminance areas that will stress the long lines associated with its components.

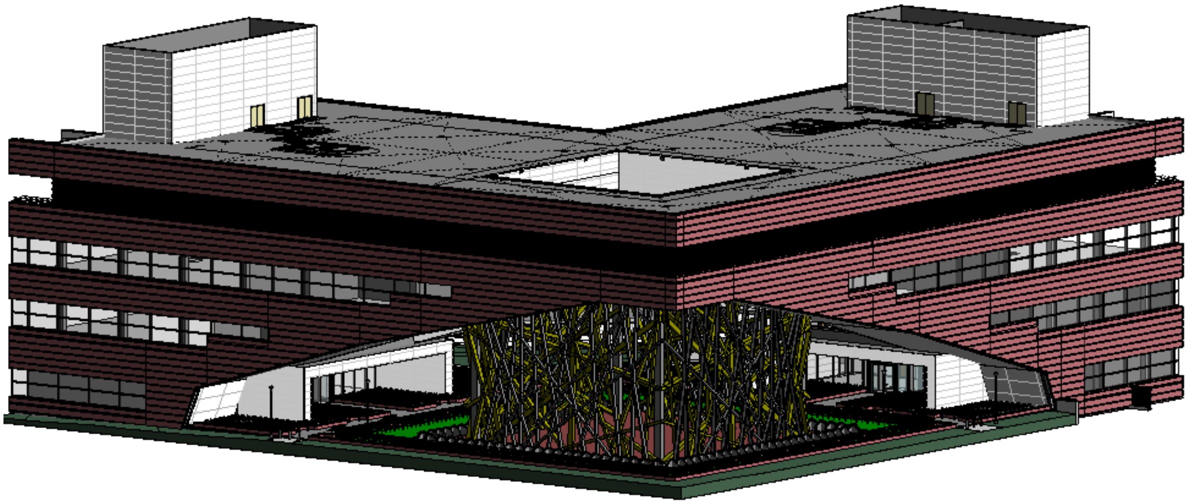


Figure 3.16: Cantilever Courtyard 3D Representation

FLOOR PLAN

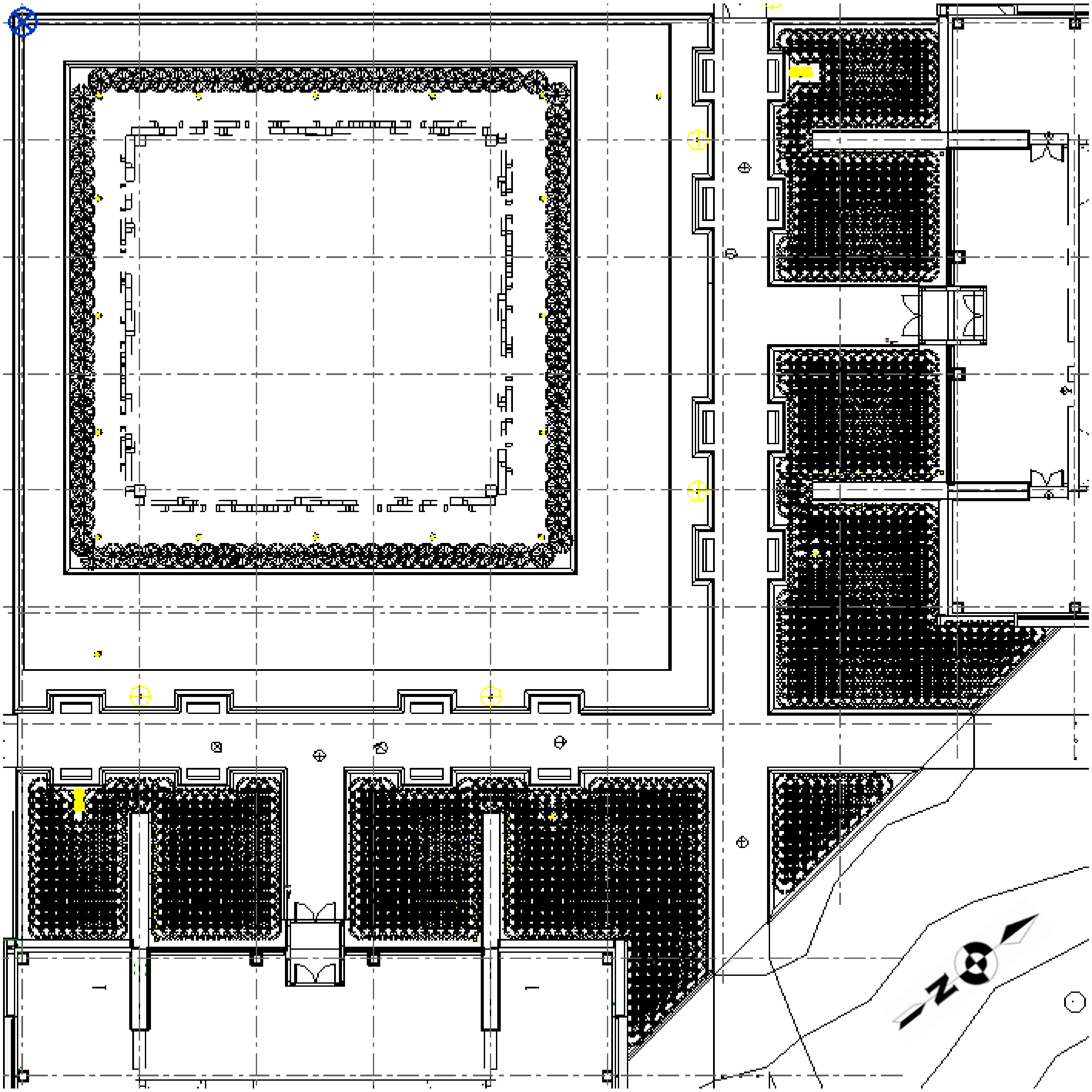


Figure 3.17: Cantilever Courtyard Plan from KGB Maser Central Revit Model

APPLICABLE MATERIALS

There is a wide variety of materials that are present within this space, more so than an interior space. Occupants are able to visualize the exterior of the building – brick and two different metal panels – as well as landscaping from mulch to grass, river rock to shrubs, and finally the steel sculpture at the center of the courtyard. The table below lists the applicable materials for the lighting design of the courtyard:

Surface	Material Description	Reflectance	Specification
Entryway Panels	Steel panel assembly consisting of two panels sandwiched around extruded plastic core. Stainless steel finish.	0.34	05730
Entryway Glazing	Various acceptable manufacturers with the following properties: VLT = 70% SHGC = 0.38 Winter U = 0.29 Shading Coeff. = 0.44 LSG = 1.85 Summer U = 0.26	0.11	08800
Cantilever Soffit	Steel panel assembly consisting of two panels sandwiched around extruded plastic core. Red-orange finish.	0.34	05730
Façade Panels	Pre-cast concrete "C" panels with Norman-sized burgundy brick embedded within the face of the concrete. Redesign includes an overall panel thickness of 1'-0" from exterior face to interior face of panel.	0.26	Unknown
Ground Cover	Including, but not limited to rocks, grass, mulch, and other plantings	0.15 or 0.26	N/A
Sidewalks	Cast-in-place site concrete	0.22	02515
Decorative Steel	HSS steel tubing wrapped with one of two finishes – brushed aluminum or blue aluminum	0.24	05730*
Structural Steel	Nominal 2'x2' wide flange columns	0.34	05100/05120**
Light Well Panels	Steel panel assembly consisting of two panels sandwiched around extruded plastic core. Stainless steel finish.	0.34	05730
*The redesign decorative steel falls under this specification and would need to be added to the specification section **Structural specification only, no information given for architectural interest			

TASKS AND ACTIVITIES

Occupants of the courtyard will not be participating in a wide variety of tasks as someone in a conference or multi-purpose room would. Users will mostly be navigating the grounds by foot into and out of the Millennium Science Complex. Secondary activities may include congregating around the courtyard, sitting on the low level boundary wall around the space, or holding discussions outside. Many of these activities are most likely to occur during the daytime hours, so the electric lighting will not be addressing these activities. What activities will be taking place are essentially secondary when compared to the main goal of the space – discouraging pedestrian traffic over the nanotechnology labs.

DESIGN CRITERIA

Building Exteriors

Active Entrances	5 fc horizontal, 3 fc vertical

Entrances are the first impression when approaching any building. Nearly every aspect of lighting design can be considered important in these types of spaces. Occupants are introduced to the building at this juncture, so the lighting design must show consideration for aesthetics. The appearance of the entry area must dictate that, without a doubt, this is the point where one will enter the building. The luminaires themselves must show that careful consideration was taken to comfort the visitor by showing quality of products. Visitors may be meeting other occupants in the entrances before passing into the building, so there must be ample light for modeling of faces, detecting others in one's peripheral vision, and knowing points of interest (such as announcements, sculptures, or other information). The scope of this space redesign does not include the entry ways. The existing design will be modeled and reported on for its compliance with these design criteria.

Prominent Structures — 5 fc horizontal, 3 fc vertical

The structural redesign of the cantilever will fall into this category of design criteria. Appearance is paramount in this design – every aspect of the design must be as appealing as the sculpture itself. The luminaires must fit the aesthetics of the structure, or be hidden from the view of onlookers. Uniform distribution must be kept across the structure to ensure that, in this case, all sides of the structure are illuminated evenly so as to not cause too much focus on one side of the structure. Having hidden or properly mounted luminaires will also aid in keeping the geometric relationship between the light source and the occupant eye from causing glare and shadows.

Buildings and Monuments, Floodlighted

Light and Dark Surroundings — 3-10 fc vertical

The courtyard application for the Millennium Science Complex has two goals as discussed in the introduction to this space. The first goal is to graze the structure; the second is to floodlight the underside of the building. To keep luminance levels tolerable for visitors to the space, the ideal scenario would include lower illuminance levels on lighter surfaces and higher illuminance on darker surfaces. This range of illuminance holds true for lighter surroundings. For darker surroundings, a uniform illuminance of three footcandles is deemed sufficient.

Parks, Plazas, and Pedestrian Malls — 5 fc horizontal, 3 fc vertical

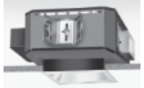
As discussed in other criteria sections, occupants must be able to navigate the space without hindrance and lack of light. This specific design scenario will be applied to the areas immediately surrounding the structure. For simplicity and uniformity, this criterion will include walkways.

REDESIGN PLANS, SECTIONS, AND ELEVATIONS

For the following plans, sections, and elevations, see Appendix 3.B:

A103A – Courtyard Plan Area A
A103B – Courtyard Plan Area B
LE401A – Enlarged Courtyard Lighting Plan Area A
LE401B – Enlarged Courtyard Lighting Plan Area B
LE401C – Enlarged Courtyard Lighting Plan Area C
LE401D – Enlarged Courtyard Lighting Plan Area D

LUMINAIRE SCHEDULE

<table>
<tr><th colspan="10">Courtyard Luminaire Schedule</th></tr>
<tr><th>Tag</th><th>Image</th><th>Manufac.</th><th>Product</th><th>Catalog No.</th><th>Description</th><th>Lamp</th><th>Input Watts</th><th>Voltage</th><th>Ballast</th></tr>
<tr><td colspan="10">New Design Luminaires (including two existing)</td></tr>
<tr><td>FL-1</td><td></td><td>Deco Lighting</td><td>D457 Wall Pack</td><td>D457-250-M-MT-CG-BL</td><td>Wall-mounted flood light to wash interior of cantilever light well; black housing; clear lens; adjustable height; mounted within reach from roof platform</td><td>(1) MCP250/PS/BU-ONLY/940PB
Osram Sylvania</td><td>272</td><td>277</td><td>71A5737 BPEE
Philips Advance</td></tr>
<tr><td>UL-1</td><td></td><td>Philips AllScape</td><td>SL-23</td><td>SL-23-70MH-T6-277-MFLD-F-BK</td><td>In-ground medium flood distribution; fixture must be able to graze structure and wash cantilever at same time; black housing; clear lens; minimum CRI of 80; color temperature must match all courtyard fixtures; 277V</td><td>(1) MC70T6/ U/G12/ 830PB
Osram Sylvania</td><td>85</td><td>277</td><td>71A5237BP
Philips Advance</td></tr>
<tr><td>UL-2</td><td></td><td>Kim Lighting</td><td>ALF10 Series</td><td>AFL11/70PMH 277/ BL/HDS/FH/BL/ SM18BL</td><td>Wide distribution flood luminaire; mounted at 1’-0” above grade; oriented with lamps along cantilever direction; must match CCT with other courtyard fixtures; minimum 80 CRI</td><td>(1) MC70T6/ U/G12/ 830PB
Osram Sylvania</td><td>85</td><td>277</td><td>71A5237BP
Philips Advance</td></tr>
<tr><td>XAM-1</td><td></td><td>Lightolier</td><td>Calculite HID</td><td>C6P30 MHACLW/ C6A39P30E2</td><td>Recessed adjustable flood light; specular reflector; adjust coverage after installation to uniformly light surface below</td><td>(1) MCP39PAR30LN /U/830/FL/ ECO PB
Osram Sylvania</td><td>48</td><td>277</td><td>71A5037BP
Philips Advance</td></tr>
<tr><td>XPO-1</td><td></td><td>Louis Poulsen</td><td>Kipp Post Cutoff</td><td>KIP/1/100W/ MH/ED-17 medium/ 277V/BLK/ CUTOFF</td><td>PSU standard existing metal halide post lantern</td><td>(1) 100W/MH/ED-17/4000K/Min. 92 CRI</td><td>118</td><td>277</td><td>71A5337BP
Philips Advance</td></tr>
<tr><td colspan="10">Existing Luminiares – No manufacturer data will be given</td></tr>
<tr><td>DC-5</td><td></td><td>Kurt Versen</td><td>Square Aperture</td><td>H8643-SY-LP</td><td>6”x6”square aperture ceiling recessed compact fluorescent down lights with regressed lens</td><td>(1) 42W Triple Tube CFL</td><td>48</td><td>277</td><td>Unspecified</td></tr>
<tr><td>XDM-1</td><td></td><td>Kurt Versen</td><td>Square Aperture</td><td>H8406-SW-LP</td><td>4.5”x4.5” square aperture damp rated metal halide recessed downlights with prismatic lens</td><td>(1) 39W T6 metal halide / 4000K</td><td>48</td><td>277</td><td>Unspecified</td></tr>
<tr><td>XWM-1</td><td></td><td>Kurt Versen</td><td>Square Aperture</td><td>H8452-SY-LP</td><td>4.5” square aperture ceiling recessed mount metal halide wall washers with lens</td><td>(1) 39W PAR20 metal halide / 4000K</td><td>48</td><td>277</td><td>Unspecified</td></tr>
</table>

CONTROL EQUIPMENT

For control equipment cut sheets, see Appendix 3.C. For wiring diagrams, see "Dimming and Wiring Diagrams" in the electrical portion of this document.

Courtyard Control Equipment Schedule

Tag	Image	Manufac.	Product	Catalog No.	Description
Z-5C		Eaton Corporation	Pow-R-Command 1000 Lighting Control System	Unknown	Provide with Pow-R-Command 1000 Lighting Optimization Software to allow for at least one central workstation and one lighting optimization work station
Z-5P		Eaton Corporation	Pow-R-Command 1000 Panelboard	Unknown	Line-voltage 277V operation; LCD display and keypad; 225A main bus with ability to override lighting circuits by daylight sensor – off during daylight conditions, on selected night conditions; up to (7) expansion panel outputs to control other exterior lighting zones; consult with manufacturer for additional specific component requirements

For a detailed discussion on how the presented control equipment will operate within the space, see the "Control Descriptions" section of the electrical portion of this document.

PERFORMANCE DATA

The table below summarizes light loss factors used in illuminance calculations for the courtyard. The cantilever area consists of all indirect lighting with the maximum allowable cleaning cycle by IES standards.

Courtyard Light Loss Factors

	Mark	Ballast Factor	Lamp Lumen Depreciation	Luminaire Dirt Depreciation	Total Light Loss Factor
New Design	FL-1*	1.00	0.80	0.77	0.62
	LP-1	1.00	0.75	0.77	0.58
	UL-1	1.00	0.80	0.625	0.50
	UL-2	1.00	0.80	0.625	0.50
	XAM-1	1.00	0.80	0.875	0.70
Exist.*	DC-5	0.98	0.86	0.875	0.74
	XDM-1	1.00	0.80	0.875	0.70
	XWM-1	1.00	0.80	0.875	0.70

*Same specification as existing conditions
**Existing luminaires, lamps, etc. will not be included in the manufacturer pages of this report.

The following figures illustrate the lighting redesign for the cantilever courtyard in several different media – AGI32, AutoDesk 3D Studio Max Design, and AutoDesk Revit Architecture. To see a further discussion on the model sharing process for lighting design in this space, refer to Unit 1 of this document.

Figure 3.18: Courtyard 3D Studio Max Design Render

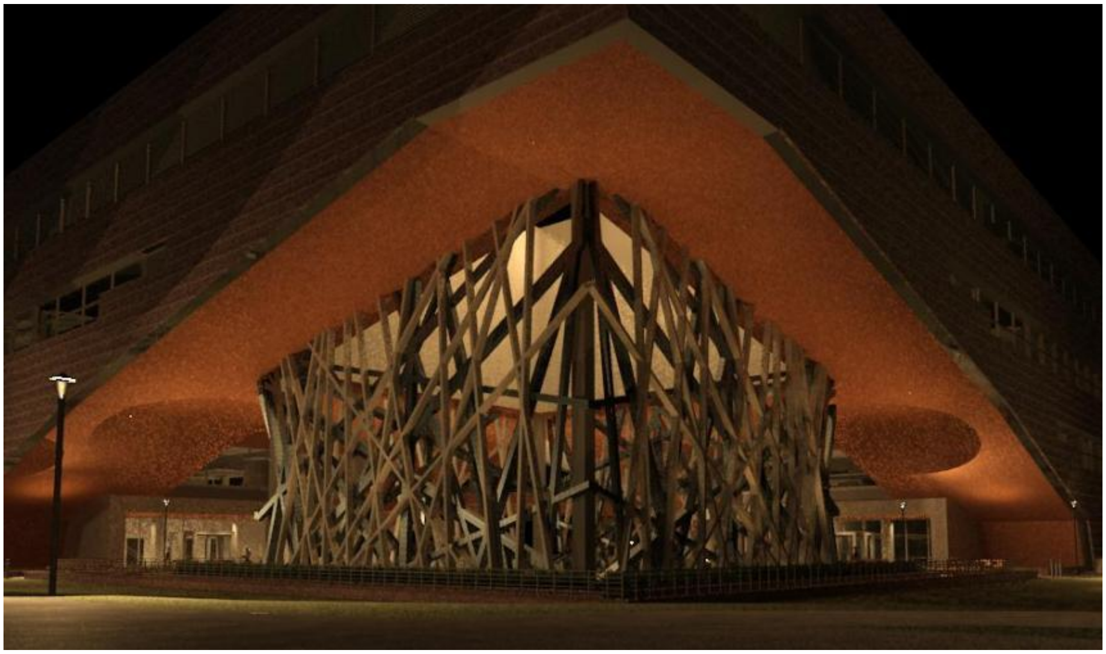


Figure 3.19: Courtyard Rendering in Revit Architecture

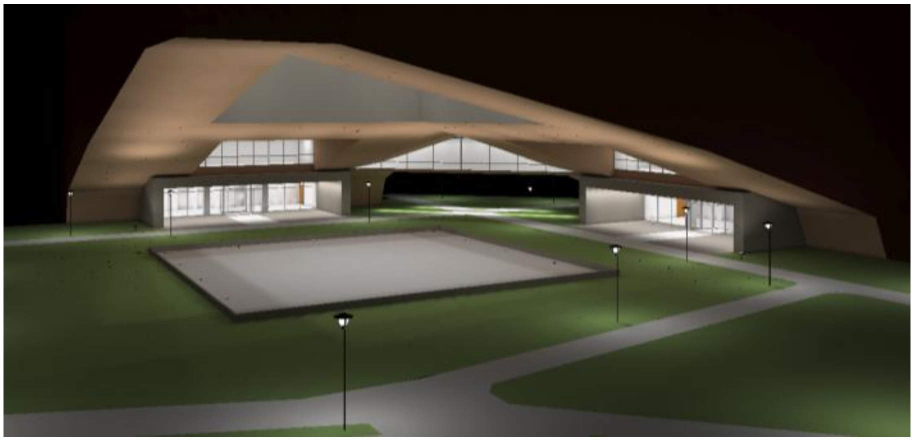
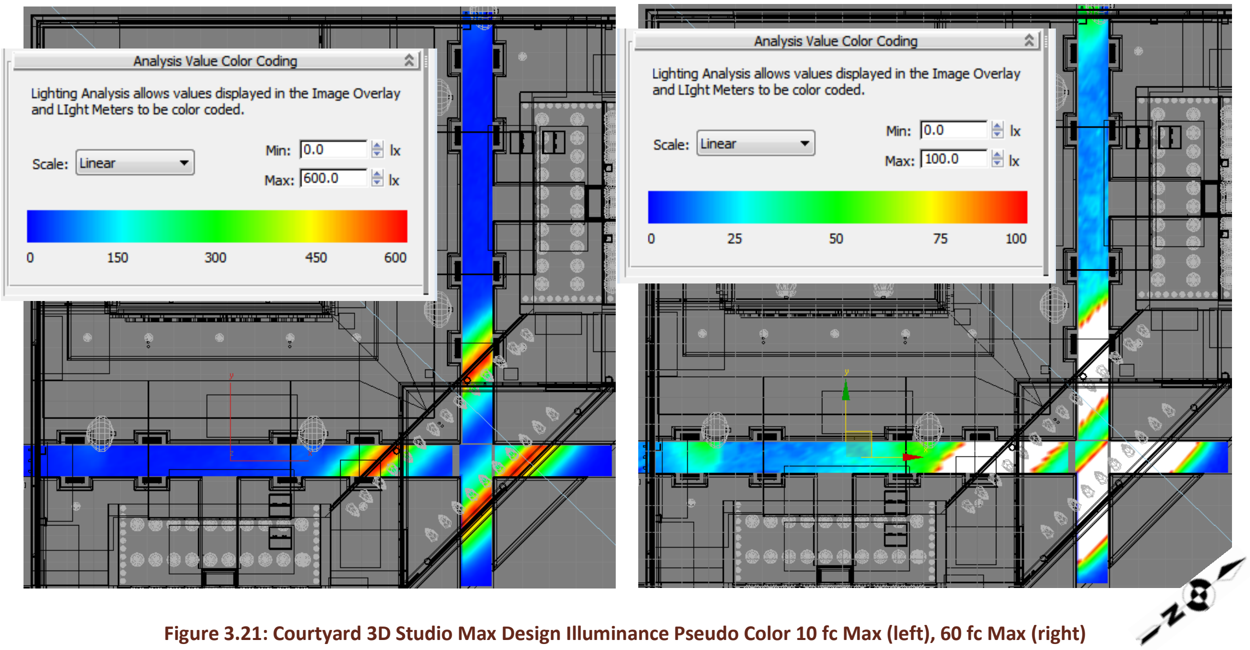


Figure 3.20: Courtyard AGI32 Render *Steel redesign omitted due to surface complexity



Analysis Value Color Coding

Lighting Analysis allows values displayed in the Image Overlay and LIght Meters to be color coded.

Scale: Linear
Min: 0.0 lx
Max: 600.0 lx

Analysis Value Color Coding

Lighting Analysis allows values displayed in the Image Overlay and LIght Meters to be color coded.

Scale: Linear
Min: 0.0 lx
Max: 100.0 lx

Figure 3.21: Courtyard 3D Studio Max Design Illuminance Pseudo Color 10 fc Max (left), 60 fc Max (right)

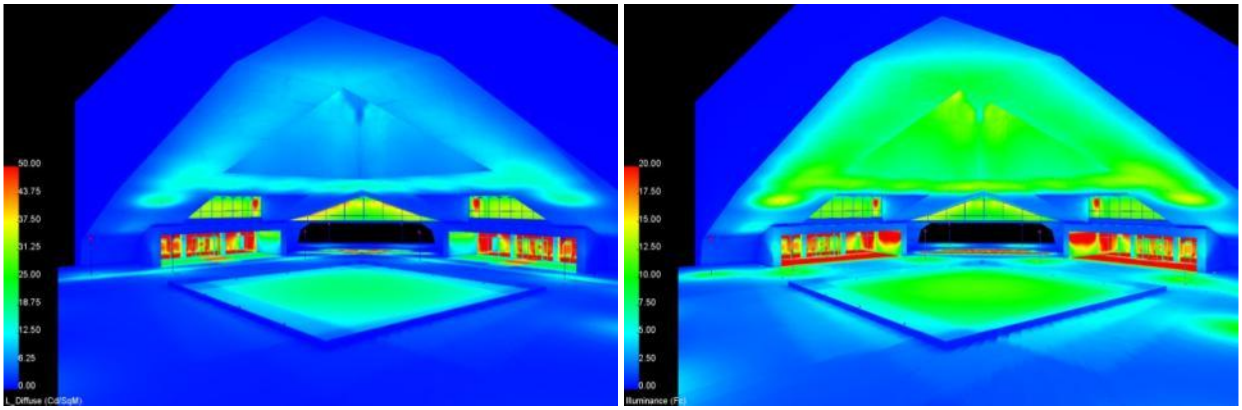


Figure 3.22: Courtyard AGI32 Pseudo Color Images – Luminance in cd/m^2 (left) and Illuminance in fc (right)

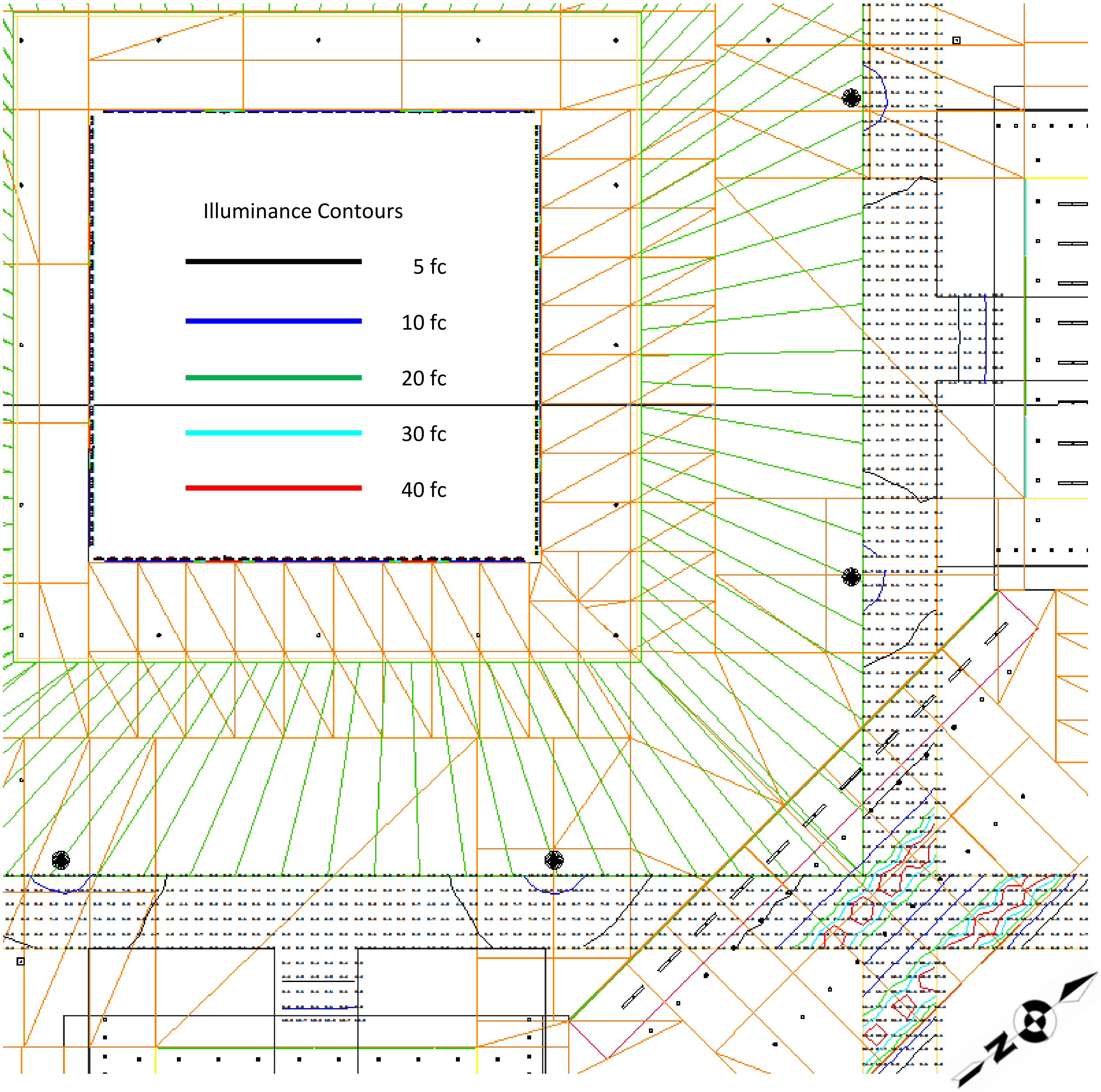


Figure 3.23: Courtyard AGI32 Illuminance Contours

ASHRAE Standard 90.1 Compliance

Lighting Type	Area (ft^2)	Allowable LPD (W/ft^2) or (W/Lf)	Allowable Power (W)**	Total Power Used (W)	Actual LPD (W/ft^2)
Building Grounds*	See Area Summary Table Below	1.0 W/Lf	339.5	7191.00 (total redesign – all luminaires)	0.25 (All surfaces redesign is intended to illuminate)
Plaza Areas and Walkways (>10' Wide)*	See Area Summary Table Below	0.2 W/sq.ft.	N/A		
Canopies and Overhangs*	See Area Summary Table Below	1.25 W/sq.ft	32599.35 to 38044.35		
Building Façades	See Area Summary Table Below	1.25 W/sq.ft.	11910.13 to 24219.83	2176.00 to 3791.00	0.16 to 0.23

*Areas are tradable by ASHRAE Standard 90.1, Table 9.4.5
**Allowable power varies depending upon the classification of the areas in the table below

Area Location	Area (ft^2)
Walkway	4703.50
Courtyard Grass	7962.42
Courtyard Planting	8877.38
Cantilever Soffit*	14691.73
Light Well Walls	9528.10
Entry Outer Planting	5526.18

*Area of slope that will be floodlighted

Illuminance Summary Table

Courtyard Illuminance Summary									
Calculation Grid	AGI Illuminance (fc)			3ds Illuminance (fc)			AGI Specific Values		
	Min.	Avg.	Max.	Min.	Avg.	Max.	Max./Min.	Coeff. Of Variation	Uniformity Gradient
Paths	1.10	7.72	63.20	0.102	23.15	59.00	57.45	1.16	3.10
LS Interior Well	1.90	10.32	72.40	Not Measured			38.11	0.59	13.30
LS Exterior Well	1.80	9.33	39.10				21.72	0.41	7.48
MS Interior Well	1.90	9.91	47.60				25.05	0.49	15.03
MS Exterior Well	2.00	9.68	54.10				27.05	0.51	18.03

Ambient light for pathways are designed to be delivered from diffuse sources such as the light well and bouncing off of the underside of the cantilever. To accommodate for such low levels from these sources, campus standard lighting has been carried through the orthogonal paths leading to the entrances of the Millennium Science Complex. As stated previously, the major design goal of this space is to light the sculpture that is the cantilever redesign structure. The following discussions outline how the lighting design achieved the design goals stated at the beginning of this redesign section:

Building Exteriors

Active Entrances 5 fc horizontal, 3 fc vertical

There is some irony when discussing this aspect of the courtyard space. The original design included a pathway that meandered through a relaxing landscape. The irony of this space is that due to the sensitive nature of the nanotechnology labs beneath ground level, foot traffic needs to be limited, so this space needs to draw occupants into the building, yet not over the main surfaces. The lighting redesign achieves this by not changing existing design in the entryways and using floodlighting for ambient light. Examining Figure 3.22, it is evident that there is ample light present at the building entrances while the Louis Poulsen post luminaires lead pedestrians along the pathway to these well-lit entrances. This design can be considered successful, however it shall be suggested that the entryway lamping be cut in half to save energy.

Prominent Structures	5 fc horizontal, 3 fc vertical

The prominent structure within this space is apparent to the onlooker from afar. The redesign is the definition of prominent structure. Figure 3.22 illustrates that the area of the courtyard around the structure is illuminated to 10 fc in the center of the structure and 5 fc within its landscape walls. Since the structure was not included in the AGI32 renderings, it is unclear whether the vertical illuminance reaches 3 fc. However, grazing portions of the uplighting will undoubtedly illuminate the structure to 3 fc at the height of the viewer.

