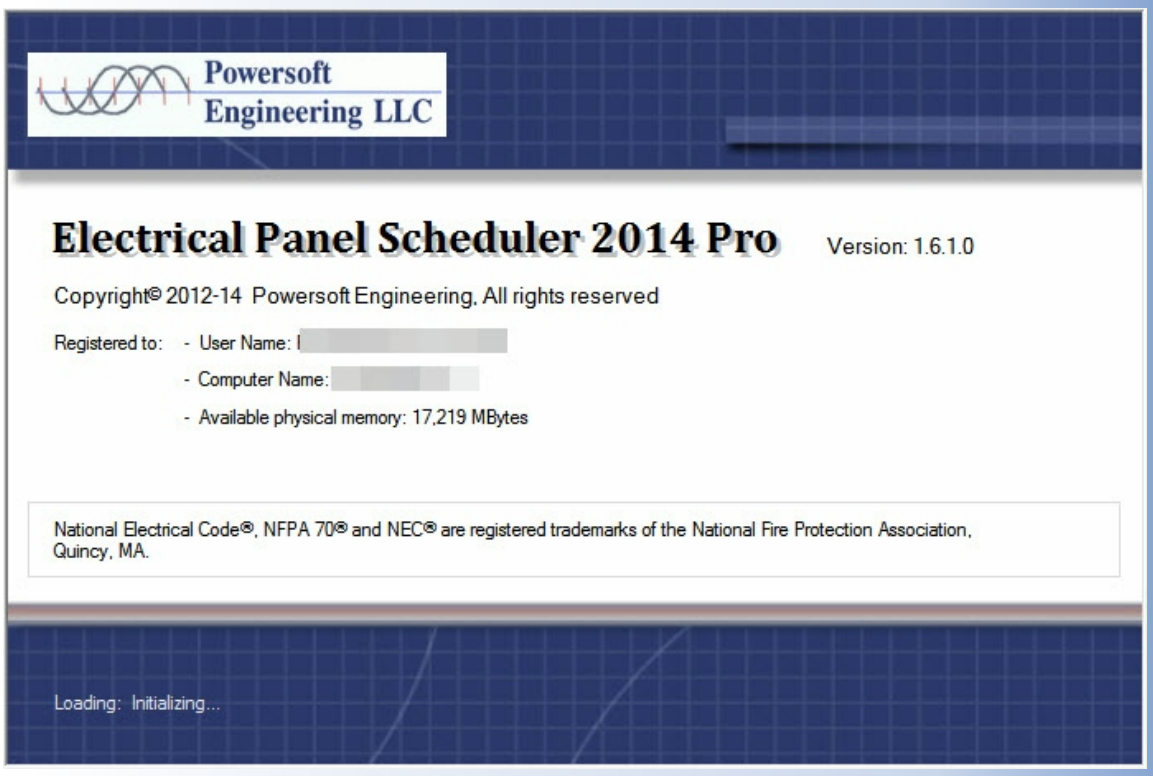
Electrical Panelboard Scheduler 2014 Pro



USER GUIDE

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Powersoft Engineering LLC
West Columbia, SC 29171

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Contents

Chapter 1

Welcome to Electrical Panelboard Scheduler 2014 Pro

EPS Pro was designed with the electrical community in mind for aiding Electrical Engineers, Contractors, Estimators, and Designers to build panelboards that can range from small 6 circuit 30 amps load centers to large 168 circuit 6000 amp switchgears and wire sizing functions to 18 parallel runs, which can be changed, and minimum to maximum wire size configurations specified by the user. Other settings can be tailored to make the design process effortless and accurate. There are many features in the Pro version which allow users to be very efficient in wiring and solving most any need.

EPS uses an incredibly elaborate set of algorithms and table lookup functions that will achieve any electrical scenario. These algorithms can be used to produce any sort of electrical installation situation.

EPS can offer designers built-in functionality that will show exactly what loads, voltage drops and conduit fills are for each circuit with minimal efforts. A good background in NFPA codes and regulations is required so designs using EPS can be compliant with meeting these codes. All final design submittals should be supervised by a Licensed Professional Engineer.

EPS 2014 Pro, is designed to include riser diagrams and short circuit calc ratings for using point to point method.

Microsoft® Excel® is required to output each panelboard schedule and AutoCAD is required to export schedules for drawing files.

Key Features

Here are some of the key features of EPS:

- Displays full time connected and demand load factors with amperage.
- Voltage drop calculations.
- Conduit fill factors
- Panels can be from 30 amp load centers to 168 circuit (one or 2 section) 6000 amp switchgears.
- Exporting schedules to AutoCAD.
- Importing comma delimited files from Revit data circuiting schedules to create many circuits in seconds.
- Short circuit AIC rating for riser diagrams using point to point method.
- User defined panelboard load tolerance calculator for phase balancing to utility.
- Drag and drop riser elements which can be connected and removed while sizing updating any breakers which are required for connection.
- Project designs can be tracked with a log file that explains who, when and how much time is spent in each schedule in a continuous log file.
- Automatic wire, conduit and breaker sizing functions based on tables provided by *NFPA*.
- Export panel schedule to preview, save and print in MS Excel 2007. There are many options for exporting exactly which information you want to provide.
- Begin any riser with utility transformers or existing panelboard.
- Ability to export entire riser to Excel in one click.
- Ability to export an overview or riser elements to Excel to give designers a overview look at wire sizes serving all elements.
- Clicking or riser elements allow users to see load summaries and other information.
- Double click any riser element to edit.
- One button allows users to recalculate entire riser when updating loads in panels.
- Voltage drops are updated constantly along with wire lengths to and from the utility so users know the exact voltage at any given point in the system.
- Circuit wizard for sizing smaller loads, with lookup tables which include receptacles, lights, motors, a three step process for sizing HVAC loads and two step process for calculating heat loads.

- Ability to input any world-wide voltage based on 50 or 60 hertz.
- Ability to edit diversity factors based on panel specifications to a panelboard summary. EPS has 19 diversity factor fields to combine flexibility.
- Ability to modify minimum and maximum wire size and standard circuit conduit and wire types, based on project settings.
- Ability to copy, move or swap, by drag and drop, circuits from one panel to another, one pole to another and then modify these circuits once they are placed. This presents an excellent opportunity to balance loads throughout a riser.
- Provide minor warning messages for correction or investigation.
- EPS can also provide the user with easy to read panel schedules inside the program to show which circuits are shared neutrals, 2 or 3 pole circuits. These groups can also show separate background colors and are easily changeable making the schedules very easy to read and manipulate.
- Riser visualization and ease of drag and drop make EPS most effective when completing a project infrastructure.
- Panels can be started as templates then saved to a new name reducing much time required for setting up a project.
- EPS windows can be configured for user preferences and use multiple monitors to remember where and how those windows are placed.
- New ideas in circuit layouts allow users to create one circuit and copy it to many circuits with one click.
- Automatically create spare circuit to any desired number of circuits in one click.
- Users can begin one circuit and copy it to any multiple sequence of numbers in one click.
- Context menus allow users to increase wire size by one wire size without having to go back to the load apply window.
- A warning system that lets users know when problems occur, but is limited to give users flexibility.
- A percentage counter that lets users know the exact percentage of free space available in a panels or risers.
- When introducing transformers into the system, EPS windows let users know exactly what circuit breakers are required to serve incoming and outgoing power and show what loads are connected.

Over ten years of ideas and testing have gone into EPS and we are confident you will enjoy using EPS once you become accustomed to the interface. New ideas and functions are occurring all the time as it grows. We have many new ideas for the future and hope you will continue to use EPS by providing feedback along the way.

Installation

A standard and easy to use installer program is supplied with EPS. This will allow you to install the software on your computer without difficulty.

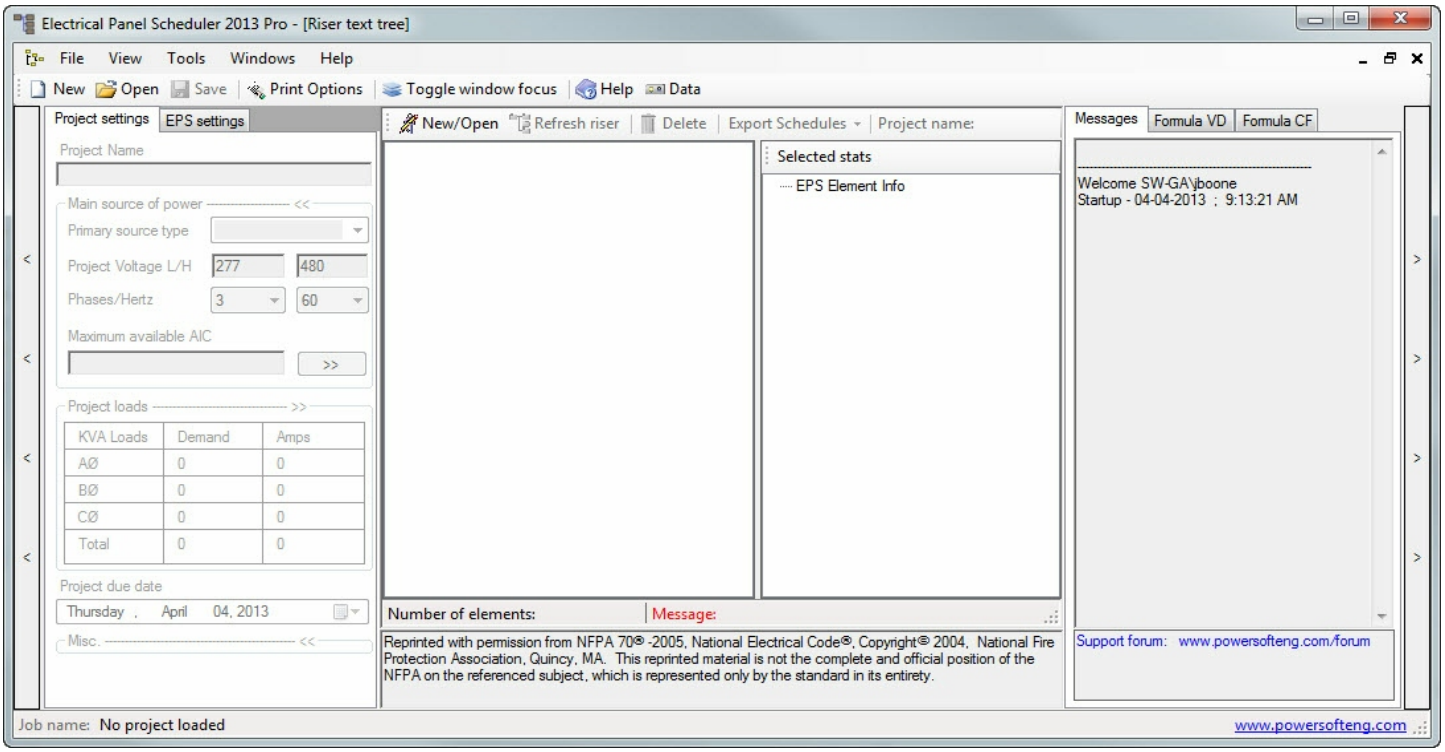
Upon installation, you will have a 15 days trial period to evaluate for the 32 bit or 64 bit versions. If you decide to keep EPS after this time, please purchase a license from our web site and to continue to use EPS for as long as you like. EPS will continue to be updated at least every three years for new codes, but technically, are fine till sizing tables changes occur which have not happened for a long time.

Support

Should you require technical support:
http://www.powersofteng.com/forum/index.php.
You will have to register to post messages. This is the best place to ask questions because it may contain ideas the community may use.

Chapter 2

Interface guide



EPS Main Screen

A good understanding of electrical circuits and *National Electrical Code*® is required before using *EPS Pro* but is designed so that tedious requirements of writing panel schedules is reduced.

The interface begins with a simple layout designed so the users will have as little input from the program as possible for designing circuits. Of course the amount of combinations for circuit is limitless and is laid out in a manor to help the users to achieve that goal. Some program variables may be changed, during design, to facilitate some input requirements for circuiting. The variables in the EPS settings will alleviate users input for each individual circuit. This interface guide will explain each input and describe what each one does.

There are 3 basic parts to the screen shown above. To the left is shown a two tab panel for EPS setting and element selection and creation. The EPS settings tab contains a set of variables that are used by the program for panelboard and circuits wire sizing. All wire calculating functions rely on this information to be accurate so it can return appropriate wire sizes. With a good understanding on *NEC* this is fairly straight forward. Most of these settings may never have to be changed except if panelboard wire type, wire insulation type and conduit type are different from job to job. There may be some instances when they will have to be changed within a project, or even to overhead or underground circuits. The settings here can be changed at any time within the design process to alleviate changing a set of circuits. Of course, the user can always change a circuit to some other values at a later time. This section is collapsible by pressing the button to the left.

The center section is where EPS uses to show riser and load summaries when building projects. Currently there is no project loaded.

The right most section shows messages that EPS posts to show users which panels were edited or viewed and display potential problems. When creating projects, a record is kept in a log file of all the displayed message occurrences. It also shows voltage drop and conduit fill calculator in separate tabs. This section is collapsible by pressing the button to the right.

Menu

File

New project
A new project will be created. A project in EPS is defined as consisting of a "service" or system of panels and transformers and should be stored in a separate directory from other systems, even if they serve the same building(s) or an engineering project. Often times we have wired many building in a complex and kept all building elements in a EPS "project". Each time a new "service" is used, a new project should be created to facilitate a new utility transformer or existing panelboard since those can only be tapped a maximum of six times and only of those can be used at a time.

Open project
As mentioned above, this menu item will open a previously setup project.

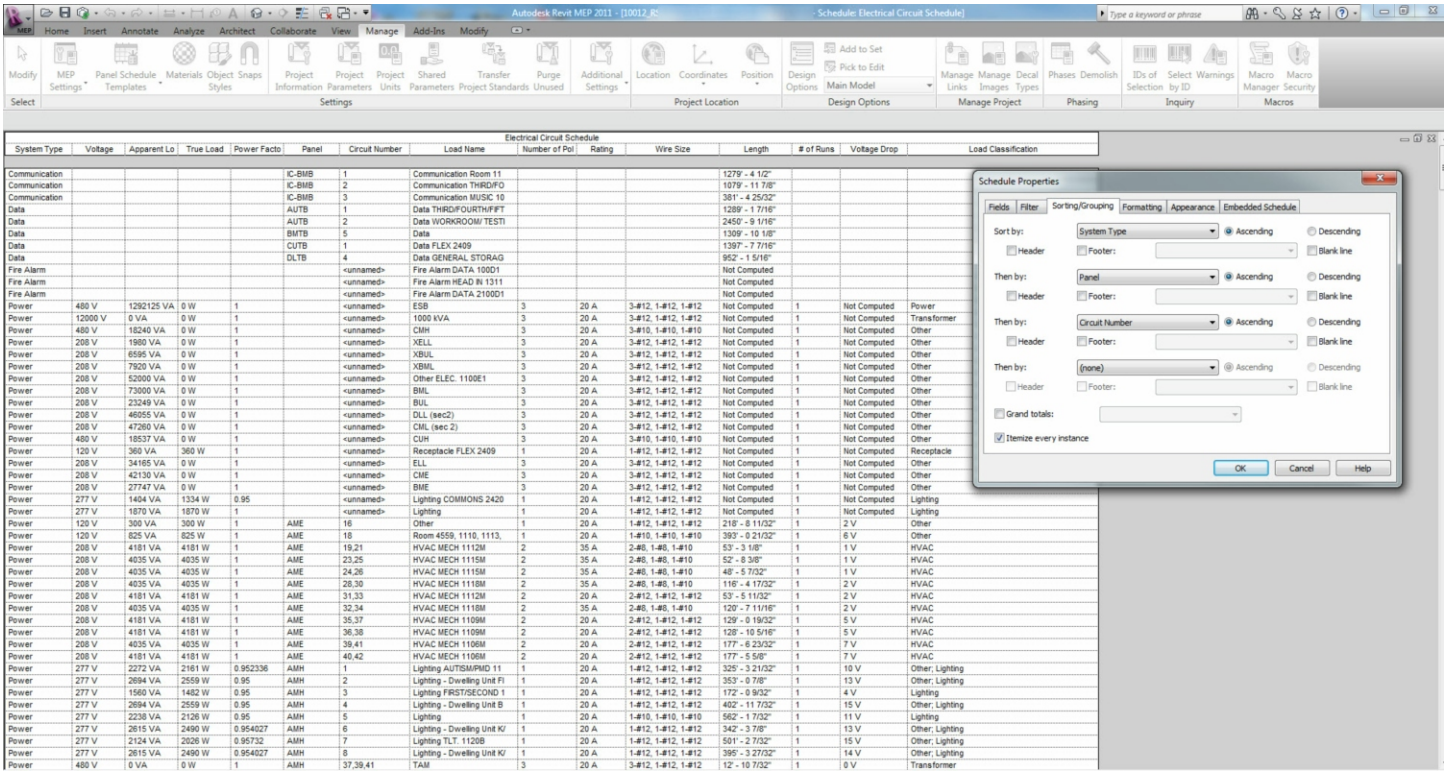
Save project
Will save current project file.

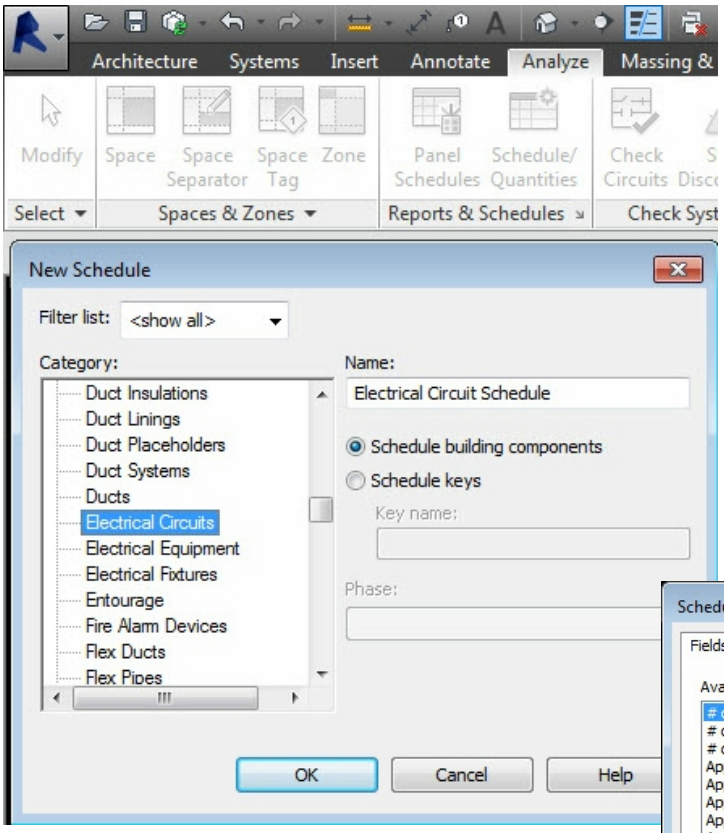
Close project
This will close out of a project so a new one can be started. We do not recommend starting a new project while one is open.