Buildings and Monuments, Floodlighted

Light and Dark Surroundings	3-10 fc vertical

The floodlighting portion of the presented design criteria can be embodied in the soffit face of the cantilever and the light well above the center structure. Also visible in Figure 3.22, the light well surface is uniformly illuminated to 10 fc, with the exclusion of surfaces very close to the light sources. The cantilever soffit is also floodlighted to a uniform 10 fc seen in Figure 3.22. The application of wide floodlights next to the entrance area balances illuminance and luminance at the outer ends of the entryways. There are small hot-spots on this section of the soffit, but they can be dismissed due to the average eye sensitivity. These hot-spots are at approximately 15 fc while the surrounding surfaces are in the 10-12 fc range. This design criterion can be considered to be achieved.

Parks, Plazas, and Pedestrian Malls	5 fc horizontal, 3 fc vertical

The pathways under the cantilever may fall within this blanket of design spaces. Figures 3.21, 22, and 23 can be consulted for design effectiveness for the pedestrian areas. Examining Figure 3.21 first, the light meters within 3D Studio Max calculate an average of 23.5 fc of illuminance on the pathways. This is also including the more powerful luminaires under the second floor walkway. Excluding the higher power luminaires, the campus standard lighting slightly under illuminates the pathways around the building (in Revit and 3D Studio models). This underachievement is due to modeling translation between programs. For this design will achieve its goals due to its ambient nature, flooding the area with reflectance off of the cantilever structure.

The cantilever space concludes the lighting portion of this unit. For a more in-depth discussion on the modeling processes used to achieve the presented lighting goals, as mentioned throughout this document, see Unit 1 of KGB Maser’s final report. The following section is an in-depth design of the power delivery to each of the aforementioned redesign spaces. Secondly, it will include coordination with KGB Maser’s mechanical engineer on the Penn State IPD/BIM thesis team.

ELECTRICAL OVERVIEW

The following section presents the electrical requirements of AE482. There are three spaces that have been redesigned along with two depth topics. The spaces include a student study area connected to a corridor, a perimeter office, and the courtyard space below the large cantilever of the Millennium Science Complex. The first depth topic entails modeling a portion of the existing electrical system in SKM Power Tools for Windows. The second depth topic comprises of a motor control center design in reaction to mechanical changes in the building.

Located on the perimeter of the third floor, the student study area allows occupants to have views to the exterior and to be able to work at computer stations along an open portion of the corridor. The lighting redesign includes overhead luminaires being changed from recessed to pendant mounted and additional task lighting at the desk plane. The overhead lighting will operate at 277V while the task lighting will operate at 120V. The overhead lighting is connected to a dimmable system and all space lighting will be connected to occupancy sensors. A second aspect in the redesign includes two rows of bottom-up shading devices connected to a computer system with an open-loop daylight sensor override.

Offices are also located around the perimeter of the building. The largest difference between these spaces and the study areas is their isolation from the corridor. The lighting redesign includes new 2-lamp T8 luminaires that are controlled by dimming switches, the addition of a chalkboard light to illuminate shelving, and a wall wash application to balance luminance levels between the windows and the opposite wall. Neither the shading nor the dimming lighting will be automatically controlled as this space has no real known hours of operation.

A major architectural redesign for KGB Maser is the courtyard beneath the cantilever. A steel structure and sculpture was added for two reasons – to limit pedestrian traffic over the nanotechnology labs and to add a second artistic feature to the corner of the complex. All lighting redesign in this space is high intensity discharge metal halide that is controlled by Eaton Pow-R-Command lighting optimization. Luminaires within the footprint of the courtyard have three basic functions. The first is to flood the underside of the cantilever and light well walls, the second is to graze the structure, and the third is to provide area lighting on site pathways. The Pow-R-Command 1000 system allows for daylight on/off switching allowing for building façade lighting at any hour of the evening in which night falls.

Depth topic 1 involves creating a power system model in SKM Power Tools for Windows®. The three IPD/BIM lighting students collaborated to create a large portion of the base model, and then each completed his own portion of the remaining system. KGB Maser's remaining portion of the system includes motors affected by changing from air handling units to chilled beams.

Depth topic 2 is reactionary to equipment addition and sizing from applying chilled beams to the mechanical system. After chilled beam usage has been finalized and sized, the motors for the remaining mechanical system will be consolidated into several motor control centers.

Panelboards						
Panelboard Tag	**Voltage**	**System**	**Study Area**	**Office**	**Courtyard**	**Chilled Beam Application**
HL-3D	480Y/277V, 3P, 4W	N	X	X		
HLE-3D	480Y/277V, 3P, 4W	N/E	X			
LR-3D1	208Y/120V, 3P, 4W	N	X			
LCP-1	480Y/277V, 3P, 4W	N			X	
EDPS-M41	480Y/277V, 3P, 4W	N/E				X
EDPS-M42	480Y/277V, 3P, 4W	N/E				X
MDP-M41	480Y/277V, 3P, 4W	N				X
MDP-M42	480Y/277V, 3P, 4W	N				X

EXISTING CONDITIONS REVIEW

The electrical system for the Millennium Science Complex is a 12.47kV service feeding a set of dual 5000A, 480Y/277V switchgears (main-tie-main) through two pad mounted transformers. Distribution begins with 480Y/277V for lighting and other systems, 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.

CONTROL DESCRIPTIONS

STUDENT STUDY AREA AND CORRIDOR

The student study area and corridor within the scope of the space occupy three zones in the new control system. The first zone consists of overhead pendant luminaires within the study area. This zone is controlled through a digitally addressable dimming system with an occupancy sensor override. The second zone is also within the study area and includes under shelf task lighting. These task lights are controlled by integrated switches at each luminaire. Since the study area has hours of operation that are essentially open, the task luminaires will be switched off by vacancy sensors located on the back of the cabinets at the end of selected rows. Shading within the study area is operated using the MechoShade SolarTrac system. This system includes a computer-based settings program and override sensors to allow for the shades to be "off" during times of overcast conditions.

Control wiring diagrams for both the lighting system and shading system can be found in the "Dimming and Wiring Diagrams" section of this unit.

OFFICE LOCATIONS

Office throughout the Millennium Science Complex will be controlled similarly to the perimeter study areas, but without the automatic features such as dimming and shading. The office occupancy schedule does not coincide with general building usage hours, so automatic shading and dimming will be overridden by vacancy sensors for most operation. The overhead lights and shelf lights will be controlled by a three-way, two-load wall switch at the main entry to the room and an additional set of local switches. The local three-way switch for the overhead lighting will include dimming capability and the local switch for the shelves will be a simple three-way on/off switch. The wall washing application will be controlled by its own switch at the main entry door, as its primary goal is to balance its wall luminance with the window wall. The shading system will be controlled by the user at the window by a single line-voltage up/off/down switch.

Control wiring diagrams for both the lighting system and shading system can be found in the "Dimming and Wiring Diagrams" section of this unit.

COURTYARD

The area within the scope of work for the courtyard beneath the cantilever includes areas enclosed by the building footprint, but outside of entryway canopies. All ballasts for the HID luminaires within the redesigned space will be controlled at the head-end by the Eaton Pow-R-Command Lighting Optimization System. This system includes the building automation system SOAP/XML client, at least one SOAP/XML server, a workstation to run the optimization software, the network access control device, and the Pow-R-Command 1000 lighting control panels. The system will be connected to a daylight sensor for override – when predetermined daylight levels have been reached, the system will switch off the night-time environment that is illuminating the courtyard. Additionally, the interface is programmable with up to thirty holidays and has custom occupancy scheduling ability within its software. Information on the product, such as exact wiring diagrams, could not be found; however a simplified control system wiring diagram can be found in the "Dimming and Wiring Diagrams" section of this document.

LUMINAIRE CONTROL AND CIRCUITING

The following drawings appear in Appendix 3.B:

LE101 – Study Area Luminaire Layout and Switching
LE102* – Office Luminaire Layout and Switching
    *Includes Conduit and Tick-mark Diagram
LE103A – Courtyard Light Well Layout and Switching A
LE103B – Courtyard Light Well Layout and Switching B
LE401A – Courtyard Lighting Layout and Switching A
LE401B – Courtyard Lighting Layout and Switching B
LE401C – Courtyard Lighting Layout and Switching C
LE401D – Courtyard Lighting Layout and Switching D

EXISTING PANELBOARD AND DIMMING SCHEDULES

In the following existing panelboard schedules, colored highlighting corresponds to which circuits will be changed as a result of lighting redesign. Each color is analogous to the redesign summary table in the electrical executive summary. Naming conventions – including typographical errors – have not been changed in the existing schedules.

BRANCH CIRCUIT PANELBOARD SCHEDULE

Panel Name: HL-3D		Mounting:	Surface:			X	Main Lugs Only:				.	Amp Main CB	200
277/480, 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	Poles	Poles	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 LTG*	2
3	*ELECTROACTIVE POLY LTG*	20		1.60		3	4		1.90		20	*STUDENT LIGHTING*	4
5	*ORGANIC ELEC & PHO LTG*	20			1.60	5	6			1.90	20	*STUDENT LIGHTING*	6
7	*DRY LAB A&B, STAFF LTG*	20	1.41			7	8	2.20			20	*STAFF LIGHTING*	8
9	*STAFF ADMIN, KITCHEN LTG*	20		1.23		9	10		1.32		20	*CONFERENCE ROOM LTG*	10
11	*DRY LAB, MISC. COMP. LTG*	20			1.28	11	12			1.52	20	*CONFERENCE ROOM LTG*	12
13	*CORRIDOR LIGHTING*	20	1.60			13	14				20	*SPARE*	14
15	*CORRIDOR LIGHTING*	20		1.54		15	16				20	*SPARE*	16
17	*CORRIDOR LIGHTING*	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			90.00 %				Demand Factor	
		Phase B:			7.59 kVA			20.98 kVA				Demand Load	
		Phase C:			7.98 kVA			26.22 kVA				Load x 1.25	
	Total Connected Load:	23.31 kVA						31.58 A				AMP	

Figure 3.24: Existing panelboard schedule for HL-3D

BRANCH CIRCUIT PANELBOARD SCHEDULE

Panel Name: HLE-3D		Mounting:	Surface:			X	Main Lugs Only:				.	Amp Main CB	100
277/480, 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	Poles	Poles	KVA/Phase A	KVA/Phase B	KVA/Phase C	TRIP (Amp)	Load	CKT No.
1	*EXIT SIGN*	20	0.10			1	2	1.02				*STAIR N-1 LIGHTING*	2
3	*TOILET & CORRIDOR LTG*	20		2.16		3	4		1.45			*STAIR N-1 LIGHTING*	4
5	*OFFICE LIGHTING*	20			2.30	5	6					*SPARE*	6
7	*SPARE*	20				7	8					*SPARE*	8
9	*SPARE*	20				9	10					*SPARE*	10
11	*SPARE*	20				11	12					*SPARE*	12
13	*SPARE*	20				13	14					*SPARE*	14
15	*SPARE*	20				15	16					*SPARE*	16
17	*SPARE*	20				17	18					*SPARE*	18
19	*SPARE*	20				19	20					*SPARE*	20
21	*SPARE*	20				21	22					*SPARE*	22
23	*SPARE*	20				23	24					*SPARE*	24
25	*SPARE*	20				25	26					*SPARE*	26
27	*SPARE*	20				27	28					*SPARE*	28
29	*SPARE*	20				29	30					*SPARE*	30
31	*SPARE*	20				31	32					*SPARE*	32
33	*SPARE*	20				33	34					*SPARE*	34
35	*SPARE*	20				35	36					*SPARE*	36
37	*PENEL LE-3D VIA*	50	4.94			37	38					*SPARE*	38
39	*XFMR 'TRE-LE-3D'*			3.80		39	40					*SPARE*	40
41	*(50G)*	3P			3.80	41	42					*SPARE*	42
	Subtotals (kVA):		5.04	5.96	6.10			1.02	1.45	0.00		Subtotals (kVA)	
	Total Loads:	Phase A:			6.06 kVA			60.00 %				Demand Factor	
		Phase B:			7.41 kVA			11.74 kVA				Demand Load	
		Phase C:			6.10 kVA			14.68 kVA				Load x 1.25	
	Total Connected Load:	19.6 kVA						17.68 A				AMP	

Figure 3.25: Existing panelboard schedule for HLE-3D

BRANCH CIRCUIT PANELBOARD SCHEDULE

Panel Name: LR-3D1	Mounting: Surface:	X	Main Lugs Only:	.	Amp Main CB	225
120/208, 3 Phase, 4 Wire	Flush:	.	Shunt Trip Main:	.	Amp Bus	225
10,000MIN A.I.C. SYM	In MCC	.	Feed Through:	X	Ground Bus	X
Neutral: 200%	Number of Poles:	42	TVSS:	.	Isolated Ground Bus	X

CKT No.	Load	TRIP (Amp)	KVA/Phase A	B	C	Poles	Poles	KVA/Phase A	B	C	TRIP (Amp)	Load	CKT No.
1	*P.C. RECEPTACLE*	20	0.80			1	2	0.80			20	*P.C. RECEPTACLE*	2
3	*RECEPTACLE*	20		1.08		3	4		0.80		20	*P.C. RECEPTACLE*	4
5	*P.C. RECEPTACLE*	20			0.80	5	6			0.80	20	*P.C. RECEPTACLE*	6
7	*RECEPTACLE*	20	1.08			7	8	0.80			20	*P.C. RECEPTACLE*	8
9	*P.C. RECEPTACLE*	20		0.80		9	10		0.80		20	*P.C. RECEPTACLE*	10
11	*RECEPTACLE*	20			0.54	11	12			0.80	20	*P.C. RECEPTACLE*	12
13	*P.C. RECEPTACLE*	20	0.80			13	14	0.80			20	*P.C. RECEPTACLE*	14
15	*SPARE*	20				15	16		0.80		20	*P.C. RECEPTACLE*	16
17	*P.C. RECEPTACLE*	20			1.16	17	18			0.80	20	*P.C. RECEPTACLE*	18
19	*RECEPTACLE*	20	1.08			19	20	0.80			20	*P.C. RECEPTACLE*	20
21	*P.C. RECEPTACLE*	20		0.72		21	22		0.80		20	*CLEANING RECEPTACLE*	22
23	*P.C. RECEPTACLE*	20			0.90	23	24			0.80	20	*CLEANING RECEPTACLE*	24
25	*P.C. RECEPTACLE*	20	0.72			25	26	0.80			20	*CLEANING RECEPTACLE*	26
27	*RECEPTACLE*	20		0.72		27	28		0.80		20	*CLEANING RECEPTACLE*	28
29	*P.C. RECEPTACLE*	20			0.40	29	30				20	*SPARE*	30
31	*RECEPTACLE*	20	0.36			31	32				20	*SPARE*	32
33	*RECEPTACLE*	20		0.72		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):		4.84	4.04	3.80			4.00	4.00	3.20		Subtotals (kVA)	

Total Loads:	Phase A:	8.84 kVA	60.00 %	Demand Factor
	Phase B:	8.04 kVA	14.33 kVA	Demand Load
	Phase C:	7.00 kVA	17.91 kVA	Load x 1.25
Total Connected Load:		23.88 kVA	49.77 A	AMP

Figure 3.26: Existing panelboard schedule LR-3D1

BRANCH CIRCUIT PANELBOARD SCHEDULE

Panel Name: LCP-1	Mounting: Surface:	X	Main Lugs Only:	.	Amp Main CB	.
277/480, 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	B	C	Poles	Poles	KVA/Phase A	B	C	TRIP (Amp)	Load	CKT No.
1	**ZONE 1 LS LOBBY LTG*	20	0.42					0.72			20	*ZONE 18 SITE LIGHTING**	2
3	*SPARE*	20							0.24		20	*ZONE 19 SITE LIGHTING**	4
5	**ZONE 3 EXTERIOR LTG*	20			1.40					0.24	20	*ZONE 20 SITE LIGHTING**	6
7	**ZONE 4 LS LOBBY LTG*	20	0.31					0.36			20	*ZONE 21 SITE LIGHTING**	8
9	**ZONE 5 LS LOBBY LTG*	20		0.56					0.70		20	*ZONE 22 SITE LIGHTING*	10
11	**ZONE 6 EXTERIOR LTG*	20			1.25						20	*SPARE*	12
13	**ZONE 7 ML LOBBY LTG*	20	0.84					0.38			20	*ZONE 24 SITE LIGHTING**	14
15	**ZONE 8 ML LOBBY LTG*	20		0.56							20	*SPARE*	16
17	**ZONE 9 EXTERIOR LTG*	20			1.40					0.40	20	*ZONE 26 SITE LIGHTING**	18
19	*SPARE*	20						0.05			20	*ZONE 27 SITE LIGHTING**	20
21	**ZONE 11 EXTERIOR LTG*	20		1.25					0.40		20	*ZONE 28 SITE LIGHTING**	22
23	**ZONE 12 ML LOBBY LTG*	20			0.31					0.27	20	*ZONE 29 EXTERIOR LTG**	24
25	**ZONE 13 EXTERIOR LTG*	20	0.63					0.27			20	*ZONE 30 EXTERIOR LTG**	26
27	**ZONE 14 EXTERIOR LTG*	20		0.84					0.23		20	*ZONE 31 EXTERIOR LTG**	28
29	**ZONE 15 SITE LIGHTING*	20			1.70					0.20	20	*ZONE 32 EXTERIOR LTG**	30
31	**ZONE 16 SITE LIGHTING*	20	1.40					0.23			20	*ZONE 33 EXTERIOR LTG**	32
33	**ZONE 17 SITE LILGHTING*	20		1.60					0.27		20	*ZONE 34 EXTERIOR LTG**	34
35	**ZONE 35 ML LOBBY LTG*	20			0.46					0.42	20	*ZONE 36 LS LOBBY LTG*	36
37	*SPARE*	20									20	*SPARE*	38
39	*SPARE*	20									20	*SPARE*	40
41	*SPARE*	20									20	*SPARE*	42
	Subtotals (kVA):		3.60	4.81	6.52			2.01	1.84	1.53		Subtotals (kVA)	

Total Loads:	Phase A:	5.61 kVA	80.00 %	Demand Factor
	Phase B:	6.65 kVA	16.25 kVA	Demand Load
	Phase C:	8.05 kVA	20.31 kVA	Load x 1.25
Total Connected Load:		20.31 kVA	24.46 A	AMP

REMARKS: * - DENOTES REMOTE CONTROL BREAKER

Figure 3.27: Existing panelboard schedule LCP-1

DISTRIBUTION PANEL SCHEDULE

Panel Name: EDPS-M41	Mounting:	Surface:	X	Main Lugs Only:	.	Amp Main CB	800
277/480, 3 Phase, 4 Wire		Flush:	.	Shunt Trip Main:	.	Amp Bus	800
65,000MIN A.I.C. SYM		In MCC	.	Feed Through:	.	100% NEUTRAL	

CKT NO.	EQUIPMENT	LOAD (CONN)			BREAKER			WIRE SIZE / REMARKS
		AMPS	KVA	HP	FRAME (AMPS)	TRIP (AMPS)	Poles	
1	*ACF-1*	253.90	211.00	100	600A	450A	3	*460G*
2	*ACF-3*	253.90	211.00	100	600A	450A	3	*460G*
3	*ACF-5*	253.90	211.00	100	600A	450A	3	*460G (STAND-BY)*
4	*HMS-0B - HMS-3B*	23.80	20.00		225A	225A	3	*300G*
5	*RO-2*	11.00	9.00	7.5	100A	40A	3	*40G*
6	*PRE-TREATMENT*	7.60	6.32	5	100A	30A	3	*30G*
7	*CONTROL PANEL*	20.00	16.00		100A	30A	3	*30NG*
8	*SPACE*							
9	*EFN-24*	65.00		50	100A	70A	3	*115G (STAND-BY)*
10	*EFN-26*	72.20	60.00	75	225A	150A	3	*150G (STAND-BY)*
11	*SPARE*				100A	100A	3	
12	*SPARE*				225A	225A	3	
13								
14								
15								
16								
17								
18								

PROVIDE INTEGRAL TVSS UNIT

Figure 3.28: Existing panelboard schedule EDPS-M41

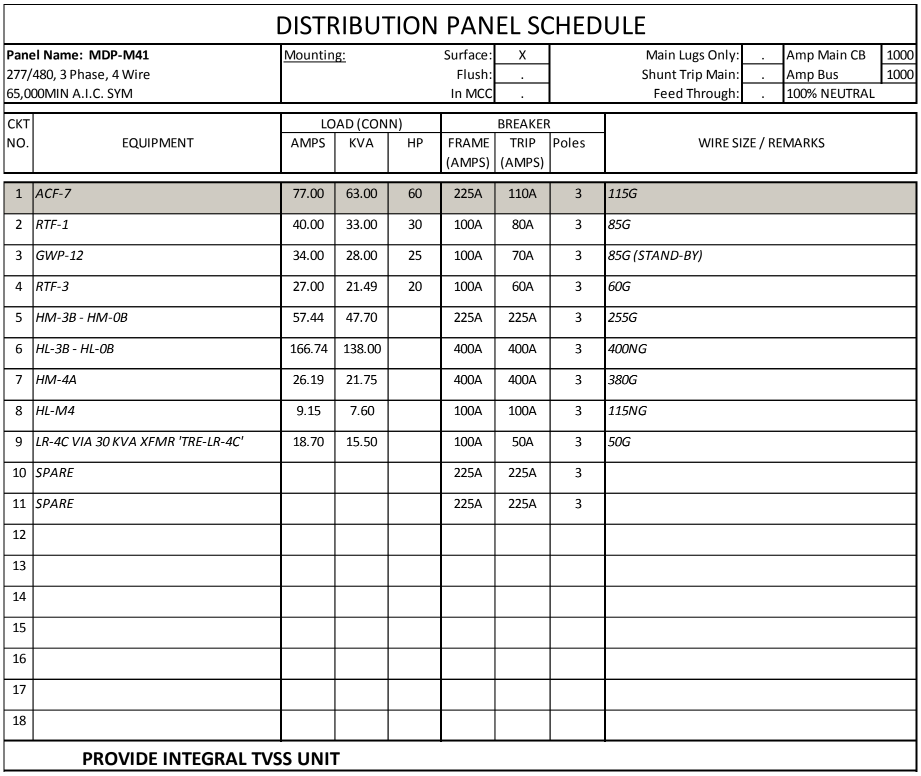
DISTRIBUTION PANEL SCHEDULE

Panel Name: EDPS-M42	Mounting:	Surface:	X	Main Lugs Only:	.	Amp Main CB	800
277/480, 3 Phase, 4 Wire		Flush:	.	Shunt Trip Main:	.	Amp Bus	800
65,000MIN A.I.C. SYM		In MCC	.	Feed Through:	.	100% NEUTRAL	

CKT NO.	EQUIPMENT	LOAD (CONN)			BREAKER			WIRE SIZE / REMARKS
		AMPS	KVA	HP	FRAME (AMPS)	TRIP (AMPS)	Poles	
1	*ACF-2*	253.90	211.00	100	400A	380A	3	*400G*
2	*ACF-4*	253.90	211.00	100	400A	380A	3	*400G*
3	*ACF-9*	52.00	30.00	40	100A	100A	3	*115G (STAND-BY)*
4	*ACF-10*	52.00	30.00	40	100A	100A	3	*115G*
5	*ACF-11*	34.00	28.00	25	100A	70A	3	*85G*
6	*HMS-0D - HMS-3D*	16.00	13.30		225A	225A	3	*300NG*
7	*ACF-12*	156.00	94.00	125	225A	225A	3	*230G*
8	*VACUUM PUMP (VCP-1)*	104.00		3(40)	200A	200A	3	*200G - (2 ACTIVE, 1 STAND-BY)*
9	*SPARE*				100A	30A	3	
10	*SPARE*				100A	30A	3	
11								
12								
13								
14								
15								
16								
17								
18								

PROVIDE INTEGRAL TVSS UNIT

Figure 3.29: Existing panelboard schedule EDPS-M42



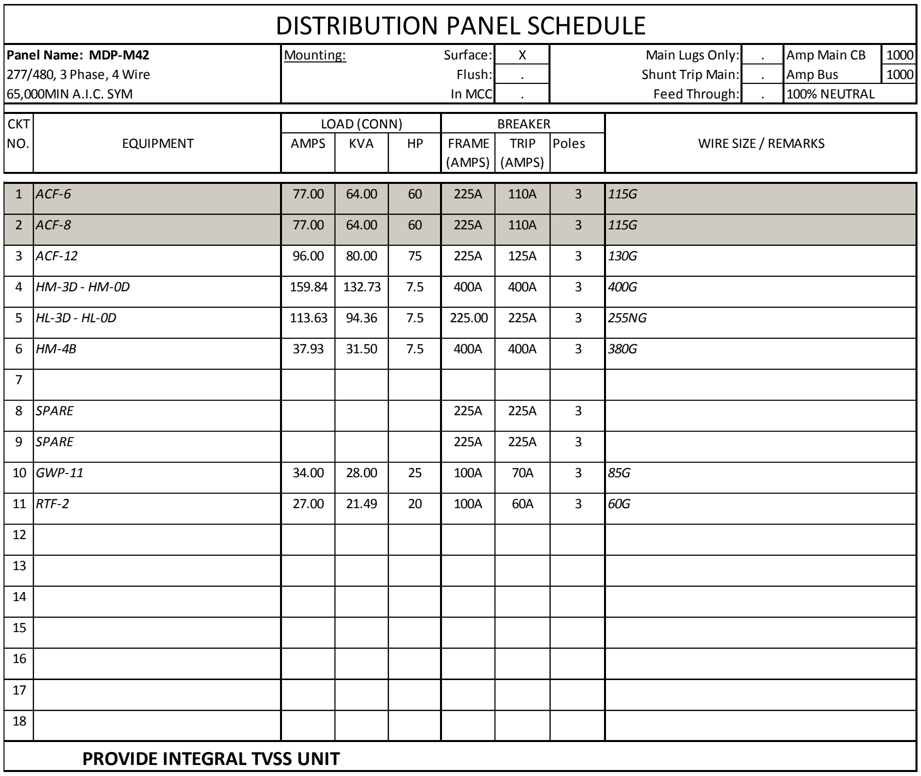
DISTRIBUTION PANEL SCHEDULE

Panel Name: MDP-M41	Mounting:	Surface:	X	Main Lugs Only:	.	Amp Main CB	1000
277/480, 3 Phase, 4 Wire		Flush:	.	Shunt Trip Main:	.	Amp Bus	1000
65,000MIN A.I.C. SYM		In MCC	.	Feed Through:	.	100% NEUTRAL	

CKT		LOAD (CONN)			BREAKER			
NO.	EQUIPMENT	AMPS	KVA	HP	FRAME (AMPS)	TRIP (AMPS)	Poles	WIRE SIZE / REMARKS
1	*ACF-7*	77.00	63.00	60	225A	110A	3	*115G*
2	*RTF-1*	40.00	33.00	30	100A	80A	3	*85G*
3	*GWP-12*	34.00	28.00	25	100A	70A	3	*85G (STAND-BY)*
4	*RTF-3*	27.00	21.49	20	100A	60A	3	*60G*
5	*HM-3B - HM-0B*	57.44	47.70		225A	225A	3	*255G*
6	*HL-3B - HL-0B*	166.74	138.00		400A	400A	3	*400NG*
7	*HM-4A*	26.19	21.75		400A	400A	3	*380G*
8	*HL-M4*	9.15	7.60		100A	100A	3	*115NG*
9	*LR-4C VIA 30 KVA XFMR 'TRE-LR-4C'*	18.70	15.50		100A	50A	3	*50G*
10	*SPARE*				225A	225A	3	
11	*SPARE*				225A	225A	3	
12								
13								
14								
15								
16								
17								
18								

PROVIDE INTEGRAL TVSS UNIT

Figure 3.30: Existing panelboard schedule MDP-M41



DISTRIBUTION PANEL SCHEDULE

Panel Name: MDP-M42	Mounting:	Surface:	X	Main Lugs Only:	.	Amp Main CB	1000
277/480, 3 Phase, 4 Wire		Flush:	.	Shunt Trip Main:	.	Amp Bus	1000
65,000MIN A.I.C. SYM		In MCC	.	Feed Through:	.	100% NEUTRAL	

CKT		LOAD (CONN)			BREAKER			
NO.	EQUIPMENT	AMPS	KVA	HP	FRAME (AMPS)	TRIP (AMPS)	Poles	WIRE SIZE / REMARKS
1	*ACF-6*	77.00	64.00	60	225A	110A	3	*115G*
2	*ACF-8*	77.00	64.00	60	225A	110A	3	*115G*
3	*ACF-12*	96.00	80.00	75	225A	125A	3	*130G*
4	*HM-3D - HM-0D*	159.84	132.73	7.5	400A	400A	3	*400G*
5	*HL-3D - HL-0D*	113.63	94.36	7.5	225.00	225A	3	*255NG*
6	*HM-4B*	37.93	31.50	7.5	400A	400A	3	*380G*
7								
8	*SPARE*				225A	225A	3	
9	*SPARE*				225A	225A	3	
10	*GWP-11*	34.00	28.00	25	100A	70A	3	*85G*
11	*RTF-2*	27.00	21.49	20	100A	60A	3	*60G*
12								
13								
14								
15								
16								
17								
18								

PROVIDE INTEGRAL TVSS UNIT

Figure 3.31: Existing panelboard schedule MDP-M42

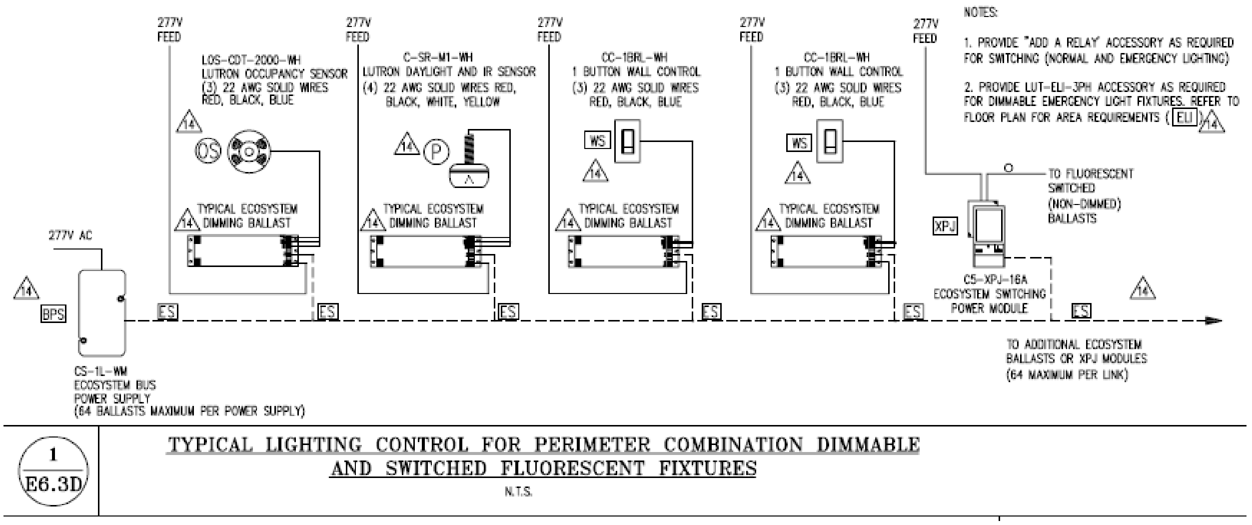


Figure 3.32: Existing control system for dimmable zones

PANELBOARD WORKSHEETS

The following figures are to serve as calculations for sizing panelboards that have been affected by changes in lighting design. There are two factors that have been addressed with respect to the unique nature of these panelboards. First, as most of the affected panelboards have more than 60% spare capacity already built in, the calculation has been changed to address each spare individually, rather than one multiplier to the connected load. Secondly, all receptacle circuits have been addressed with respect to NFPA 70: The National Electric Code Table 220.44 (seen below in Figure 3.23). This calculation was built-in to the panelboard sizing worksheet.

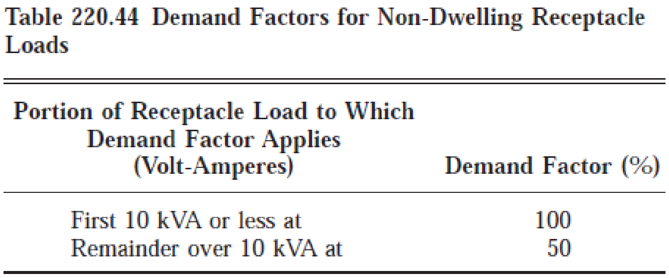


Table 220.44 Demand Factors for Non-Dwelling Receptacle Loads

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 3.33: NEC Table 220.44

The spare capacity sizing was performed under a "worst case scenario" including the application of continuous loading and maximum branch circuit current per breaker. The two scenarios were computed as follows:

20A Branch Circuit Protection for "Spare" circuits

20A x 80% Loaded x 80% for continuous = 12.8A

This current is then applied to both 120V and 277V

12.8A x 120V panelboard voltage = 1536 VA
→ Round to 1500 VA for a 208Y/120V Branch Circuit

12.8A x 277V panelboard voltage = 3545.6 VA
→ Round to 3500 VA for a 480Y/277V Branch Circuit

Please not that each circuit redesign load was calculated as if it were feeding only the space being changed. This means that if corridor lights appear on both the office redesign and the study redesign circuits, only the color-coded space will be applied. The summary of all redesigned circuits are as follows:

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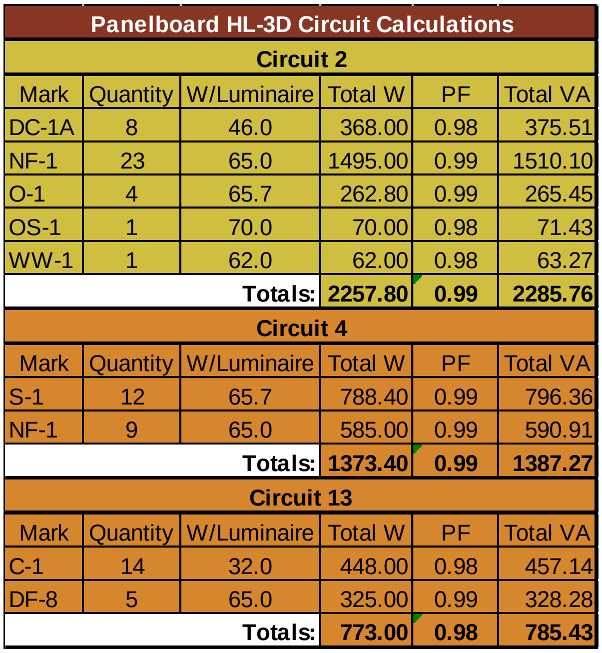
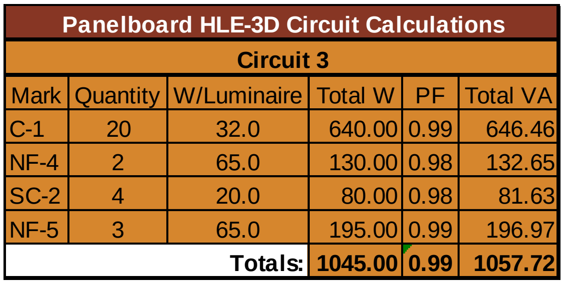
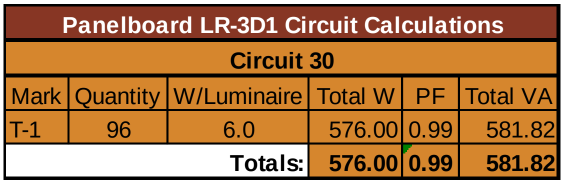


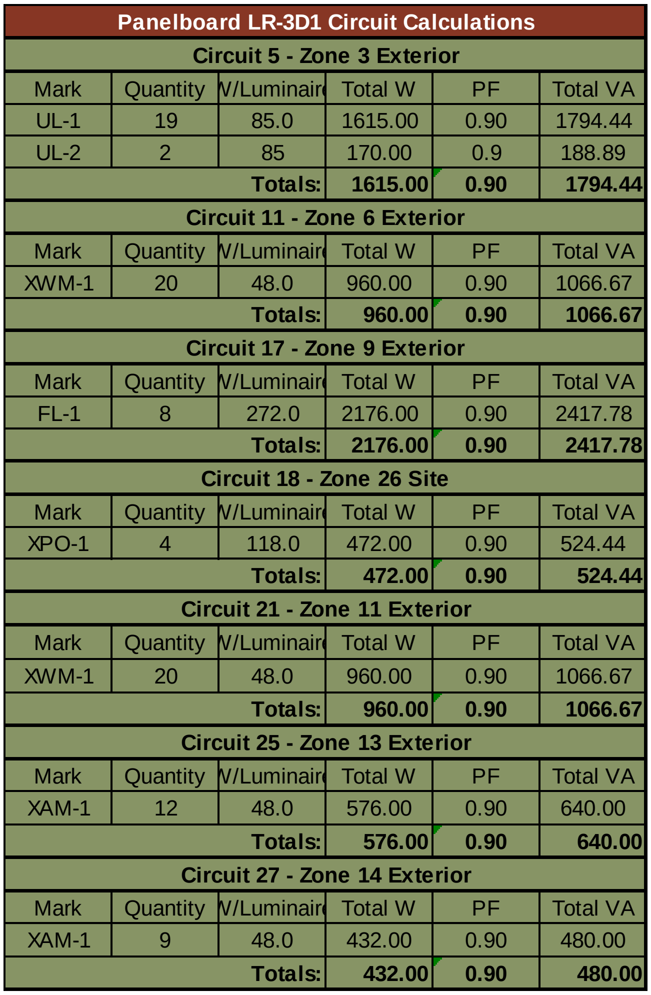
Panelboard HL-3D Circuit Calculations					
Circuit 2					
Mark	Quantity	W/Luminaire	Total W	PF	Total VA
DC-1A	8	46.0	368.00	0.98	375.51
NF-1	23	65.0	1495.00	0.99	1510.10
O-1	4	65.7	262.80	0.99	265.45
OS-1	1	70.0	70.00	0.98	71.43
WW-1	1	62.0	62.00	0.98	63.27
		Totals:	**2257.80**	**0.99**	**2285.76**
Circuit 4					
Mark	Quantity	W/Luminaire	Total W	PF	Total VA
S-1	12	65.7	788.40	0.99	796.36
NF-1	9	65.0	585.00	0.99	590.91
		Totals:	**1373.40**	**0.99**	**1387.27**
Circuit 13					
Mark	Quantity	W/Luminaire	Total W	PF	Total VA
C-1	14	32.0	448.00	0.98	457.14
DF-8	5	65.0	325.00	0.99	328.28
		Totals:	**773.00**	**0.98**	**785.43**



Panelboard HLE-3D Circuit Calculations					
Circuit 3					
Mark	Quantity	W/Luminaire	Total W	PF	Total VA
C-1	20	32.0	640.00	0.99	646.46
NF-4	2	65.0	130.00	0.98	132.65
SC-2	4	20.0	80.00	0.98	81.63
NF-5	3	65.0	195.00	0.99	196.97
		Totals:	**1045.00**	**0.99**	**1057.72**

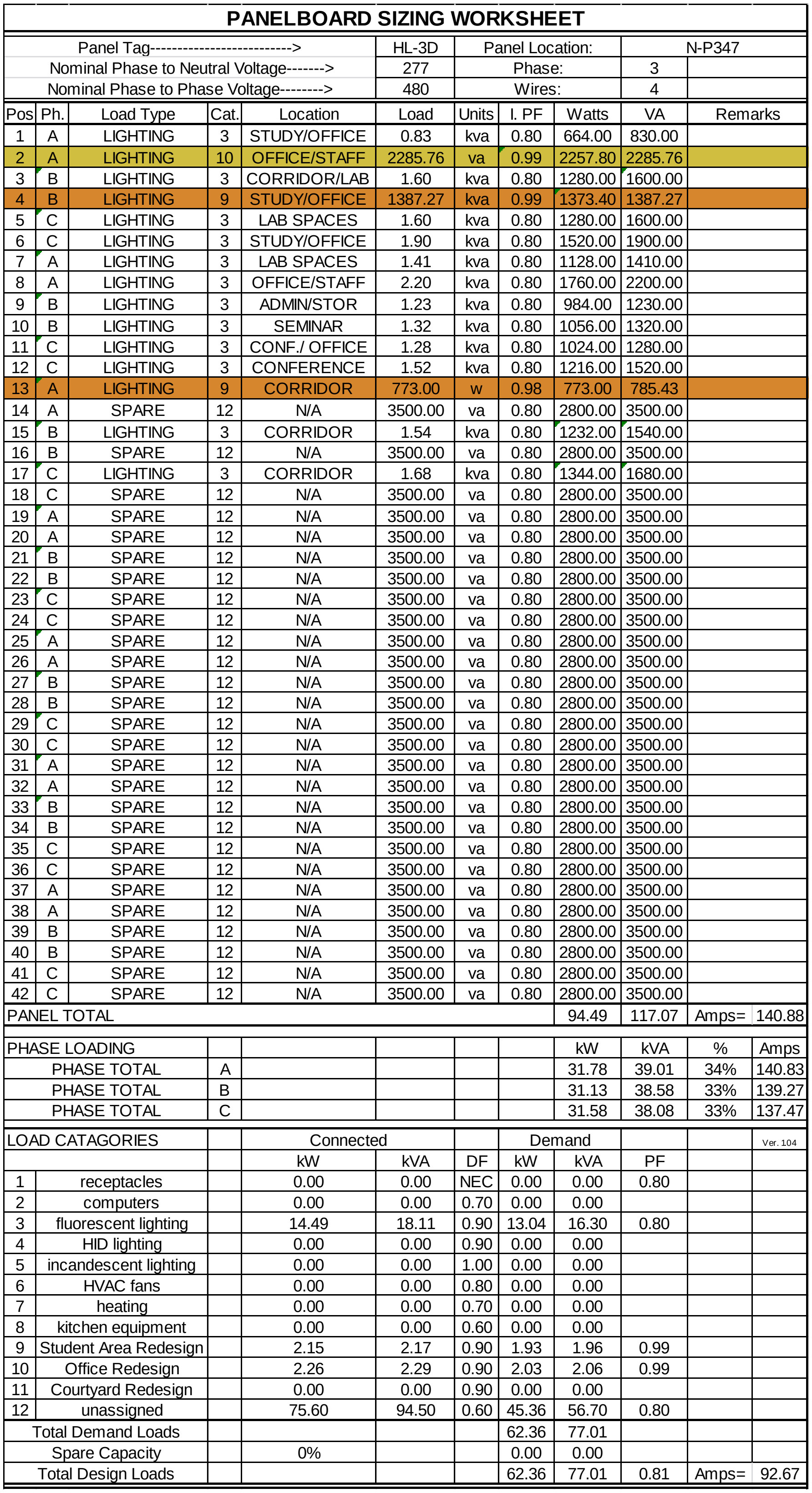


Panelboard LR-3D1 Circuit Calculations					
Circuit 30					
Mark	Quantity	W/Luminaire	Total W	PF	Total VA
T-1	96	6.0	576.00	0.99	581.82
		Totals:	**576.00**	**0.99**	**581.82**



Panelboard LR-3D1 Circuit Calculations					
Circuit 5 - Zone 3 Exterior					
Mark	Quantity	W/Luminair	Total W	PF	Total VA
UL-1	19	85.0	1615.00	0.90	1794.44
UL-2	2	85	170.00	0.9	188.89
		Totals:	**1615.00**	**0.90**	**1794.44**
Circuit 11 - Zone 6 Exterior					
Mark	Quantity	W/Luminair	Total W	PF	Total VA
XWM-1	20	48.0	960.00	0.90	1066.67
		Totals:	**960.00**	**0.90**	**1066.67**
Circuit 17 - Zone 9 Exterior					
Mark	Quantity	W/Luminair	Total W	PF	Total VA
FL-1	8	272.0	2176.00	0.90	2417.78
		Totals:	**2176.00**	**0.90**	**2417.78**
Circuit 18 - Zone 26 Site					
Mark	Quantity	W/Luminair	Total W	PF	Total VA
XPO-1	4	118.0	472.00	0.90	524.44
		Totals:	**472.00**	**0.90**	**524.44**
Circuit 21 - Zone 11 Exterior					
Mark	Quantity	W/Luminair	Total W	PF	Total VA
XWM-1	20	48.0	960.00	0.90	1066.67
		Totals:	**960.00**	**0.90**	**1066.67**
Circuit 25 - Zone 13 Exterior					
Mark	Quantity	W/Luminair	Total W	PF	Total VA
XAM-1	12	48.0	576.00	0.90	640.00
		Totals:	**576.00**	**0.90**	**640.00**
Circuit 27 - Zone 14 Exterior					
Mark	Quantity	W/Luminair	Total W	PF	Total VA
XAM-1	9	48.0	432.00	0.90	480.00
		Totals:	**432.00**	**0.90**	**480.00**

Since the spare circuits were addressed individually, no spare capacity multiplier appears in the panelboard sizing worksheets. The following figures contain calculations for panelboard sizing:



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	I. PF	Watts	VA	Remarks	
1	A	LIGHTING	3	STUDY/OFFICE	0.83	kva	0.80	664.00	830.00		
2	A	LIGHTING	10	OFFICE/STAFF	2285.76	va	0.99	2257.80	2285.76		
3	B	LIGHTING	3	CORRIDOR/LAB	1.60	kva	0.80	1280.00	1600.00		
4	B	LIGHTING	9	STUDY/OFFICE	1387.27	kva	0.99	1373.40	1387.27		
5	C	LIGHTING	3	LAB SPACES	1.60	kva	0.80	1280.00	1600.00		
6	C	LIGHTING	3	STUDY/OFFICE	1.90	kva	0.80	1520.00	1900.00		
7	A	LIGHTING	3	LAB SPACES	1.41	kva	0.80	1128.00	1410.00		
8	A	LIGHTING	3	OFFICE/STAFF	2.20	kva	0.80	1760.00	2200.00		
9	B	LIGHTING	3	ADMIN/STOR	1.23	kva	0.80	984.00	1230.00		
10	B	LIGHTING	3	SEMINAR	1.32	kva	0.80	1056.00	1320.00		
11	C	LIGHTING	3	CONF./ OFFICE	1.28	kva	0.80	1024.00	1280.00		
12	C	LIGHTING	3	CONFERENCE	1.52	kva	0.80	1216.00	1520.00		
13	A	LIGHTING	9	CORRIDOR	773.00	w	0.98	773.00	785.43		
14	A	SPARE	12	N/A	3500.00	va	0.80	2800.00	3500.00		
15	B	LIGHTING	3	CORRIDOR	1.54	kva	0.80	1232.00	1540.00		
16	B	SPARE	12	N/A	3500.00	va	0.80	2800.00	3500.00		
17	C	LIGHTING	3	CORRIDOR	1.68	kva	0.80	1344.00	1680.00		
18	C	SPARE	12	N/A	3500.00	va	0.80	2800.00	3500.00		
19	A	SPARE	12	N/A	3500.00	va	0.80	2800.00	3500.00		
20	A	SPARE	12	N/A	3500.00	va	0.80	2800.00	3500.00		
21	B	SPARE	12	N/A	3500.00	va	0.80	2800.00	3500.00		
22	B	SPARE	12	N/A	3500.00	va	0.80	2800.00	3500.00		
23	C	SPARE	12	N/A	3500.00	va	0.80	2800.00	3500.00		
24	C	SPARE	12	N/A	3500.00	va	0.80	2800.00	3500.00		
25	A	SPARE	12	N/A	3500.00	va	0.80	2800.00	3500.00		
26	A	SPARE	12	N/A	3500.00	va	0.80	2800.00	3500.00		
27	B	SPARE	12	N/A	3500.00	va	0.80	2800.00	3500.00		
28	B	SPARE	12	N/A	3500.00	va	0.80	2800.00	3500.00		
29	C	SPARE	12	N/A	3500.00	va	0.80	2800.00	3500.00		
30	C	SPARE	12	N/A	3500.00	va	0.80	2800.00	3500.00		
31	A	SPARE	12	N/A	3500.00	va	0.80	2800.00	3500.00		
32	A	SPARE	12	N/A	3500.00	va	0.80	2800.00	3500.00		
33	B	SPARE	12	N/A	3500.00	va	0.80	2800.00	3500.00		
34	B	SPARE	12	N/A	3500.00	va	0.80	2800.00	3500.00		
35	C	SPARE	12	N/A	3500.00	va	0.80	2800.00	3500.00		
36	C	SPARE	12	N/A	3500.00	va	0.80	2800.00	3500.00		
37	A	SPARE	12	N/A	3500.00	va	0.80	2800.00	3500.00		
38	A	SPARE	12	N/A	3500.00	va	0.80	2800.00	3500.00		
39	B	SPARE	12	N/A	3500.00	va	0.80	2800.00	3500.00		
40	B	SPARE	12	N/A	3500.00	va	0.80	2800.00	3500.00		
41	C	SPARE	12	N/A	3500.00	va	0.80	2800.00	3500.00		
42	C	SPARE	12	N/A	3500.00	va	0.80	2800.00	3500.00		
PANEL TOTAL								94.49	117.07	Amps=	140.88
PHASE LOADING								kW	kVA	%	Amps
PHASE TOTAL			A					31.78	39.01	34%	140.83
PHASE TOTAL			B					31.13	38.58	33%	139.27
PHASE TOTAL			C					31.58	38.08	33%	137.47
LOAD CATAGORIES				Connected			Demand				Ver. 104
				kW	kVA	DF	kW	kVA	PF		
1	receptacles			0.00	0.00	NEC	0.00	0.00	0.80		
2	computers			0.00	0.00	0.70	0.00	0.00			
3	fluorescent lighting			14.49	18.11	0.90	13.04	16.30	0.80		
4	HID lighting			0.00	0.00	0.90	0.00	0.00			
5	incandescent lighting			0.00	0.00	1.00	0.00	0.00			
6	HVAC fans			0.00	0.00	0.80	0.00	0.00			
7	heating			0.00	0.00	0.70	0.00	0.00			
8	kitchen equipment			0.00	0.00	0.60	0.00	0.00			
9	Student Area Redesign			2.15	2.17	0.90	1.93	1.96	0.99		
10	Office Redesign			2.26	2.29	0.90	2.03	2.06	0.99		
11	Courtyard Redesign			0.00	0.00	0.90	0.00	0.00			
12	unassigned			75.60	94.50	0.60	45.36	56.70	0.80		
Total Demand Loads							62.36	77.01			
Spare Capacity				0%			0.00	0.00			
Total Design Loads							62.36	77.01	0.81	Amps=	92.67

Figure 3.34: Panelboard worksheet for HL-3D

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	12	CORRIDOR	0.10	kva	0.80	80.00	100.00		
2	A	LIGHTING	3	STAIR N-1	1.02	kva	0.80	816.00	1020.00		
3	B	LIGHTING	9	RR/CORRIDOR	1.05	w	0.99	1045.00	1057.72		
4	B	LIGHTING	3	STAIR N-1	1.45	kva	0.80	1160.00	1450.00		
5	C	LIGHTING	3	OFFICE	2.30	kva	0.80	1840.00	2300.00		
6	C	SPARE	12	N/A	3500.00	va	0.80	2800.00	3500.00		
7	A	SPARE	12	N/A	3500.00	va	0.80	2800.00	3500.00		
8	A	SPARE	12	N/A	3500.00	va	0.80	2800.00	3500.00		
9	B	SPARE	12	N/A	3500.00	va	0.80	2800.00	3500.00		
10	B	SPARE	12	N/A	3500.00	va	0.80	2800.00	3500.00		
11	C	SPARE	12	N/A	3500.00	va	0.80	2800.00	3500.00		
12	C	SPARE	12	N/A	3500.00	va	0.80	2800.00	3500.00		
13	A	SPARE	12	N/A	3500.00	va	0.80	2800.00	3500.00		
14	A	SPARE	12	N/A	3500.00	va	0.80	2800.00	3500.00		
15	B	SPARE	12	N/A	3500.00	va	0.80	2800.00	3500.00		
16	B	SPARE	12	N/A	3500.00	va	0.80	2800.00	3500.00		
17	C	SPARE	12	N/A	3500.00	va	0.80	2800.00	3500.00		
18	C	SPARE	12	N/A	3500.00	va	0.80	2800.00	3500.00		
19	A	SPARE	12	N/A	3500.00	va	0.80	2800.00	3500.00		
20	A	SPARE	12	N/A	3500.00	va	0.80	2800.00	3500.00		
21	B	SPARE	12	N/A	3500.00	va	0.80	2800.00	3500.00		
22	B	SPARE	12	N/A	3500.00	va	0.80	2800.00	3500.00		
23	C	SPARE	12	N/A	3500.00	va	0.80	2800.00	3500.00		
24	C	SPARE	12	N/A	3500.00	va	0.80	2800.00	3500.00		
25	A	SPARE	12	N/A	3500.00	va	0.80	2800.00	3500.00		
26	A	SPARE	12	N/A	3500.00	va	0.80	2800.00	3500.00		
27	B	SPARE	12	N/A	3500.00	va	0.80	2800.00	3500.00		
28	B	SPARE	12	N/A	3500.00	va	0.80	2800.00	3500.00		
29	C	SPARE	12	N/A	3500.00	va	0.80	2800.00	3500.00		
30	C	SPARE	12	N/A	3500.00	va	0.80	2800.00	3500.00		
31	A	SPARE	12	N/A	3500.00	va	0.80	2800.00	3500.00		
32	A	SPARE	12	N/A	3500.00	va	0.80	2800.00	3500.00		
33	B	SPARE	12	N/A	3500.00	va	0.80	2800.00	3500.00		
34	B	SPARE	12	N/A	3500.00	va	0.80	2800.00	3500.00		
35	C	SPARE	12	N/A	3500.00	va	0.80	2800.00	3500.00		
36	C	SPARE	12	N/A	3500.00	va	0.80	2800.00	3500.00		
37	A	FEEDER	12	TO LE-3D	4.94	kva	0.80	3952.00	4940.00		
38	A	SPARE	12	N/A	3500.00	va	0.80	2800.00	3500.00		
39	B	FEEDER	12	TO LE-3D	3.80	kva	0.80	3040.00	3800.00		
40	B	SPARE	12	N/A	3500.00	va	0.80	2800.00	3500.00		
41	C	FEEDER	12	TO LE-3D	3.80	kva	0.80	3040.00	3800.00		
42	C	SPARE	12	N/A	3500.00	va	0.80	2800.00	3500.00		
PANEL TOTAL								110.17	137.47	Amps=	165.42
PHASE LOADING								kW	kVA	%	Amps
PHASE TOTAL			A					35.65	44.56	33%	160.87
PHASE TOTAL			B					36.05	44.81	33%	161.76
PHASE TOTAL			C					38.48	46.64	34%	168.38
LOAD CATAGORIES				Connected			Demand				Ver. 104
				kW	kVA	DF	kW	kVA	PF		
1	receptacles			0.00	0.00	NEC	0.00	0.00	0.80		
2	computers			0.00	0.00	0.70	0.00	0.00			
3	fluorescent lighting			3.82	4.77	0.90	3.43	4.29	0.80		
4	HID lighting			0.00	0.00	0.90	0.00	0.00			
5	incandescent lighting			0.00	0.00	1.00	0.00	0.00			
6	HVAC fans			0.00	0.00	0.80	0.00	0.00			
7	heating			0.00	0.00	0.70	0.00	0.00			
8	kitchen equipment			0.00	0.00	0.60	0.00	0.00			
9	Student Area Redesign			1.05	1.06	0.90	0.94	0.95	0.99		
10	Corridor Redesign			0.00	0.00	0.90	0.00	0.00			
11	Office Redesign			0.00	0.00	0.90	0.00	0.00			
12	unassigned			105.31	131.64	0.60	63.19	78.98	0.80		
Total Demand Loads							67.56	84.23			
Spare Capacity				0%			0.00	0.00			
Total Design Loads							67.56	84.23	0.80	Amps=	101.36

Figure 3.35: Panelboard worksheet for HLE-3D

PANELBOARD SIZING WORKSHEET

Panel Tag------------------------->					LR-3D1	Panel Location:			N-P346		
Nominal Phase to Neutral Voltage------->					120	Phase:			3		
Nominal Phase to Phase Voltage-------->					208	Wires:			4		
Pos	Ph.	Load Type	Cat.	Location	Load	Units	I. PF	Watts	VA	Remarks	
1	A	PC RECEP	2	3F MAT SCI	0.80	kva	0.88	704.00	800.00		
2	A	PC RECEP	2	3F MAT SCI	0.80	kva	0.88	704.00	800.00		
3	B	RECEPTACLE	1	3F MAT SCI	1.08	kva	0.80	864.00	1080.00		
4	B	PC RECEP	2	3F MAT SCI	0.80	kva	0.88	704.00	800.00		
5	C	PC RECEP	2	3F MAT SCI	0.80	kva	0.88	704.00	800.00		
6	C	PC RECEP	2	3F MAT SCI	0.80	kva	0.88	704.00	800.00		
7	A	RECEPTACLE	1	3F MAT SCI	1.08	kva	0.80	864.00	1080.00		
8	A	PC RECEP	2	3F MAT SCI	0.80	kva	0.88	704.00	800.00		
9	B	PC RECEP	2	3F MAT SCI	0.80	kva	0.88	704.00	800.00		
10	B	PC RECEP	2	3F MAT SCI	0.80	kva	0.88	704.00	800.00		
11	C	RECEPTACLE	1	3F MAT SCI	0.54	kva	0.80	432.00	540.00		
12	C	PC RECEP	2	3F MAT SCI	0.80	kva	0.88	704.00	800.00		
13	A	PC RECEP	2	3F MAT SCI	0.80	kva	0.88	704.00	800.00		
14	A	PC RECEP	2	3F MAT SCI	0.80	kva	0.88	704.00	800.00		
15	B	SPARE	12	N/A	1500.00	va	0.80	1200.00	1500.00		
16	B	PC RECEP	2	3F MAT SCI	0.80	kva	0.88	704.00	800.00		
17	C	PC RECEP	2	3F MAT SCI	1.16	kva	0.88	1020.80	1160.00		
18	C	PC RECEP	2	3F MAT SCI	0.80	kva	0.88	704.00	800.00		
19	A	RECEPTACLE	1	3F MAT SCI	1.08	kva	0.80	864.00	1080.00		
20	A	PC RECEP	2	3F MAT SCI	0.80	kva	0.88	704.00	800.00		
21	B	PC RECEP	2	3F MAT SCI	0.72	kva	0.88	633.60	720.00		
22	B	CLN RECEP	1	3F MAT SCI	0.80	kva	0.80	640.00	800.00		
23	C	PC RECEP	2	3F MAT SCI	0.90	kva	0.88	792.00	900.00		
24	C	CLN RECEP	1	3F MAT SCI	0.80	kva	0.80	640.00	800.00		
25	A	PC RECEP	2	3F MAT SCI	0.72	kva	0.88	633.60	720.00		
26	A	CLN RECEP	1	3F MAT SCI	0.80	kva	0.80	640.00	800.00		
27	B	RECEPTACLE	1	3F MAT SCI	0.72	kva	0.80	576.00	720.00		
28	B	CLN RECEP	1	3F MAT SCI	0.80	kva	0.80	640.00	800.00		
29	C	PC RECEP	2	3F MAT SCI	0.40	kva	0.88	352.00	400.00		
30	C	LIGHTING	9	N-324 THRU 328	576.00	w	0.80	576.00	720.00		
31	A	RECEPTACLE	1	N/A	0.36	kva	0.80	288.00	360.00		
32	A	SPARE	12	N/A	1500.00	va	0.80	1200.00	1500.00		
33	B	RECEPTACLE	1	N/A	0.72	kva	0.80	576.00	720.00		
34	B	SPARE	12	N/A	1500.00	va	0.80	1200.00	1500.00		
35	C	SPARE	12	N/A	1500.00	va	0.80	1200.00	1500.00		
36	C	SPARE	12	N/A	1500.00	va	0.80	1200.00	1500.00		
37	A	SPARE	12	N/A	1500.00	va	0.80	1200.00	1500.00		
38	A	SPARE	12	N/A	1500.00	va	0.80	1200.00	1500.00		
39	B	SPARE	12	N/A	1500.00	va	0.80	1200.00	1500.00		
40	B	SPARE	12	N/A	1500.00	va	0.80	1200.00	1500.00		
41	C	SPARE	12	N/A	1500.00	va	0.80	1200.00	1500.00		
42	C	SPARE	12	N/A	1500.00	va	0.80	1200.00	1500.00		
PANEL TOTAL								34.09	41.10	Amps=	114.17
PHASE LOADING								kW	kVA	%	Amps
PHASE TOTAL			A					11.11	13.34	33%	111.17
PHASE TOTAL			B					11.55	14.04	35%	117.00
PHASE TOTAL			C					11.43	13.12	32%	109.33
LOAD CATAGORIES				Connected			Demand				Ver. 104
				kW	kVA	DF	kW	kVA	PF		
1	receptacles			7.02	8.78	NEC	7.02	8.78	0.80		
2	computers			13.29	15.10	0.70	9.30	10.57	0.88		
3	fluorescent lighting			0.00	0.00	0.90	0.00	0.00			
4	HID lighting			0.00	0.00	0.90	0.00	0.00			
5	incandescent lighting			0.00	0.00	1.00	0.00	0.00			
6	HVAC fans			0.00	0.00	0.80	0.00	0.00			
7	heating			0.00	0.00	0.70	0.00	0.00			
8	kitchen equipment			0.00	0.00	0.60	0.00	0.00			
9	Student Area Redesign			0.58	0.72	0.90	0.52	0.65	0.80		
10	Corridor Redesign			0.00	0.00	0.90	0.00	0.00			
11	Office Redesign			0.00	0.00	0.90	0.00	0.00			
12	unassigned			13.20	16.50	0.60	7.92	9.90	0.80		
Total Demand Loads							24.76	29.90			
Spare Capacity				0%			0.00	0.00			
Total Design Loads							24.76	29.90	0.83	Amps=	83.05

Figure 3.36: Panelboard worksheet for LR-3D1

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	LIGHTING	3	ZONE 1 LS LBY	0.42	kva	0.80	336.00	420.00	
2	A	LIGHTING	12	ZONE 18 SITE	0.72	kva	0.80	576.00	720.00	
3	B	SPARE	12	N/A	3500.00	va	0.80	2800.00	3500.00	
4	B	SPARE	12	N/A	3500.00	va	0.80	2800.00	3500.00	
5	C	LIGHTING	11	ZONE 3 EXT	1615.00	w	0.90	1615.00	1794.44	
6	C	LIGHTING	12	ZONE 20 SITE	0.24	kva	0.80	192.00	240.00	
7	A	LIGHTING	3	ZONE 4 LS LBY	0.31	kva	0.80	248.00	310.00	
8	A	SPARE	12	N/A	3500.00	va	0.80	2800.00	3500.00	
9	B	LIGHTING	3	ZONE 5 LS LBY	0.56	kva	0.80	448.00	560.00	
10	B	LIGHTING	12	ZONE 22 SITE	0.70	kva	0.80	560.00	700.00	
11	C	LIGHTING	11	ZONE 6 EXT	960.00	w	0.90	960.00	1066.67	
12	C	SPARE	12	N/A	3500.00	va	0.80	2800.00	3500.00	
13	A	LIGHTING	3	ZONE 7 ML LBY	0.84	kva	0.80	672.00	840.00	
14	A	SPARE	12	N/A	3500.00	va	0.80	2800.00	3500.00	
15	B	LIGHTING	3	ZONE 8 ML LBY	0.56	kva	0.80	448.00	560.00	
16	B	SPARE	12	N/A	3500.00	va	0.80	2800.00	3500.00	
17	C	LIGHTING	11	ZONE 9 EXT	2176.00	w	0.90	2176.00	2417.78	
18	C	LIGHTING	11	ZONE 26 SITE	472.00	w	0.90	472.00	524.44	
19	A	SPARE	12	N/A	3500.00	va	0.80	2800.00	3500.00	
20	A	LIGHTING	12	ZONE 27 SITE	0.05	kva	0.80	40.00	50.00	
21	B	LIGHTING	11	ZONE 11 EXT	960.00	w	0.90	960.00	1066.67	
22	B	LIGHTING	12	ZONE 28 SITE	0.40	kva	0.80	320.00	400.00	
23	C	LIGHTING	3	ZONE 12 ML LBY	0.31	kva	0.80	248.00	310.00	
24	C	LIGHTING	4	ZONE 29 EXT	0.27	kva	0.90	243.00	270.00	
25	A	LIGHTING	11	ZONE 13 EXT	576.00	w	0.90	576.00	640.00	
26	A	LIGHTING	4	ZONE 30 EXT	0.27	kva	0.90	243.00	270.00	
27	B	LIGHTING	11	ZONE 14 EXT	432.00	w	0.90	432.00	480.00	
28	B	LIGHTING	4	ZONE 31 EXT	0.23	kva	0.90	207.00	230.00	
29	C	LIGHTING	12	ZONE 15 SITE	1.70	kva	0.80	1360.00	1700.00	
30	C	LIGHTING	4	ZONE 32 EXT	0.20	kva	0.90	180.00	200.00	
31	A	LIGHTING	12	ZONE 16 SITE	1.40	kva	0.80	1120.00	1400.00	
32	A	LIGHTING	4	ZONE 33 EXT	0.23	kva	0.90	207.00	230.00	
33	B	LIGHTING	12	ZONE 17 SITE	1.60	kva	0.80	1280.00	1600.00	
34	B	LIGHTING	4	ZONE 34 EXT	0.27	kva	0.90	243.00	270.00	
35	C	LIGHTING	3	ZONE 35 ML LBY	0.46	kva	0.80	368.00	460.00	
36	C	LIGHTING	3	ZONE 36 LS LBY	0.42	kva	0.80	336.00	420.00	
37	A	SPARE	12	N/A	3500.00	va	0.80	2800.00	3500.00	
38	A	SPARE	12	N/A	3500.00	va	0.80	2800.00	3500.00	
39	B	SPARE	12	N/A	3500.00	va	0.80	2800.00	3500.00	
40	B	SPARE	12	N/A	3500.00	va	0.80	2800.00	3500.00	
41	C	SPARE	12	N/A	3500.00	va	0.80	2800.00	3500.00	
42	C	SPARE	12	N/A	3500.00	va	0.80	2800.00	3500.00	
PANEL TOTAL								53.47	65.65	Amps= 79.00