Exit
This will exit out of EPS

Import > tab delimited text file
Importing a tab delimited file was an attempt at getting Revit circuiting into EPS. This import can of course be done from any text file provided the data in each columns all match correctly Use the import window to show which fields are required. This is minimal data EPS can use to create a power system.

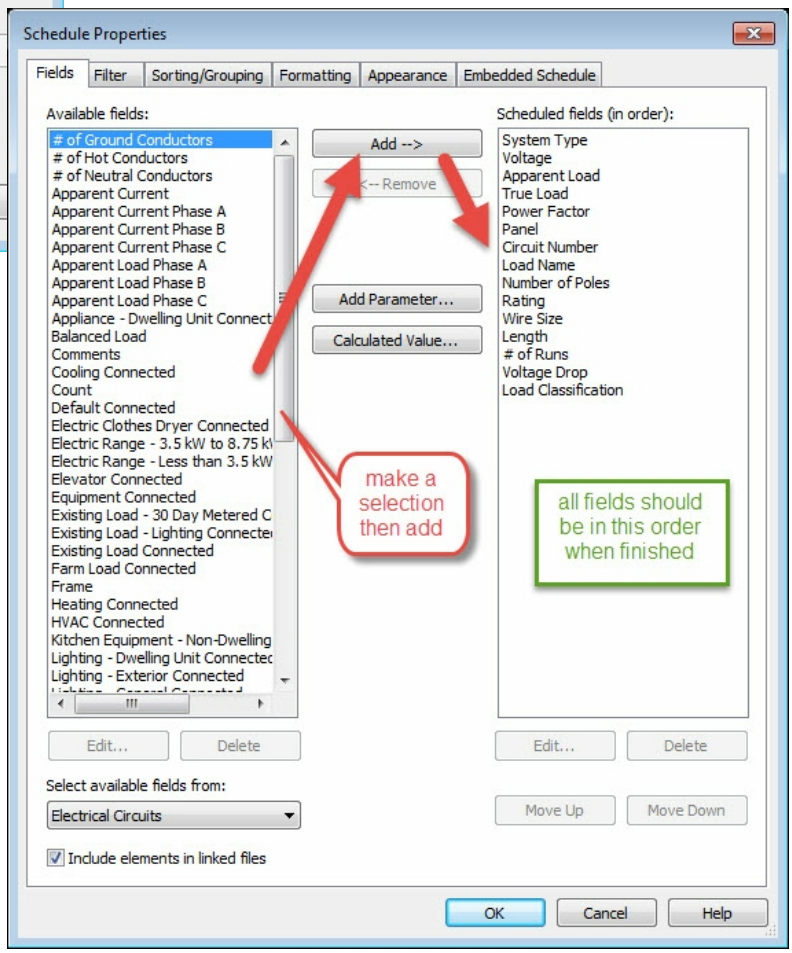
From Revit 2011 we setup a table of electrical circuits. It has many systems which included communications, data, fire alarm and telephone. This was then exported to a tab delimited file and manually edited to remove those unwanted systems so we are left with only panelboaerd connected circuits. This is why we began our filter lists with power system so finding and removing those unwanted systems would be simple. Because of the methods used for sequencing panels, panels must be sorted, then circuit number. There are 438 circuits and 34 panelboards, so to prevent from asking the users lots of questions, this method works quite well.



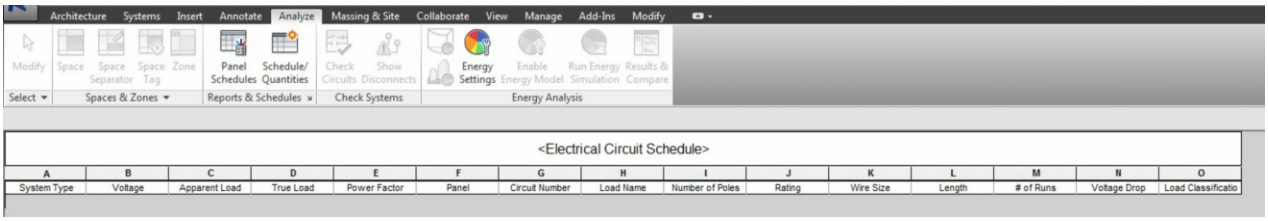


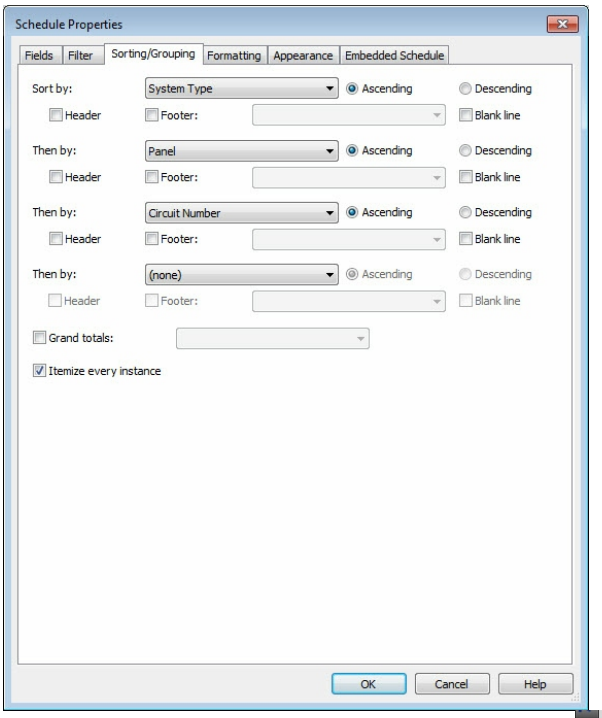
To set up an export within Revit use the following screen shots to help set up a schedule with all circuit names and numbers. The project must be complete before using this export method because EPS does not interact to with Revit or can not grab small sections of newer circuits. The good news is that this process is very quick but the bad news is that all of the circuits must be shown manually which circuits are shared on the same neutral. Unlike Revit though the user will have full control of wire and conduit size very easily and see those circuits very quickly.

Add all the fields shown in these examples.



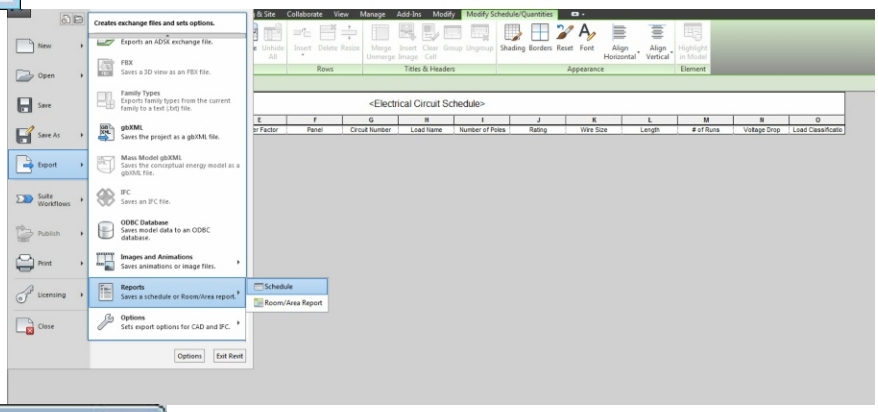
The schedule should look similar to this illustration when finished.

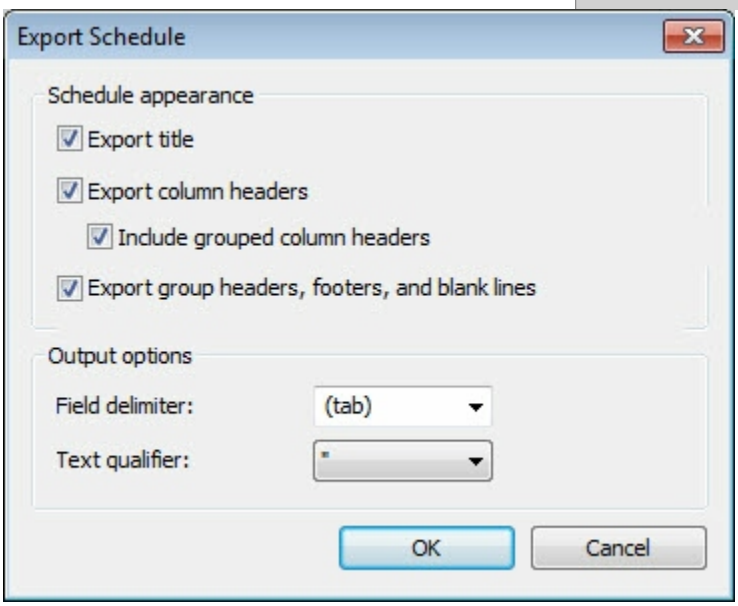




Set the filters as shown.

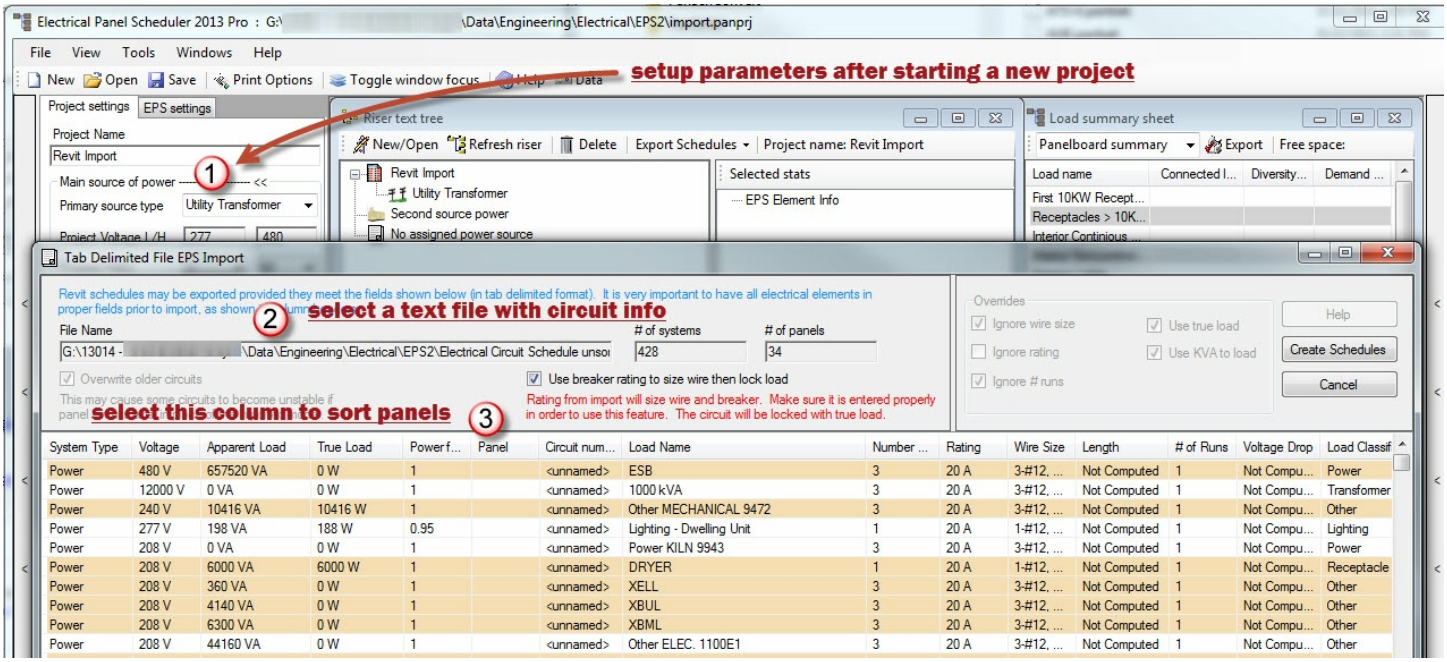
There should now be a completed list of circuits once finished with the ordering. This project did not have circuits assigned and meant to illustrate the process of completion.





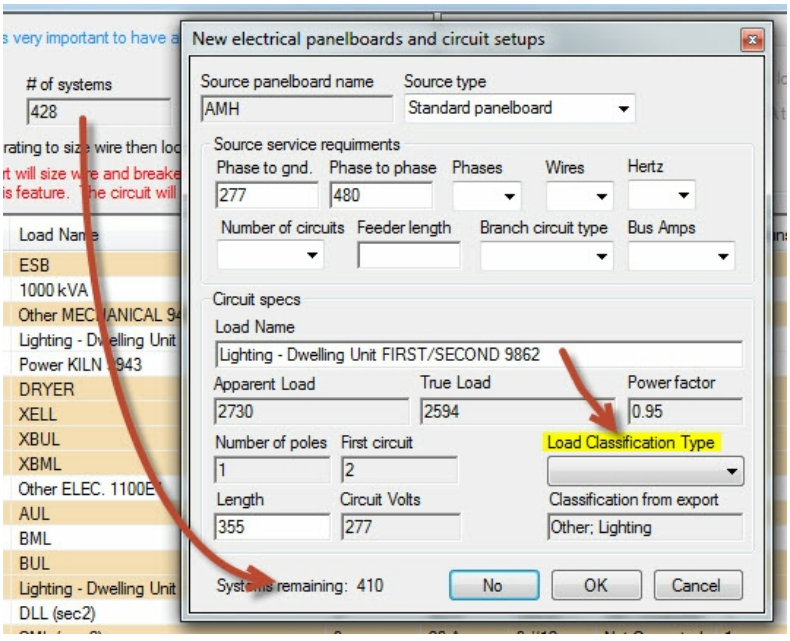
Complete the text file export from Revit as shown as a tab delimited file. Suggest placing the file in your EPS directory for future reference.

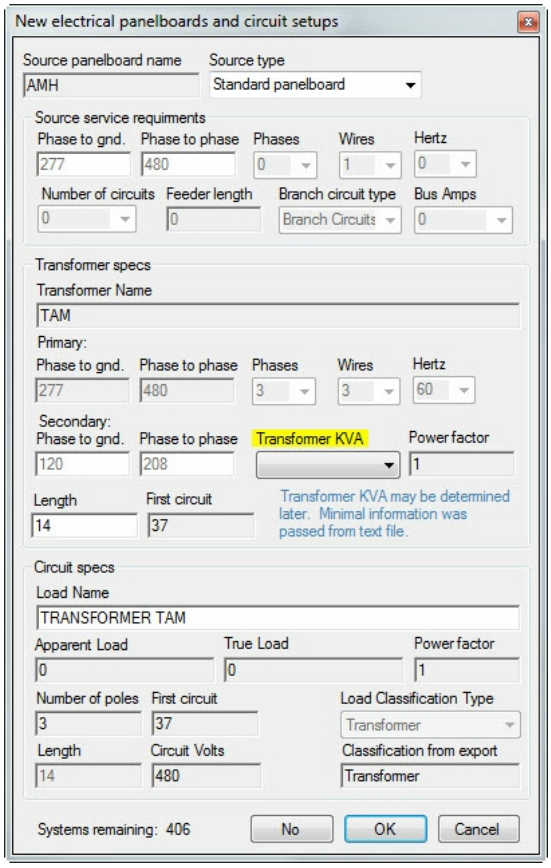
Begin importing circuits by selecting a file that was exported from Revit.



Press the create schedules button and be prepared to run the program till the circuits counter are exhausted. You may choose to preview each circuit, but pressing and holding down the enter key will advance the program till an error is encountered. The program will halt when an unknown field(s) is reached and will highlight the problem for correction. Any element in this list which don't have panels will not be circuited. Make sure everything has a designation when exporting from Revit or some circuit will not be shown in panel schedules.

Shown here are examples of errors that were found in the text file that need to be corrected. The first time EPS finds a panelboard, some information needs to be input so there won't be errors with the schedule. Load classification is a common problem. EPS also halts on the first instance of creating panels because some information is not known. Input those panels information when the need arises.





View

Toolbar
If a user wishes to turn off the toolbar, this is the switch to turn it off or on.

Status bar
This switch is used to off the status bar at the bottom of main window.

Formula chart
Opens formula cheat sheet PDF.

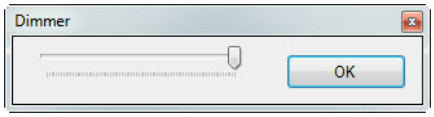
Sizing chart
Open sizing cheat sheet PDF.

Tools

Print options
Displays print options window for user to select which fields are visible in the schedule exports. When the always on top selection is checked the designer windows will always stay on top. If the Window focus is checked, the window will behave like a normal window.

EPS always on top
This switch will allow EPS to always be on top or to hide behind other windows when not being used. To have it always on top while working with AutoCAD or other programs is sometimes useful, but can of course be set per user preference.

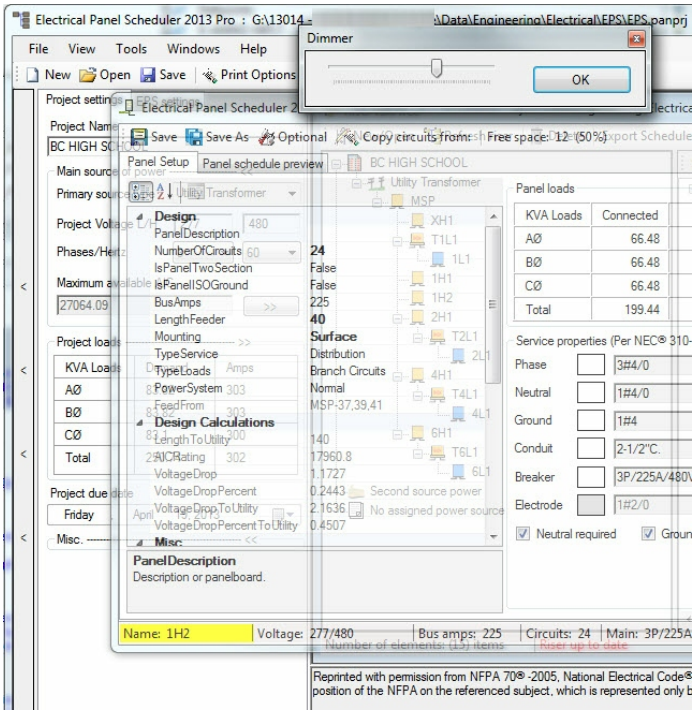
Dimmer control
The dimmer control acts to reduce background transparency so the user can see through the designer. This is helpful when using a CAD background on a single monitor system. The user can adjust the background visibility to whatever setting is comfortable or not at all. This illustration shows zero percent transparency. The maximum background transparency is 20% (illustrated below) when the slider is to the far left.



There is a ghostlike appearance when dimming is turned all the way down. The designer is barely visible.