PHASE LOADING		kW	kVA	%	Amps
PHASE TOTAL	A	18.02	22.38	34%	80.79
PHASE TOTAL	B	18.90	23.37	36%	84.36
PHASE TOTAL	C	16.55	19.90	30%	71.85

LOAD CATAGORIES		Connected			Demand				
									Ver. 104
		kW	kVA	DF	kW	kVA	PF		
1	receptacles	0.00	0.00	NEC	0.00	0.00	0.80		
2	computers	0.00	0.00	0.70	0.00	0.00			
3	fluorescent lighting	3.10	3.88	0.90	2.79	3.49	0.80		
4	HID lighting	1.32	1.47	0.90	1.19	1.32	0.90		
5	incandescent lighting	0.00	0.00	1.00	0.00	0.00			
6	HVAC fans	0.00	0.00	0.80	0.00	0.00			
7	heating	0.00	0.00	0.70	0.00	0.00			
8	kitchen equipment	0.00	0.00	0.60	0.00	0.00			
9	Student Area Redesign	0.00	0.00	0.90	0.00	0.00			
10	Office Redesign	0.00	0.00	0.90	0.00	0.00			
11	Courtyard (HID)	7.19	7.99	0.90	6.47	7.19	0.90		
12	unassigned	41.85	52.31	0.60	25.11	31.39	0.80		
Total Demand Loads					35.57	43.39			
Spare Capacity		0%			0.00	0.00			
Total Design Loads					35.57	43.39	0.82	Amps=	52.22

Figure 3.37: Panelboard worksheet for LCP-1

Air Handling Unit Branch Circuit Sizing

According to the National Electrical Code Article 430.24 and Article 430.53(C), several motors on one circuit, as in the case of the mechanical system redesign, the total ampacity of the circuit conductor cannot be less than 125% of the largest motor full load current plus 100% of the full load current of each additional motor and the overcurrent device can be sized to 250% of the largest motor full load amps in the circuit's motor group. These sections of the NEC results in the following calculation for air handling units:

$$43\ Series, 75hp\ Circuits$$

$$Conductor\ Ampacity = (1.25)(96A) + 96A = 216A$$

4/0 AWG feeding into the air handling unit

$$Overcurrent\ Device = (96A)(2.5) = 240A$$

250A inverse-time current circuit breaker

#4 ground based on breaker size

$$35\ Series, 50hp\ Circuits$$

$$Conductor\ Ampacity = (1.25)(65A) + 65A = 146.25A$$

1/0 AWG feeding into the air handling unit

$$Overcurrent\ Device = (65A)(2.5) = 162.5A$$

175A inverse-time current circuit breaker

#6 ground based on breaker size

REVISED PANELBOARD SCHEDULES

As discussed in the "Panelboard Worksheets" section of this unit, the spare circuits were addressed individually. These appear in the revised panelboard schedules as having "3.5kVA" or "1.5kVA" loads, whereas the original panelboard schedules have been left blank. These sizing adjustments allow for a worst-case-scenario of feeder sizing for each panel. The demand factors seen in the revised panelboard schedules were computed using the panelboard worksheets seen in the previous section. A summary of the demand factor calculation is as follows:

Panelboard Demand Factor Summary

Panelboard	Connected VA	Demand VA	Calculated DF
HL-3D	117.07	77.01	65.78%
HLE-3D	137.47	84.23	64.27%
LR-3D1	41.10	29.90	72.74%
LCP-1	65.50	43.39	66.24%

As with the existing panelboard schedules, some naming conventions and some original typographical errors have not changed. The revised feeder schedule and panelboard schedules are as follows:

BRANCH CIRCUIT PANELBOARD SCHEDULE

Panel Name: HL-3D	Mounting:	Surface:	X	Main Lugs Only:	.	Amp Main CB	125
277/480, 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	Load	TRIP	KVA/Phase			Poles	Poles	KVA/Phase			TRIP	Load	CKT
No.		(Amp)	A	B	C			A	B	C	(Amp)		No.
1	*STUDENT LIGHTING*	20	0.83			1	2	2.29			20	*STAFF & FACULTY LTG*	2
3	*ELECTROACTIVE POLY LTG*	20		1.60		3	4		1.39		20	*STUDENT LIGHTING*	4
5	*ORGANIC ELEC & PHO LTG*	20			1.60	5	6			1.90	20	*STUDENT LIGHTING*	6
7	*DRY LAB A&B, STAFF LTG*	20	1.41			7	8	2.20			20	*STAFF LIGHTING*	8
9	*STAFF ADMIN, KITCHEN LTG*	20		1.23		9	10		1.32		20	*CONFERENCE ROOM LTG*	10
11	*DRY LAB, MISC. COMP. LTG*	20			1.28	11	12			1.52	20	*CONFERENCE ROOM LTG*	12
13	*CORRIDOR LIGHTING*	20	0.79			13	14	3.50			20	*SPARE*	14
15	*CORRIDOR LIGHTING*	20		1.54		15	16		3.50		20	*SPARE*	16
17	*CORRIDOR LIGHTING*	20			1.68	17	18			3.50	20	*SPARE*	18
19	*SPARE*	20	3.50			19	20	3.50			20	*SPARE*	20
21	*SPARE*	20		3.50		21	22		3.50		20	*SPARE*	22
23	*SPARE*	20			3.50	23	24			3.50	20	*SPARE*	24
25	*SPARE*	20	3.50			25	26	3.50			20	*SPARE*	26
27	*SPARE*	20		3.50		27	28		3.50		20	*SPARE*	28
29	*SPARE*	20			3.50	29	30			3.50	20	*SPARE*	30
31	*SPARE*	20	3.50			31	32	3.50			20	*SPARE*	32
33	*SPARE*	20		3.50		33	34		3.50		20	*SPARE*	34
35	*SPARE*	20			3.50	35	36			3.50	20	*SPARE*	36
37	*SPARE*	20	3.50			37	38	3.50			20	*SPARE*	38
39	*SPARE*	20		3.50		39	40		3.50		20	*SPARE*	40
41	*SPARE*	20			3.50	41	42			3.50	20	*SPARE*	42
	Subtotals (kVA):		17.03	18.37	18.56			21.99	20.21	20.92		Subtotals (kVA)	

Total Loads:	Phase A:	39.02 kVA	65.78 %	Demand Factor (worksheet)
	Phase B:	38.58 kVA	77.02 kVA	Demand Load
	Phase C:	39.48 kVA	96.27 kVA	Load x 1.25
Total Connected Load:		117.08 kVA	115.93 A	AMP

Figure 3.38: Revised panelboard schedule for HL-3D

BRANCH CIRCUIT PANELBOARD SCHEDULE

Panel Name: HLE-3D	Mounting:	Surface:	X	Main Lugs Only:	.	Amp Main CB	150
277/480, 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	Load	TRIP	KVA/Phase			Poles	Poles	KVA/Phase			TRIP	Load	CKT
No.		(Amp)	A	B	C			A	B	C	(Amp)		No.
1	*EXIT SIGN*	20	0.10			1	2	1.02				*STAIR N-1 LIGHTING*	2
3	*TOILET & CORRIDOR LTG*	20		1.06		3	4		1.45			*STAIR N-1 LIGHTING*	4
5	*OFFICE LIGHTING*	20			2.30	5	6			3.50		*SPARE*	6
7	*SPARE*	20	3.50			7	8	3.50				*SPARE*	8
9	*SPARE*	20		3.50		9	10		3.50			*SPARE*	10
11	*SPARE*	20			3.50	11	12			3.50		*SPARE*	12
13	*SPARE*	20	3.50			13	14	3.50				*SPARE*	14
15	*SPARE*	20		3.50		15	16		3.50			*SPARE*	16
17	*SPARE*	20			3.50	17	18			3.50		*SPARE*	18
19	*SPARE*	20	3.50			19	20	3.50				*SPARE*	20
21	*SPARE*	20		3.50		21	22		3.50			*SPARE*	22
23	*SPARE*	20			3.50	23	24			3.50		*SPARE*	24
25	*SPARE*	20	3.50			25	26	3.50				*SPARE*	26
27	*SPARE*	20		3.50		27	28		3.50			*SPARE*	28
29	*SPARE*	20			3.50	29	30			3.50		*SPARE*	30
31	*SPARE*	20	3.50			31	32	3.50				*SPARE*	32
33	*SPARE*	20		3.50		33	34		3.50			*SPARE*	34
35	*SPARE*	20			3.50	35	36			3.50		*SPARE*	36
37	*PENEL LE-3D VIA*	50	4.94			37	38	3.50				*SPARE*	38
39	*XFMR 'TRE-LE-3D'*			3.80		39	40		3.50			*SPARE*	40
41	*(50G)*	3P			3.80	41	42			3.50		*SPARE*	42
	Subtotals (kVA):		22.54	22.36	23.60			22.02	22.45	24.50		Subtotals (kVA)	

Total Loads:	Phase A:	44.56 kVA	61.27 %	Demand Factor (worksheet)
	Phase B:	44.81 kVA	84.23 kVA	Demand Load
	Phase C:	48.10 kVA	105.28 kVA	Load x 1.25
Total Connected Load:		137.5 kVA	126.79 A	AMP

Figure 3.39: Revised panelboard schedule for HLE-3D

BRANCH CIRCUIT PANELBOARD SCHEDULE

Panel Name: LR-3D1	Mounting:	Surface:	X	Main Lugs Only:	.	Amp Main CB	110
120/208, 3 Phase, 4 Wire		Flush:	.	Shunt Trip Main:	.	Amp Bus	225
10,000MIN A.I.C. SYM		In MCC	.	Feed Through:	X	Ground Bus	X
Neutral: 200%	Number of Poles:		42	TVSS:	.	Isolated Ground Bus	X

CKT	Load	TRIP	KVA/Phase			Poles	Poles	KVA/Phase			TRIP	Load	CKT
No.		(Amp)	A	B	C			A	B	C	(Amp)		No.
1	*P.C. RECEPTACLE*	20	0.80			1	2	0.80			20	*P.C. RECEPTACLE*	2
3	*RECEPTACLE*	20		1.08		3	4		0.80		20	*P.C. RECEPTACLE*	4
5	*P.C. RECEPTACLE*	20			0.80	5	6			0.80	20	*P.C. RECEPTACLE*	6
7	*RECEPTACLE*	20	1.08			7	8	0.80			20	*P.C. RECEPTACLE*	8
9	*P.C. RECEPTACLE*	20		0.80		9	10		0.80		20	*P.C. RECEPTACLE*	10
11	*RECEPTACLE*	20			0.54	11	12			0.80	20	*P.C. RECEPTACLE*	12
13	*P.C. RECEPTACLE*	20	0.80			13	14	0.80			20	*P.C. RECEPTACLE*	14
15	*SPARE*	20		1.50		15	16		0.80		20	*P.C. RECEPTACLE*	16
17	*P.C. RECEPTACLE*	20			1.16	17	18			0.80	20	*P.C. RECEPTACLE*	18
19	*RECEPTACLE*	20	1.08			19	20	0.80			20	*P.C. RECEPTACLE*	20
21	*P.C. RECEPTACLE*	20		0.72		21	22		0.80		20	*CLEANING RECEPTACLE*	22
23	*P.C. RECEPTACLE*	20			0.90	23	24			0.80	20	*CLEANING RECEPTACLE*	24
25	*P.C. RECEPTACLE*	20	0.72			25	26	0.80			20	*CLEANING RECEPTACLE*	26
27	*RECEPTACLE*	20		0.72		27	28		0.80		20	*CLEANING RECEPTACLE*	28
29	*P.C. RECEPTACLE*	20			0.40	29	30			0.72	20	*STUDY AREA TASK LIGHTING*	30
31	*RECEPTACLE*	20	0.36			31	32	1.50			20	*SPARE*	32
33	*RECEPTACLE*	20		0.72		33	34		1.50		20	*SPARE*	34
35	*SPARE*	20			1.50	35	36			1.50	20	*SPARE*	36
37	*SPARE*	20	1.50			37	38	1.50			20	*SPARE*	38
39	*SPARE*	20		1.50		39	40		1.50		20	*SPARE*	40
41	*SPARE*	20			1.50	41	42			1.50	20	*SPARE*	42
	Subtotals (kVA):		6.34	7.04	6.80			7.00	7.00	6.92		Subtotals (kVA)	
	Total Loads:	Phase A:			13.34 kVA			72.74 %				Demand Factor (worksheet)	
		Phase B:			14.04 kVA			29.90 kVA				Demand Load	
		Phase C:			13.72 kVA			37.37 kVA				Load x 1.25	
	Total Connected Load:	41.10 kVA						103.85 A				AMP	

Figure 3.40: Revised panelboard schedule for LR-3D1

BRANCH CIRCUIT PANELBOARD SCHEDULE

Panel Name: LCP-1	Mounting:	Surface:	X	Main Lugs Only:	.	Amp Main CB	.
277/480, 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	Load	TRIP	KVA/Phase			Poles	Poles	KVA/Phase			TRIP	Load	CKT
No.		(Amp)	A	B	C			A	B	C	(Amp)		No.
1	**ZONE 1 LS LOBBY LTG*	20	0.42			1	2	0.72			20	*ZONE 18 SITE LIGHTING**	2
3	*SPARE*	20		3.50		3	4		3.50		20	*SPARE*	4
5	**ZONE 3 COURTYARD UPLT*	20			1.79	5	6			0.24	20	*ZONE 20 SITE LIGHTING**	6
7	**ZONE 4 LS LOBBY LTG*	20	0.31			7	8	3.50			20	*SPARE*	8
9	**ZONE 5 LS LOBBY LTG*	20		0.56		9	10		0.70		20	*ZONE 22 SITE LIGHTING*	10
11	**ZONE 6 EXTERIOR LTG*	20			1.07	11	12			3.50	20	*SPARE*	12
13	**ZONE 7 ML LOBBY LTG*	20	0.84			13	14	3.50			20	*SPARE*	14
15	**ZONE 8 ML LOBBY LTG*	20		0.56		15	16		3.50		20	*SPARE*	16
17	**ZONE 9 LIGHT WELL FLOOD*	20			2.42	17	18			0.52	20	*ZONE 26 COURTYARD SITE**	18
19	*SPARE*	20	3.50			19	20	0.05			20	*ZONE 27 SITE LIGHTING**	20
21	**ZONE 11 EXTERIOR LTG*	20		1.07		21	22		0.40		20	*ZONE 28 SITE LIGHTING**	22
23	**ZONE 12 ML LOBBY LTG*	20			0.31	23	24			0.27	20	*ZONE 29 EXTERIOR LTG**	24
25	**ZONE 13 EXTERIOR LTG*	20	0.64			25	26	0.27			20	*ZONE 30 EXTERIOR LTG**	26
27	**ZONE 14 EXTERIOR LTG*	20		0.48		27	28		0.23		20	*ZONE 31 EXTERIOR LTG**	28
29	**ZONE 15 SITE LIGHTING*	20			1.70	29	30			0.20	20	*ZONE 32 EXTERIOR LTG**	30
31	**ZONE 16 SITE LIGHTING*	20	1.40			31	32	0.23			20	*ZONE 33 EXTERIOR LTG**	32
33	**ZONE 17 SITE LILGHTING*	20		1.60		33	34		0.27		20	*ZONE 34 EXTERIOR LTG**	34
35	**ZONE 35 ML LOBBY LTG*	20			0.46	35	36			0.42	20	*ZONE 36 LS LOBBY LTG*	36
37	*SPARE*	20	3.50			37	38	3.50			20	*SPARE*	38
39	*SPARE*	20		3.50		39	40		3.50		20	*SPARE*	40
41	*SPARE*	20			3.50	41	42			3.50	20	*SPARE*	42
	Subtotals (kVA):		10.61	11.27	11.25			11.77	12.10	8.65		Subtotals (kVA)	
	Total Loads:	Phase A:			22.38 kVA			66.24% %				Demand Factor	
		Phase B:			23.37 kVA			43.49 kVA				Demand Load	
		Phase C:			19.90 kVA			54.36 kVA				Load x 1.25	
	Total Connected Load:	65.65 kVA						65.46 A				AMP	

Figure 3.41: Revised panelboard schedule for LCP-1

DISTRIBUTION PANEL SCHEDULE

Panel Name: EDPS-M41	Mounting:	Surface: X	Main Lugs Only:	.	Amp Main CB 1200
277/480, 3 Phase, 4 Wire		Flush: .	Shunt Trip Main:	.	Amp Bus 1200
65,000MIN A.I.C. SYM		In MCC .	Feed Through:	.	100% NEUTRAL

CKT NO.	EQUIPMENT	LOAD (CONN)			BREAKER			WIRE SIZE / REMARKS
		AMPS	KVA	HP	FRAME (AMPS)	TRIP (AMPS)	Poles	
1	*AHU-INT-LS1*	192.00	159.55	75	400A	250A	3	*(3) 4/0 phase conductors, (1) #4 ground in 2"C*
2	*AHU-INT-LS2*	192.00	159.55	75	400A	250A	3	*(3) 4/0 phase conductors, (1) #4 ground in 2"C*
3	*SPACE*							
4	*HMS-0B - HMS-3B*	23.80	20.00		225A	225A	3	*300G*
5	*RO-2*	11.00	9.00	7.5	100A	40A	3	*40G*
6	*PRE-TREATMENT*	7.60	6.32	5	100A	30A	3	*30G*
7	*CONTROL PANEL*	20.00	16.00		100A	30A	3	*30NG*
8	*SPACE*							
9	*EFN-24*	65.00	54.02	50	100A	70A	3	*115G (STAND-BY)*
10	*EFN-26*	72.20	60.00	75	225A	150A	3	*150G (STAND-BY)*
11	*SPARE*	80.00	66.48		100A	100A	3	
12	*SPARE*	180.00	149.58		225A	225A	3	
13								
14								
15								
16								
17								
18								

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Figure 3.42: Revised panelboard schedule for EDPS-M41

DISTRIBUTION PANEL SCHEDULE

Panel Name: EDPS-M42	Mounting:	Surface: X	Main Lugs Only:	.	Amp Main CB 1600
277/480, 3 Phase, 4 Wire		Flush: .	Shunt Trip Main:	.	Amp Bus 2500
65,000MIN A.I.C. SYM		In MCC .	Feed Through:	.	100% NEUTRAL

CKT NO.	EQUIPMENT	LOAD (CONN)			BREAKER			WIRE SIZE / REMARKS
		AMPS	KVA	HP	FRAME (AMPS)	TRIP (AMPS)	Poles	
1	*AHU-INT-MS1*	192.00	159.55	75	400A	250A	3	*(3) 4/0 phase conductors, (1) #4 ground in 2"C*
2	*AHU-INT-MS2*	192.00	159.55	75	400A	250A	3	*(3) 4/0 phase conductors, (1) #4 ground in 2"C*
3	*ACF-9*	52.00	30.00	40	100A	100A	3	*115G (STAND-BY)*
4	*ACF-10*	52.00	30.00	40	100A	100A	3	*115G*
5	*ACF-11*	34.00	28.00	25	100A	70A	3	*85G*
6	*HMS-0D - HMS-3D*	16.00	13.30		225A	225A	3	*300NG*
7	*ACF-12*	156.00	94.00	125	225A	225A	3	*230G*
8	*VACUUM PUMP (VCP-1)*	104.00	86.42	3(40)	200A	200A	3	*200G - (2 ACTIVE, 1 STAND-BY)*
9	*SPARE*	80.00	66.48		100A	30A	3	
10	*SPARE*	80.00	66.48		100A	30A	3	
11								
12								
13								
14								
15								
16								
17								
18								

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Figure 3.43: Revised panelboard schedule for EDPS-M42

DISTRIBUTION PANEL SCHEDULE

Panel Name: MDP-M41	Mounting:	Surface:	X	Main Lugs Only:	.	Amp Main CB 1000
277/480, 3 Phase, 4 Wire		Flush:	.	Shunt Trip Main:	.	Amp Bus 1200
65,000MIN A.I.C. SYM		In MCC	.	Feed Through:	.	100% NEUTRAL

CKT		LOAD (CONN)			BREAKER			
NO.	EQUIPMENT	AMPS	KVA	HP	FRAME (AMPS)	TRIP (AMPS)	Poles	WIRE SIZE / REMARKS
1	SPACE							
2	RTF-1	40.00	33.00	30	100A	80A	3	85G
3	GWP-12	34.00	28.00	25	100A	70A	3	85G (STAND-BY)
4	RTF-3	27.00	21.49	20	100A	60A	3	60G
5	HM-3B - HM-0B	57.44	47.70		225A	225A	3	255G
6	HL-3B - HL-0B	166.74	138.00		400A	400A	3	400NG
7	HM-4A	26.19	21.75		400A	400A	3	380G
8	HL-M4	9.15	7.60		100A	100A	3	115NG
9	LR-4C VIA 30 KVA XFMR 'TRE-LR-4C'	18.70	15.50		100A	50A	3	50G
10	SPARE	180.00	149.58		225A	225A	3	
11	SPARE	180.00	149.58		225A	225A	3	
12								
13								
14								
15								
16								
17								
18								

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Figure 3.44: Revised panelboard schedule for MDP-M41

DISTRIBUTION PANEL SCHEDULE

Panel Name: MDP-M42	Mounting:	Surface:	X	Main Lugs Only:	.	Amp Main CB 1600
277/480, 3 Phase, 4 Wire		Flush:	.	Shunt Trip Main:	.	Amp Bus 2500
65,000MIN A.I.C. SYM		In MCC	.	Feed Through:	.	100% NEUTRAL

CKT		LOAD (CONN)			BREAKER			
NO.	EQUIPMENT	AMPS	KVA	HP	FRAME (AMPS)	TRIP (AMPS)	Poles	WIRE SIZE / REMARKS
1	AHU-EXT-1	130.00	108.03	50	225A	175A	3	(3) 1/0 phase conductors, (1) #6 ground in 1.5"C
2	AHU-EXT-2	130.00	108.03	50	225A	175A	3	(3) 1/0 phase conductors, (1) #6 ground in 1.5"C
3	ACF-12	96.00	80.00	75	225A	125A	3	130G
4	HM-3D - HM-0D	159.84	132.73	7.5	400A	400A	3	400G
5	HL-3D - HL-0D	113.63	94.36	7.5	225.00	225A	3	255NG
6	HM-4B	37.93	31.50	7.5	400A	400A	3	380G
7								
8	SPARE	180.00	149.58		225A	225A	3	
9	SPARE	180.00	149.58		225A	225A	3	
10	GWP-11	34.00	28.00	25	100A	70A	3	85G
11	RTF-2	27.00	21.49	20	100A	60A	3	60G
12								
13								
14								
15								
16								
17								
18								

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Figure 3.45: Revised panelboard schedule for MDP-M42

REVISED PANELBOARD FEEDER SIZING

Each panelboard redesign also includes a resizing of its main circuit protection and feeder. The spare circuits are already sized below allowable maximum current by the National Electric Code by 25%. The NEC multiplier for continuous loads has been applied to the lighting circuits of each panelboard. The following NEC tables have been applied to each panelboard feeder calculation (in order of NEC article):

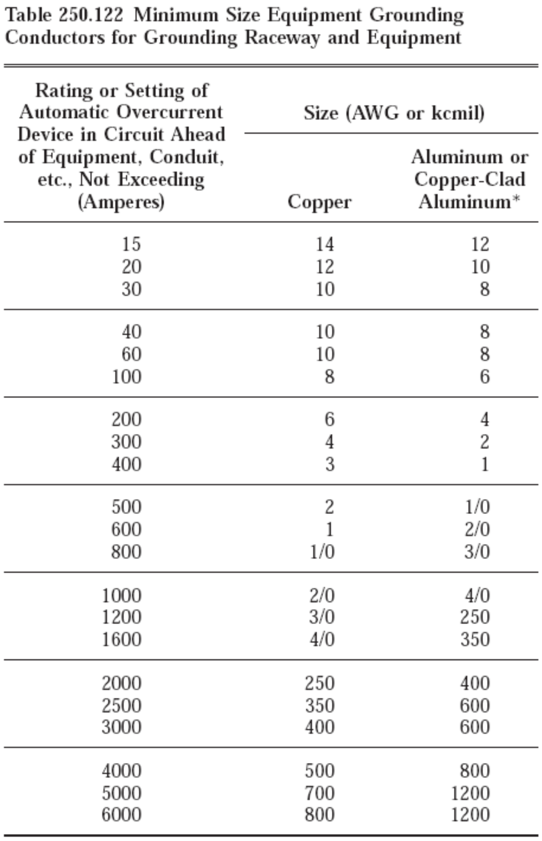

Table 250.122 Minimum Size Equipment Grounding Conductors for Grounding Raceway and Equipment

Rating or Setting of Automatic Overcurrent Device in Circuit Ahead of Equipment, Conduit, etc., Not Exceeding (Amperes)	Size (AWG or kcmil)	
	Copper	Aluminum or Copper-Clad Aluminum*
15	14	12
20	12	10
30	10	8
40	10	8
60	10	8
100	8	6
200	6	4
300	4	2
400	3	1
500	2	1/0
600	1	2/0
800	1/0	3/0
1000	2/0	4/0
1200	3/0	250
1600	4/0	350
2000	250	400
2500	350	600
3000	400	600
4000	500	800
5000	700	1200
6000	800	1200

Figure 3.46: NEC Table 250.122 – Raceway and Equipment Grounding Conductor Sizes

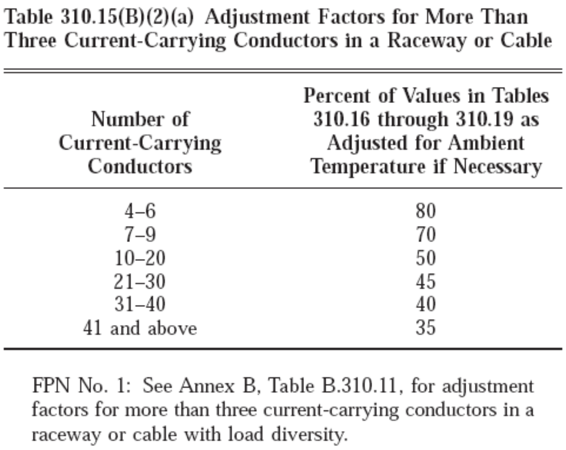

Table 310.15(B)(2)(a) Adjustment Factors for More Than Three Current-Carrying Conductors in a Raceway or Cable

Number of Current-Carrying Conductors	Percent of Values in Tables 310.16 through 310.19 as Adjusted for Ambient Temperature if Necessary
4–6	80
7–9	70
10–20	50
21–30	45
31–40	40
41 and above	35

FPN No. 1: See Annex B, Table B.310.11, for adjustment factors for more than three current-carrying conductors in a raceway or cable with load diversity.

Figure 3.47: NEC Table 310.15(B)(2)(a) Adjustments for more than three current carrying conductors

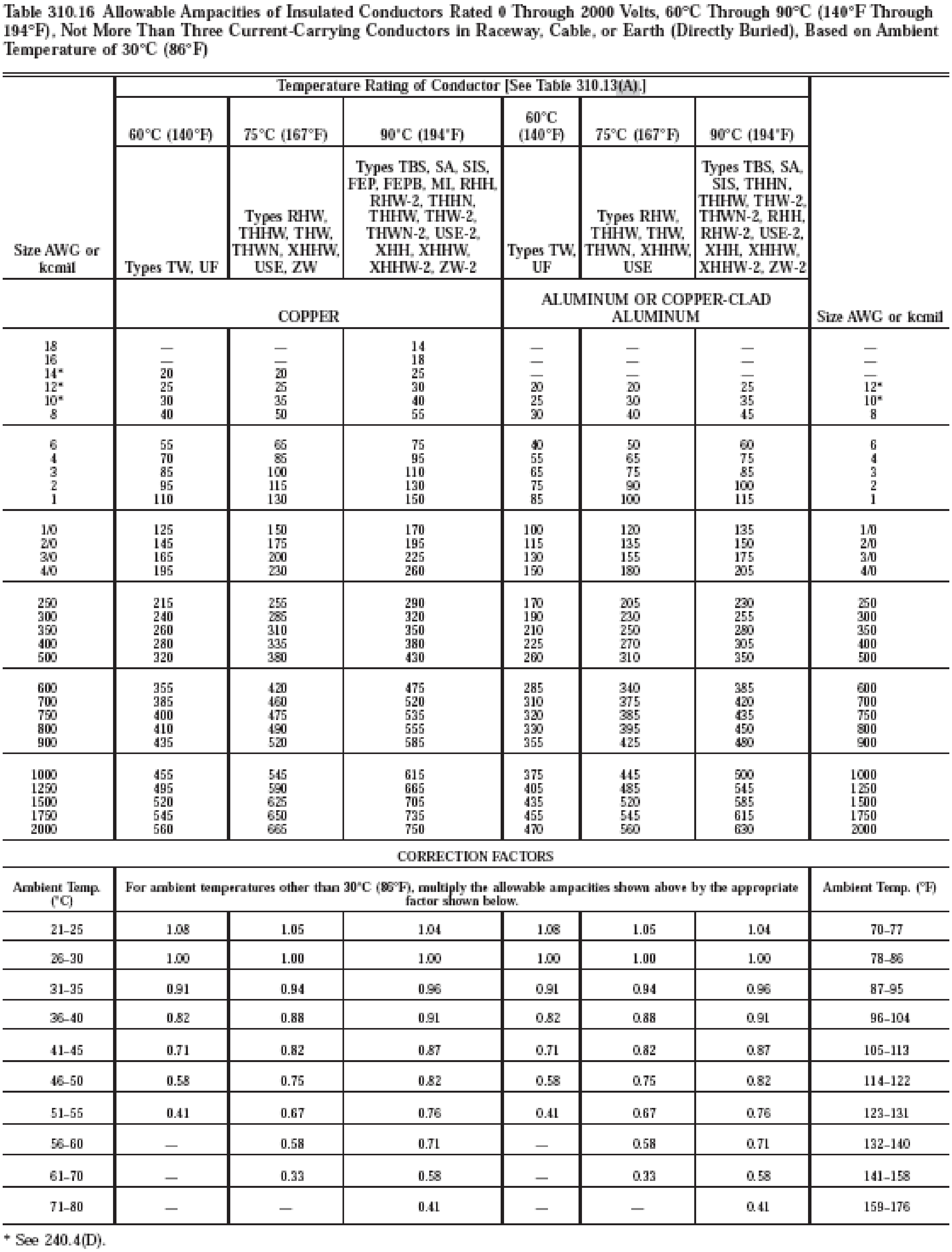

Table 310.16 Allowable Ampacities of Insulated Conductors Rated 0 Through 2000 Volts, 60°C Through 90°C (140°F Through 194°F), Not More Than Three Current-Carrying Conductors in Raceway, Cable, or Earth (Directly Buried), Based on Ambient Temperature of 30°C (86°F)

	Temperature Rating of Conductor [See Table 310.13(A).]						
	60°C (140°F)	75°C (167°F)	90°C (194°F)	60°C (140°F)	75°C (167°F)	90°C (194°F)	
Size AWG or kcmil	Types TW, UF	Types RHW, THHW, THW, THWN, XHHW, USE, ZW	Types TBS, SA, SIS, FEP, FEPB, MI, RHH, RHW-2, THHN, THHW, THW-2, THWN-2, USE-2, XHH, XHHW, XHHW-2, ZW-2	Types TW, UF	Types RHW, THHW, THW, THWN, XHHW, USE	Types TBS, SA, SIS, THHN, THHW, THW-2, THWN-2, RHH, RHW-2, USE-2, XHH, XHHW, XHHW-2, ZW-2	
	COPPER			ALUMINUM OR COPPER-CLAD ALUMINUM			Size AWG or kcmil
18	—	—	14	—	—	—	—
16	—	—	18	—	—	—	—
14*	20	20	25	—	—	—	—
12*	25	25	30	20	20	25	12*
10*	30	35	40	25	30	35	10*
8	40	50	55	30	40	45	8
6	55	65	75	40	50	60	6
4	70	85	95	55	65	75	4
3	85	100	110	65	75	85	3
2	95	115	130	75	90	100	2
1	110	130	150	85	100	115	1
1/0	125	150	170	100	120	135	1/0
2/0	145	175	195	115	135	150	2/0
3/0	165	200	225	130	155	175	3/0
4/0	195	230	260	150	180	205	4/0
250	215	255	290	170	205	230	250
300	240	285	320	190	230	255	300
350	260	310	350	210	250	280	350
400	280	335	380	225	270	305	400
500	320	380	430	260	310	350	500
600	355	420	475	285	340	385	600
700	385	460	520	310	375	420	700
750	400	475	535	320	385	435	750
800	410	490	555	330	395	450	800
900	435	520	585	355	425	480	900
1000	455	545	615	375	445	500	1000
1250	495	590	665	405	485	545	1250
1500	520	625	705	435	520	585	1500
1750	545	650	735	455	545	615	1750
2000	560	665	750	470	560	630	2000
CORRECTION FACTORS							
Ambient Temp. (°C)	For ambient temperatures other than 30°C (86°F), multiply the allowable ampacities shown above by the appropriate factor shown below.						Ambient Temp. (°F)
21–25	1.08	1.05	1.04	1.08	1.05	1.04	70–77
26–30	1.00	1.00	1.00	1.00	1.00	1.00	78–86
31–35	0.91	0.94	0.96	0.91	0.94	0.96	87–95
36–40	0.82	0.88	0.91	0.82	0.88	0.91	96–104
41–45	0.71	0.82	0.87	0.71	0.82	0.87	105–113
46–50	0.58	0.75	0.82	0.58	0.75	0.82	114–122
51–55	0.41	0.67	0.76	0.41	0.67	0.76	123–131
56–60	—	0.58	0.71	—	0.58	0.71	132–140
61–70	—	0.33	0.58	—	0.33	0.58	141–158
71–80	—	—	0.41	—	—	0.41	159–176

* See 240.4(D).

Figure 3.48: NEC Table 310.16 - Allowable Ampacities of Insulated Conductors Rated 0-2000V

Table C.1 *Continued*

CONDUCTORS											
	Conductor Size	Metric Designator (Trade Size)									
Type	(AWG kcmil)	16 (½)	21 (¾)	27 (1)	35 (1¼)	41 (1½)	53 (2)	63 (2½)	78 (3)	91 (3½)	103 (4)
RHH*, RHW*, RHW-2*, TW, THW, THHW, THW-2	6	1	3	4	8	11	18	32	48	63	81
	4	1	1	3	6	8	13	24	36	47	60
	3	1	1	3	5	7	12	20	31	40	52
	2	1	1	2	4	6	10	17	26	34	44
	1	1	1	1	3	4	7	12	18	24	31
	1/0	0	1	1	2	3	6	10	16	20	26
	2/0	0	1	1	1	3	5	9	13	17	22
	3/0	0	1	1	1	2	4	7	11	15	19
	4/0	0	0	1	1	1	3	6	9	12	16
	250	0	0	1	1	1	3	5	7	10	13
	300	0	0	1	1	1	2	4	6	8	11
	350	0	0	0	1	1	1	4	6	7	10
	400	0	0	0	1	1	1	3	5	7	9
	500	0	0	0	1	1	1	3	4	6	7
	600	0	0	0	1	1	1	2	3	4	6
	700	0	0	0	0	1	1	1	3	4	5
	750	0	0	0	0	1	1	1	3	4	5
	800	0	0	0	0	1	1	1	3	3	5
	900	0	0	0	0	0	1	1	2	3	4
	1000	0	0	0	0	0	1	1	2	3	4
	1250	0	0	0	0	0	1	1	1	2	3
	1500	0	0	0	0	0	1	1	1	1	2
	1750	0	0	0	0	0	0	1	1	1	2
	2000	0	0	0	0	0	0	1	1	1	1

Figure 3.49: Portion of NEC Table C.1 - Maximum current carrying conductors in EMT

Table 4 Dimensions and Percent Area of Conduit and Tubing
(Areas of Conduit or Tubing for the Combinations of Wires Permitted in Table 1, Chapter 9)

Article 358 — Electrical Metallic Tubing (EMT)													
		Nominal Internal Diameter		Total Area 100%		60%		1 Wire 53%		2 Wires 31%		Over 2 Wires 40%	
Metric Designator	Trade Size	mm	in.	mm^2	in.^{2}	mm^2	in.^{2}	mm^2	in.^{2}	mm^2	in.^{2}	mm^2	in.^{2}
16	½	15.8	0.622	196	0.304	118	0.182	104	0.161	61	0.094	78	0.122
21	¾	20.9	0.824	343	0.533	206	0.320	182	0.283	106	0.165	137	0.213
27	1	26.6	1.049	556	0.864	333	0.519	295	0.458	172	0.268	222	0.346
35	1¼	35.1	1.380	968	1.496	581	0.897	513	0.793	300	0.464	387	0.598
41	1½	40.9	1.610	1314	2.036	788	1.221	696	1.079	407	0.631	526	0.814
53	2	52.5	2.067	2165	3.356	1299	2.013	1147	1.778	671	1.040	866	1.342
63	2½	69.4	2.731	3783	5.858	2270	3.515	2005	3.105	1173	1.816	1513	2.343
78	3	85.2	3.356	5701	8.846	3421	5.307	3022	4.688	1767	2.742	2280	3.538
91	3½	97.4	3.834	7451	11.545	4471	6.927	3949	6.119	2310	3.579	2980	4.618
103	4	110.1	4.334	9521	14.753	5712	8.852	5046	7.819	2951	4.573	3808	5.901

Figure 3.50: Portion of NEC Chapter 9, Table 4 - Percent Area of EMT

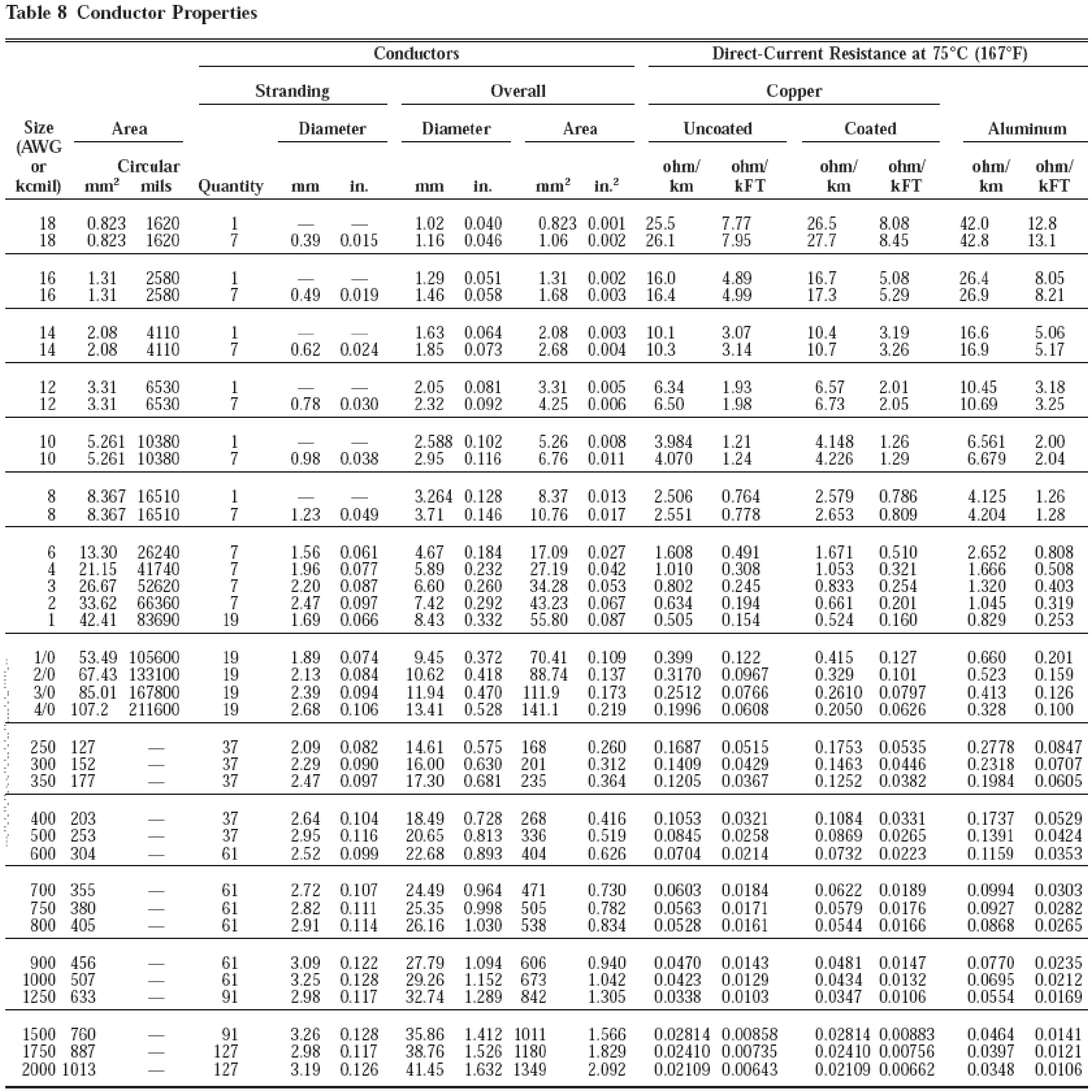

Table 8 Conductor Properties

			Conductors							Direct-Current Resistance at 75°C (167°F)					
			Stranding			Overall				Copper					
Size (AWG or kcmil)	Area			Diameter		Diameter		Area		Uncoated		Coated		Aluminum	
	mm²	Circular mils	Quantity	mm	in.	mm	in.	mm²	in.²	ohm/km	ohm/kFT	ohm/km	ohm/kFT	ohm/km	ohm/kFT
18	0.823	1620	1	—	—	1.02	0.040	0.823	0.001	25.5	7.77	26.5	8.08	42.0	12.8
18	0.823	1620	7	0.39	0.015	1.16	0.046	1.06	0.002	26.1	7.95	27.7	8.45	42.8	13.1
16	1.31	2580	1	—	—	1.29	0.051	1.31	0.002	16.0	4.89	16.7	5.08	26.4	8.05
16	1.31	2580	7	0.49	0.019	1.46	0.058	1.68	0.003	16.4	4.99	17.3	5.29	26.9	8.21
14	2.08	4110	1	—	—	1.63	0.064	2.08	0.003	10.1	3.07	10.4	3.19	16.6	5.06
14	2.08	4110	7	0.62	0.024	1.85	0.073	2.68	0.004	10.3	3.14	10.7	3.26	16.9	5.17
12	3.31	6530	1	—	—	2.05	0.081	3.31	0.005	6.34	1.93	6.57	2.01	10.45	3.18
12	3.31	6530	7	0.78	0.030	2.32	0.092	4.25	0.006	6.50	1.98	6.73	2.05	10.69	3.25
10	5.261	10380	1	—	—	2.588	0.102	5.26	0.008	3.984	1.21	4.148	1.26	6.561	2.00
10	5.261	10380	7	0.98	0.038	2.95	0.116	6.76	0.011	4.070	1.24	4.226	1.29	6.679	2.04
8	8.367	16510	1	—	—	3.264	0.128	8.37	0.013	2.506	0.764	2.579	0.786	4.125	1.26
8	8.367	16510	7	1.23	0.049	3.71	0.146	10.76	0.017	2.551	0.778	2.653	0.809	4.204	1.28
6	13.30	26240	7	1.56	0.061	4.67	0.184	17.09	0.027	1.608	0.491	1.671	0.510	2.652	0.808
4	21.15	41740	7	1.96	0.077	5.89	0.232	27.19	0.042	1.010	0.308	1.053	0.321	1.666	0.508
3	26.67	52620	7	2.20	0.087	6.60	0.260	34.28	0.053	0.802	0.245	0.833	0.254	1.320	0.403
2	33.62	66360	7	2.47	0.097	7.42	0.292	43.23	0.067	0.634	0.194	0.661	0.201	1.045	0.319
1	42.41	83690	19	1.69	0.066	8.43	0.332	55.80	0.087	0.505	0.154	0.524	0.160	0.829	0.253
1/0	53.49	105600	19	1.89	0.074	9.45	0.372	70.41	0.109	0.399	0.122	0.415	0.127	0.660	0.201
2/0	67.43	133100	19	2.13	0.084	10.62	0.418	88.74	0.137	0.3170	0.0967	0.329	0.101	0.523	0.159
3/0	85.01	167800	19	2.39	0.094	11.94	0.470	111.9	0.173	0.2512	0.0766	0.2610	0.0797	0.413	0.126
4/0	107.2	211600	19	2.68	0.106	13.41	0.528	141.1	0.219	0.1996	0.0608	0.2050	0.0626	0.328	0.100
250	127	—	37	2.09	0.082	14.61	0.575	168	0.260	0.1687	0.0515	0.1753	0.0535	0.2778	0.0847
300	152	—	37	2.29	0.090	16.00	0.630	201	0.312	0.1409	0.0429	0.1463	0.0446	0.2318	0.0707
350	177	—	37	2.47	0.097	17.30	0.681	235	0.364	0.1205	0.0367	0.1252	0.0382	0.1984	0.0605
400	203	—	37	2.64	0.104	18.49	0.728	268	0.416	0.1053	0.0321	0.1084	0.0331	0.1737	0.0529
500	253	—	37	2.95	0.116	20.65	0.813	336	0.519	0.0845	0.0258	0.0869	0.0265	0.1391	0.0424
600	304	—	61	2.52	0.099	22.68	0.893	404	0.626	0.0704	0.0214	0.0732	0.0223	0.1159	0.0353
700	355	—	61	2.72	0.107	24.49	0.964	471	0.730	0.0603	0.0184	0.0622	0.0189	0.0994	0.0303
750	380	—	61	2.82	0.111	25.35	0.998	505	0.782	0.0563	0.0171	0.0579	0.0176	0.0927	0.0282
800	405	—	61	2.91	0.114	26.16	1.030	538	0.834	0.0528	0.0161	0.0544	0.0166	0.0868	0.0265
900	456	—	61	3.09	0.122	27.79	1.094	606	0.940	0.0470	0.0143	0.0481	0.0147	0.0770	0.0235
1000	507	—	61	3.25	0.128	29.26	1.152	673	1.042	0.0423	0.0129	0.0434	0.0132	0.0695	0.0212
1250	633	—	91	2.98	0.117	32.74	1.289	842	1.305	0.0338	0.0103	0.0347	0.0106	0.0554	0.0169
1500	760	—	91	3.26	0.128	35.86	1.412	1011	1.566	0.02814	0.00858	0.02814	0.00883	0.0464	0.0141
1750	887	—	127	2.98	0.117	38.76	1.526	1180	1.829	0.02410	0.00735	0.02410	0.00756	0.0397	0.0121
2000	1013	—	127	3.19	0.126	41.45	1.632	1349	2.092	0.02109	0.00643	0.02109	0.00662	0.0348	0.0106

Figure 3.51: NEC Chapter 9, Table 8 – Conductor Properties

Additionally, the existing panelboard feeders are sized to either 100% or 200% neutral conductor. These conventions will be adopted in the redesign of panelboards.

The feeder and conduit sizing calculations were performed with the above figures and an automatic raceway calculation spreadsheet. The calculation for each panelboard feeder ampacity, wire size, and conduit is as follows:

Panelboard HL-3D:

$$\frac{(117.08\ kVA)(1000)}{(3)(277\ V)} = 140.9\ A,\quad and \quad (140.9\ A)(1.25\ Continuous)(1.25\ Growth) = 220.14\ A$$

Panelboard HLE-3D:

$$\frac{(124.93\ kVA)(1000)}{(3)(277\ V)} = 150.3\ A,\quad and \quad (150.3\ A)(1.25\ Continuous) = 187.92\ A\ Lighting$$

$$\frac{(12.54\ kVA)(1000)}{(3)(277\ V)} = 15.09\ A\ Other\ Loads$$

$$Total\ Ampacity = (187.92 + 15.09)(1.25\ Growth) = 253.76\ A$$

Panelboard LR-3D1:

$$\frac{(0.72\ kVA)(1000)}{(3)(120\ V)} = 2.00\ A,\quad and \quad (2.00\ A)(1.25\ Continuous) = 2.50\ A\ Lighting$$

$$\frac{(25.28\ kVA)(1000)}{(3)(120\ V)} = 70.2\ A\ Other\ Loads$$

$$\frac{(15.10\ kVA)(1000)}{(3)(120\ V)} = 41.9\ A,\quad and \quad (41.9\ A)(1.25\ Harmonics) = 52.43\ A\ Computers$$

$$Total\ Ampacity = \frac{(2.50 + 70.2 + 52.43)(1.25\ Growth)}{0.80\ for\ five\ conductors} = 195.52\ A$$

With the large number of computer loads on this panel, the neutral will be doubled. This will cause a de-rating in wire ampacity since there will be five current carrying conductors in the conduit.

Panelboard LCP-1:

$$\frac{(65.65\ kVA)(1000)}{(3)(277\ V)} = 79.0\ A,\quad and \quad (79.0\ A)(1.25\ Continuous)(1.25\ Growth) = 123.44\ A$$

The above calculations are summarized in the following table for all panelboards in the redesign:

Panelboard						
	Tag		HL-3D	HLE-3D	LR-3D1	LCP-1
	Voltage System		480Y/277 V	480Y/277 V	208Y/120 V	480Y/277 V
	Calculated Design Load (kW)		147.64	169.01	46.94	83.55
	Calculated Power Factor		0.807	0.801	0.833	0.81
	Calculated Design Load (kVA)		182.94	210.88	56.32	102.58
	Calculated Design Load (A)		220.14	253.76	156.44*	123.44
Feeder						
	Feeder Protection Size		125 A	150 A	110 A	70 A
	Number of Sets		1	1	1	1
	Wire Size					
		Phase	(3) 4/0	(3) 250 kcmil	(3) 3/0	(3) #1
		Neutral	(1) 4/0	(1) 250 kcmil	(2) 3/0	(1) #1
		Ground	#6	#6	#6	#8
	Wire Area (Sq. in.) (Table above)					
		Each Phase	0.3718	0.4598	0.3117	0.1901
		Total – All Phases	1.1154	1.3788	0.9351	0.5703
		Neutral	0.3718	0.4598	0.6234	0.1901
		Ground	0.0726	0.0726	0.0726	0.0437
		Total – All Wires	1.5598	1.911	1.6311	0.8041
	Minimum Conduit Area (Sq. in.) (Above x 2.5)		4.0513	4.9293	4.1395	4.1395
	Conduit Size (NEC Chapter 9, Table 4)		2.50" EMT	2.50" EMT	2.50" EMT	2.50" EMT
	Conduit Size (NEC Table C.1)		2.50" EMT	2.50" EMT	2.50" EMT	2.50" EMT
	Feeder Length		207 ft.	25 ft.	140 ft.	140 ft.
	Final Voltage Drop (V)		4.80	0.60	1.70	1.70
	Final Voltage Drop (%)		1.00%	0.12%	1.4%	1.4%
	Feeder Re-sizing		Not Needed	Not Needed	Not Needed	Not Needed

The final panelboard redesigns include circuits affected by mechanical system design changes. To size the feeder into the units, the National Electrical Code Table 430.250 below was used.

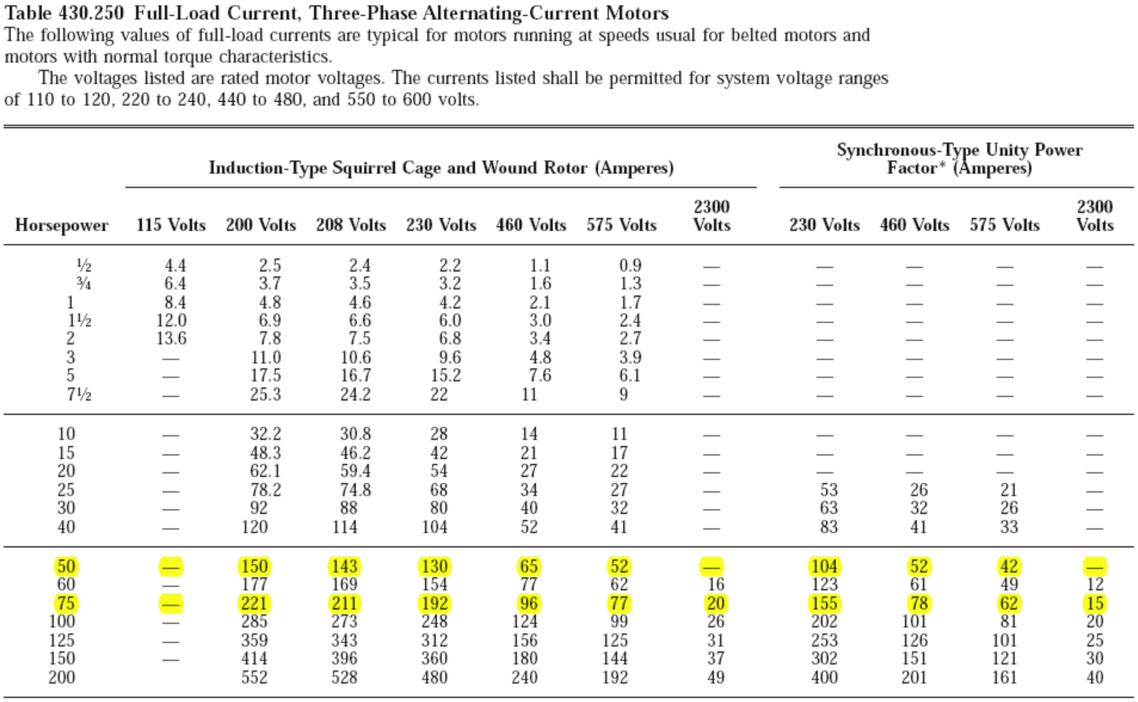

Table 430.250 Full-Load Current, Three-Phase Alternating-Current Motors

The following values of full-load currents are typical for motors running at speeds usual for belted motors and motors with normal torque characteristics.

The voltages listed are rated motor voltages. The currents listed shall be permitted for system voltage ranges of 110 to 120, 220 to 240, 440 to 480, and 550 to 600 volts.

	Induction-Type Squirrel Cage and Wound Rotor (Amperes)							Synchronous-Type Unity Power Factor* (Amperes)			
Horsepower	115 Volts	200 Volts	208 Volts	230 Volts	460 Volts	575 Volts	2300 Volts	230 Volts	460 Volts	575 Volts	2300 Volts
½	4.4	2.5	2.4	2.2	1.1	0.9	—	—	—	—	—
¾	6.4	3.7	3.5	3.2	1.6	1.3	—	—	—	—	—
1	8.4	4.8	4.6	4.2	2.1	1.7	—	—	—	—	—
1½	12.0	6.9	6.6	6.0	3.0	2.4	—	—	—	—	—
2	13.6	7.8	7.5	6.8	3.4	2.7	—	—	—	—	—
3	—	11.0	10.6	9.6	4.8	3.9	—	—	—	—	—
5	—	17.5	16.7	15.2	7.6	6.1	—	—	—	—	—
7½	—	25.3	24.2	22	11	9	—	—	—	—	—
10	—	32.2	30.8	28	14	11	—	—	—	—	—
15	—	48.3	46.2	42	21	17	—	—	—	—	—
20	—	62.1	59.4	54	27	22	—	—	—	—	—
25	—	78.2	74.8	68	34	27	—	53	26	21	—
30	—	92	88	80	40	32	—	63	32	26	—
40	—	120	114	104	52	41	—	83	41	33	—
50	—	150	143	130	65	52	—	104	52	42	—
60	—	177	169	154	77	62	16	123	61	49	12
75	—	221	211	192	96	77	20	155	78	62	15
100	—	285	273	248	124	99	26	202	101	81	20
125	—	359	343	312	156	125	31	253	126	101	25
150	—	414	396	360	180	144	37	302	151	121	30
200		552	528	480	240	192	49	400	201	161	40

Figure 3.52: NEC Table 430.250 FLA for 3-Phase Motors

The panelboard feeder design for EDPS-M41, EDPS-M42, MDP-M41, and MDP-M42 consists of removing ACFs numbers 1-8 and replacing them with the following equipment:

Mechanical System Redesign Air Handling Units					
Tag	Manufacturer	Product	Supply Fan (hp)	Exhaust Fan (hp)	Total NEC Current (A)*
AHU-INT-LS1	SEMCO	EP Series 43	75	75	192.00
AHU-INT-LS2	SEMCO	EP Series 43	75	75	192.00
AHU-EXT-1	SEMCO	EP Series 35	50	50	130.00
AHU-EXT-2	SEMCO	EP Series 35	50	50	130.00
AHU-INT-MS1	SEMCO	EP Series 43	75	75	192.00
AHU-INT-MS2	SEMCO	EP Series 43	75	75	192.00
*NEC current sized from Table 430.250					

Switchboards EDPS-M41, EDPS-M42, MDP-M41, and MDP-M42

The switchboards that have been affected by mechanical system redesign are still under design in the documents accessible to KGB Maser. However, the feeders for each switchboard and the main circuit protection will be sized per the minimum sizing in Article 215.2(A)(1) of the National Electrical Code. The process includes summing the total current (including 80% of spare breaker ratings) and kVA on the panel and multiplying by 125% before multiplying by an assumed power factor of 0.80. The sizing is summarized in the table below:

Switchboard				
Tag	EDPS-M41	EDPS-M42	MDP-M41	MDP-M42
Voltage System	480Y/277V	480Y/277V	480Y/277V	480Y/277V
Calculated Design Load (kW)	700.87	796.10	614.29	904.46
Calculated Power Factor	0.80	0.80	0.80	0.80
Calculated Design Load (kVA)	876.08	955.12	767.86	1130.58
Calculated Design Load (A)	1054.25	1197.50	924.03	1360.50
Feeder				
Feeder Protection Size	1200A	1600A*	1000A	1600A
Number of Sets	3	4	3**	4***
Wire Size				
Phase	500 kcmil	350 kcmil	350 kcmil	500 kcmil
Neutral	500 kcmil	350 kcmil	350 kcmil	500 kcmil
Ground	3/0	4/0	2/0	4/0
Wire Area (Sq. in.) (Table above)				
Each Phase	0.7901	0.5958	0.5958	0.7901
Total – All Phases	2.3703	1.7874	1.7874	2.3703
Neutral	0.7901	0.5958	0.5958	0.7901
Ground	0.3117	0.3718	0.2624	0.3718
Total – All Wires	3.4721	2.7550	2.6456	3.5322
Minimum Conduit Area (Sq. in.) (Above x 2.5)	8.6803	6.8875	6.6140	8.8305
Conduit Size (NEC Chapter 9, Table 4)	3.0" EMT	3.0" EMT	3.0" EMT	3.0" EMT
Conduit Size (NEC Table C.1)	3.0" EMT	3.0" EMT	3.0" EMT	3.0" EMT
Feeder Length	300 ft.	150 ft.	750 ft.	750 ft.
Final Voltage Drop (V)	2.7	1.7	8.5	6.6
Final Voltage Drop (%)	0.97%	0.61%	3.07%	2.38%
Feeder Re-sizing	Not Needed	Not Needed	500 kcmil**	See Below
*Main circuit protection is too close to the next breaker size to be considered free from accidental trip **Feeder size change to 4 sets of (3) 500 kcmil + (1) 500 kcmil neutral to yield 4.5V (1.62%) drop ***Voltage drop calculation yields adding an extra set with the same 500 kcmil cables				

DIMMING AND WIRING DIAGRAMS

Please note that some of the information provided in the following diagrams was obtained through brochures. They are mostly schematic-level diagrams and would need manufacturer consulting to install properly. Standard wiring diagrams have been omitted including individual shade motor control and office wall wash application.