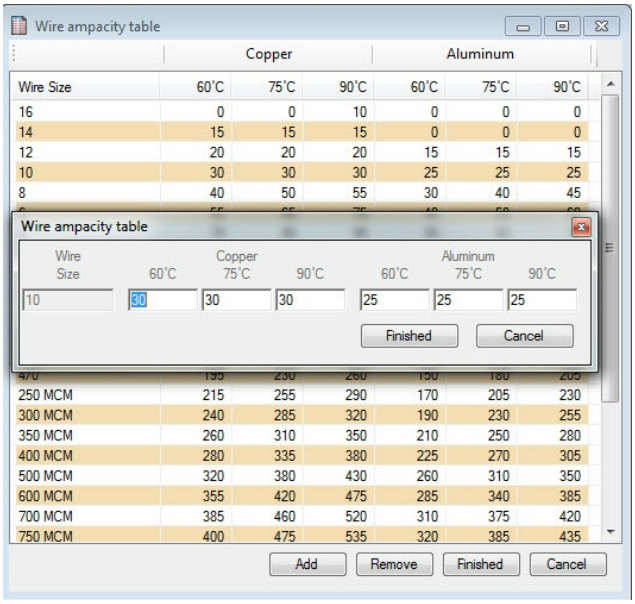
EPS also supports the use of a two monitor system and will always open in the last position it was closed in.

At 70% dimmed this boxes begins to be quite transparent.



Windows

Edit wire ampacity
The wire ampacity tables may be edited or modified but is not recommended. To edit any row, double click any wire size. This will modify all calculations EPS does for sizing wire based on ampacity.

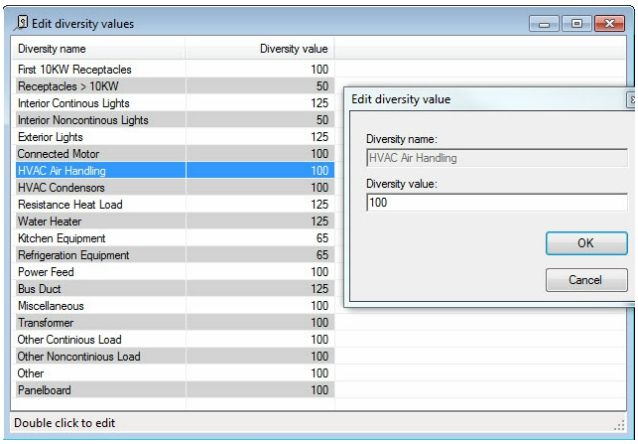


Edit ballast table

To edit ballast, this window can be used to add delete and modify ballasts, used only in the circuiting wizard, otherwise is not required for any calculations.

Edit diversity factors

Any diversity factor can be modified for demand load in a system.



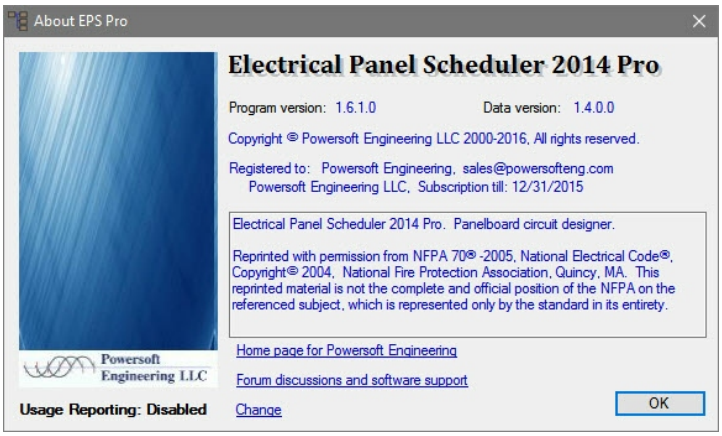
Tile vertical/horizontal

His button tiles windows within the main window based on the orientation. EPS captures size and locations of windows in this framework and will restore them based on the last closed session. EPS is dual monitor capable and will also reorient locations if only one monitor is present.

Help menu

These menus offer various functions for opening this user guide and links to helpful pages on the web site.

About



Displays version and copyrights information.

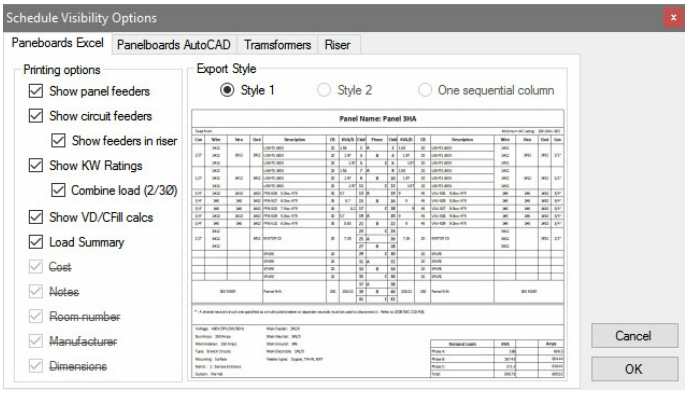
Toolbar

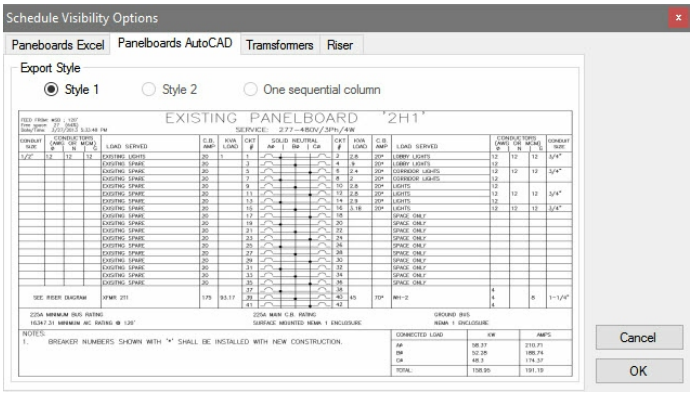
New
This button allows users to create a new project.

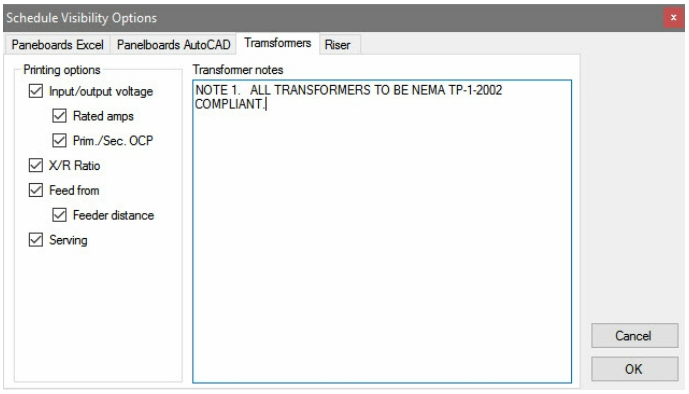
Open
This button allows users to open an existing project.

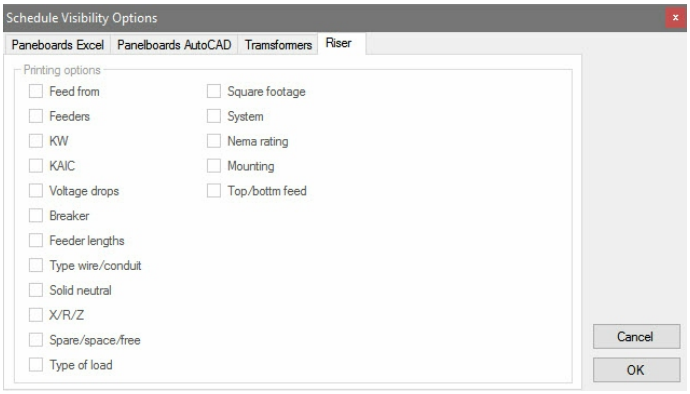
Save
This button allows users to save an open project.

Print options
This button allows users to project printing options.









There are many options for export to Excel. Select options needed for your companies best needs. There are no configurable options for the riser. It is meant to display as much information as possible and still be useful.

As of this publishing, there are no options for changing riser export items.

Panel Name: MSB

Feed from: Utility Transformer — Minimum AIC rating: 28394.5 (Min: 175')

Con	Wire	Neu	Gnd	Description	CB	KVA/D	Ckt#	Phase	Ckt#	KVA/D	CB	Description	Wire	Neu	Gnd	Con
	SEE RISER			PANEL 3HDP	600	307.65	1	A	2							
							3	B	4	313.39	600	PANEL 2HDP	SEE RISER			
							5	C	6							
	SEE RISER			PANEL 5HDP	600	245.18	7	A	8							
							9	B	10	311.39	600	PANEL 4HDP	SEE RISER			
							11	C	12							
				SPACE ONLY	225		13	A	14							
							15	B	16		225	SPACE ONLY				
							17	C	18							
	SEE RISER			PANEL 1HB	225	126.1	19	A	20							
							21	B	22	33.14	100	PANEL 1HA	SEE RISER			
							23	C	24							
	SEE RISER			PANEL ATS-XO	100	56	25	A	26							
							27	B	28	48.39	175	XFMR T1LA	SEE RISER			
							29	C	30							
				SPACE ONLY	100		31	A	32							
							33	B	34	124.65	150	PANEL AHU	SEE RISER			
							35	C	36							
	SEE RISER			PANEL ATS-XE	225	121.75	37	A	38							
							39	B	40	328.71	600	PANEL 5HM1	SEE RISER			
							41	C	42							

Minimum AIC rating shall be increased if minimum wire length shown is decreased.

Voltage: 277-480V/3Ph/4W/60Hz
Bus Amps: 3000 Amps
Main breaker: 3000 Amps
Type: Distribution
Mounting: Surface
Nema: 1 : Service Entrance
System: Normal

Main Feeder: (8) PARRELL RUNS EACH 8 Parallel runs of 3#750 MCM
Main Neutral: (8) PARRELL RUNS EACH 8 Parallel runs of 1#750 MCM
Main Conduit: (8) PARRELL RUNS EACH 3-1/2"
Main Electrode: (8) PARRELL RUNS EACH 1#250 MCM
Feeder types: Aluminum, THHN, Rigid

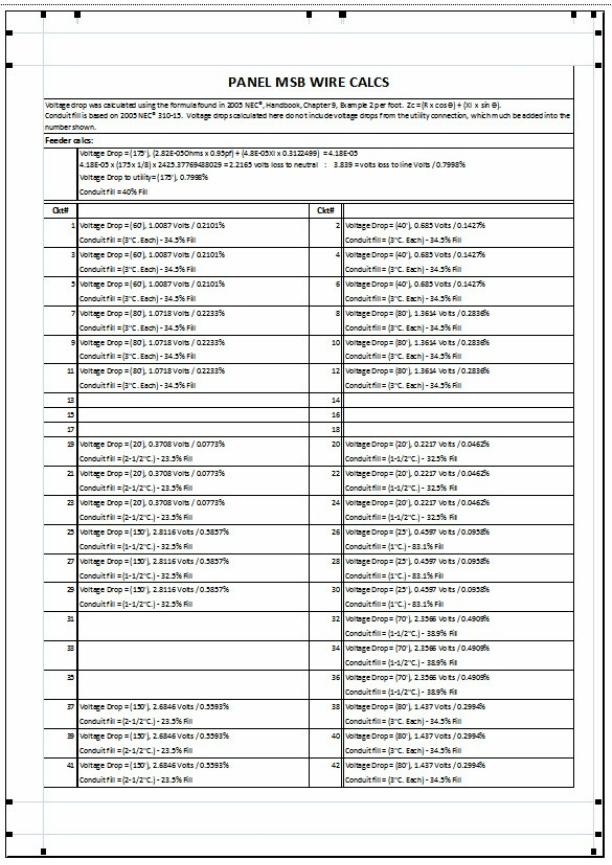
Demand Loads	KVA		Amps
Phase A:	692.83		2501.19
Phase B:	674.1		2433.57
Phase C:	649.43		2344.51
Total:	2016.36		2425.38

this button controls grid layout handles some adjustment may be needed to print correctly

1 of 1

Screen shot of EPS exported schedule to Excel

Shown here is and example of an Excel export as one possible solution of the final preview. In Excel some adjustment may be required for keeping the schedule within bounds of printing. Use the print preview to adjust these handles and adjust accordingly. The wire calculations and load summery are just two other options to panelboard Excel exporting.



PANEL MSB WIRE CALCS

Voltage drop was calculated using the formula found in 2005 NEC®, Handbook, Chapter 9, Example 2 per foot. Zc=(R x cosθ)+(Xl x sin θ).
Conduit fill is based on 2005 NEC® 310-15. Voltage drops calculated here do not include voltage drops from the utility connection, which much be added into the number shown.

Feeder calcs:
Voltage Drop = [175'], [2.82E-05Ohms x 0.95pf] + [4.38E-05X) x 0.3122499] = 4.18E-05
4.18E-05 x [175 x 1/3] x 2425.3776948029 = 2.2165 volts loss to neutral : 3.839 = volts loss to line Volts / 0.7998%
Voltage Drop to utility= [175'], 0.7998%
Conduit fill = 40% Fill

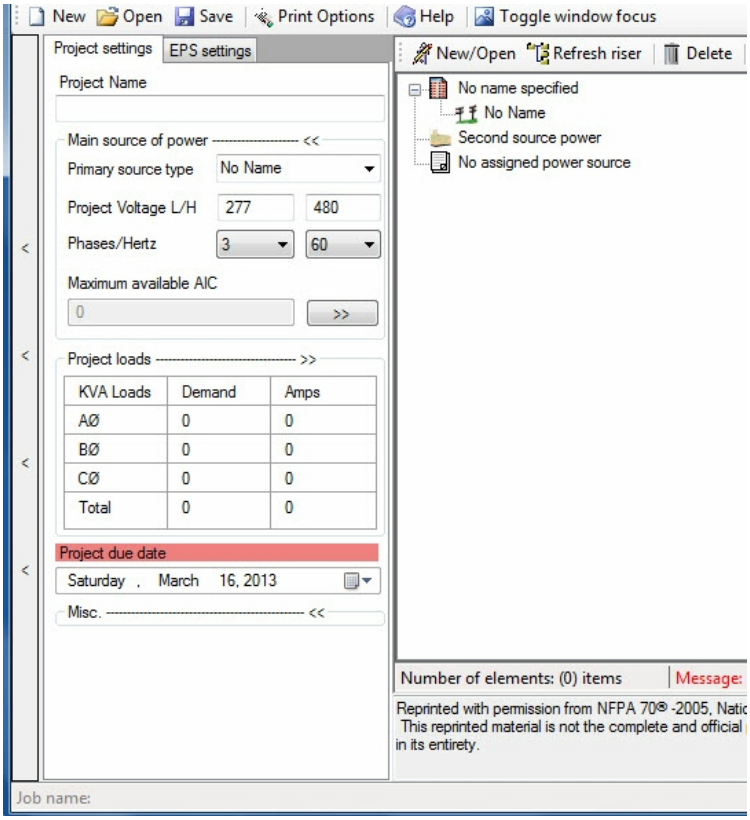
Ckt#		Ckt#	
1	Voltage Drop = [60'], 1.0087 Volts / 0.2101% Conduit Fill = [3"C. Each] - 34.5% Fill	2	Voltage Drop = [40'], 0.685 Volts / 0.1427% Conduit fill = [3"C. Each] - 34.5% Fill
3	Voltage Drop = [60'], 1.0087 Volts / 0.2101% Conduit Fill = [3"C. Each] - 34.5% Fill	4	Voltage Drop = [40'], 0.685 Volts / 0.1427% Conduit fill = [3"C. Each] - 34.5% Fill
5	Voltage Drop = [60'], 1.0087 Volts / 0.2101% Conduit Fill = [3"C. Each] - 34.5% Fill	6	Voltage Drop = [40'], 0.685 Volts / 0.1427% Conduit fill = [3"C. Each] - 34.5% Fill
7	Voltage Drop = [80'], 1.0718 Volts / 0.2233% Conduit Fill = [3"C. Each] - 34.5% Fill	8	Voltage Drop = [80'], 1.3614 Volts / 0.2836% Conduit fill = [3"C. Each] - 34.5% Fill
9	Voltage Drop = [80'], 1.0718 Volts / 0.2233% Conduit Fill = [3"C. Each] - 34.5% Fill	10	Voltage Drop = [80'], 1.3614 Volts / 0.2836% Conduit fill = [3"C. Each] - 34.5% Fill
11	Voltage Drop = [80'], 1.0718 Volts / 0.2233% Conduit Fill = [3"C. Each] - 34.5% Fill	12	Voltage Drop = [80'], 1.3614 Volts / 0.2836% Conduit fill = [3"C. Each] - 34.5% Fill
13		14	
15		16	
17		18	
19	Voltage Drop = [20'], 0.3708 Volts / 0.0772% Conduit Fill = [2-1/2"C.] - 23.5% Fill	20	Voltage Drop = [20'], 0.2217 Volts / 0.0462% Conduit fill = [1-1/2"C.] - 32.5% Fill
21	Voltage Drop = [20'], 0.3708 Volts / 0.0772% Conduit Fill = [2-1/2"C.] - 23.5% Fill	22	Voltage Drop = [20'], 0.2217 Volts / 0.0462% Conduit fill = [1-1/2"C.] - 32.5% Fill
23	Voltage Drop = [20'], 0.3708 Volts / 0.0772% Conduit Fill = [2-1/2"C.] - 23.5% Fill	24	Voltage Drop = [20'], 0.2217 Volts / 0.0462% Conduit fill = [1-1/2"C.] - 32.5% Fill
25	Voltage Drop = [150'], 2.8116 Volts / 0.5857% Conduit Fill = [1-1/2"C.] - 32.5% Fill	26	Voltage Drop = [25'], 0.4597 Volts / 0.0958% Conduit fill = [1"C.] - 83.1% Fill
27	Voltage Drop = [150'], 2.8116 Volts / 0.5857% Conduit Fill = [1-1/2"C.] - 32.5% Fill	28	Voltage Drop = [25'], 0.4597 Volts / 0.0958% Conduit fill = [1"C.] - 83.1% Fill
29	Voltage Drop = [150'], 2.8116 Volts / 0.5857% Conduit Fill = [1-1/2"C.] - 32.5% Fill	30	Voltage Drop = [25'], 0.4597 Volts / 0.0958% Conduit fill = [1"C.] - 83.1% Fill
31		32	Voltage Drop = [70'], 2.3566 Volts / 0.4909% Conduit fill = [1-1/2"C.] - 38.9% Fill
33		34	Voltage Drop = [70'], 2.3566 Volts / 0.4909% Conduit fill = [1-1/2"C.] - 38.9% Fill
35		36	Voltage Drop = [70'], 2.3566 Volts / 0.4909% Conduit fill = [1-1/2"C.] - 38.9% Fill
37	Voltage Drop = [150'], 2.6846 Volts / 0.5593% Conduit Fill = [2-1/2"C.] - 23.5% Fill	38	Voltage Drop = [80'], 1.437 Volts / 0.2994% Conduit fill = [3"C. Each] - 34.5% Fill
39	Voltage Drop = [150'], 2.6846 Volts / 0.5593% Conduit Fill = [2-1/2"C.] - 23.5% Fill	40	Voltage Drop = [80'], 1.437 Volts / 0.2994% Conduit fill = [3"C. Each] - 34.5% Fill
41	Voltage Drop = [150'], 2.6846 Volts / 0.5593% Conduit Fill = [2-1/2"C.] - 23.5% Fill	42	Voltage Drop = [80'], 1.437 Volts / 0.2994% Conduit fill = [3"C. Each] - 34.5% Fill

Panel MSB load summary

Load Type	Connected Load (KW)	Demand factor	Demand Load (KW)
AØ	723.922		692.832
BØ	700.722		674.099
CØ	680.322		649.431
Total	**2104.965**		**2016.362**
* Panel/Transformer	2104.965	100	2104.965
* Number of Dist. Sources	11	-	-
* Number of 1P spares	9	-	-
* Panel/Transformer load shown in panel summary for info only. Not part of calculations.			