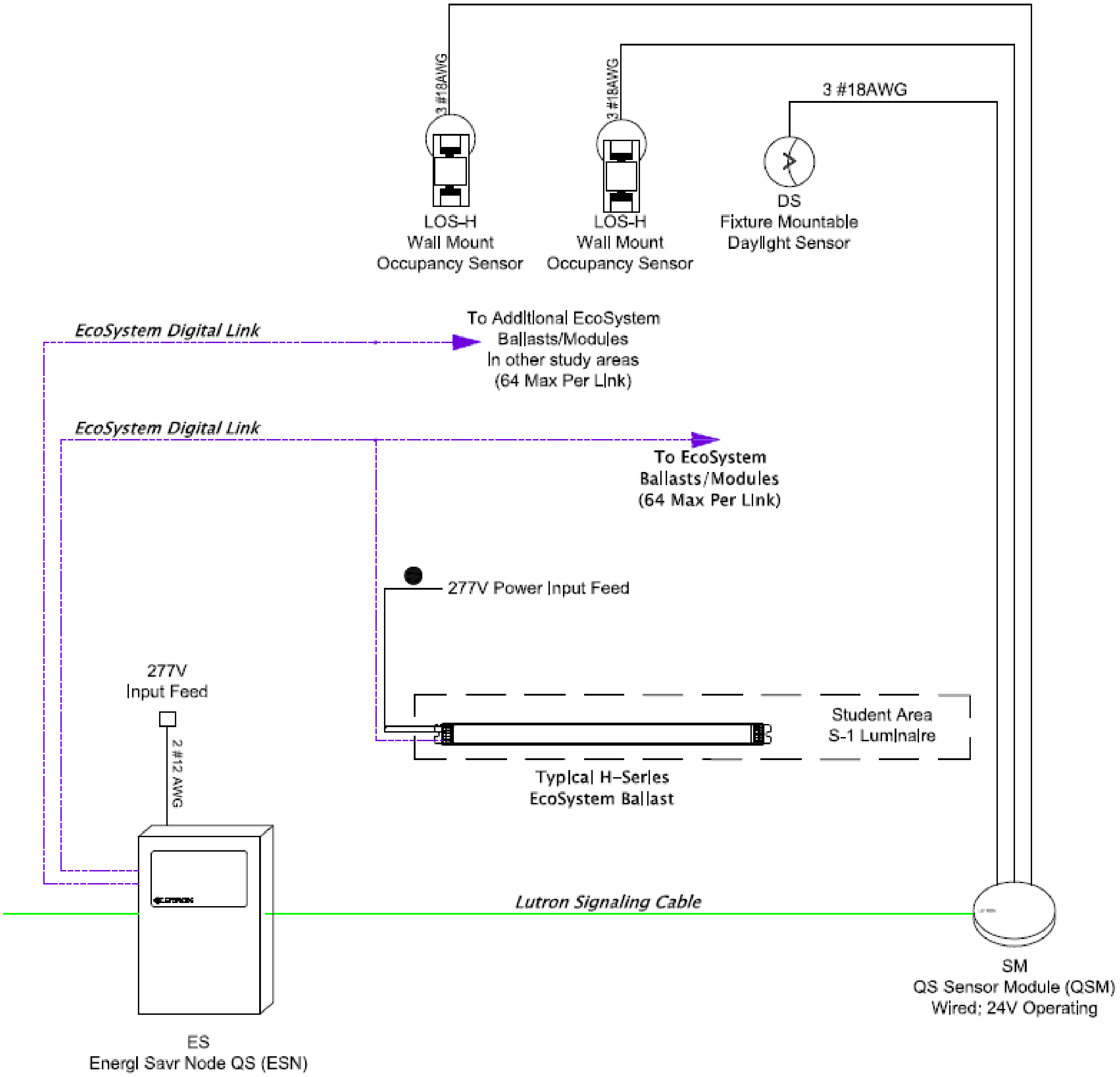

Figure 3.53: Student Study Area overhead control wiring diagram

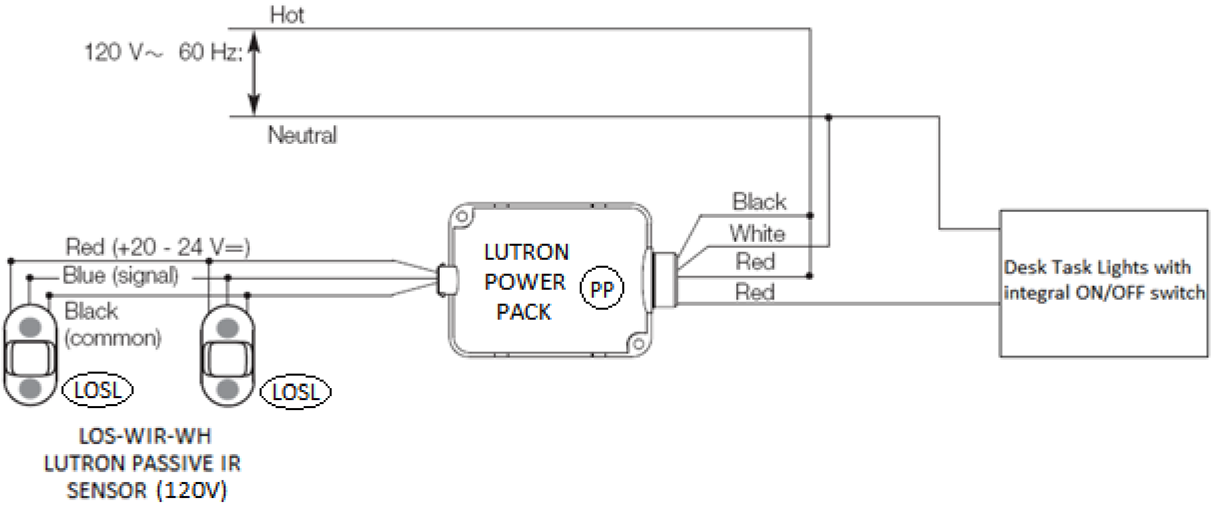

Figure 3.54: Student Study Area task control wiring diagram

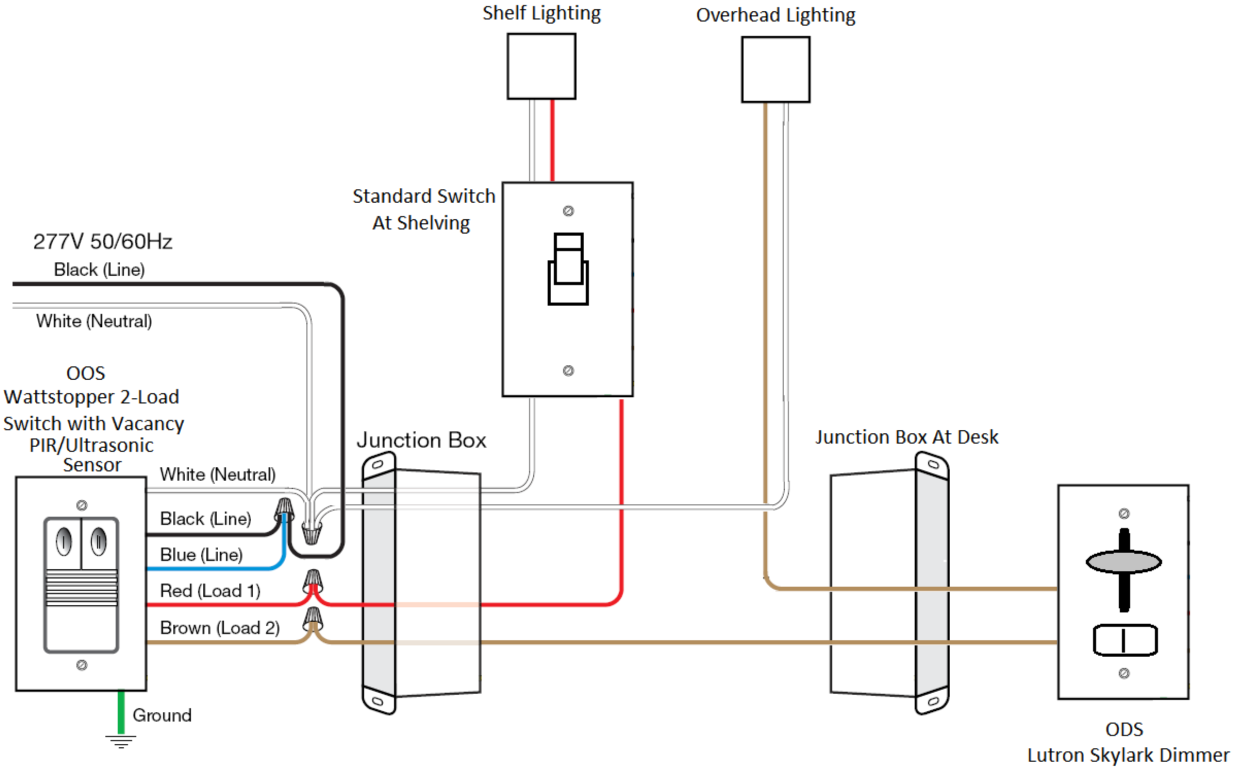

Figure 3.55: Office overhead and task control wiring diagram

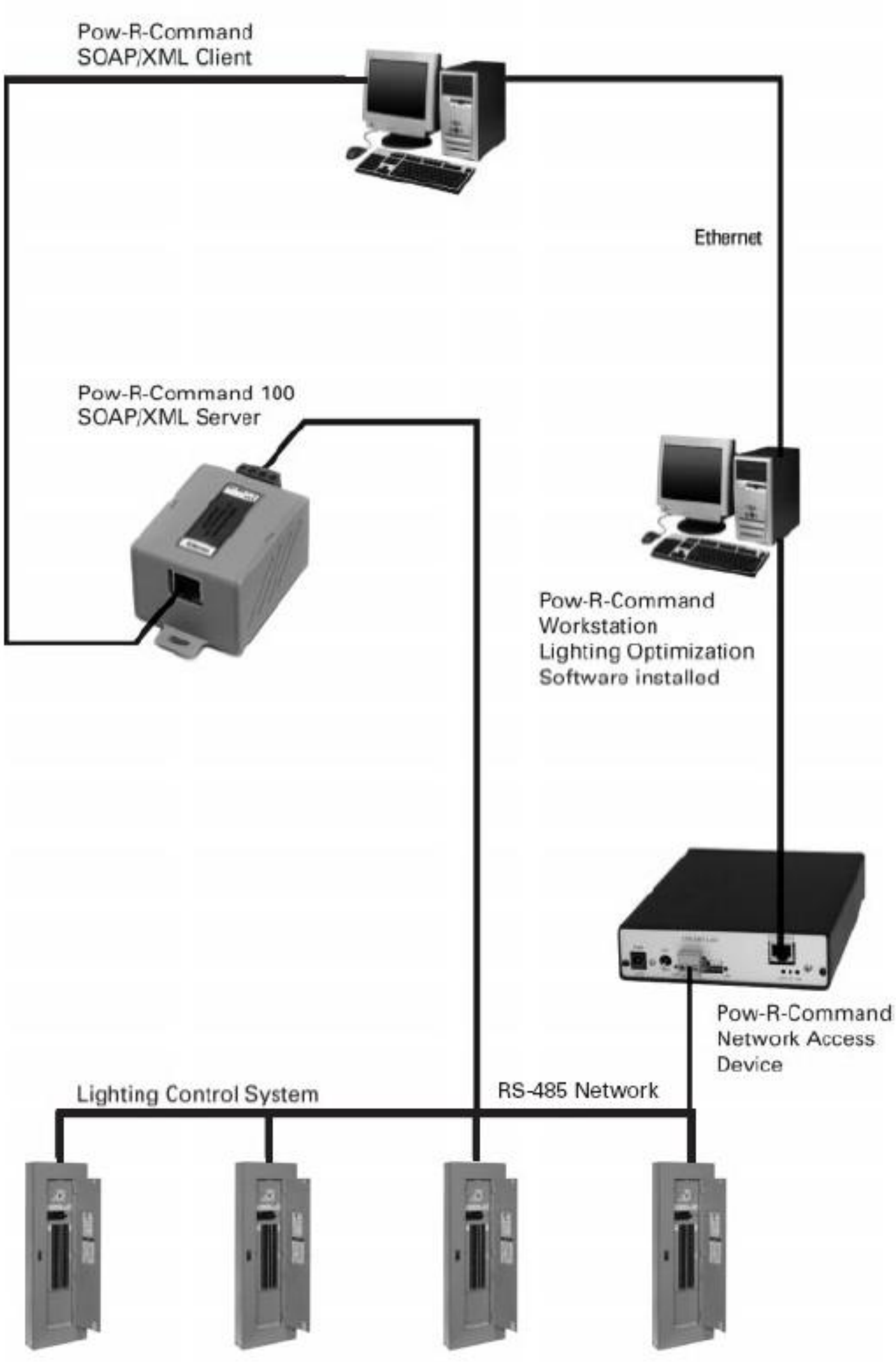

Figure 3.56: Courtyard control wiring diagram *Limited information from manufacturer

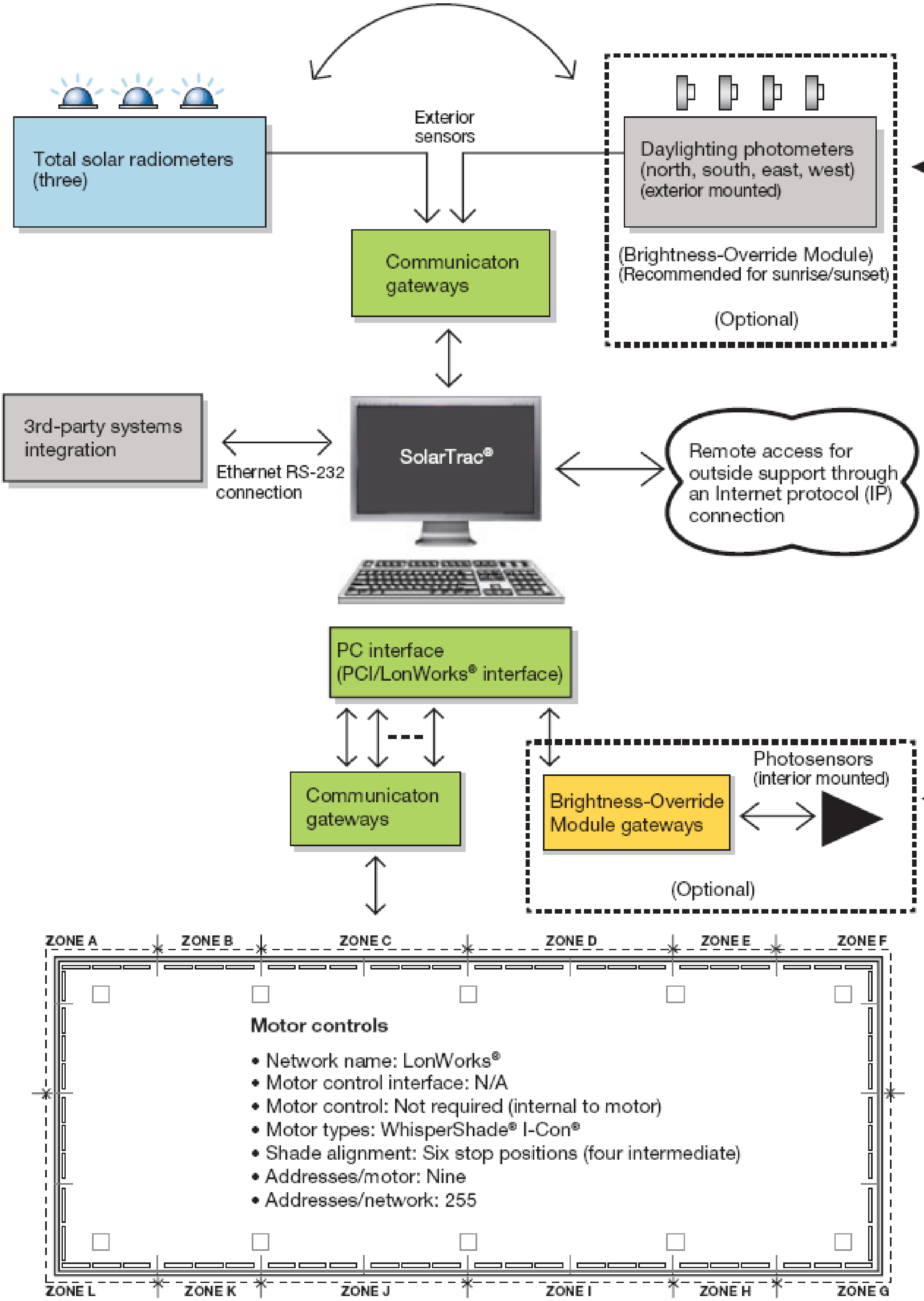

Figure 3.57: Automatic shading control diagram from MechoShade Solar Trac brochure

SHORT CIRCUIT CALCULATION

As part of the requirements for AE482, a hand calculation for short circuit capacity for a section of the power system will be performed. Figure 3.58 illustrates the fault current path that will be used for the short circuit calculation. Utility contribution was calculated from information gained from Penn State OPP. The two utility transformers for the Millennium Science Complex have different short circuit contributions to the calculation. PSU-1, the left transformer, contributes 37,246 A while PSU-2, the right transformer, will contribute 34,732 A. However, since the transformer secondary available fault current was given, that is where the given calculation information will begin. This calculation will be performed using the per-unit method with a base kVA of 10,000. Impedance values for distribution equipment, excluding conductors, have been taken from the SKM model used to perform Depth Topic 1. Using the per-unit method, the available short circuit current at any point can be determined by the following equation:

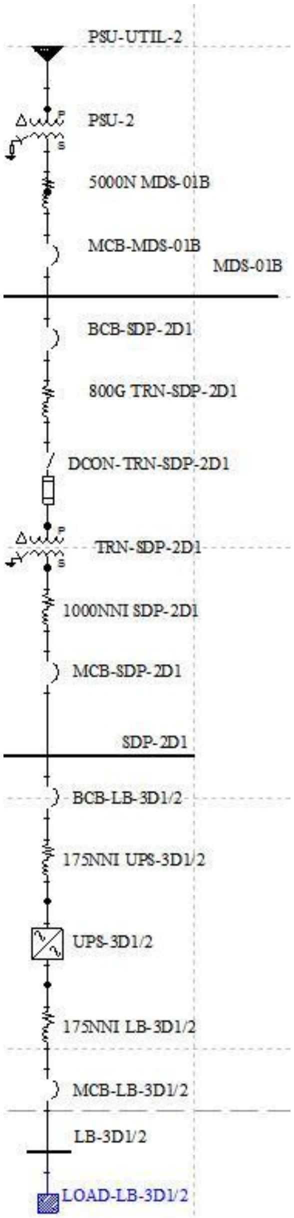

Figure 3.58: Short circuit hand calculation path

$$I_{SC} = \frac{10{,}000kVA}{(\sqrt{3})(kV\ at\ short)\left(\sum_{utility}^{calc\ point} Z_u\right)}$$

Once at PSU-2, the transformer's per-unit impedance and resistance were calculated as follows (typical for other transformers):

$$X_u = \frac{(0.0573)(10{,}000kVA_{base})}{5{,}000kVA_{rating}} = 0.1146$$

$$R_u = \frac{(0.00478)(10{,}000kVA_{base})}{5{,}000kVA_{rating}} = 0.00956$$

$$Z_u = \sqrt{0.1146^2 + 0.00956^2} = 0.114997$$

Since the given information starts at the secondary side of the service transformer, the utility contribution must be calculated in the opposite direction of the short circuit calculation, using the equation for short circuit current above:

$$34{,}372A = \frac{10{,}000kVA}{(\sqrt{3})(0.480)(0.114997 + Z_{utility})}$$

$$28576.34(0.114997 + Z_{utility}) = 10{,}000$$

$$Z_{utility} = 0.23494$$

Now that the utility impedance value has been calculated, the utility contribution in MVA can be obtained. Assuming no resistance from the utility, the following equation can be used to calculate the utility contribution:

$$Utility\ X_u = Utility\ Z_u = \frac{10{,}000kVA_{base}}{(Utility\ MVA)(1000)}$$

$$0.23494 = \frac{10{,}000kVA_{base}}{(Utility\ MVA)(1000)}$$

$$Utility\ MVA = \frac{10{,}000kVA_{base}}{(0.23494)(1000)} = 42.56\ MVA$$

Now the calculation is fluid from the utility contribution through the service transformer. Following the service transformer, the feeder to MDS-01B can be calculated for its contribution to mitigating the available short circuit current as follows (typical for all cable contributions):

Feeder MDS-01B Contribution
600 kcmil, 30ft feeder, 480V

$$X = \frac{(0.038)(30ft)}{(1000ft)(12\ sets)} = 0.000095 \qquad R = \frac{(0.024)(30ft)}{(1000ft)(12\ sets)} = 0.000065$$

$$X_u = \frac{(0.019)(10{,}000kVA_{base})}{(1000)(0.48kV_{system}^2)} = 0.004 \qquad R_u = \frac{(0.012)(10{,}000kVA_{base})}{(1000)(0.48kV_{system}^2)} = 0.003$$

The table below summarizes the calculations for the circuit displayed in Figure 3.58 at the beginning of this section, excluding overcurrent protection:

$$Base\ kVA = 10{,}000 \qquad Utility\ MVA = 42.56 \qquad Utility\ X_u = \frac{10{,}000kVA}{(42.56MVA)(1000)} = 0.235$$

Equipment Characteristics											Per-Unit Value Table				
Mark	%X	%R	%Z	kVA	X/1000ft	R/1000ft	Z/1000ft	Length	# sets	3Ph Voltage (V)	Mark	Xu	Ru	Zu	Isc
Utility	0.235			42563.553						12470	Utility	0.235		0.235	
															1970.656
PSU-2	5.730	0.478	5.750	5000.000							PSU-2	0.115	0.010	0.115	
															34371.978
FEEDER MDS-01B					0.038	0.018	0.042	30.000	12.000	480	FEEDER MDS-01B	0.004	0.002	0.005	
															33931.372
MDS-01B											MDS-01B				
															33931.372
FEEDER TRN-SDP-2D1					0.039	0.022	0.045	1000.000	2.000	480	FEEDER TRN-SDP-2D1	0.846	0.484	0.975	
															9047.603
TRN-SDP-2D1	2.070	4.000	4.504	300.000							TRN-SDP-2D1	0.690	1.333	1.501	
															9805.714
FEEDER SDP-2D1					0.040	0.033	0.052	154.000	3.000	208	FEEDER SDP-2D1	0.475	0.393	0.616	
															8053.162
SDP-2D1											SDP-2D1				
															8053.162
FEEDER UPS-3D1/2					0.043	0.101	0.110	200.000	1.000	208	FEEDER UPS-3D1/2	1.988	4.669	5.075	
															3257.397
UPS-3D1/2	0.992	0.012	0.992	50.000							UPS-3D1/2	1.984	0.025	1.984	
															2642.175
FEEDER LB-3D1/2					0.043	0.101	0.110	10.000	1.000	208	FEEDER LB-3D1/2	0.099	0.233	0.254	
															2579.866
LB-3D1/2											LB-3D1/2				

OVERCURRENT PROTECTION COORDINATION

The previous section calculates available short circuit for a sample path through the Millennium Science Complex. This section provides sample breaker coordination for the said section of the distribution system. The image in this section was composed by overlaying breaker time current curves within image editing software and lining up transparencies at the appropriate scale on each axis. Two of the overcurrent devices in this section are supplied by 480V equipment (MCB MDS-01B and BCB SDP-2D1) and three are at 208V (MCB SDP-2D1, BCB UPS-3D1/2, and MCB LB-3D1/2).

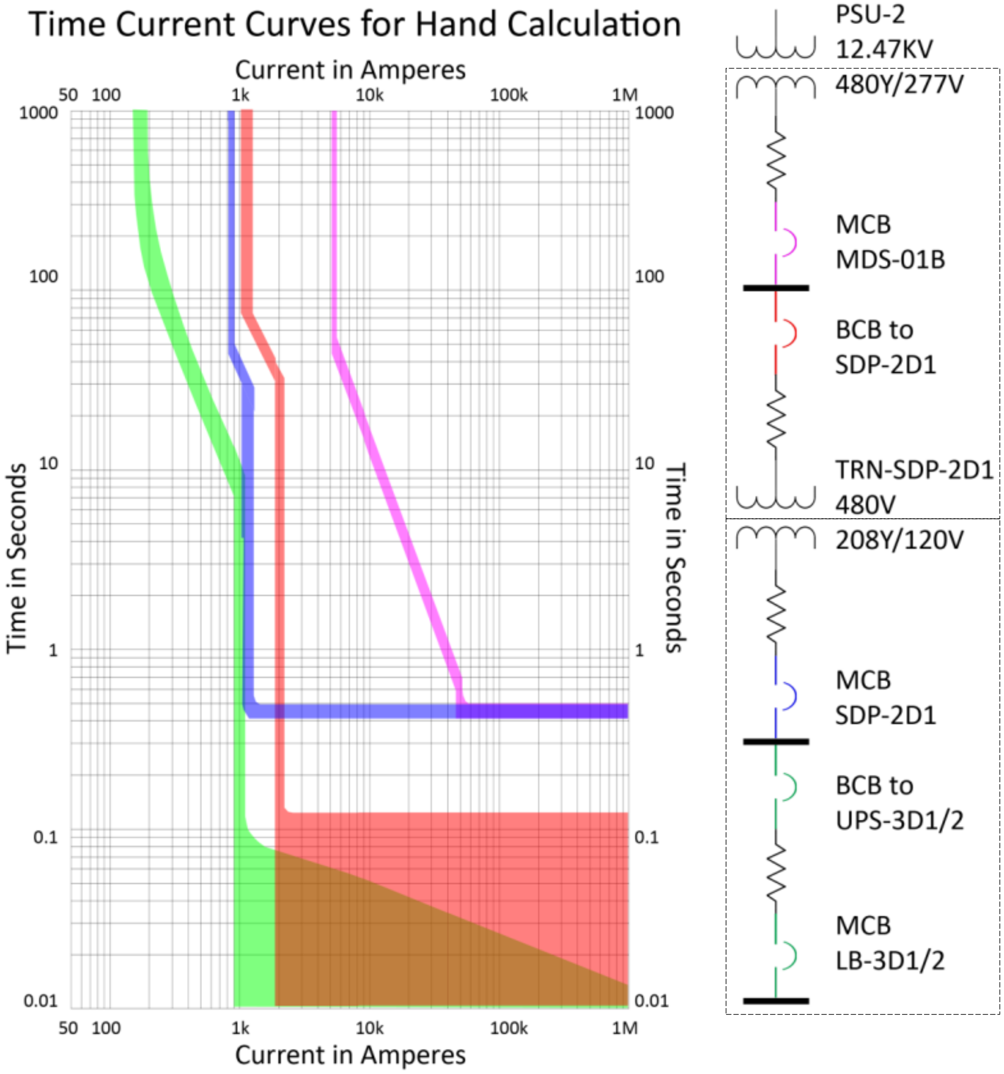

Figure 3.59: Short Circuit Path Device Coordination with One-Line Section

Unique to this path through the distribution system is the extensive use of digital-trip units. All circuit protection ahead of distribution panelboard SDP-2D1 utilizes digital trips. These units are very flexible and allow for custom time-current curves. To complete this analysis, the thermal-magnetic trip units after distribution panelboard SDP-2D1 must be plotted on the time-current graph first. Once the non-negotiable time-current curve is set, the digital trip units can be customized around it. The largest challenge in applying digital trip units is selecting the settings for the unit. This exercise was attempted to the best of the ability of the student. The following Eaton Electrical time-current curves were combined to compose the figure above:

Overcurrent Protection Data

Device Name	Voltage	Frame Size (A)	Trip Rating (A)	Eaton Time-Current Curve(s)
MCB MDS-01B	480Y/277V	5000	5000	70C1006 70C1007 70C1008
BCB SDP-2D1		800	800	70C1010 70C1295 70C1296
MCB SDP-2D1	208Y/120V	1200	1000	SC-5376-92A SC-5377-92A
BCB UPS-3D1/2		225	175	SC-4247-87C
MCB LB-3D1/2				

If each voltage system is addressed individually, the overcurrent protection is coordinated effectively. Once the figure above is separated, it is easier to visualize the two different voltage systems:

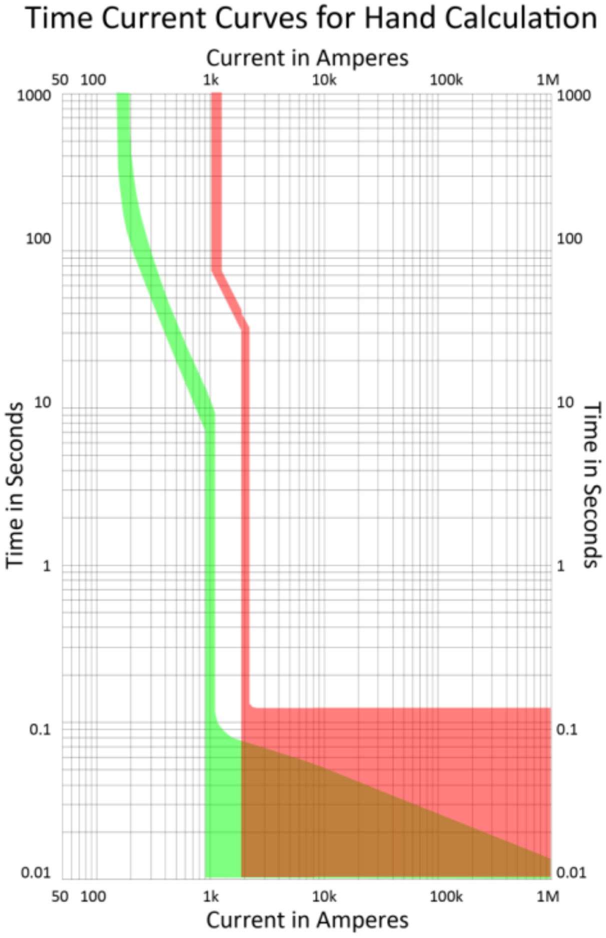

Figure 3.60: 208V Breaker Coordination

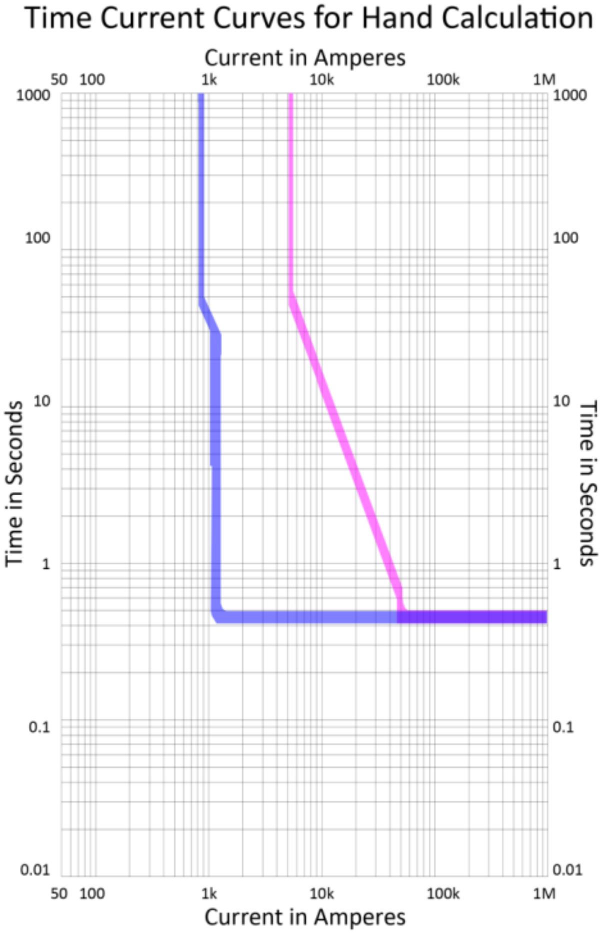

Figure 3.61: 480V Breaker Coordination

From the above images, it can be inferred that the down-stream breaker will trip in overload conditions. The instantaneous trip function overlaps in each scenario for a portion of the curve. Under those conditions, one or both breakers will trip.

ELECTRICAL DEPTH TOPICS

TOPIC 1: SYSTEM MODELING IN SKM

This electrical depth topic was performed cooperatively between the lighting/electrical 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 the table below:

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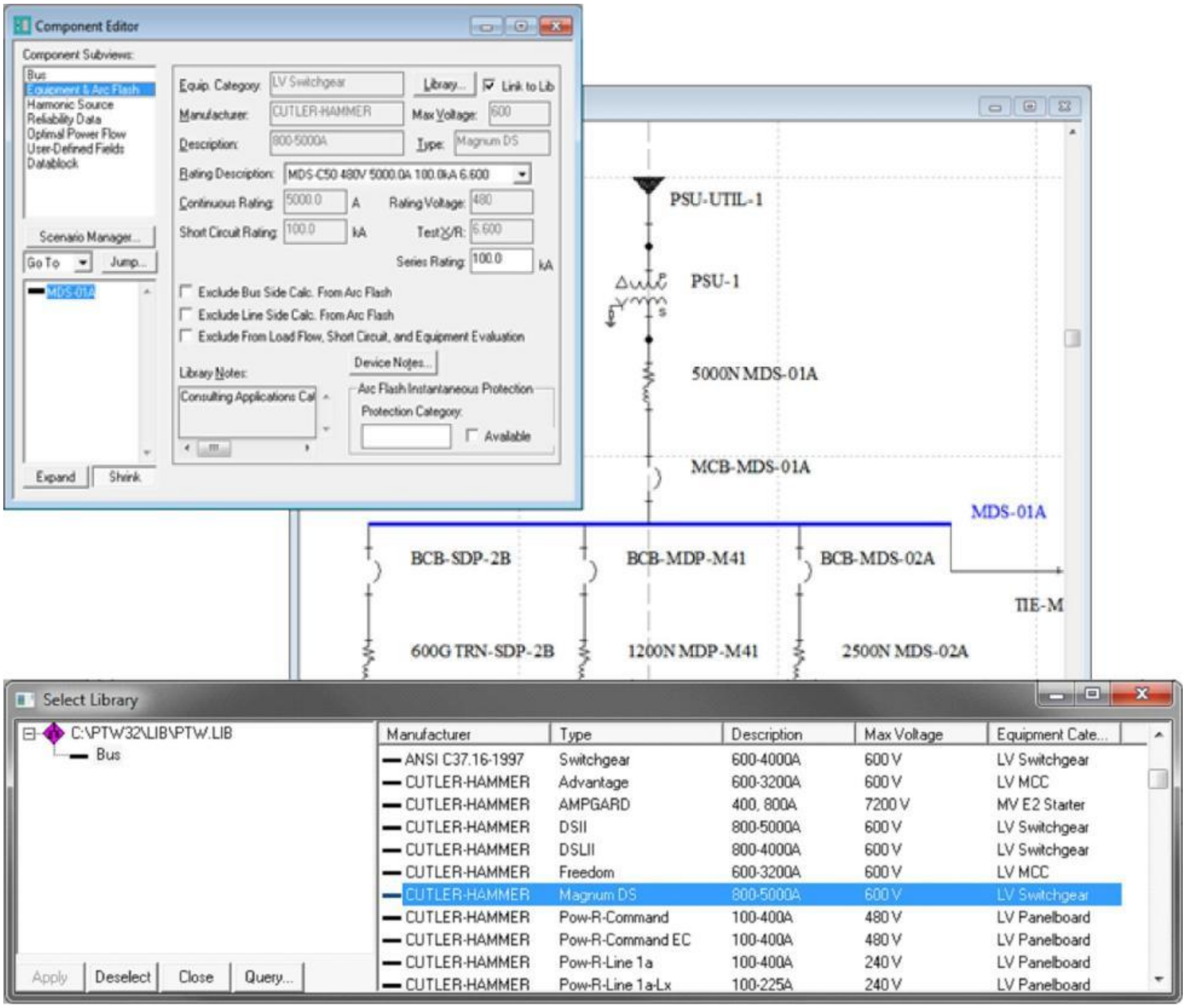
SKM Model Equipment Schedule

	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
	Lvl 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
	Pent.	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	Mezz.	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**		**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 3.62 below shows the library and component editor overlaid on the one-line diagram for a bus that is used as a main switchgear.