Project Settings Tab

This tab contents is only active when a project is loaded or a new project is started.

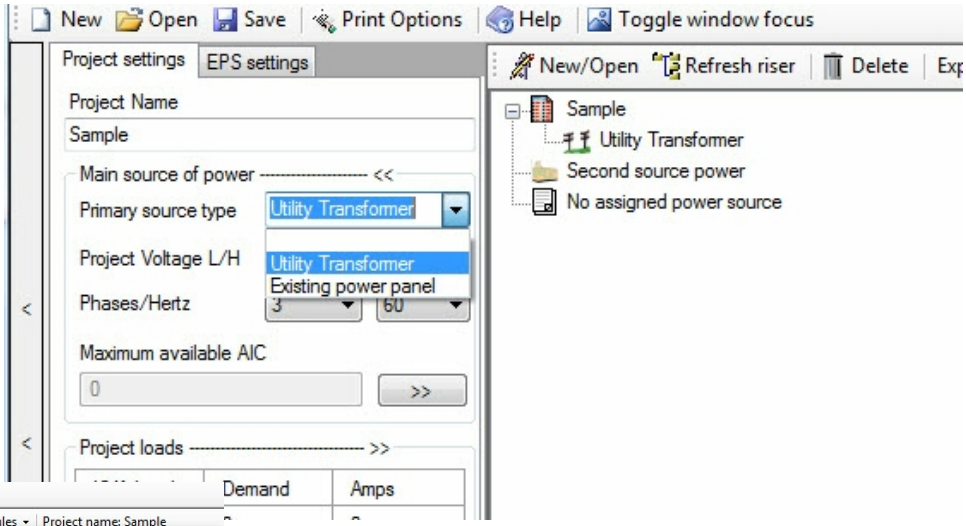


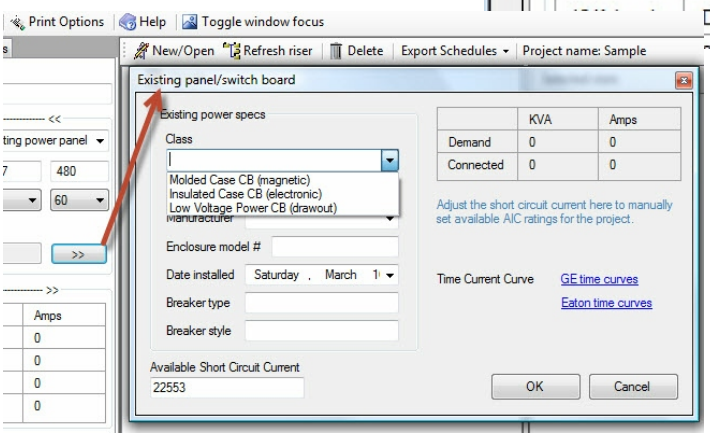
When starting a new project, press the new button. Specify the file name and directory location to where the project will be stored. Do not share directories with other windows files that EPS does not create or other EPS projects because EPS scans for panels and transformers stored in this location. Users may copy panels from other project locations, but they must be disconnected from any source feeding it as well as having any "Other", "Panelboard" or "Transformer" loads. These loads have a specific purpose in EPS. There will be unpredictable results if a user manually adds or removes elements from the riser while there elements are still attached to them from the directory.

Project name can be any string of text including numbers and is stored in the data file. It can be changed at any time and is reflected in the riser diagram.

The voltage, number of poles and hertz should be entered before beginning any further steps.

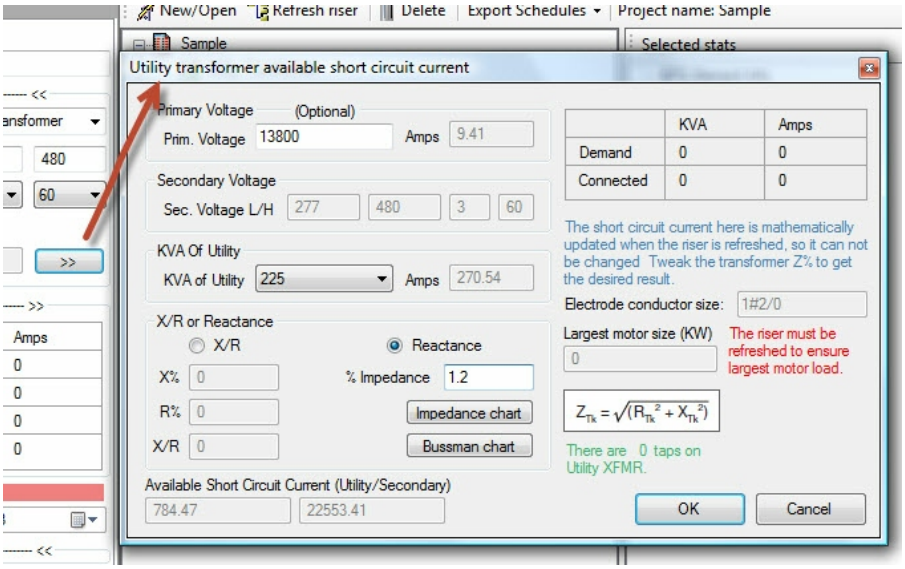
Project source can be one of two choices and should not be changed after panels and transformers are attached to the riser. If a user should choose to change the name, you should remove any and all connections to the source which is a utility transformer and a existing panel. The short circuit current available if mathematically calculated when using a utility





transformer and manually input when using an existing panel.

Existing panels contains fields here which are for information only and none of the fields, except for short current available is required.

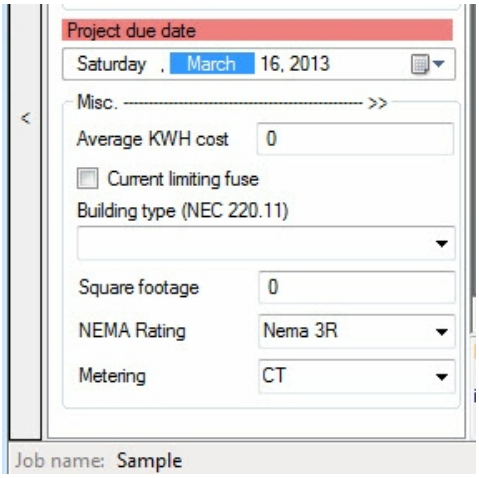


The utility window has three inputs but only two are required. A lot of times it will be difficult to determine what a utility voltage is, unless you ask. Not to worry. That is optional. The transformer KVA must be entered to give the math required characteristics of the front end.

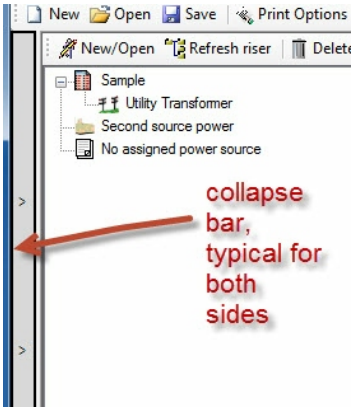
The third requirement is impedance or X/R rating. This will characterize the available short circuit amps. There are charts to help with this input but when designing infrastructure riser diagrams we usually size to the maximum possible value.

Designing systems to small for AIC could result in serious injury to field electricians and result in substantial cost increases and/or liabilities. All AIC ratings should be finalized with independent study and under engineering supervision.

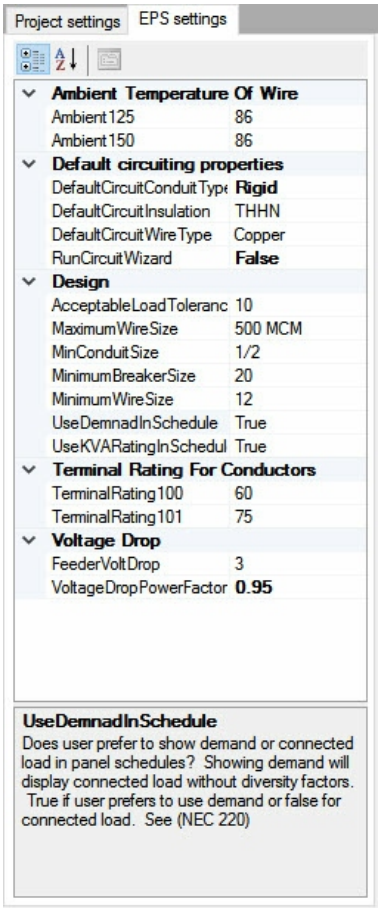
When starting EPS, the date field will be red since it is now due or the date since it was started. Selecting a new later due date will resolve that problem. As with any field areas on this tab, they can be expanded or shrunk by selecting the text for those fields. In this illustration shown, clicking on Misc ———>>, or any boxes in this window with the >> symbols, will expand the box as shown. This particular example fields is for information and no calculations are performed.



There is a collapsible bar on each side of the main window that will minimize the respective side toobar and to stay that way until a user expands it. EPS saves these user options so is saved. It is very useful for maximizing the workspace when viewing risers and load summaries and to keep the EPS program streamlined.



EPS Settings Tab



All of the settings shown in the setting tab are stored under the documents folder: C:\Users\username\Documents\Electrical Panel Scheduler 2014 Pro

These setting will change from each new version to another, but it sores vital information that can control the basic program functions with sizing and user preferences. It plays a very important part for what EPS does. Listed below is an explanation of how each aspect behaves in EPS. Changing minimum conduit size at any point in circuit design will affect how conduit sizes are used from that point on. This may require changing this switch, but ensures the user of proper sizing.

Ambient Temperature of Wire

NEC Table 310.16 shows the ambient temperature of wire as a correction factor used when sizing wire. Changing this number will modify the correction factors of any amperage above or below 125 amps.

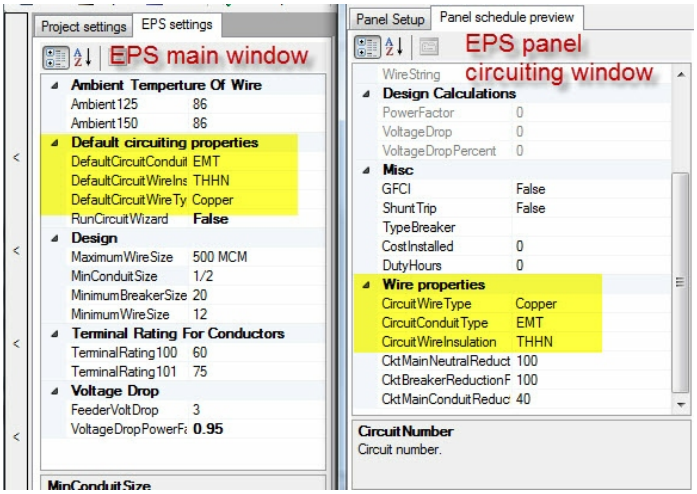
CORRECTION FACTORS

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

Table from NEC 310.16

Default Wire Properties

EPS relies on these fields to not being empty so we assign the highlighted fields when beginning new panels as a default. Those parameters are assigned to the maximum number of circuits and must be individually changed for each one if those properties change for a specific circuit, so it recommended to choose a majority when starting new panelboards. It may be changed very easily then changed back for further panels. Of course this would be true for any circuit which is a spare or space only. The settings within this main properties tab will use and define circuits till the point they are changed.



The run circuit wizard question will run a circuiting wizard for the less experienced users. By default this is turned off.

There are short descriptions at the bottom to explain each required field.

Any of these fields can be changed at any time if a special panelboards should need to be designed differently.

Design
Design section is based on any circuit or panelboard feeders that will require parallel runs, if required, or the minimum size of branch circuits as well as minimum breaker size.

Acceptable Load Tolerance
To keep loads balanced in panelboards, a user may input any percentage variable to trip when warnings in the panel board are shown. Refer to panelboard section about these warnings and how they are displayed. EPS takes the average of all phases and calculates the percentage factor to display the results if they exceed those factors. Of course loads will vary throughout the day and fluctuate depending on what is running, so good judgement must be considered when factoring the value but it also serves as a reminder to balance as much as possible. If course entering a higher value will cause the panel to show less warnings.

Maximum Wire Size
Users may enter a maximum wire size or can be maximized to highest feeder available as needed. Maximum possible parallel runs of conduit can not exceed 18 runs. A higher wire may be required in some cases.

Minimum Conduit Size
Users may choose to use a minimum of 3/4" of some jobs per owner request. This will allow EPS to return that conduit size on on circuits till it switched to something different.

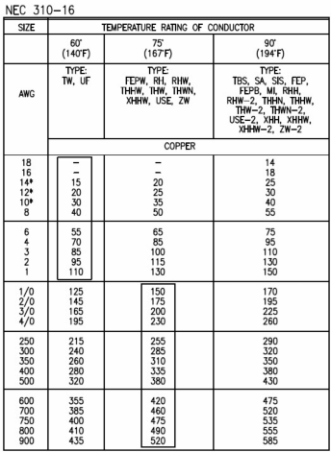
Minimum Breaker Size
A minim breaker is 15 amps. This switch prevents EPS from under sizing according to job type.

Minimum Wire Size
Minimum wire size is #18AWG. Commercial jobs require #12 AWG. This switch prevents circuits from being circuited with less than standard sizes.

Use Demand In Schedule
This gives users the option to display demand load versus connected loads in panel schedules. Putting demand loads on some circuits may them them to increase or decrease depending on their rating. Use as desired. Power companies usually like to see connected loads so they can use history based knowledge and load consumption data on the load types. A load summery export is available in EPS.

Use KVA In Schedule
This gives uses the option to display loads with or without power factors. Power factors lower the overall load of the circuit so seeing and adjusting for worst case may be desired.

Terminal Ratings of Conductors
When sizing wire, the terminal ratings are based on table lookups for wire over/below 110 amps. Normally wire under 110 amps is rated for 60 degree terminals while wire above that is rated for 75 degrees. The illustration shows the terminal rating wire sizes by default. This may also be changed during the course of sizing circuits to ensure proper circuit properties.


NEC 310-16

SIZE	TEMPERATURE RATING OF CONDUCTOR		
	60° (140°F)	75° (167°F)	90° (194°F)
AWG	TYPE: TW, UF	TYPE: FEPW, RH, RHW, THHW, THW, THWN, XHHW, USE, ZW	TYPE: TBS, SA, SIS, FEP, FEPB, MI, RHH, RHW-2, THHN, THHW, THW-2, THWN-2, USE-2, XHH, XHHW, XHHW-2, ZW-2
	COPPER		
18	–	–	14
16	–	–	18
14*	15	20	25
12*	20	25	30
10*	30	35	40
8	40	50	55
6	55	65	75
4	70	85	95
3	85	100	110
2	95	115	130
1	110	130	150
1/0	125	150	170
2/0	145	175	195
3/0	165	200	225
4/0	195	230	260
250	215	255	290
300	240	285	320
350	260	310	350
400	280	335	380
500	320	380	430
600	355	420	475
700	385	460	520
750	400	475	535
800	410	490	555
900	435	520	585

Feeder Voltage Drop
Voltage drop is calculated for each circuit including the main feeders of a panelboard in real time. Highlights on circuits will warn the user if the drop is higher than the amount shown under Voltage Drop here.

Voltage Drop Power Factor
Power factors are also required for voltage drop formulas calculations. This value can only be changed here at any time but will not affect any calculations for previous circuits.

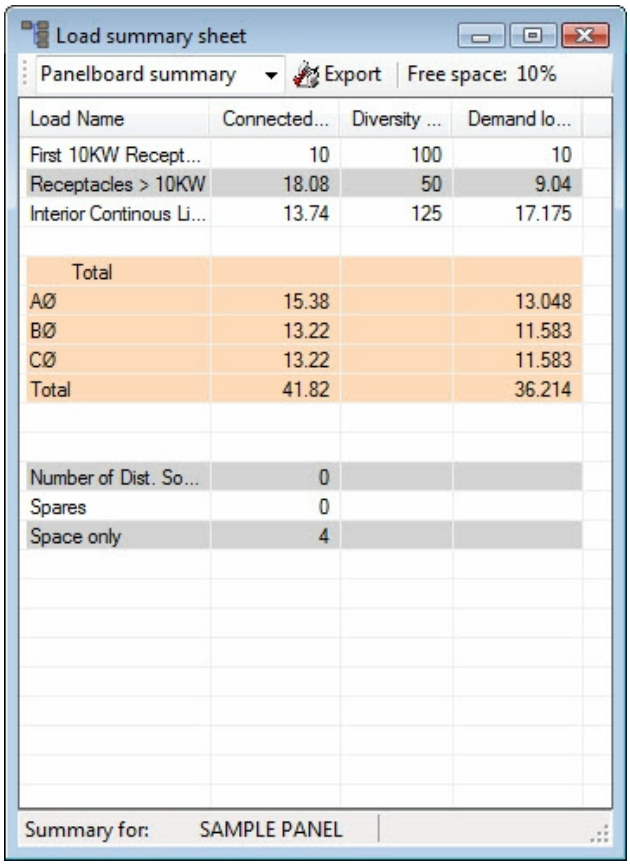
Any changes to the variables in this section after circuits have been assigned in panelboards will not affect those circuits till the user reassigns new branch or service feeders. All runs will have to be recalculated if there are any changes to desired circuits.