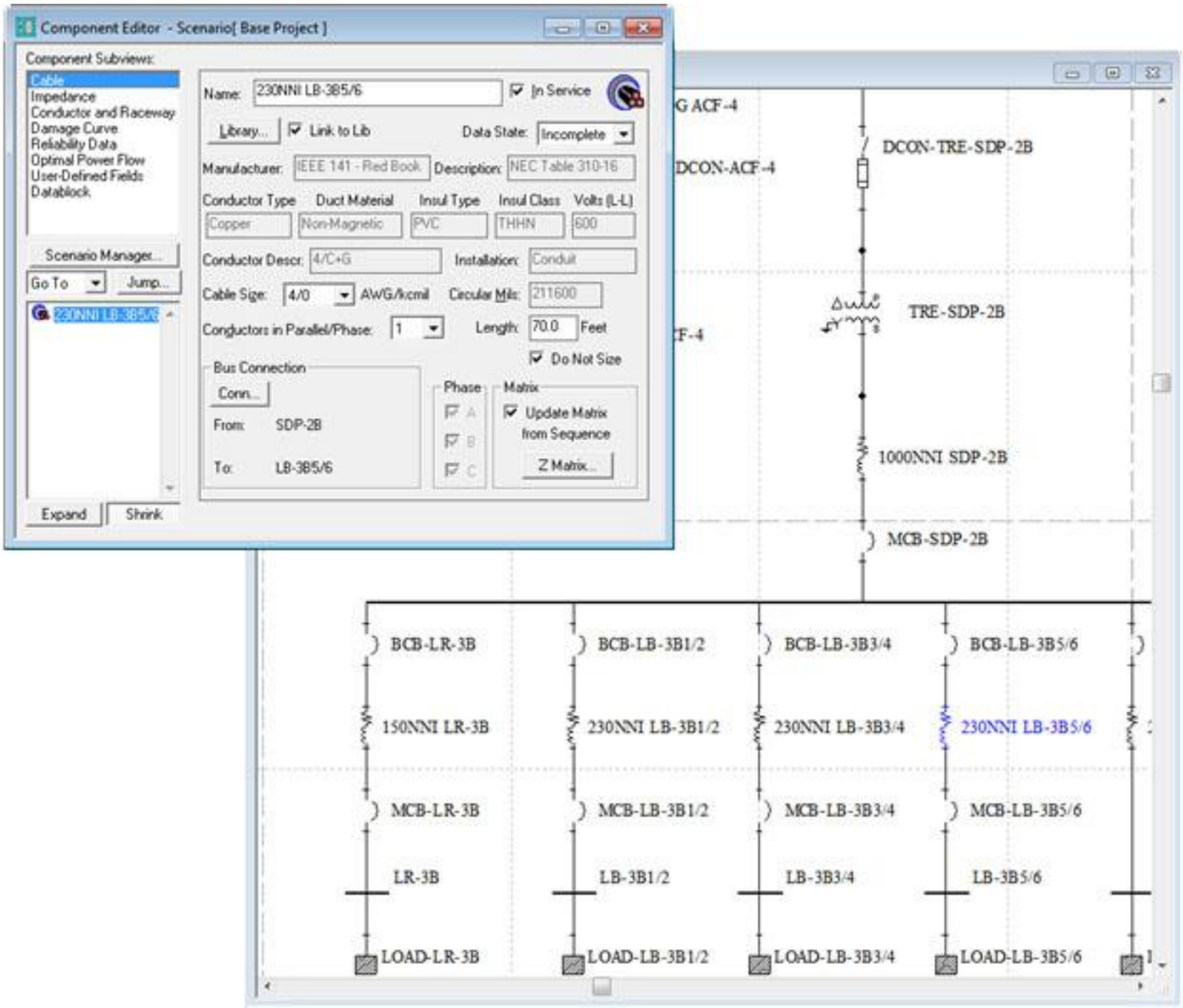


Equip. Category: LV Switchgear
☑ Link to Lib
Manufacturer: CUTLER-HAMMER
Max Voltage: 600
Description: 800-5000A
Type: Magnum DS
Rating Description: MDS-C50 480V 5000.0A 100.0kA 6.600
Continuous Rating: 5000.0 A
Rating Voltage: 480
Short Circuit Rating: 100.0 kA
Test X/R: 6.600
Series Rating: 100.0 kA
☐ Exclude Bus Side Calc. From Arc Flash
☐ Exclude Line Side Calc. From Arc Flash
☐ Exclude From Load Flow, Short Circuit, and Equipment Evaluation
Library Notes: Consulting Applications Cat
Arc Flash Instantaneous Protection
Protection Category:
☐ Available

Manufacturer	Type	Description	Max Voltage	Equipment Cate...
ANSI C37.16-1997	Switchgear	600-4000A	600 V	LV Switchgear
CUTLER-HAMMER	Advantage	600-3200A	600 V	LV MCC
CUTLER-HAMMER	AMPGARD	400, 800A	7200 V	MV E2 Starter
CUTLER-HAMMER	DSII	800-5000A	600 V	LV Switchgear
CUTLER-HAMMER	DSLII	800-4000A	600 V	LV Switchgear
CUTLER-HAMMER	Freedom	600-3200A	600 V	LV MCC
CUTLER-HAMMER	Magnum DS	800-5000A	600 V	LV Switchgear
CUTLER-HAMMER	Pow-R-Command	100-400A	480 V	LV Panelboard
CUTLER-HAMMER	Pow-R-Command EC	100-400A	480 V	LV Panelboard
CUTLER-HAMMER	Pow-R-Line 1a	100-400A	240 V	LV Panelboard
CUTLER-HAMMER	Pow-R-Line 1a-Lx	100-225A	240 V	LV Panelboard

Figure 3.62: 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 3.63 below:



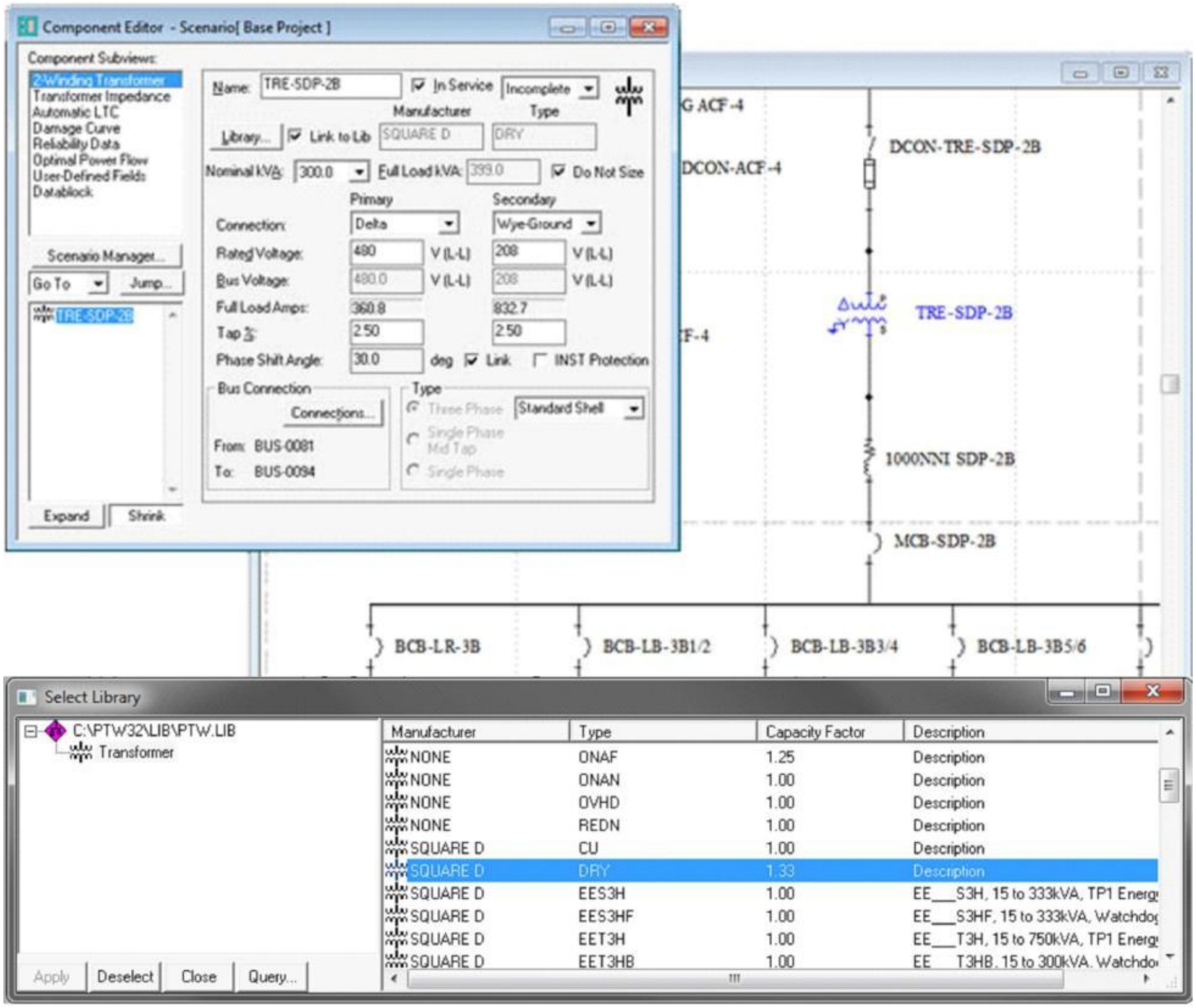
Component Editor - Scenario[Base Project]

Component Subviews: Cable

Name: 230NNI LB-3B5/6
☑ In Service
☑ Link to Lib
Data State: Incomplete
Manufacturer: IEEE 141 - Red Book
Description: NEC Table 310-16
Conductor Type: Copper
Duct Material: Non-Magnetic
Insul Type: PVC
Insul Class: THHN
Volts (L-L): 600
Conductor Descr: 4/C+G
Installation: Conduit
Cable Size: 4/0 AWG/kcmil
Circular Mils: 211600
Conductors in Parallel/Phase: 1
Length: 70.0 Feet
☑ Do Not Size
Bus Connection
From: SDP-2B
To: LB-3B5/6
Phase: ☑ A ☑ B ☑ C
Matrix: ☑ Update Matrix from Sequence

Figure 3.63: 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 3.64 below:



Name: TRE-SDP-2B ☑ In Service Incomplete

Manufacturer: SQUARE D Type: DRY ☑ Link to Lib

Nominal kVA: 300.0 Full Load kVA: 399.0 ☑ Do Not Size

	Primary		Secondary	
Connection:	Delta		Wye-Ground	
Rated Voltage:	480	V (L-L)	208	V (L-L)
Bus Voltage:	480.0	V (L-L)	208	V (L-L)
Full Load Amps:	360.8		832.7	
Tap %:	2.50		2.50	
Phase Shift Angle:	30.0	deg		

☑ Link ☐ INST Protection

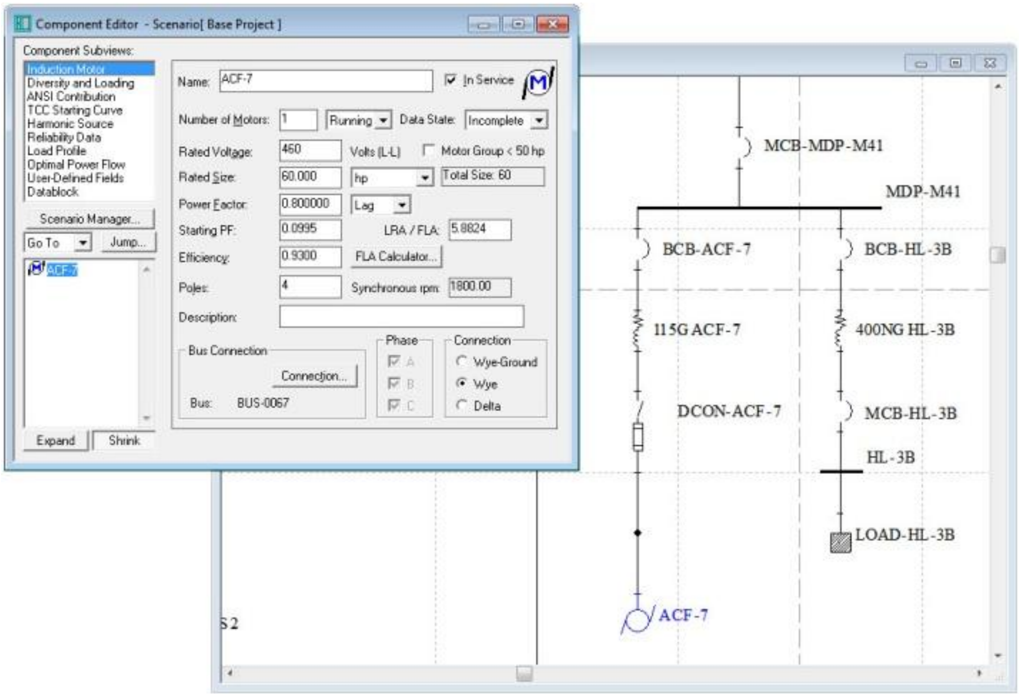
Bus Connection
From: BUS-0081
To: BUS-0094

Type
● Three Phase Standard Shell
○ Single Phase Mid Tap
○ Single Phase

Manufacturer	Type	Capacity Factor	Description
NONE	ONAF	1.25	Description
NONE	ONAN	1.00	Description
NONE	OVHD	1.00	Description
NONE	REDN	1.00	Description
SQUARE D	CU	1.00	Description
SQUARE D	DRY	1.33	Description
SQUARE D	EES3H	1.00	EE___S3H, 15 to 333kVA, TP1 Energ
SQUARE D	EES3HF	1.00	EE___S3HF, 15 to 333kVA, Watchdo
SQUARE D	EET3H	1.00	EE___T3H, 15 to 750kVA, TP1 Energ
SQUARE D	EET3HB	1.00	EE___T3HB, 15 to 300kVA, Watchdo

Figure 3.64: 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. Figures 3.65 and 3.66 below illustrate the inclusion of an induction motor load and non-motor panelboard load for the third floor of the Millennium Science Complex.


Component Editor - Scenario[Base Project]

Component Subviews: Induction Motor

Name: ACF-7

☑ In Service

Number of Motors: 1

Running

Data State: Incomplete

Rated Voltage: 460 Volts (L-L)

☐ Motor Group < 50 hp

Rated Size: 60.000 hp

Total Size: 60

Power Factor: 0.800000 Lag

Starting PF: 0.0995

LRA / FLA: 5.8824

Efficiency: 0.9300

Poles: 4

Synchronous rpm: 1800.00

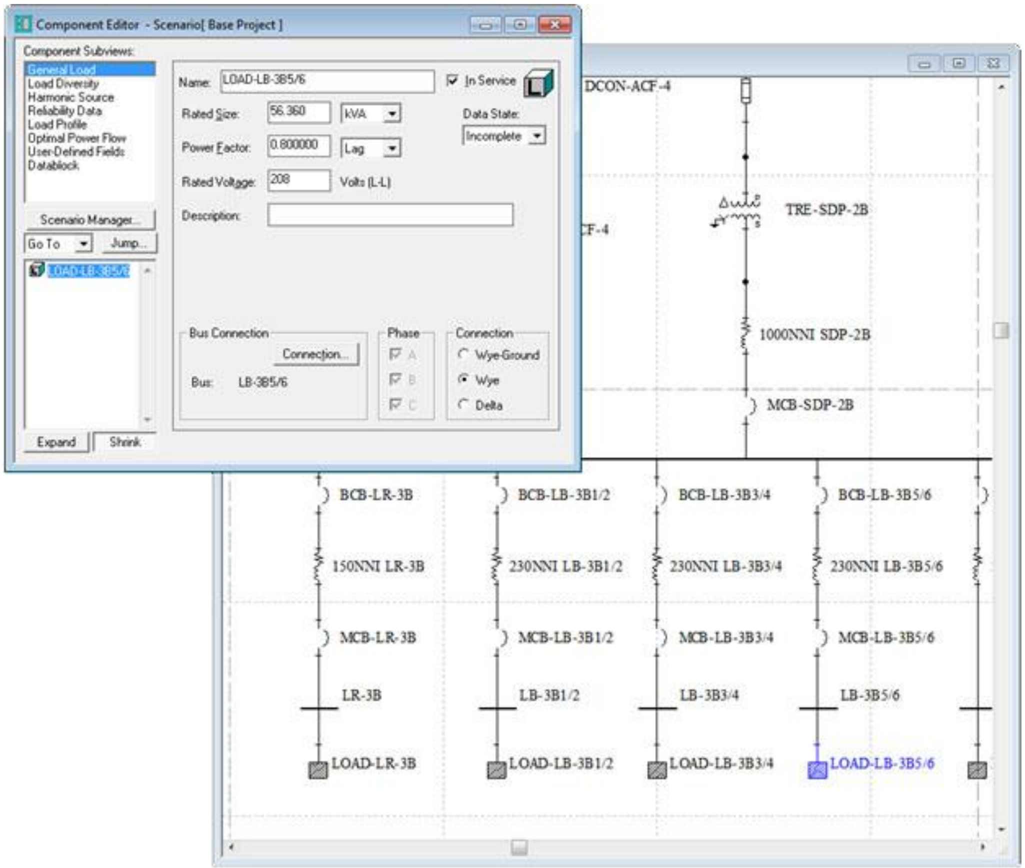
Description:

Bus: BUS-0067

Phase: ☑ A ☑ B ☑ C

Connection: ○ Wye-Ground ● Wye ○ Delta

Figure 3.65: Induction Motor Inputs in SKM


Component Editor - Scenario[Base Project]

Component Subviews: General Load

Name: LOAD-LB-3B5/6

☑ In Service

Rated Size: 56.360 kVA

Data State: Incomplete

Power Factor: 0.800000 Lag

Rated Voltage: 208 Volts (L-L)

Description:

Bus: LB-3B5/6

Phase: ☑ A ☑ B ☑ C

Connection: ○ Wye-Ground ● Wye ○ Delta

Figure 3.66: 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:

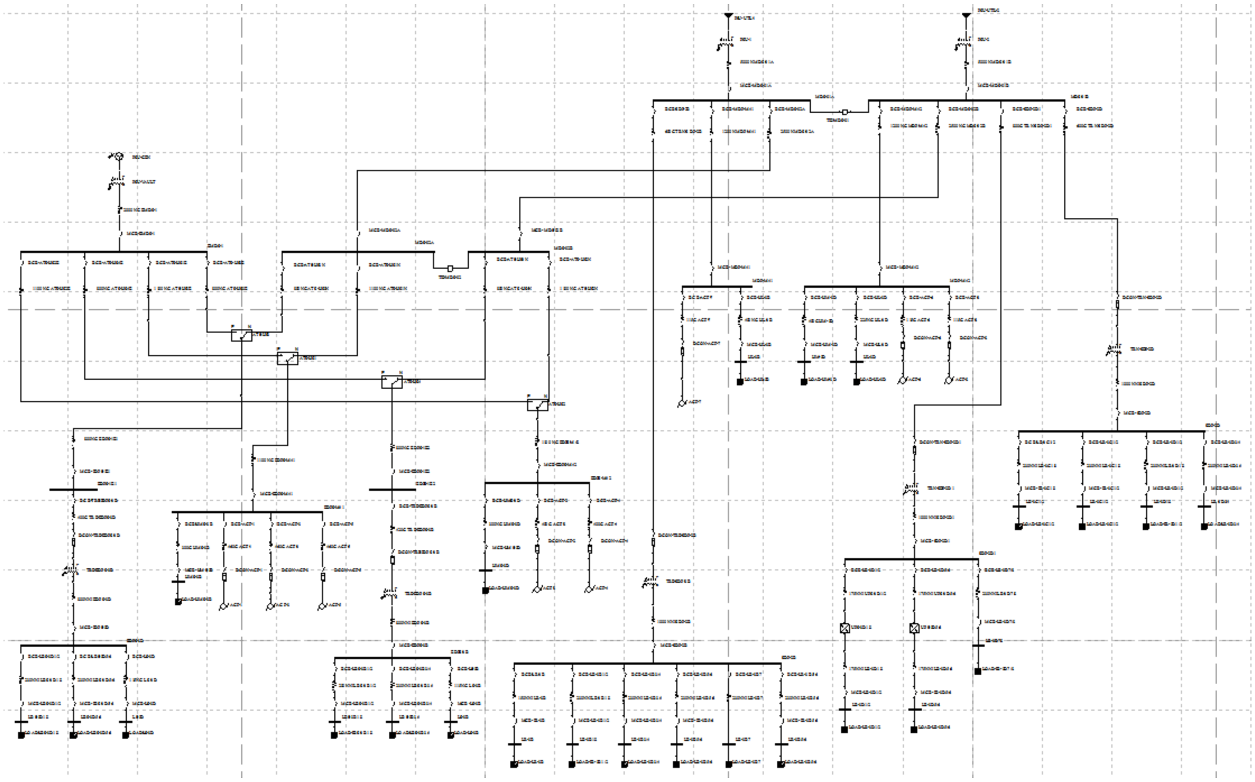


Figure 3.67: Millennium Science Complex third floor service equipment one-line diagram

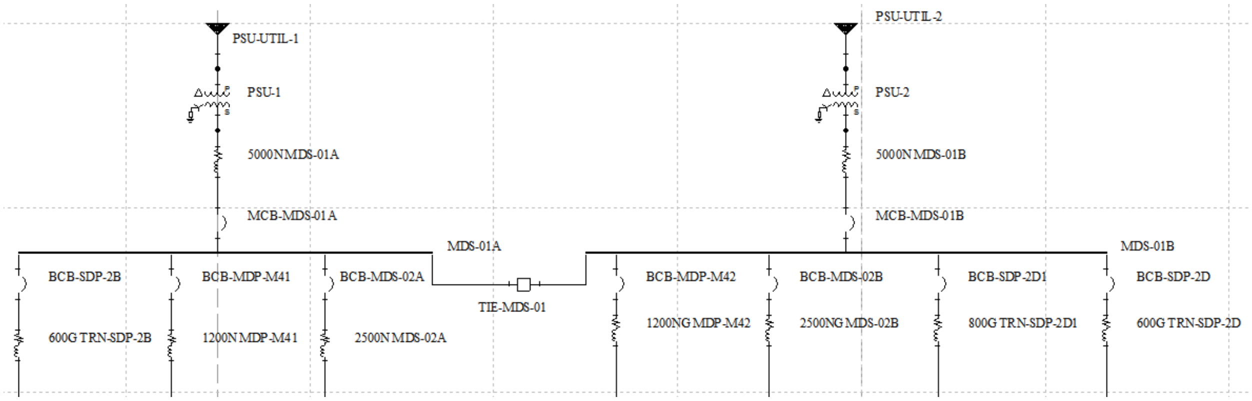


Figure 3.68: MDS-01A and MDS-01B one-line diagram

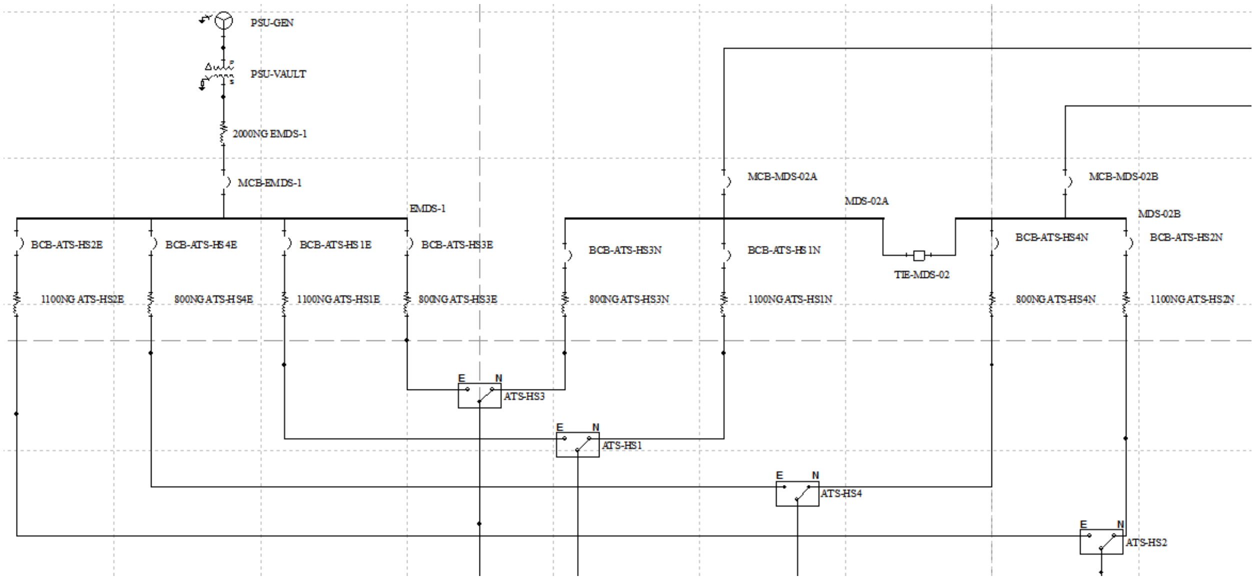


Figure 3.69: EMDS-1, MDS-02A, MDS-02B, and ATSs one-line diagram

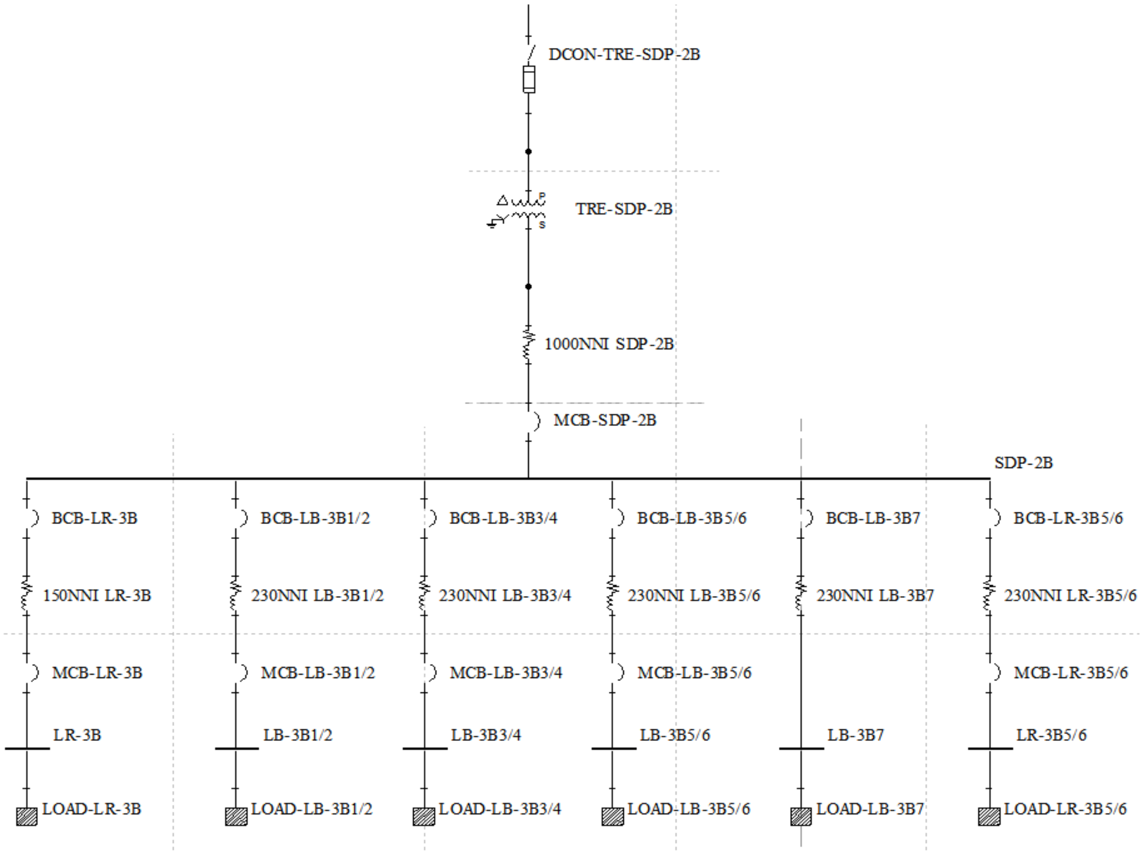


Figure 3.70: SDP-2B and loads one-line diagram

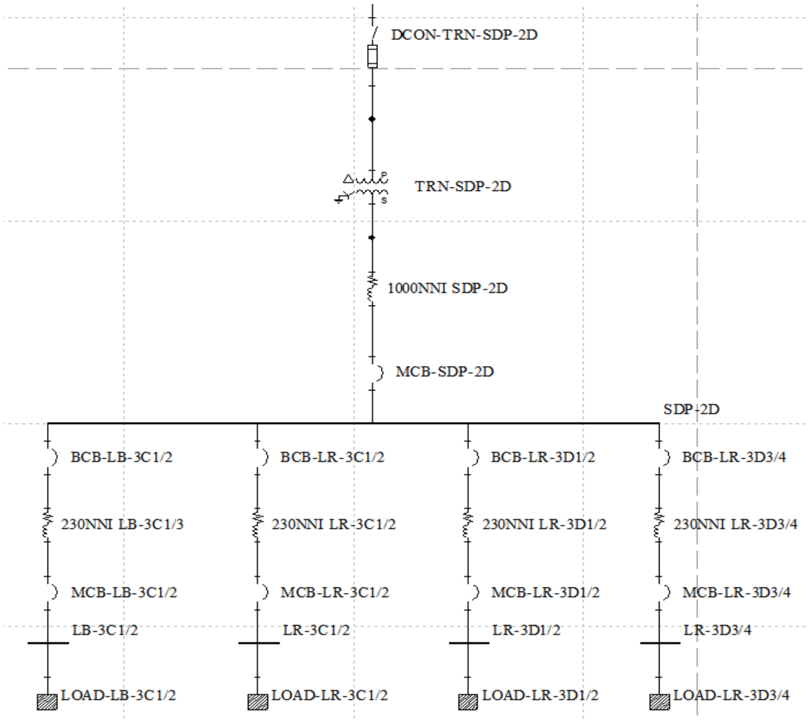


Figure 3.71: SDP-2D and loads one-line diagram

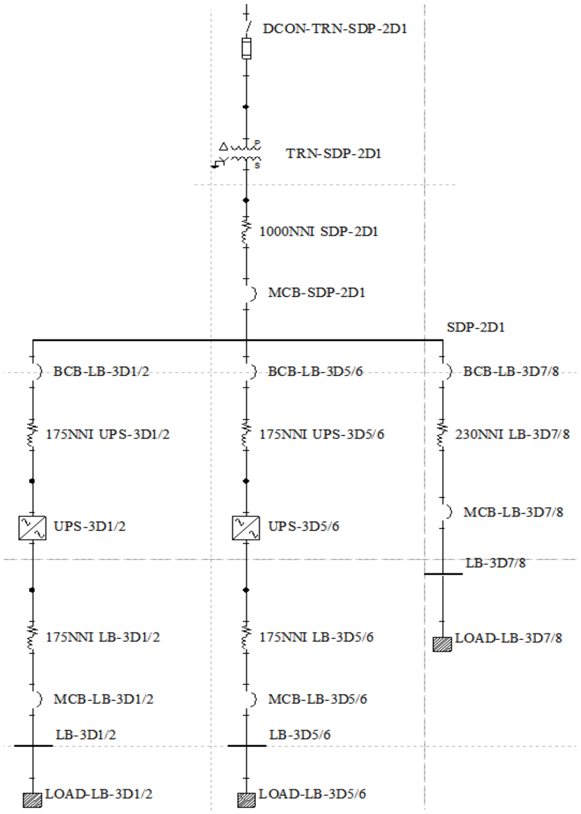


Figure 3.72: SDP-2D1 and loads one-line diagram

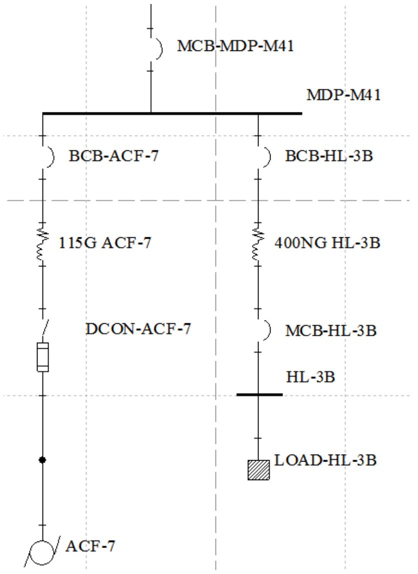


Figure 3.73: MDP-M41 and loads one-line diagram

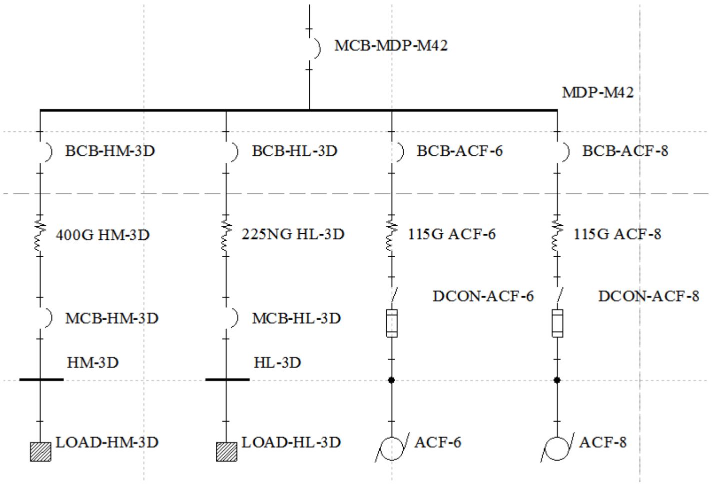


Figure 3.74: MDP-M42 and loads one-line diagram

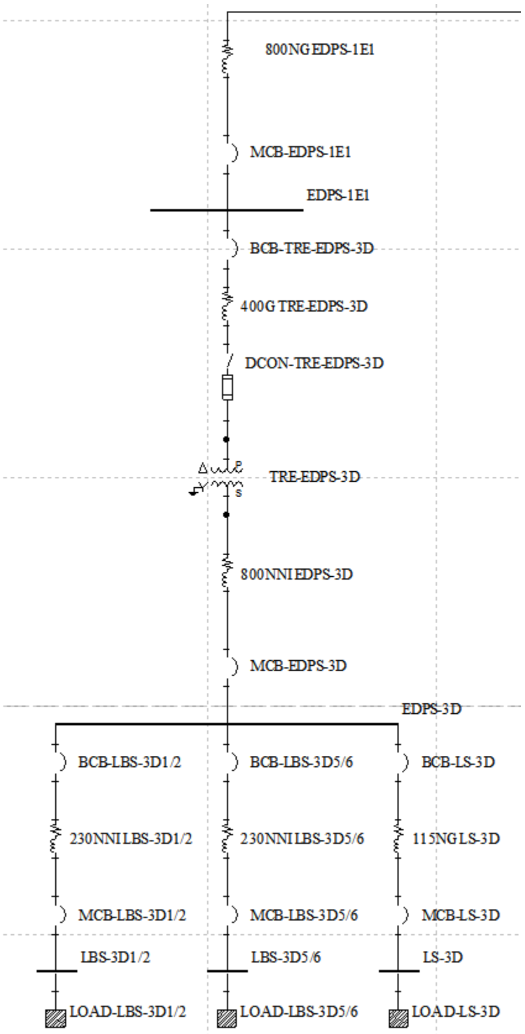


Figure 3.75: EDPS-1E1 and loads one-line diagram

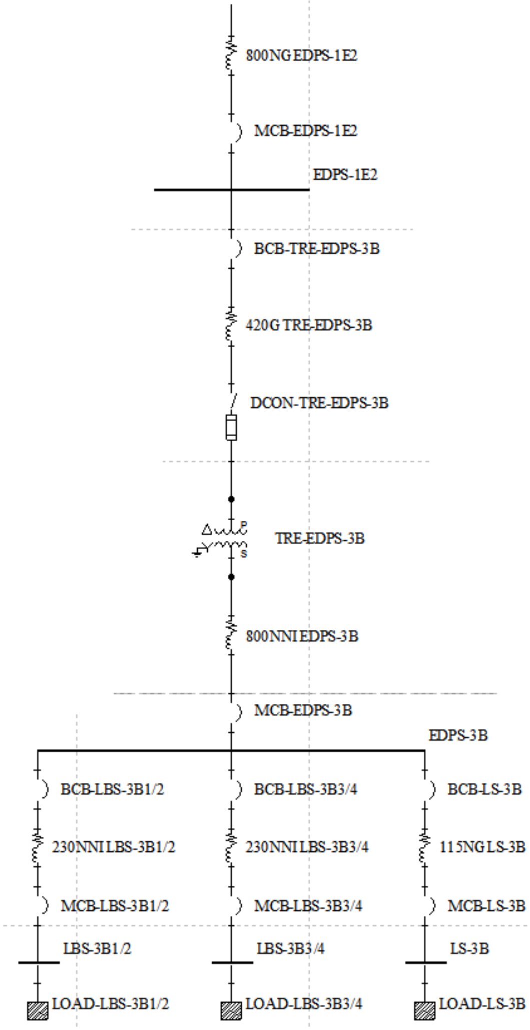


Figure 3.76: EDPS-3B and loads one-line diagram

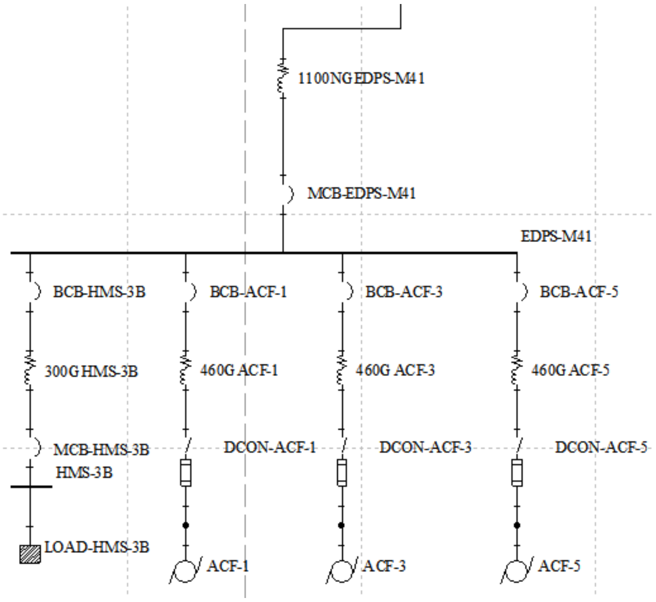


Figure 3.77: EDPS-M41 and loads one-line diagram

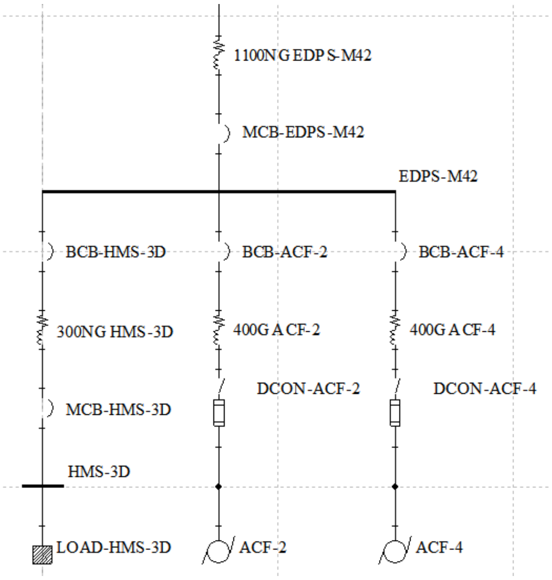


Figure 3.78: EDPS-M41 and loads one-line diagram

Once the one-line diagram is finalized in the model 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 from utility transformer PSU-1 and 34,372A from utility transformer PSU-2 to the system. The impedance values of the transformers are summarized in the table below:

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

Based on the impedances of the transformer tables above, the analyses can be performed and summarized in reports compiled by SKM Power Tools. These reports appear as text documents – file extension .rpt or .rp2 – but can be printed to PDF if the user has that type of converter installed on his or her machine. For simplicity and to conserve space, the SKM report will not be included in this document, but a summary has been composed in table format. Bus short circuit results from the SKM analysis can be seen in the table below:

Fault Analysis Summary

Bus Name	Voltage	Available Fault Current			
		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

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 the table above 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 panelboards (H- prefix) are currently rated for 14,000 AIC. The two HMS panelboards 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.