Panelboard Summary Sheet window

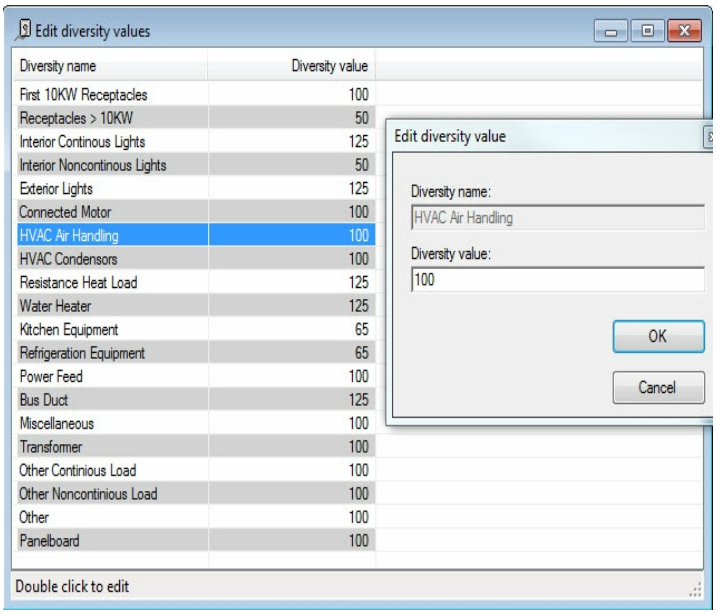
Load Summary Sheet

This window is used for displaying the load requirements for panelboards and projects. Since EPS Pro is a multi-panel based system, this window will only display loads for one panelboard. A variety of load type can be separated and displayed here for load breakdowns, all of which are user selectable. The number of spares and spaces can also be totaled.

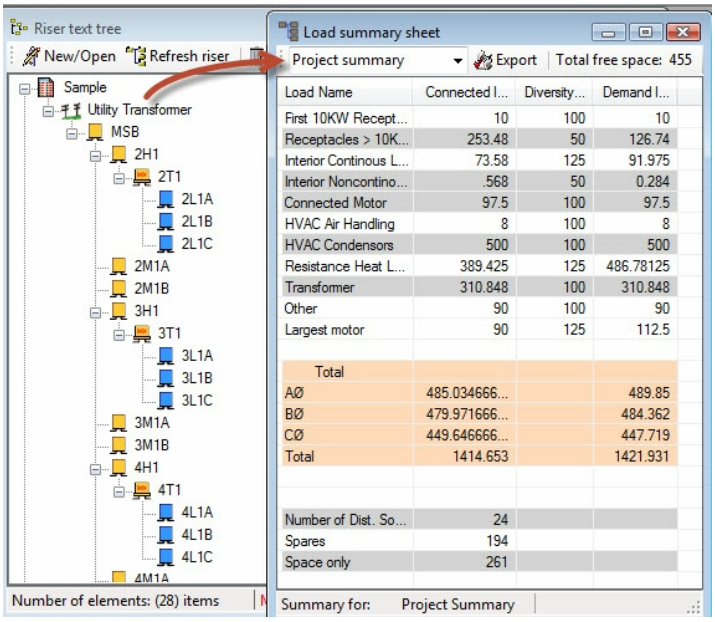
Each time an element is selected in the riser, the summary will populate all the fields available in the panelboard and none of the ones that don't have data. These loads are based on the diversity factors, which can be viewed and edited from the main window.



To edit the diversity factors for user preference, go to the main window and select window > edit diversity factors. The list of diversity that can be displayed in the panel summary will be visible. Simply double click one of the fields to edit and from this point on, when the riser is updated, so will the entire project elements and saved back to each respective panelboard. If these are temporary modifications, be sure to save it back as these changes will be saved with the program settings.

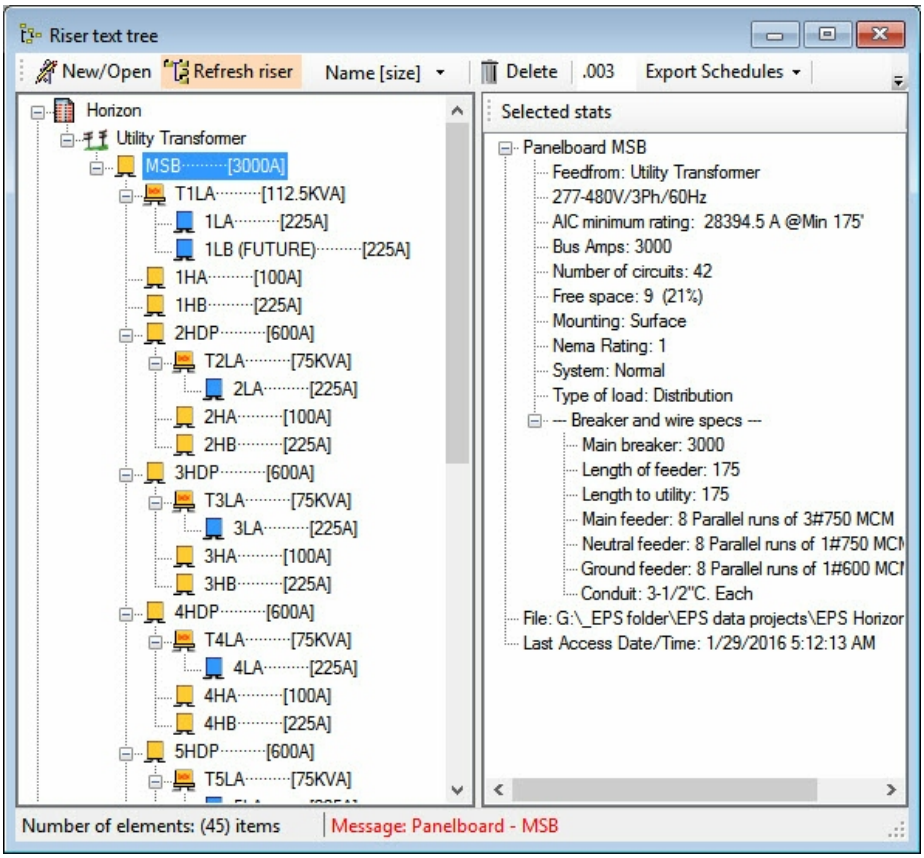


The project summary is quite different and will let the user know when it is displayed. Only connected panelboards and transformers are summed together in separate fields to show all used diversity factors in the project. Simply selecting the utility icon or use the drop-down box for project to show those loads. There is also a summation of spare circuits available.



Riser tree window

Riser diagram



This window is used for displaying the loads and connections to other elements

Shown in this example, we have a fairly large riser diagram of a project completed using EPS. The Yellow icon is a 277-480V panel, the yellow icon with red writing is a transformer, and the blue icon is a 120-208V panel.

Selecting any panelboard or transformer of the riser will display information about that element in the selected stats frame. If visible, the load summery will also display information about the element selected, including the utility connection. If the main distribution panel is selected in this case, EPS will display the panels total loads and other calculated values.

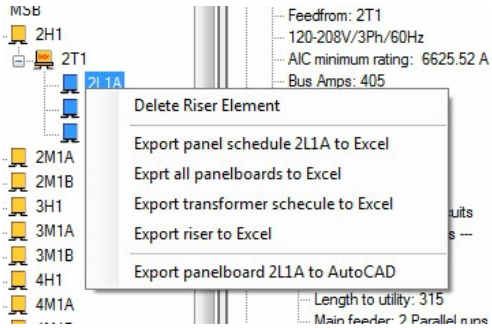
EPS uses drag and drop technology to connect the riser elements and size all breakers and loads accordingly. Everything is color coded so the elements are easy to identify when connecting. EPS also uses some error checking so improper loads cannot be connected, like voltage, of course.

The size and location of this and many other windows is saved in the EPS settings and will be exactly the same when the user returns. For this guide we will explain what settings are best for us so we can share the interactions of EPS.

Double clicking any element in the riser will open the respective window relating to that element. In other words, double clicking the utility transformer will open the utility window. Double clicking the transformer will open the transformer editing window, and the same for the panelboards.

Since this is the single most complex part of EPS, short of the wire sizing functions, it is essential to understand how the riser works and what information the user sees on the screen. There are some very complex riser building algorithms working in the background.

The name [size] button is important to display a better user preference in the riser thanks to user feedback. We are able to see the size of panelboard bus amps or transformer KVA rating without having to click on the element to display it properties. Every since this functionality was written, it was immediately clear how useful this information is to see and use. The dots are required to make the information clear as we tried many combinations for readability. For anyone who does not require this information, this switch can also turn that information off.



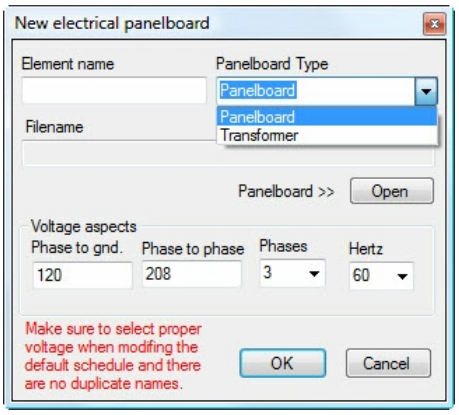
Right clicking inside the riser window will display a context sensitive menu with options for deleting a riser element and exporting schedule to Excel or single elements to AutoCAD.

As a note it is not a good idea to remove elements from a riser while they are connected to other loads. Remove the feeder to the panel and any elements served from that panel before deleting elements. This will cause errors or worse may crash you project.

Riser toolbar

The toolbar has functions for starting new panels or transformers, deleting elements and exporting schedules to Excel.

New/Open



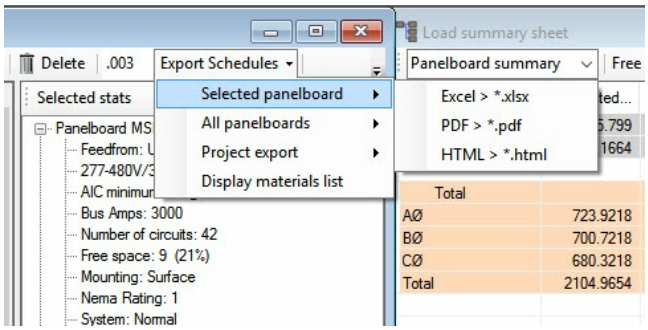
New/Open Element

This window is where create new transformers and panelboards, all of which will have a unique file name and type based on what the element is. If a new panel is started, the user will enter a panel name in the panelboard name box. It is very important to make sure the voltage and phases is correct before beginning since it can not be changed later. Once the OK button is pressed, the user will be prompted for a file name. A panelboard or transformer name will automatically be entered as a selection that can be changed, but is not recommend doing so.
Any voltage can be entered, from around the world, into the phase to ground (low) and phase to phase (high) box, the number of phases used, then phase cycles. The user then has to press OK to continue. If the user is opening a pre-designed panelboard, simply press the open button and select a filename to begin.

A file window will ask the user where to open the element from. Normally elements in a specific project will share a common directory.

Refresh riser

Since riser updating is not automatic, to save calculation time, a riser must be updated after editing and adding panels from the new/open window and when users want to update calculations in the riser. Make sure this is the final step when completing editing or adding tasks. Depending on the speed of the users processor, it may take some time on larger risers, to complete.

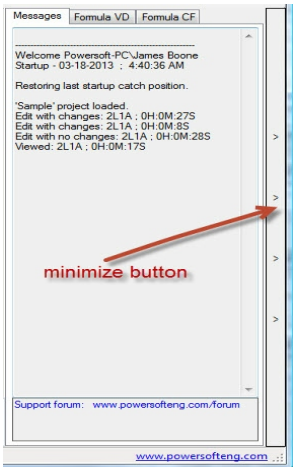


Export schedules

A wide variety of exports can be done from the export schedules button. Refer to the print options for on what information is displayed in these schedules. Each panelboard will get its own workbook. The riser table, transformer table and project load summary will get its own project workbook.

Messages and calculations panel

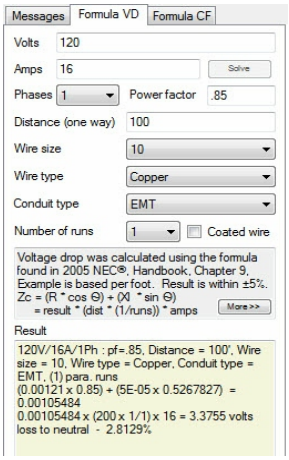
Messages tab



This window will display information based on minor or major program errors. It also displays a record of all panelboards that have been open and/or changed. This panel can be closed or opened at any time. This panel can be toggled to display on or off by pressing the miimize button. This will collapse the panel so it will not be visible. EPS is designed to let users know when errors occur by displaying this button as red. The user must click the button at least once to deactivate this colored button, so you will be ensured to see those warnings. in the messages window.

Formula VD tab

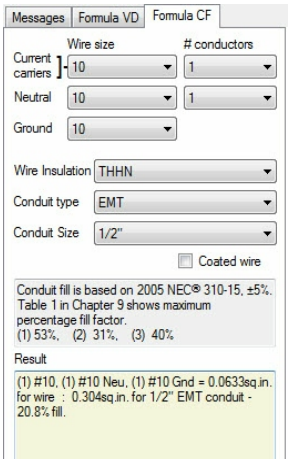
Used for instant access to voltage drop calculator.



Once the all input fields have been entered and calculations are finished the user can select the text within the two result boxes for copying to a word processor or other document. This shows the math formulas and final result if required.

Formula CF tab

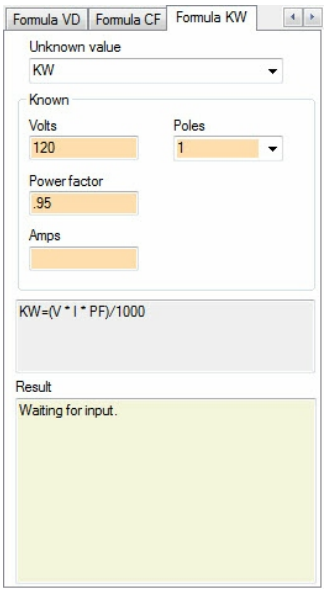
Used for instant access to conduit fill calculator.



Once the all input fields have been entered and calculations are finished the user can select the text within the two result boxes for copying to a word processor or other document. This shows the math formulas and final result if required.

Formula KW

Calculations for solving for some unknowns such as



KW

KW when HP known

KVA

AMPS when KW known

AMPS when KVA known

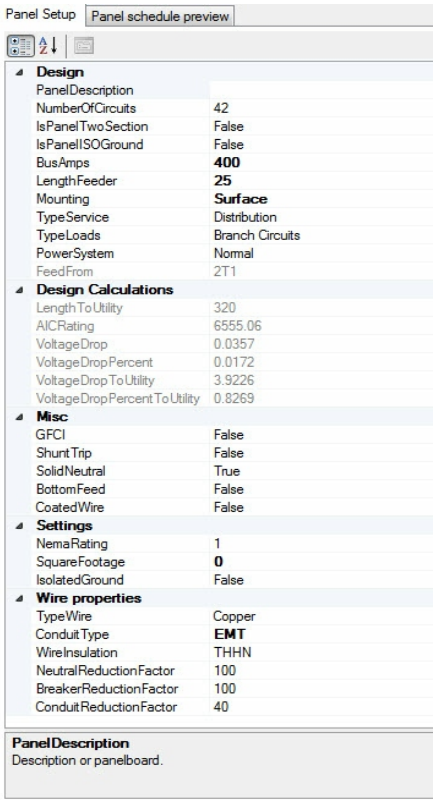
AMPS when HP known

Depending on the type of unknown selection chosen, input boxes will change based on the type of minimal inputs required to finish the calculations. Once all fields are not empty, the calculator will publish the result in the text box. All boxes with a navajo background must be finished. A formula used will display in the gray formula box.

Panel setup settings and descriptions

Panel Description

Panel Description can be any text string the users wishes to note or nothing at all. It is unimportant for the program but serves to give uses the option to let other team members information about the particular instance.



Number of circuits

Number of circuits will be used for determining the how many breaker circuits are in the panelboard. This can be any even number from 2 to 168. The user can change this number at any time. Renumbering number of circuits in the panel will not remove any stored data from the file but it will remove the data from the calculations, so if the user decides later to add a higher number back, the data will be as previously specified and the calculations will be continued. There is a delete button in the circuit design tab that allows users to remove those circuits.

Is panel two section

If the panel is two section, select true for this field.

Is panel isolated ground

If this panel has an isolated ground wire, select this switch to true.

Bus Amps

Bus Amps is used to bus amps of panel and displays some warnings that is shown in EPS. If panelboard load exceed the number specified here the user will get some warnings that will be visible when working in both tabbed areas.

Length of Feeder

Length of Feeder is important for voltage drop and short circuit ratings calculations.

Mounting

Mounting describes how the panelboard is supported. Floor, Surface and Flush.

Type service

This is primarily used for automatic determination of required neutral and/or ground. There is three possible choices, service entrance for any panelboards connected to the utility, distribution and distribution three phase. Not required for any calculations or any other determinations.

Type of Loads

Type of loads will ask for one of five types of panelboard: not required for calculations
Branch circuits, power, receptacles, lighting and distribution. Select the description that matches the loads types.

Power system

This is used for user information and is not required for calculations or other factors.

Feed From

Can only be assigned in the riser and is read only.

Length to Utility

Combined length to utility. Can only be assigned after refreshing the riser and is read only.

AIC Rating

Combined short circuit ratings to utility, but must be connected to the utility via other sources. Can only be assigned after refreshing the riser and is read only.

Voltage Drop

Voltage drop as voltage loss from the main lugs or breaker of the panelboard to the source of power based on length of conductors, phase to neutral. To calculate voltage drop from line to line, multiply 1.72 times voltage drop if more than two phases.

Voltage Drop Percent

Voltage drop as percentage from main lugs or breaker to source based on length of conductors.

Voltage Drop to Utility

Can only be assigned in the riser and is read only.

Voltage Drop Percent to Utility

Can only be assigned in the riser and is read only.

Possible load types

Receptacles ..... Note 1
Interior Continious Lights ..... Note 1
Interior Noncontinious Lights ..... Note 1
Exterior Lights ..... Note 1
Connected Motor ..... Note 1
HVAC Air Handling ..... Note 1
HVAC Condensers ..... Note 1
Resistance Heat Load ..... Note 1
Water Heat ..... Note 1
Kitchen Equipment ..... Note 1
Power Feed ..... Note 1
Bus Duct ..... Note 1
Miscellaneous ..... Note 1
Refrigeration Equipment ..... Note 1
Other Continious Load ..... Note 1
Other Noncontinious Load ..... Note 1

Transformers ..... Note 2
Panel ..... Note 2
Other .....Note 2

Number of panels ..... Note 3
Number of space ..... Note 3
Number of spare ..... Note 3
Largest motor ..... Note 3
Number of motors ..... Note 3

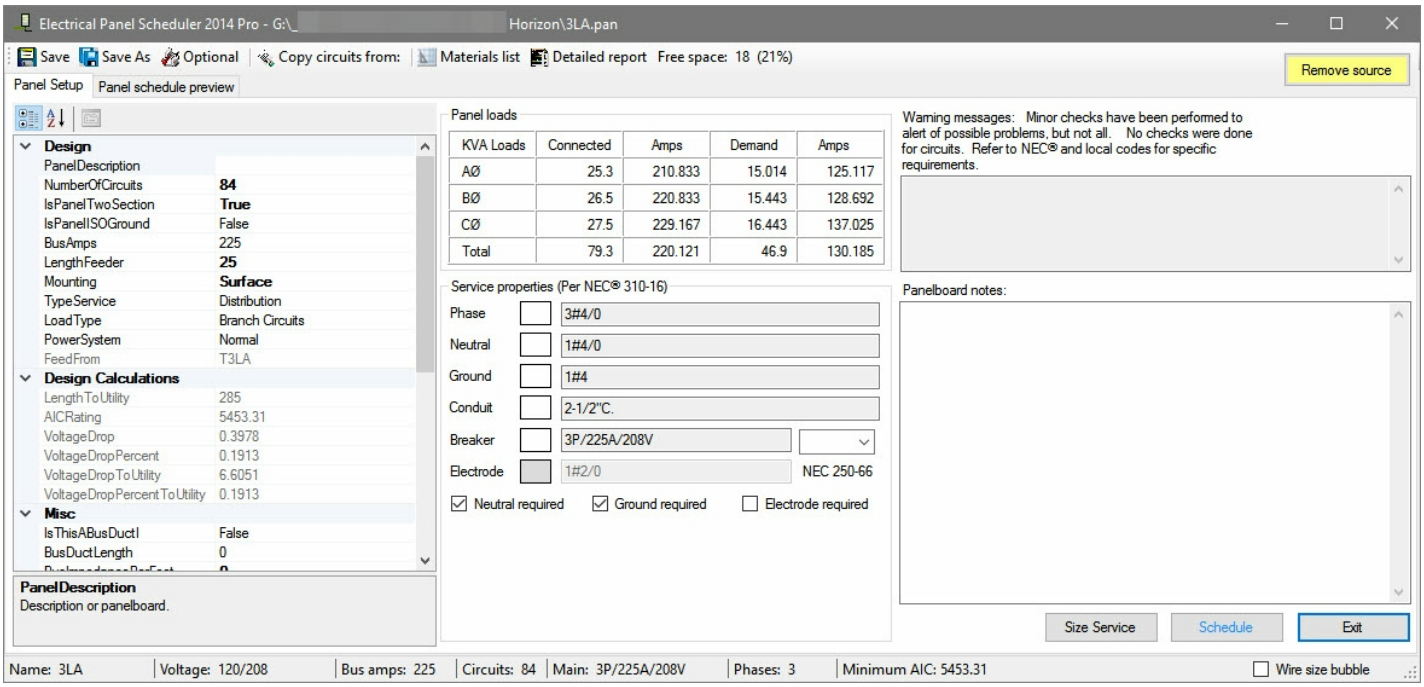
Notes:

1. All circuit loads in this category are totaled from the bottom of a riser tree to the upper most utility connection in project load calculations by using the riser refresh button.
2. Circuit designations in this category are used for telling EPS that wires will not be shown in the riser, if the switch is on in print options for a switch named “Show feeders in riser” (denotes “See riser”) within the schedule section of wire and conduit size. The transformer and panel are non selectable and may not be changed but ‘Other’ may be. Panel and transformer designations are automatically called when a riser element is connected to another element.
3. Any designations in this group are used for information only while largest motor is used for AIC calculations.

Sample Load Summery			
Load Type	**Connected Load (KW)**	**Demand factor**	**Demand Load (KW)**
First 10KW Recept.	10	100	10
Remaining Receptacles	91.526	50	45.763
Interior Cont. Lighting	17.52	125	21.9
Exterior Lighting	0.5	125	0.625
Air Handling HVAC	109.28	100	109.28
Condensors HVAC	116.31	100	116.31
Heat Load	12	125	15
Connected Motor	115.82	100	115.82
Kitchen Equipment	129.513	65	84.183
Power Feed	117.2	100	117.2
AØ	285.401		259.793
BØ	274.375		250.128
CØ	274.092		254.198
Total	833.869		764.119
Panel/Transformer	398.908	100	398.908
Largest Motor	45.3	125	56.625

Panelboard Designer window

Panel Setup

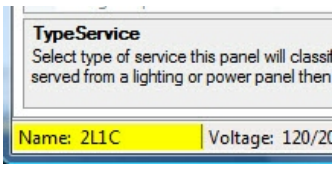


Panelboard Designer

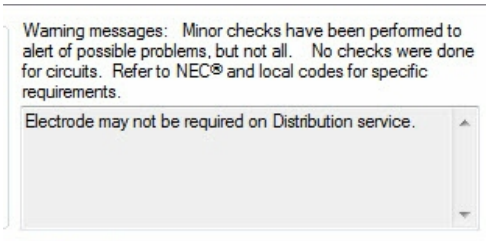
This window is designed to be as simple as possible. There are few thing things which will have to be adjusted here as possible for commercial wiring. This window gives an example of information that is shown when editing.

There are five areas of interest here.

- Panelboard design properties box.
- Panel loads
- Service properties
- Warning messages
- Panelboard notes



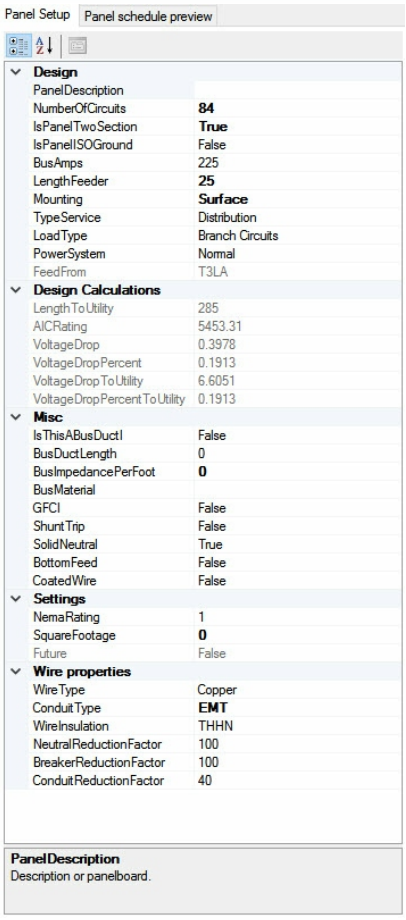
When minor warning triggers occurs, EPS will warn users by displaying the name background as yellow and the warning box then displays some *minor* warnings.



The remove source button is only visible when a panel is being served from another element. This is a method for manually removing feeds without using the riser drag and drop, but it should be used with caution. If removing a feed, you must also remove the branch from the source element too. This button will only remove all information about what it is feed from and will be branched to a no assigned power source in the project riser after pressing the refresh riser button. Not following proper procedure will cause errors in the panel riser. Do not refresh the riser till all connections have been removed. Also keep in mind that if a panel is served from a transformer, the feeds and source(s, there could be up to six) from a transformer so will have to be removed from many sources and branches. It is perfectly fine to leave branches to downstream panels. Refer to tutorials of the best methods and so you can become familiar with how to set up panels and assign riser elements.

Panel Description

Panel Description can be any text string the users wishes to note or nothing at all. It is unimportant for the program but serves to give uses the option to let other team members information about the particular instance.



Number of circuits

Number of circuits will be used for determining the how many breaker circuits are in the panelboard. This can be any even number from 2 to 168. The user can change this number at any time. Renumbering number of circuits in the panel will not remove any stored data from the file but it will remove the data from the calculations, so if the user decides later to add a higher number back, the data will be as previously specified and the calculations will be continued. There is a delete button in the circuit design tab that allows users to remove those circuits.

Is panel two section

If the panel is two section, select true for this field.

Is panel isolated ground

If this panel has an isolated ground wire, select this switch to true.

Bus Amps

Bus Amps is used to bus amps of panel and displays some warnings that is shown in EPS. If panelboard load exceed the number specified here the user will get some warnings that will be visible when working in both tabbed areas.

Length of Feeder

Length of Feeder is important for voltage drop and short circuit ratings calculations.

Mounting

Mounting describes how the panelboard is supported. Floor, Surface and Flush.

Type service

This is primarily used for automatic determination of required neutral and/or ground. There is three possible choices, service entrance for any panelboards connected to the utility, distribution and distribution three phase. Not required for any calculations or any other determinations.

Type of Loads

Type of loads will ask for one of five types of panelboard: not required for calculations

Branch circuits, power, receptacles, lighting and distribution. Select the description that matches the loads types.

Power system

This is used for user information and is not required for calculations or other factors.

Feed From

Can only be assigned in the riser and is read only.

Length to Utility

Combined length to utility. Can only be assigned after refreshing the riser and is read only.

AIC Rating

Combined short circuit ratings to utility, but must be connected to the utility via other sources. Can only be assigned after refreshing the riser and is read only.

Voltage Drop

Voltage drop as voltage loss from the main lugs or breaker of the panelboard to the source of power based on length of conductors, phase to neutral. To calculate voltage drop from line to line, multiply 1.72 times voltage drop if more than two phases.

Voltage Drop Percent

Voltage drop as percentage from main lugs or breaker to source based on length of conductors.

Voltage Drop to Utility

Can only be assigned in the riser and is read only.

Voltage Drop Percent to Utility

Can only be assigned in the riser and is read only.

Is This Bus Duct

Is this panelboard data to be treated as a bus duct? The panelboard can be considered a bus duct and anything that attaches to is can be treated as a breaker and circuit, because technically that's what it is.

The wire leading from the source panel to this point is considered the wire that serves it junction. The bus in this panel is considered the bus duct length except for being smaller and shorter than a bus duct is technically the same thing except for its length and impedance characteristics. The ohms per foot on the previous page will be used to calculated this resistance factor to this point, so this value will contain the length from the connection point minus the wire length from source panel.

Bus Duct Length

Enter maximum length of bus duct.

Bus Impedance Per Foot

Enter impedance value of bus bar in Ohms per foot.

Bus material

What is the bus bar material in duct? Usually copper clad.

GFCI

Enter true if the main breaker is type GFCI rated. For information only and not required for calculations.

Shunt Trip

Enter true if the main breaker is type Shunt Trip rated. For information only and not required for calculations.

Solid Neutral

Enter true if the ground bus is type solid neutral rated. For information only and not required for calculations.

Bottom Feed

Enter true if the main breaker or main lugs is located on bottom of panel. For information only and not required for calculations.

Coated Wire

Enter true if the main feeder conductors are coated wire. This entry is used for sizing wire and conduit fills.

NEMA Rating

Enter NEMA rating of panel. Refer to table 1, 2 or 3. For information only and not required for calculations.

Table 1
[From NEMA 250-2003]
Comparison of Specific Applications of Enclosures
for Indoor Nonhazardous Locations

Provides a Degree of Protection Against the Following Conditions	Type of Enclosure									
	1 *	2 *	4	4X	5	6	6P	12	12K	13
Access to hazardous parts	X	X	X	X	X	X	X	X	X	X
Ingress of solid foreign objects (falling dirt)	X	X	X	X	X	X	X	X	X	X
Ingress of water (Dripping and light splashing)	...	X	X	X	X	X	X	X	X	X
Ingress of solid foreign objects (Circulating dust, lint, fibers, and flyings **)	...	...	X	X	...	X	X	X	X	X
Ingress of solid foreign objects (Settling airborne dust, lint, fibers, and flyings **)	...	...	X	X	X	X	X	X	X	X
Ingress of water (Hosedown and splashing water)	...	...	X	X	...	X	X	...	...	...
Oil and coolant seepage	...	...	...	..	...	...	...	X	X	X
Oil or coolant spraying and splashing	...	...	...	...	...	...	...	...	...	X
Corrosive agents	...	...	...	X	...	...	X	...	...	...
Ingress of water (Occasional temporary submersion)	...	...	...	...	...	X	X	...	...	...
Ingress of water (Occasional prolonged submersion)	...	...	...	...	...	...	X	...	...	...

* These enclosures may be ventilated.
** These fibers and flyings are nonhazardous materials and are not considered Class III type ignitable fibers or combustible flyings. For Class III type ignitable fibers or combustible flyings see the National Electrical Code, Article 500.

Table 2
[From NEMA 250-2003]
Comparison of Specific Applications of Enclosures
for Outdoor Nonhazardous Locations

Provides a Degree of Protection Against the Following Conditions	Type of Enclosure									
	3	3X	3R*	3RX*	3S	3SX	4	4X	6	6P
Access to hazardous parts	X	X	X	X	X	X	X	X	X	X
Ingress of water (Rain, snow, and sleet **)	X	X	X	X	X	X	X	X	X	X
Sleet ***	...	...	...	...	X	X	...	...	...	...
Ingress of solid foreign objects (Windblown dust, lint, fibers, and flyings)	X	X	...	...	X	X	X	X	X	X
Ingress of water (Hosedown)	...	...	...	...	...	...	X	X	X	X
Corrosive agents	...	X	...	X	...	X	...	X	...	X
Ingress of water (Occasional temporary submersion)	...	...	...	...	...	...	...	...	X	X
Ingress of water (Occasional prolonged submersion)	...	...	...	...	...	...	...	...	...	X

* These enclosures may be ventilated.
** External operating mechanisms are not required to be operable when the enclosure is ice covered.
*** External operating mechanisms are operable when the enclosure is ice covered.

Table 3
[From NEMA 250-2003]
Comparison of Specific Applications of Enclosures
for Indoor Hazardous Locations
(If the installation is outdoors and/or additional protection is required by
Table 1 and Table 2, a combination-type enclosure is required.)

Provides a Degree of Protection Against Atmospheres Typically Containing		Enclosure Types 7 and 8, Class I Groups **				Enclosure Type 9, Class II Groups				
	Class	A	B	C	D	E	F		G	10
Acetylene	I	X	...	...	...	...		...	...	...
Hydrogen, manufactured gas	I	...	X	...	...	...		...	...	...
Diethyl ether, ethylene, cyclopropane	I	...	...	X	...	...		...	...	...
Gasoline, hexane, butane, naphtha, propane, acetone, toluene, isoprene	I	...	...	...	X	...		...	...	...
Metal dust	II	...	...	...	...	X		...	...	...
Carbon black, coal dust, coke dust	II	...	...	...	...	...		X	...	...
Flour, starch, grain dust	II	...	...	...	...	...		...	X	...
Fibers, flyings *	III	...	...	...	...	...		...	X	...
Methane with or without coal dust	MSHA	...	...	...	...	...		...	...	X

* For Class III type ignitable fibers or combustible flyings see the National Electrical Code, Article 500.
** Due to the characteristics of the gas, vapor, or dust, a product suitable for one Class or Group may not be suitable for another Class or Group unless marked on the product.

Square Footage

Enter total square footage that this panelboard serves. For information only and not required for calculations.

Isolated Ground

Is the ground wire considered isolated? Enter true for yes. For information only and not required for calculations.

Solid Neutral

Enter true if the ground bus is type solid neutral rated. For information only and not required for calculations.

Wire Properties

Before pressing the Size Service button, the user should check to ensure these settings are correct so that proper voltage drop, conduit fill and amperages will be accurate. This is very important to ensure the feeders are sized properly.
When beginning new panels, users need to be aware that when creating new panels, these fields are automatically loaded from EPS main screen setting tab.

Panel Loads

No modifications can be done here. This area is for display purposes only and allows the user to view and balance loads on the circuit side. Demand factors can be viewed and modified from the main window under Windows menu > Edit Diversity Factors. Double click to edit each field. This is then shown on the Panelboard summary screen in the main window too. These values can be changed at any time and will remain each time you start EPS up.

Panel loads

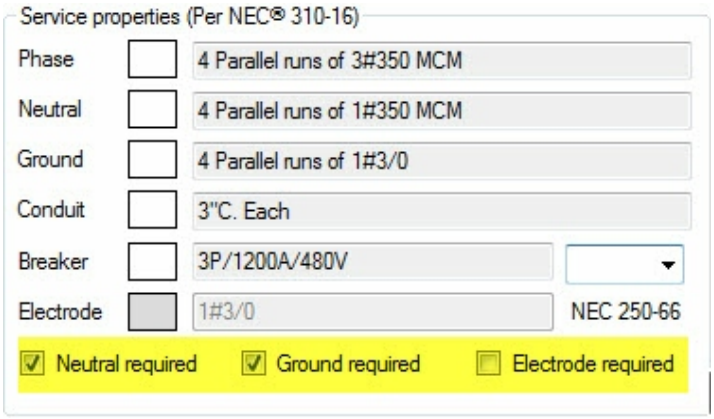
KVA Loads	Connected	Amps	Demand	Amps
AØ	186.66666	673.887	186.667	673.888
BØ	186.66666	673.887	186.667	673.888
CØ	186.66666	673.887	186.667	673.888
Total	560	673.595	560.001	673.596

Panel loads

Service Properties (Per NEC® 310-16)

Conductors are visible at all times but are not taken into account, for conduit fill or voltage drop sizing for instance, if they are dimmed. The user can un-dim the wire text boxes by checking the box beside each requirement, shown here highlighted as yellow. If a neutral is not required for instance, the user will uncheck the box. Each time a requirement is pressed a calculation for conduit fill is done but the conduit will not be sized. If the formula determines that conduit size is then to small, a warning will be displayed for the user to take action but will not automatically be taken for them.

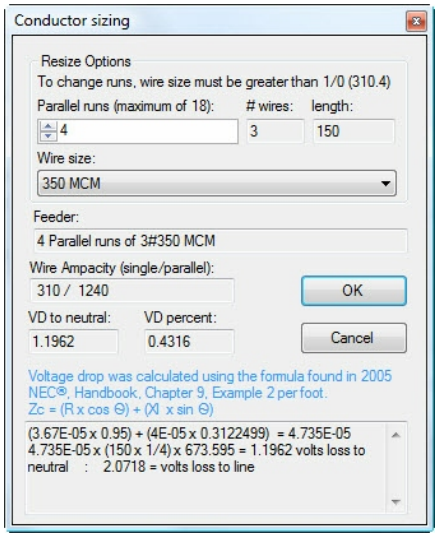
Each property may be changed by pressing the button beside the respective element.