TOPIC 2: MOTOR CONTROL CENTER DESIGN

The inspiration for this electrical depth topic comes from KGB Maser's mechanical goal to reduce energy consumption by applying chilled beams for latent energy control while reducing the size of air handling units supplying the labs and office spaces. The redesign air handling units have a single electrical connection for the entire assembly. Since this is the case, the air handling units will be excluded from the motor control center and simply replace the existing air handling units on their associated distribution panelboards. The air handling unit changes can be reviewed in the "Revised Panelboard Schedules" and "Revised Panelboard Feeder Sizing" section of this document. A summary of the total equipment changes is as follows:

Existing Equipment				
Tag	Service	Location	Supply Motor (hp)	Exhaust Motor (hp)
AHU-1	Lab	Mechanical Penthouse	100	(2) 50
AHU-2	Lab	Mechanical Penthouse	100	(2) 50
AHU-3	Lab	Mechanical Penthouse	100	(2) 50
AHU-4	Lab	Mechanical Penthouse	100	(2) 50
AHU-5	Lab	Mechanical Penthouse	100	(2) 50
AHU-6	Offices	Mechanical Penthouse	60	N/A
AHU-7	Offices	Mechanical Penthouse	60	N/A
AHU-8	Offices	Mechanical Penthouse	60	N/A
CWP-1	Chilled Water	Basement Mezzanine	150	N/A
CWP-2	Chilled Water	Basement Mezzanine	150	N/A
CWP-3	Chilled Water Standby	Basement Mezzanine	150	N/A
CWP-4	Chilled Water Low Flow	Basement Mezzanine	60	N/A
HWP-5	Ventilation Heating	First Floor	40	N/A
HWP-6	Ventilation Heating	First Floor	40	N/A

Redesign Equipment				
Tag	Service	Location	Supply Motor (hp)	Exhaust Motor (hp)
AHU-EXT-1	Lab/Office	Mechanical Penthouse	50	50
AHU-EXT-2	Lab/Office	Mechanical Penthouse	50	50
AHU-INT-LS1	Interior Labs Life Science	Mechanical Penthouse	75	75
AHU-INT-LS-2	Interior Labs Life Science	Mechanical Penthouse	75	75
AHU-INT-MS1	Interior Labs Material Science	Mechanical Penthouse	75	75
AHU-INT-MS2	Interior Labs Material Science	Mechanical Penthouse	75	75
CWP-1	Active Chilled Beams CLG	Basement Mezzanine	150	N/A
CWP-2	Active Chilled Beams CLG Standby	Basement Mezzanine	150	N/A
CWP-3	AHUs + Process Chilled Water	Basement Mezzanine	100	N/A
CWP-4	AHUs + Process Chilled Water Standby	Basement Mezzanine	100	N/A
CWP-5	Chilled Water Low Flow	Basement Mezzanine	60	N/A
HWP-5	Active Chilled Beams HTG	First Floor	50	N/A
HWP-6	Active Chilled Beams HTG Standby	First Floor	50	N/A
Will be consolidated to a motor control center in the basement Mezzanine				

Currently, the location that is possibly available is in N-P052 (electrical room on basement mezzanine level). Since there are only six motors being consolidated to this motor control center, the electrical room layout can be re-organized to accommodate a narrow control center. If the design shows a large center, then the inaccessible space N-129C may be reconfigured to include a satellite electrical closet.

The motor control center will be sized using the Eaton Electrical 2006 Consulting Application Guide with the above highlighted motors. The consulting application guide can be summarized in the table below:

Motor Control Center Summary Data									
		Eaton Application Guide Data							Totals
	Tag	CWP-1	CWP-2	CWP-3	CWP-4	CWP-5	HWP-5	HWP-6	
	Motor hp	150	150	100	100	60	50	50	
	Voltage/PH	460/3	460/3	460/3	460/3	460/3	460/3	460/3	
	Power Factor	0.95	0.95	0.95	0.95	0.95	0.95	0.95	
	Full Load Current (NEC)	180A	180A	124A	124A	77A	65A	65A	815A
	Power (kVA)	149.58	149.58	103.04	103.04	63.99	54.02	54.02	677.27
	NEMA Starter Size	5	5	4	4	4	3	3	
VFD Option	Variable Frequency Drive Type	VT*	VT	VT	VT	VT	VT	VT	
	HMCP	400	400	150	150	100	100	100	
	MCCB	500	500	300	300	175	150	150	
	Unit Height (spaces)	12	12	12	12	9	9	9	
*VT = Constant Torque drive capable of producing 200% starting torque for 10 seconds and are rated 110% overload for one minute.									

The motor control center design will be contained within an Eaton 2100 Series Freedom and Advantage Motor Control Center. After consulting with KGB Maser's mechanical engineer, it was determined that the pumps for the chilled beam supply water will be variable frequency drive. The main motor control center circuit protection will be an Eaton circuit breaker sized for a 125% of the full load amps of the largest motor plus 100% of the remaining motors connected to the center – in this case 860A. The maximum overcurrent protection by circuit breaker is 250% of the center full load current – 2037.5A, or a 2000A breaker. Considering these two boundaries, the main circuit protection for the motor control center will be an Eaton CNDC circuit breaker frame rated for 1200A with a trip setting of 1200A. This main circuit breaker will occupy 12 units of a single section (one entire section). An isometric view of the unit can be seen in Figure 3.79 below:

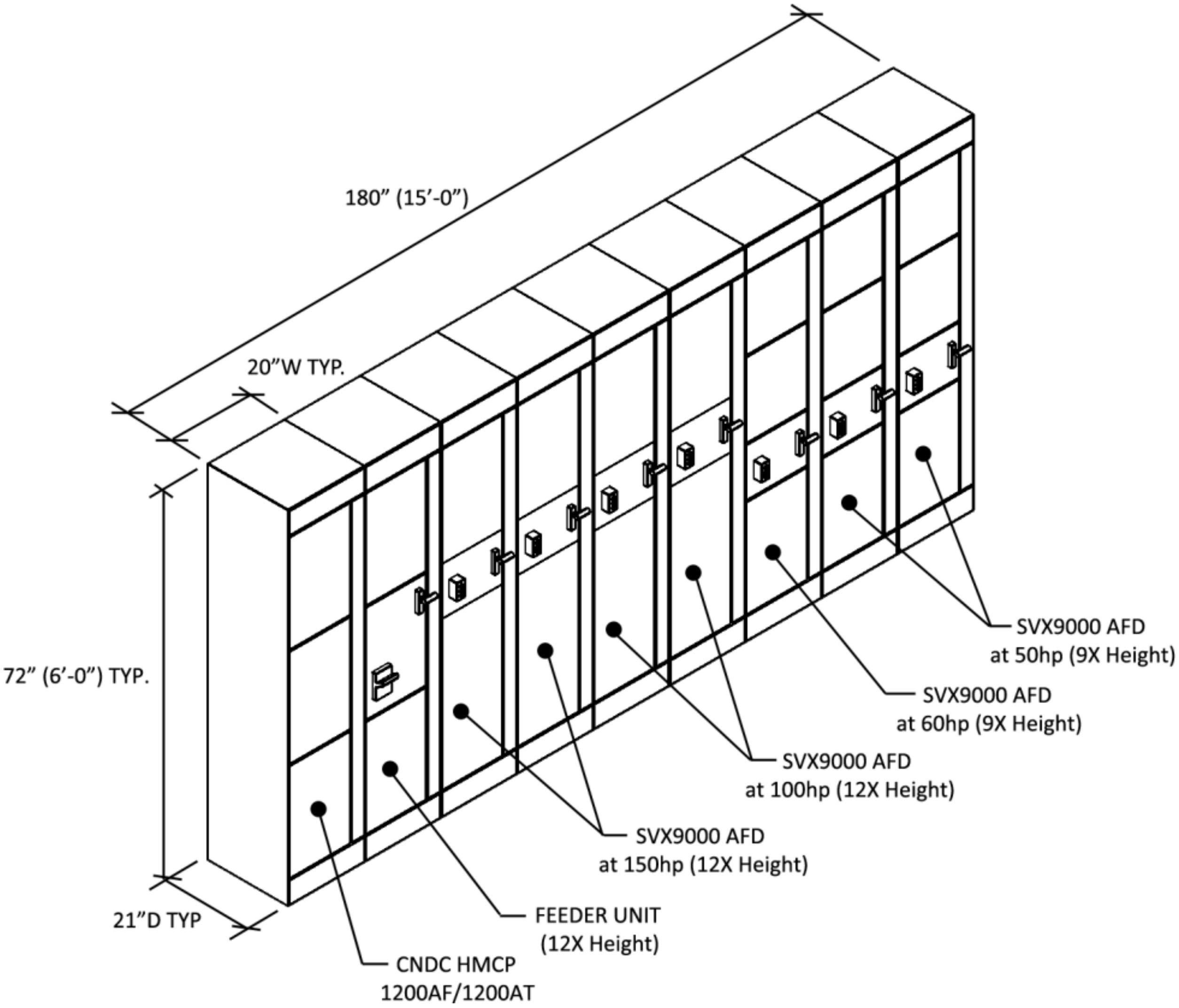
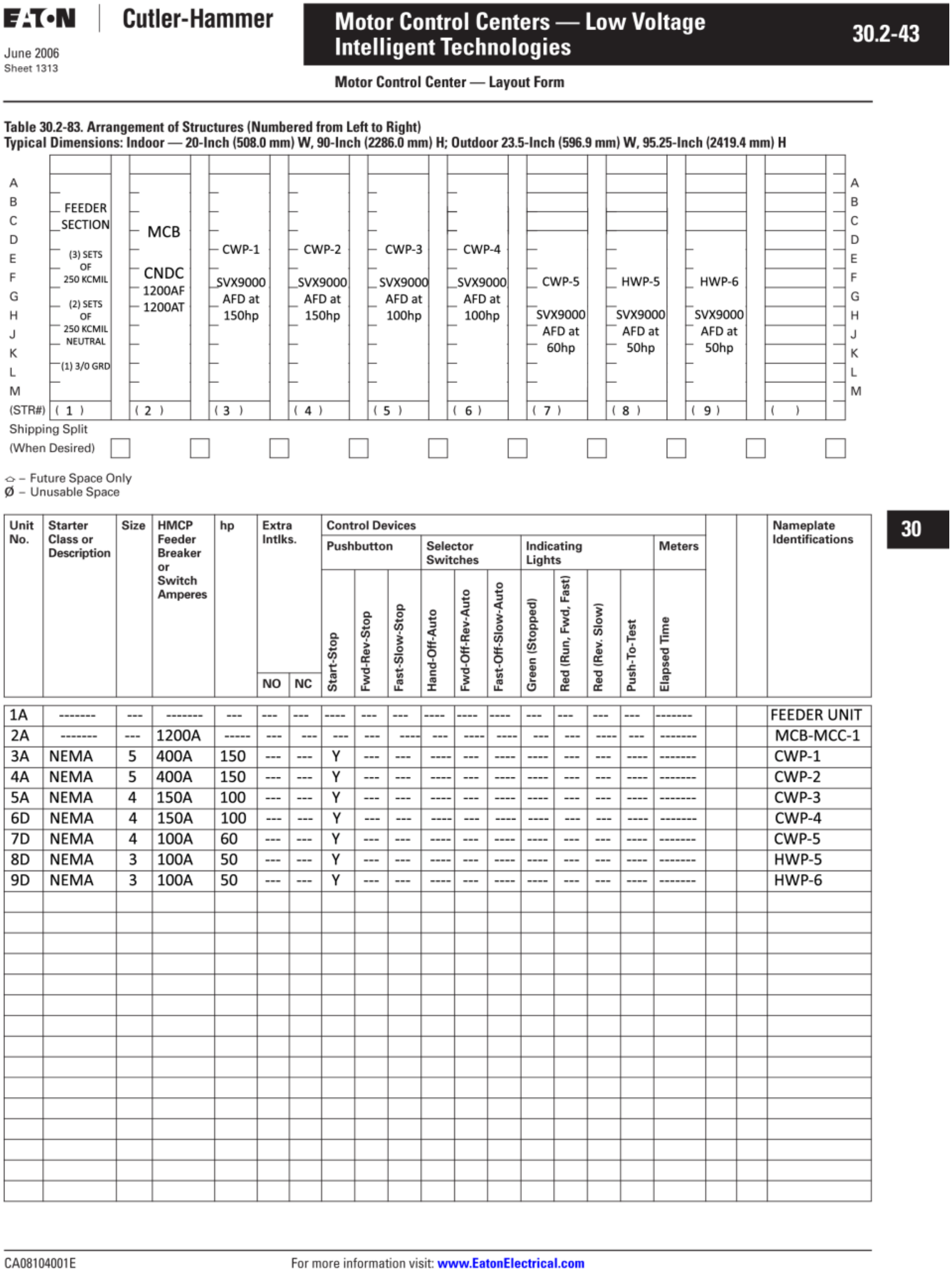


Figure 3.79: Motor Control Center Design Isometric View

Additionally, the sizing and layout sheet from Eaton's application guide can be seen in Figure 3.80:



EATON | Cutler-Hammer

June 2006
Sheet 1313

Motor Control Centers — Low Voltage Intelligent Technologies 30.2-43

Motor Control Center — Layout Form

Table 30.2-83. Arrangement of Structures (Numbered from Left to Right)
Typical Dimensions: Indoor — 20-Inch (508.0 mm) W, 90-Inch (2286.0 mm) H; Outdoor 23.5-Inch (596.9 mm) W, 95.25-Inch (2419.4 mm) H

A–M	FEEDER SECTION (3) SETS OF 250 KCMIL (2) SETS OF 250 KCMIL NEUTRAL (1) 3/0 GRD	MCB CNDC 1200AF 1200AT	CWP-1 SVX9000 AFD at 150hp	CWP-2 SVX9000 AFD at 150hp	CWP-3 SVX9000 AFD at 100hp	CWP-4 SVX9000 AFD at 100hp	CWP-5 SVX9000 AFD at 60hp	HWP-5 SVX9000 AFD at 50hp	HWP-6 SVX9000 AFD at 50hp	
(STR#)	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	( )
Shipping Split (When Desired)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

◇ – Future Space Only
Ø – Unusable Space

30

Unit No.	Starter Class or Description	Size	HMCP Feeder Breaker or Switch Amperes	hp	Extra Intlks.		Control Devices													Nameplate Identifications
							Pushbutton			Selector Switches			Indicating Lights				Meters			
					NO	NC	Start-Stop	Fwd-Rev-Stop	Fast-Slow-Stop	Hand-Off-Auto	Fwd-Off-Rev-Auto	Fast-Off-Slow-Auto	Green (Stopped)	Red (Run, Fwd, Fast)	Red (Rev. Slow)	Push-To-Test	Elapsed Time			
1A	-------	---	-------	---	---	---	----	---	---	----	----	----	---	---	---	---	-------			FEEDER UNIT
2A	-------	---	1200A	-----	---	---	---	---	----	---	----	----	---	---	----	---	-------			MCB-MCC-1
3A	NEMA	5	400A	150	---	---	Y	---	---	----	---	----	----	---	---	----	-------			CWP-1
4A	NEMA	5	400A	150	---	---	Y	---	---	----	---	----	----	---	---	----	-------			CWP-2
5A	NEMA	4	150A	100	---	---	Y	---	---	----	---	----	----	---	---	----	-------			CWP-3
6D	NEMA	4	150A	100	---	---	Y	---	---	----	---	----	----	---	---	----	-------			CWP-4
7D	NEMA	4	100A	60	---	---	Y	---	---	----	---	----	----	---	---	----	-------			CWP-5
8D	NEMA	3	100A	50	---	---	Y	---	---	----	---	----	----	---	---	----	-------			HWP-5
9D	NEMA	3	100A	50	---	---	Y	---	---	----	---	----	----	---	---	----	-------			HWP-6

CA08104001E For more information visit: www.EatonElectrical.com

Figure 3.80: Eaton Motor Control Center Layout Worksheet

After the motor control center is sized, it can be located within the building. Upon reading available space from the electrical plans, inaccessible space N-129C can be redesigned to include a concrete floor to locate the motor control center for the water pumps. This location was chosen due to the lack of space elsewhere near the pump loads served by the control center. The existing floor plan can be seen in Figure 3.81 below:

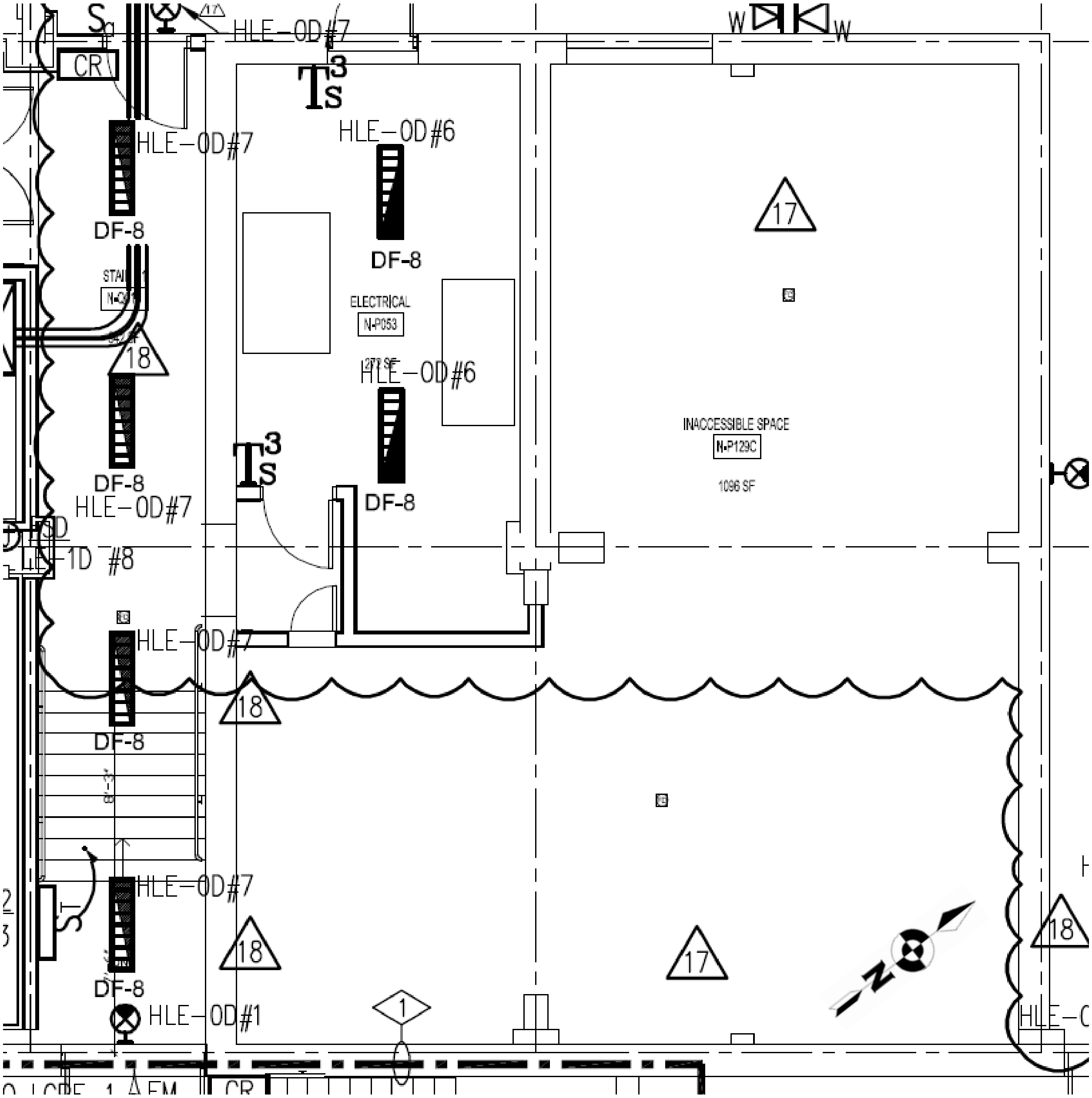


Figure 3.81: Available Space for Motor Control Center, NTS

The dimensions from the aforementioned data result in a motor control center that is 15’-0” in length. With the space now available, the motor control center can be located in the newly formed room using Revit Architecture. The plan for locating the MCC can be seen in Figure 3.82 below:

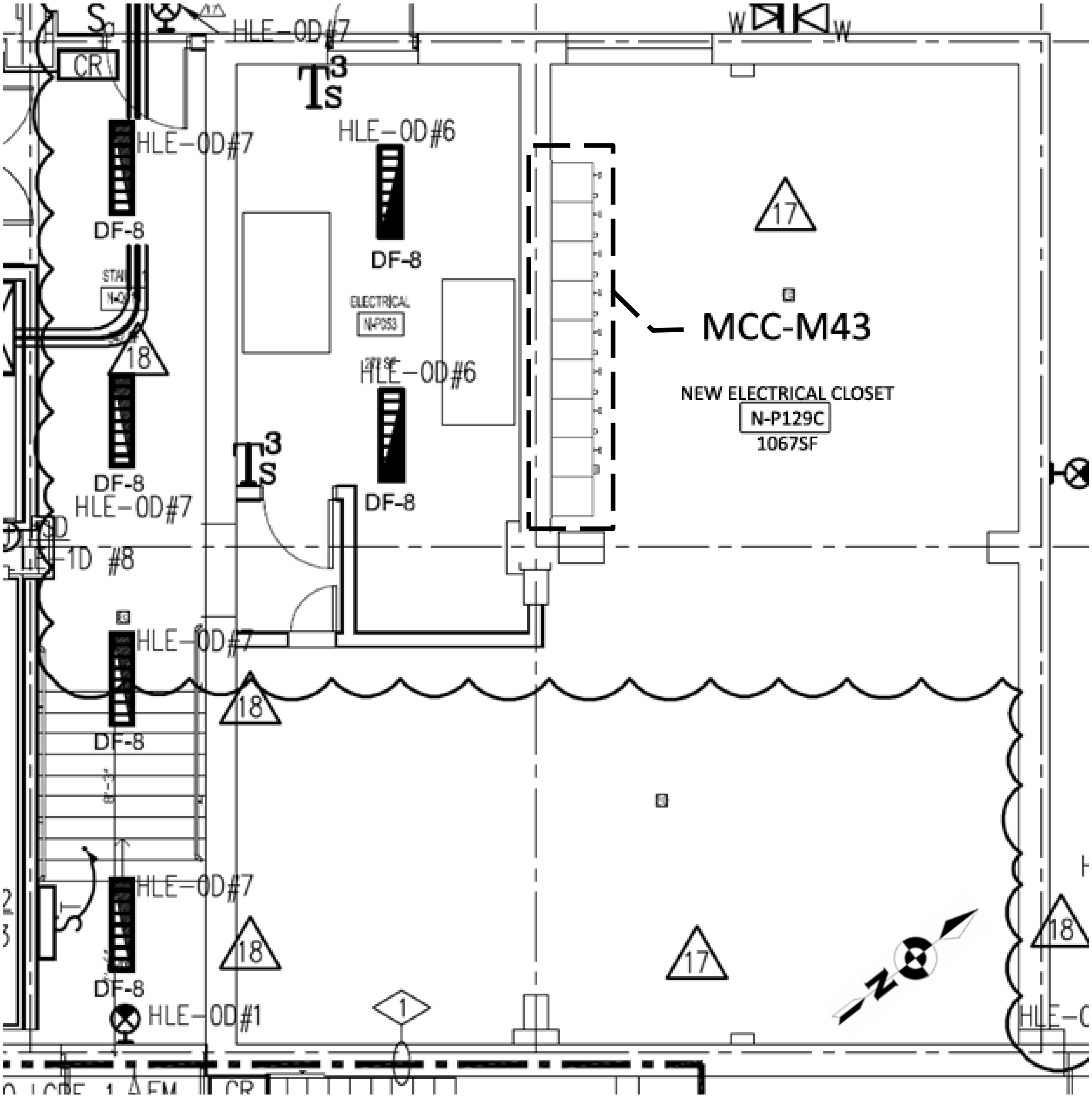


Figure 3.82: Motor Control Center Location Plan, NTS

Finally, a name-plate must be placed on the motor control center. The name-plate for this application should be similar to the following image:

MOTOR CONTROL CENTER: MCC-M43 LOCATION: SUPPLIMENTARY BASEMENT ELECTRICAL CLOSET

AMPS: 1000 VOLTS: 480Y/277 3 PH, 4 W, 60 HZ, NEMA: 2 AIC: 100,000

UNIT	CIRCUIT	HP/KVA	FLA	STARTER		CIRCUIT PROTECTION		FEEDER	NOTES
NO.				TYPE	SIZE	TYPE	TRIP		
1A	FEEDER UNIT	-----	-----	-----	-----	-----	-----	3 SETS OF (3) 250KCMIL, (2) 250KCMIL N + 3/0 G	INCOMING FEEDER
2A	MCB-MCC-1	-----	------	-----	-----	CNDC	1200A	3 SETS OF (3) 250KCMIL, (2) 250KCMIL N + 3/0 G	MCC MAIN CB
3A	CWP-1	150HP	180A	AFD	5	HMCP	400A	(3) 4/0 PHASE + #3 GRD IN 2"C	
4A	CWP-2	150HP	180A	AFD	5	HMCP	400A	(3) 4/0 PHASE + #3 GRD IN 2"C	
5A	CWP-3	100HP	124A	AFD	4	HMCP	150A	(3) 2/0 PHASE + #6 GRD IN 2"C	
6D	CWP-4	100HP	124A	AFD	4	HMCP	150A	(3) 2/0 PHASE + #6 GRD IN 2"C	
7D	CWP-5	60HP	77A	AFD	4	HMCP	100A	(3) #3 PHASE + #8 GRD IN 1.5"C	
8D	HWP-5	50HP	65A	AFD	3	HMCP	100A	(3) #4 PHASE + #8 GRD IN 1"C	
9D	HWP-6	50HP	65A	AFD	3	HMCP	100A	(3) #4 PHASE + #8 GRD IN 1"C	

Figure 3.83: Sample Motor Control Center Label

The feeders running to the pumps will need to be resized according to voltage drop regulations according to the National Electrical Code. I the figure above, they are sized at 125% of the full load current of each motor.

MANUFACTURER INFORMATION

Manufacturer information for each of the redesign spaces and for panelboard redesigns can be found in Appendix 3.C.

REFERENCES

Dimming System

Lutron Ecosystem Overview. Lutron Electronics Company. Web. 9 Feb. 2011. <http://www.lutron.com/Products/WholeBuildingSystems/EcoSystem/Pages/Overview.aspx>.

Eaton Distribution Equipment

"Electrical Selector." Eaton Electrical Homepage. Web. 12 Mar. 2011. <http://www.eaton.com/Electrical/index.htm>.

Electrical Code

National Electrical Code: 2008. Quincy, MA: National Fire Protection Association, 2007. Print.

Electrical System Modeling

Afshin, and Johnny. FAQ: Modeling an Uninterruptable Power System (UPS). Manhattan Beach, CA: SKM Systems Analysis, Inc. PDF. <http://www.skm.com/Modeling_a_UPS_in_PTW.pdf>

IES Handbook

Block, Judith, ed. IESNA Lighting Handbook. 9th ed. New York City: Illuminating Engineering Society of North America, 2000. Print.

Luminaire Products

1. Alkco Lighting - <http://www.alkco.com/>
2. LiteControl - <http://litecontrol.com/>
3. Lithonia Lighting - <http://www.lithonia.com/>
4. Kurt Versen Lighting - <http://www.kurtversen.com/>
5. Deco Lighting - <http://www.getdeco.com/>
6. AllScape Lighting - <http://www.allscape.net/new/index.html>
7. Kim Lighting - <http://www.kimlighting.com/>
8. Lightolier - <http://www.lightolier.com/home/home-swf.jsp>
9. Louis Poulsen Lighting - <http://www.louispoulsen.com/en-us.aspx>

Lutron Control Products - <http://www.lutron.com/Pages/Default.aspx>

Osram Sylvania

Osram Sylvania - Product Catalogs Home. Osram Sylvania. Web. <http://www.sylvania.com/ProductCatalogs>.

Philips Advance Transformer

Product Catalog Datasheets. Philips Advance Transformer. Web. <http://www.advance.philips.com/ecatalog/>.

Reflectance Research

1. Benjamin Moore Paint - Color Selection Tools and Resources for Design Professionals. Benjamin Moore Paints. Web. 2 Feb. 2011. <http://www.benjaminmoore.com/bmpsweb/portals/bmps.portal?_nfpb=true&_pageLabel=fa_home>.
2. Resene Paints, Coatings, Wood Stains, Decorating Ideas, Custom Paint, Interior & Exterior Paint. Resene Paints. Web. 2 Feb. 2011. <http://www.resene.co.nz>.
3. J+J/Invision Broadloom and Modular Commercial Carpet. J+J/Invision. Web. 2 Feb. 2011. <http://www.jj-invision.com/products/View_All.aspx>.

Shading System

Motorized Shades - ElectroShades - Bottom Up Shades. MechoShade Systems. Web. 9 Feb. 2011. <http://www.mechoshade.com/motorizedshades/electro_bottomup.cfm>.

SquareD Distribution Equipment

"Schneider Electric Home." Schneider Electric Is the Global Specialist in Energy Management - Schneider Electric United States. Web. 28 Feb. 2011. <http://www.schneider-electric.us/sites/us/en/home.page>.

Wattstopper Wall Box Occupancy

"Product Type - Passive Infrared." Wattstopper. Web. 25 Mar. 2011. <http://wattstopper.com/products/productline_list.html?category=37&type=Commercial>.