Service properties

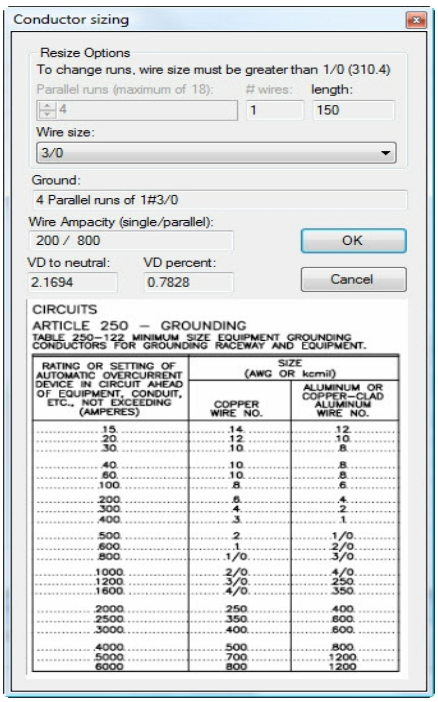
Phase/Neutral

The user has options for changing not only wire size, but the number of parallel conductors. All these factors are visible in one box such as the feeder text, wire ampacity and voltage drop based on the length of conductor which can only be changed in the properties window. If parallel wire is used for neutral wire, that will be shown here too (maximum of one).



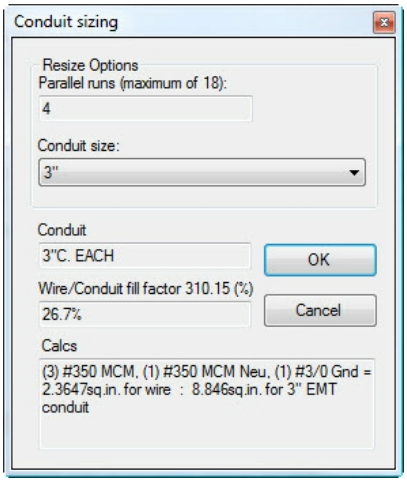
Ground

Layout is nearly the same except the addition of a lookup table for ease. Voltage drop is not calculated for this wire.



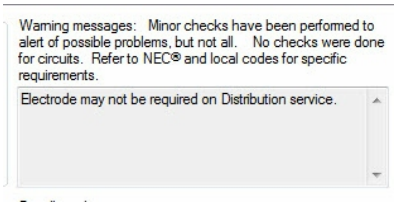
Conduit

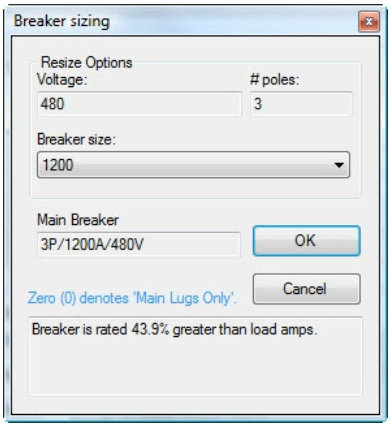
There will only be one selection here since it is only size of conduit. For information, the conduit file is shown. The can also be shown in the Panelboard output.



Warning messages

Minor checks are done to warn the user of potential problems with the inputted data, but do not always mean it is incorrect. There are many possible scenarios that would cause other problems in a code environment that may not be displayed here. Review all data prior to final completion and refer to local and national codes for other potential problems of the panel and exporting the schedule.



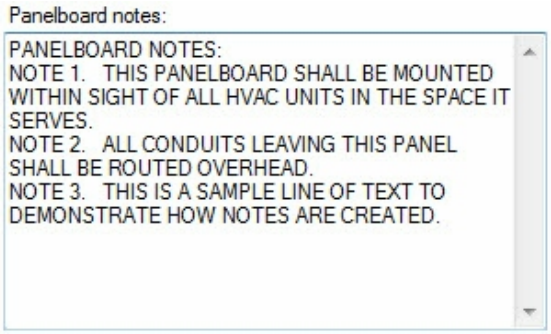


Breaker

There will only be one selection here since it is only size of breaker. For information, the conduit fill is shown. The can also be shown in the Panelboard output. This input must be with a whole number so selecting a o will signify that the panel has main lugs only and will be displayed as such on the service properties box.

Panelboard Notes:

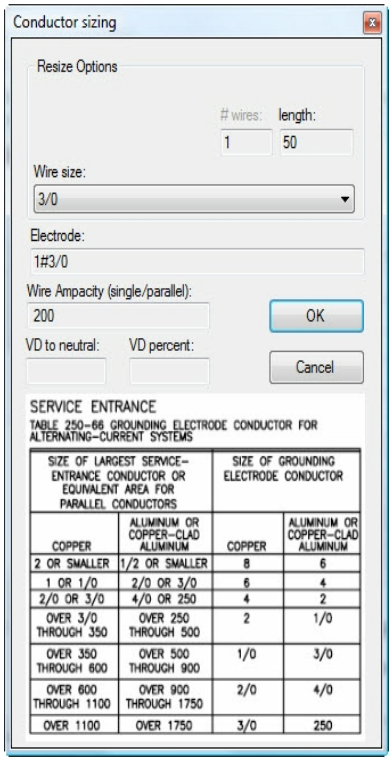
This is intended for including notes as reminders or as comment notes when scheduling. There is no limit to the amount of text, but would we not recommend not putting too much information that could be done somewhere else. This information is not required and in most cases will not be used, but the ability to do so is here.



The panel designer is keyboard smart and is programmed to exit when it sees a enter key pressed. If the user accidentally presses enter, the user may cancel so the designer does not close and may continue working. To enter a new line in this box, press and hold control button then press enter.

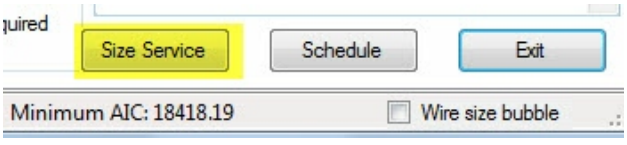
Electrode

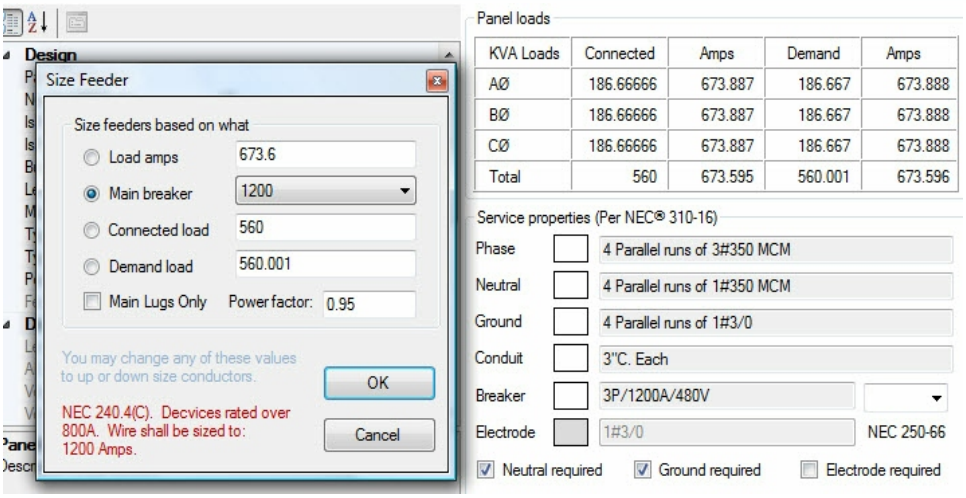
Layout is nearly the same except the addition of a lookup table for ease. Voltage drop is not calculated for this wire.



Size Service

Prior to pressing the button labeled Size Service on the panel designer window, feeder length will be required to be input so voltage drop calcs can be done.





can be changed at any time for sizing wire. This illustration shows an example of a panelboard with a connected load of 673 amps and a demand of 673 amps. The user must determine which one will be used because those values will change from panel to panel. This number can be changed at any time prior to sizing. Wire can also be calculated for a particular breaker size, or KW for connected or demand side. Each of these four selections will net the same result and does not do anything to modify the loads. It is designed for determining wire and conduit sizes only.

The user must make all determinations of wire and conduit size as per local, national and regional codes to the conditions that fit the particular need and which load is proper for the panelboard.

If there are no loads in the panel initially, EPS will constantly update those calculations in the process of load updating. EPS is designed to be as open ended as possible so the user will never have any restrictions when designing panelboards. Certain parts of the program may display NEC code references that will point the user in a particular direction but not limited to the only specific requirement. Check codes for specifics.

There are four load types which are automatically entered for the user if panel loads exist at the time, but

Clicking the Main Lugs Only button will size the conductors normally, except the panelboard will be labeled for Main Lugs Only. Set the breaker size to zero.

Click OK to finalize these sizing requirements and size wire. The values will be loaded into the service properties shown in the panel designer. This process can be repeated as many times as required when inputting loads.

Schedule

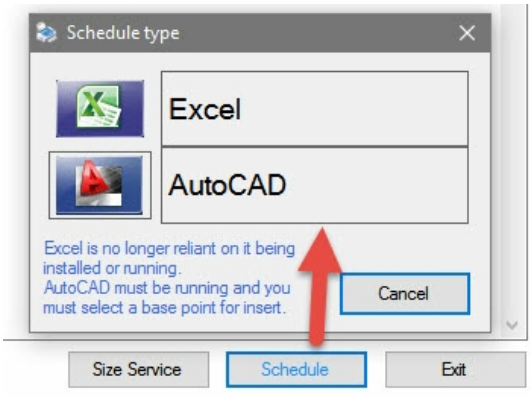
After the panelboard has been loaded and all conductors have been sized, the user can export the designer parameters to an Excel schedule. Excel 2007 or later is required in order to use this option. The output to excel will be created that is preformatted and ready in only a few seconds. It is important to remember that the Excel worksheet is created in the same directory as the panelboard file and will have the same name. It is not recommend to change these file directories and has never been tested outside this space.

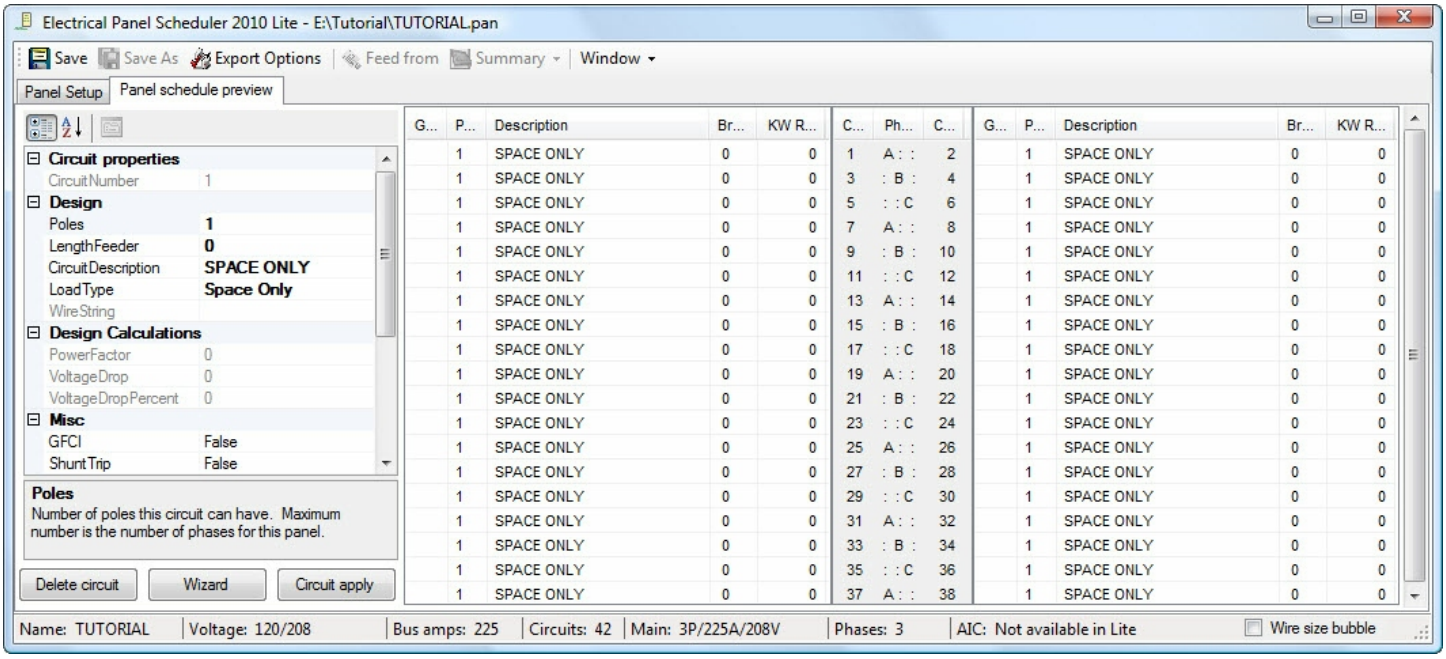
All parameters which are exported to Excel can be changed to get many results with just a few switches. All of these switches are specific to each panelboard some the results can change from panelboard to panelboard. The Export options toolbar button is how to access these switches. To best illustrate these switches we will begin by numbering the export options window and then number a marked up Excel worksheet.

Users may export out to AutoCAD or Excel. Select the proper button to begin export.

Excel is no longer reliant on being installed or running in order to use EPS. The exporting to Excel has been speeded up by over 200% with this new functionality.

AutoCAD on the other hand must be open then the user will be asked to select an insertion point.





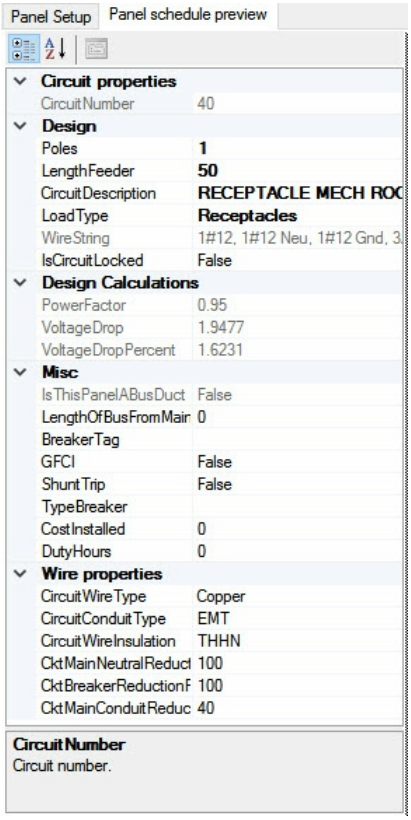
It is very important to understand what these fields do and how they are created

Circuit number

Current modifying circuit selected for editing. Even if a highlighted field is not visible in the schedule, you may always see which circuit is current and remains that way when you return to the panel for editing.

Poles

Number of poles, one, two or three. Once a circuit is set and edited to two or three poles, it should never be changed again. A circuit should be deleted if the number of poles ever needs to be changed. There are certain fields that are written in the circuit apply window that are critical for poles to be be able to link together.



Length of feeder

Distance of current modifying circuit feeder length. This may also be edited in the circuit apply window too so the voltage drop can be more visible but may also be changed here too.

Circuit description

This field uses a little bit of inelegance to recognize if a circuit is labeled for “Space only” or “Spare:“ so in that respect it must be specific for its use but in that respect the load type, below this field, must also be labeled accordingly too. A description name will change if a new circuit type is designated, but changing from one type to another, will not change the name, unless being changed from spare or space only.

Load type

Basically this diversity factor, but is specific in its purpose in EPS. Depending on its purpose in your riser, this field is critical to getting specific information used in the load summaries. The demand load is calculated based on the purpose of this field and of course can be changed by editing diversity factors on the main window.

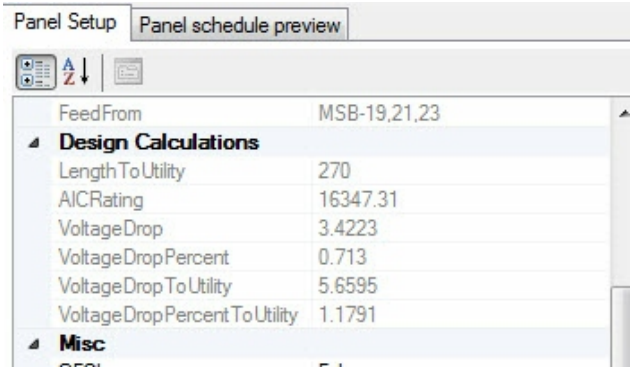
Load types Other, panelboard and transformer (which can not be selected here), tell the scheduling functions how to trim lines to let end users know when a element is shown in risers or not. A little experience is critical to this understanding and what the user can expect to see in schedules when selecting these fields. Other than these specific types mentioned above, the field will act the same for any other load type when exporting schedules and summing demand loads.

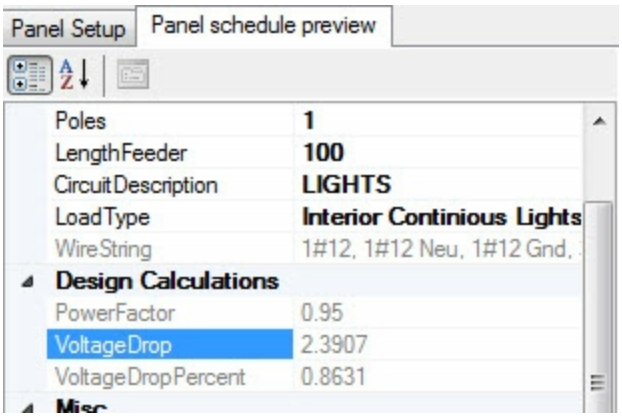
Wire string
This field only serves to let users know what the wire and conduit size of a specific circuit without using the wire balloon of circuit apply button.

Is Circuit Locked
This switch serves to be an indicator to show users if a circuit is locked, except for manual corrections.

Power factor
Each circuit type will have a specific power factor based on its use. In the circuit apply window there is a field for power factor. This number is critical for voltage drop measurements and sizing loads. The closer to number of 1 the more voltage drop on a circuit.

Voltage drop
Displays the calculated amount of voltage drop on a circuit. To calculated actual voltage, add the sum of panel feeder voltage drop and the sum of this number then subtract the panels voltage. For a 480V panel, with a drop of 3.4 volts to neutral on the main feeders and a single phase circuit drop of 2.3 on the circuit, voltage drops is 5.7 volts. So with a 277 volt circuit, this would mean that only 271.3 volts would reach this circuit at its furthermost point. NEC 215 (d) tells us what the acceptable voltage drop limit is with a trigger limit switch on the main EPS window, usually 3% and 5% to the utility.





EPS only warns if a circuit length is higher than the amount specified on circuit length and does not account for the feeder amount so up-sizing the feeders on the main may resolve any significant voltage drops.

Voltage drop Percent
As with Voltage drop this value is the same as above except in a percentage factor.

Is This Panel A Bus Duct
Shows user setting from panel setup tab if this panel is considered a bus duct.

Length Of Bus To Main
The wire leading from the source panel to this point is considered the wire that serves it junction. The bus in this panel is considered the bus duct length except for being smaller and shorter than a bus duct is technically the same thing except for its length and impedance characteristics. The ohms per foot on the previous page will be used to calculated this resistance factor to this point, so this value will contain the length from the connection point minus the wire length from source panel.

Breaker Tag
This tag will show up with exported panel schedules for Excel And AutoCAD beside breaker designation so that a note may be associated with its respective mark. For instance a 20* will be displayed in the breaker field, if a * is used here, then the user may mark a note to associate with * in the notes area of the scheduler.

GFCI
If a ground fault breaker is used, it require a separate pole to be connected in the panel. Coordinate the breaker requirements with manufacturer. Select true if this breaker will require a separate pole, and leave the next space down as space only.

Shunt trip
If a shunt trip breaker is used, it may require a separate pole to be connected in the panel. Coordinate the breaker requirements with manufacturer. Select true if this breaker will require a separate pole, and leave the next space down as space only.

Type breaker

A list of breaker types is labeled under this selection. Select the proper breaker type if different from other classes in your project. This is not the same as including breaker suffixes which will be covered under circuit apply window. The short suffix symbols after the breaker are displayed in the schedules and can be associated with panelboard notes. This breaker type is not required with the advent of the suffix methods for labeling breakers, but is being left in for clarity since the suffix is limited in what it doesn't say without proper notes.

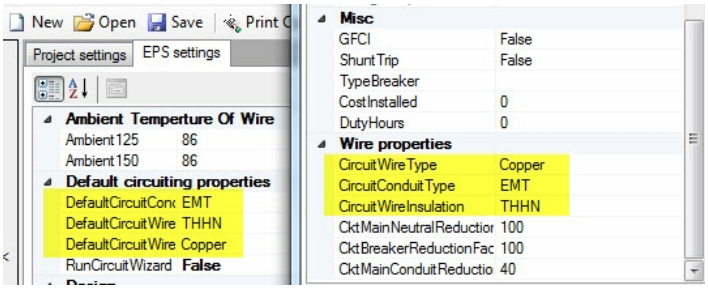
Cost installed

If pricing is required for a project, EPS provides users with a placeholder for costing with a panel. These fields are totaled each time the riser is updated to sum the project and circuit and panel cost. There is one each for each circuit and one each for each panelboard. Of course there could be many elements involved in the user calculations of each circuit including each back-box, cover plates, conduits, wires, and connectors. The price of all elements involved in the circuit should be included in each circuit in this field or may be calculated by the user and entered under a field in a window which can be found in the EPS window at Optional > Installation cost. This field is intended for pricing the entire panel short of circuits which could be the objective of this field.

Duty hours

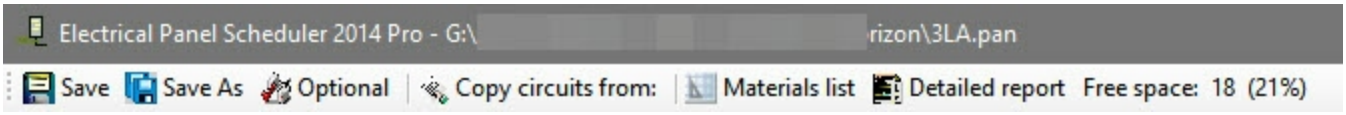
Although this field is not programmed in at this time, its original purpose was to cost of utility costs by letting the program know how many hours out of 24, a circuit would be operating and calculate the energy usage for a panel or project. With enough user requests this could be easily done, but provided a field for it now will solve problems later.

Wire Properties



The following fields for Wire Properties are defaults for panelboards from the main window > default circuiting properties field. When users begin to setup panels from the new window, these fields are coped to all circuits in a panel as default. Changing the main window fields at any time will not affect fields in panels already created, but will affect new panels.

Reduction factors are hard coded and cannot be changed by default. EPS uses these values when determining neutral, beaker and conduit reduction for sizing functions.

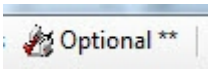


EPS Toolbar

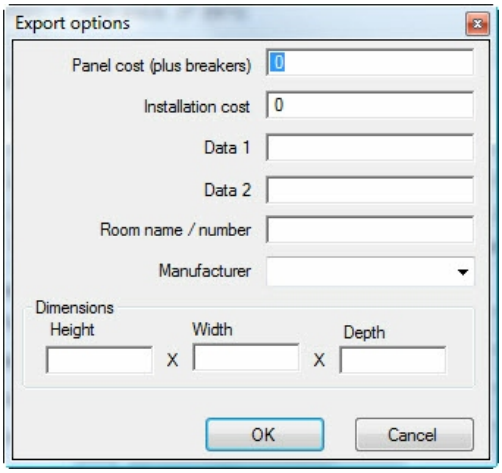
Save panel
This button will save the current state of data fields to file

Save as panel
This button will let a user save the current panel state to a new file name.

Optional
Give users an optional data fields for storing non critical information about a specific panel but is not required for any input. This lets team members know more specifics on the panelboard.



EPS will display an indicator when data fields are present to let end users know when data has been modified for a particular panel. The text on the toolbar will change to "Optional **" when data is present to any fields in this window.



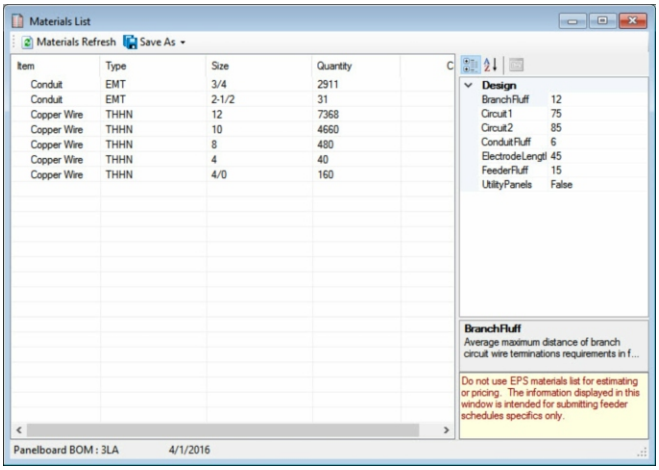
Copy Circuits From:
This button is explained on next page.

Materials List
This button sends a report that can be exported to Excel without a quantity because it should not be used for pricing. Its intent is to let users know which conduit , wire sizes and types of insulation is used in this panel.

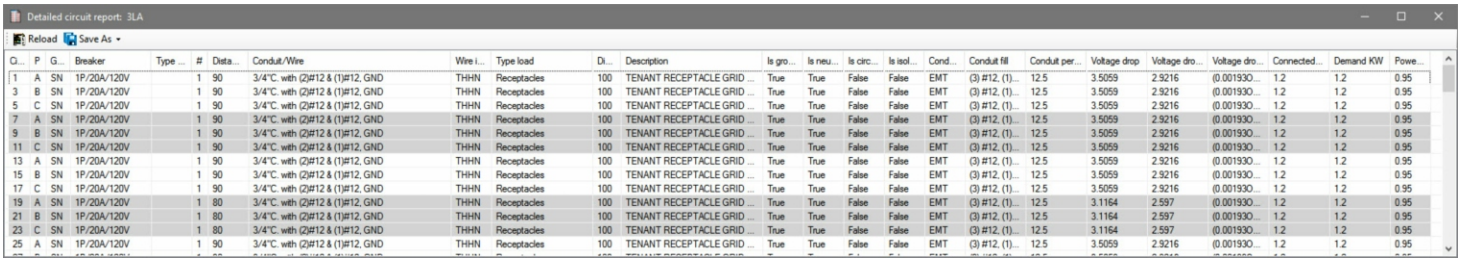
Detailed report
This is intended to show a report of all circuit s and its many properties in one glance without having to record its individualities separately. Originally intended to show debugging information, we felt this information was to good to not be shared with users.

Free space:
This display provides users with a clear means of showing how many space only or spare are free in a panelboard. A count and percentage of the total is displayed.

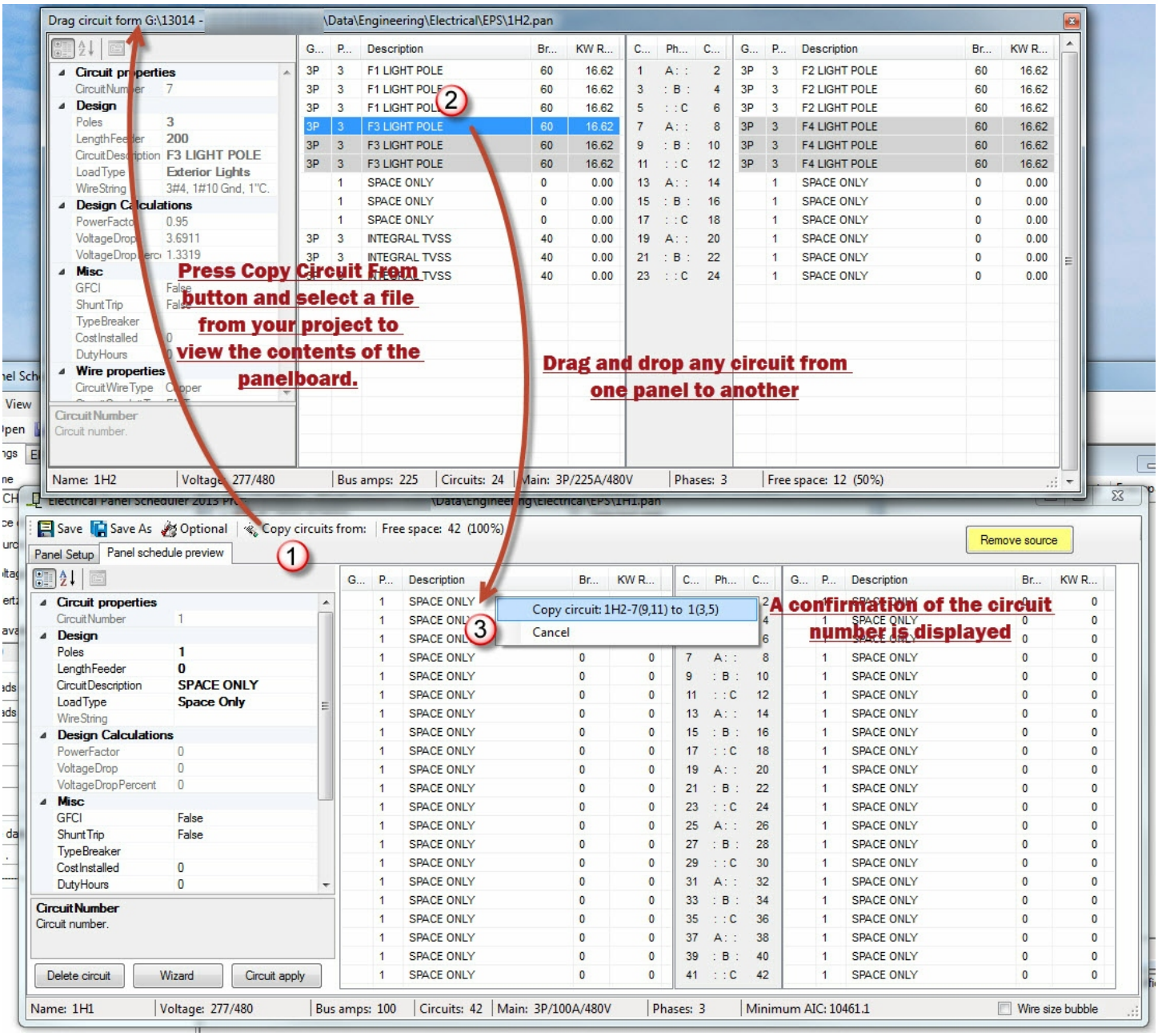
All panelboard schedules are handled in the scheduler design back page. This gives users a sense of how the schedule will look when coordinating the design. Visible columns are, breaker group name, number of poles, circuit description, breaker size and KVA rating. Without the ability to change colors on groups (conduit grouping) the schedule would be much harder



Materials List



Detailed List



Copy Circuits From

Copy circuits from:

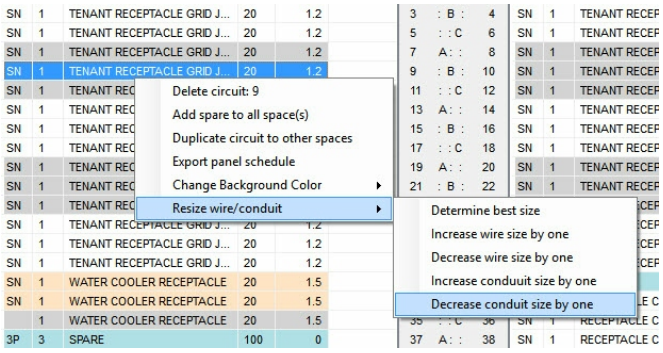
Copy circuits from is a powerful tool that allows users to copy circuit from one panelboard to another, provided of course if the voltage is the same. To use this feature, press the button to copy circuit from, then select a panelboard data file which has the data you wish to copy from. Select any circuit, except for transformer or panelboard and drop it onto the circuit you wish to copy to. If a user wishes to move this circuit, you will have to go into the file manually and delete it using the delete circuit button. An entire panel can be copied in this manner but using save as is much quicker, then deleting the circuit you don't want is more efficient. Moving circuits is not available.

The copy circuit schedule is designed to look just like the EPS window for easy understanding. All the fields available in the EPS window are available in the copy from window.

Context menus on panel schedule preview

Delete circuit

Use caution when using this function because two or three poles of a shared neutral will be deleted as shown above. This is because of the linking fields involved in telling EPS which circuit numbers are linked together and because of functions required to distribute them. If two of the other poles are to remain, they can be copied to other circuit numbers temporarily then moved back after deleting the unwanted circuit(s).

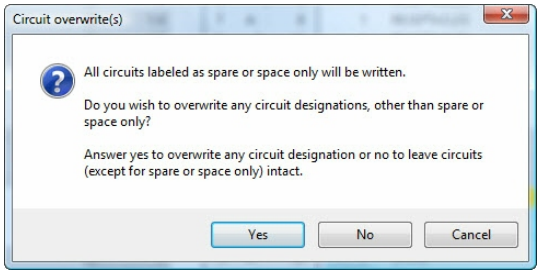


Add spare to all spaces

This function is useful in creating spare circuits to an entire panelboard or up to a number specified by the user. As an example, select any circuit in a panelboard where you want to start placing spare circuits. Select the add spares to all spaces button. Enter the last number in the sequence where the spare breakers will end. Every space only blank in the panelboard is now labeled as a spare breaker. The default is 20 but if the user goes back to the main window that can easily be changed temporarily to make minimum circuit breakers of 30 or 40 amps but only single pole.

Duplicate circuit to other spaces

This function does what the add spare does not. The function will copy any circuit from any starting point to a last designated circuit as with add spares, except it copies what ever circuit is selected and copies it to other poles without interfering with any shared neutrals.



This message box ask the user if circuits within a range are to be overwritten or to only proceed with spare and space only load types. Answering yes will write the selected circuit to all poles within the range, except for more than one pole. Shared neutrals will remain with a new circuit designation if the user pressed yes.

Export panel schedule

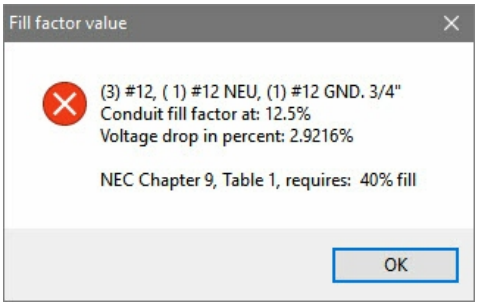
This menu item is intended to export the schedule to Excel only. There is another button on the first tab which lets users select which output like AutoCAD or Excel.

Change background color

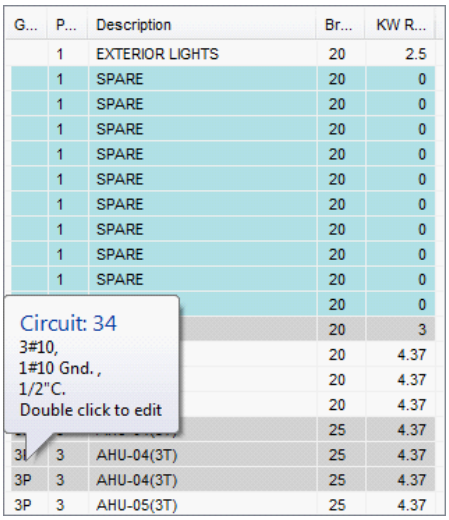
This gives users the opportunity to change the background color of the schedule without having to do it under the circuit apply window. There are 5 colors to choose from. Users may set up company standards which can be designated to mean something different, but yellow is intended to be as a warning that a voltage drop is to high, which can only be changed in calculation functions.

Resize wire/conduit

These functions allow users to increase or decrease the wire or conduit size by one without having to go into the circuit apply window. This will resize the conduit or feeders and neutral but not the ground.



Wire Size Balloon

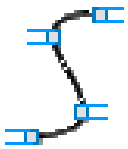


The wire size balloon switch on the status bar is normally set to unchecked by default. This switch will not remain on and must be turned on each time into the panelboard modifications. If the switch is checked off, by default, the circuit properties will not be displayed. When it is tuned on the user can hover their mouse over any circuit number in Panel Schedule Preview tab and will display wire size and circuit number. This is where all the circuit design is done. The info bubble shows minimal information and is redundant since the Design properties wire string shows this same information, but it allows quick access to any circuit prior to drag and drop.

Chapter 3

Using the AutoCAD extras

There 3 components to AutoCAD extras that may be used individually.



Eleader

Eleader is a compiled Lisp file that allows electrical designers to easily insert electrical blocks with attribute tags once when including light fixtures on a drawing so that every subsequent fixture do not have to be tagged individually. This app also contains many useful macros for placing blocks in Autodesk® AutoCAD®, based on the working annotation scale, which will rotate attributes in a block after placing then from a toolbar.

Description

Loads toolbar functions to insert electrical blocks. This app includes electrical blocks for lighting, receptacle and fire alarm. Users may customize or build and expand to suit their needs later on.

This package includes three toolbars, 238 icons and 76 electrical light fixtures, receptacle and fire alarm blocks.

This app contains many useful macros for placing blocks in Autodesk® AutoCAD®, based on the working annotation scale, which will rotate attributes in a block after placing then from a toolbar, many focused towards electrical design but can be suited for many disciplines. Three sample toolbars have been provided that be used immediately. These toolbars may be customized using the CUI interface within Autodesk® AutoCAD®.

One of the functions in these macros that will ask the user for an attribute when placing the first block, and place that block, with the attribute entered, in an unlimited number of positions and locations, till the function is canceled. This is very useful when placing light fixtures with visible tags. The attribute tag will be relayed to each block inserted during this macro and will be rotated to zero degrees. When placing fire alarm devices with visible tags, a single fixed attribute can be passed to a function which will also rotate the text to zero degrees. All macros are useful for fire alarm and light fixture or any blocks which require visible attribute tags to be rotated to zero degrees after placing them in a drawing file.

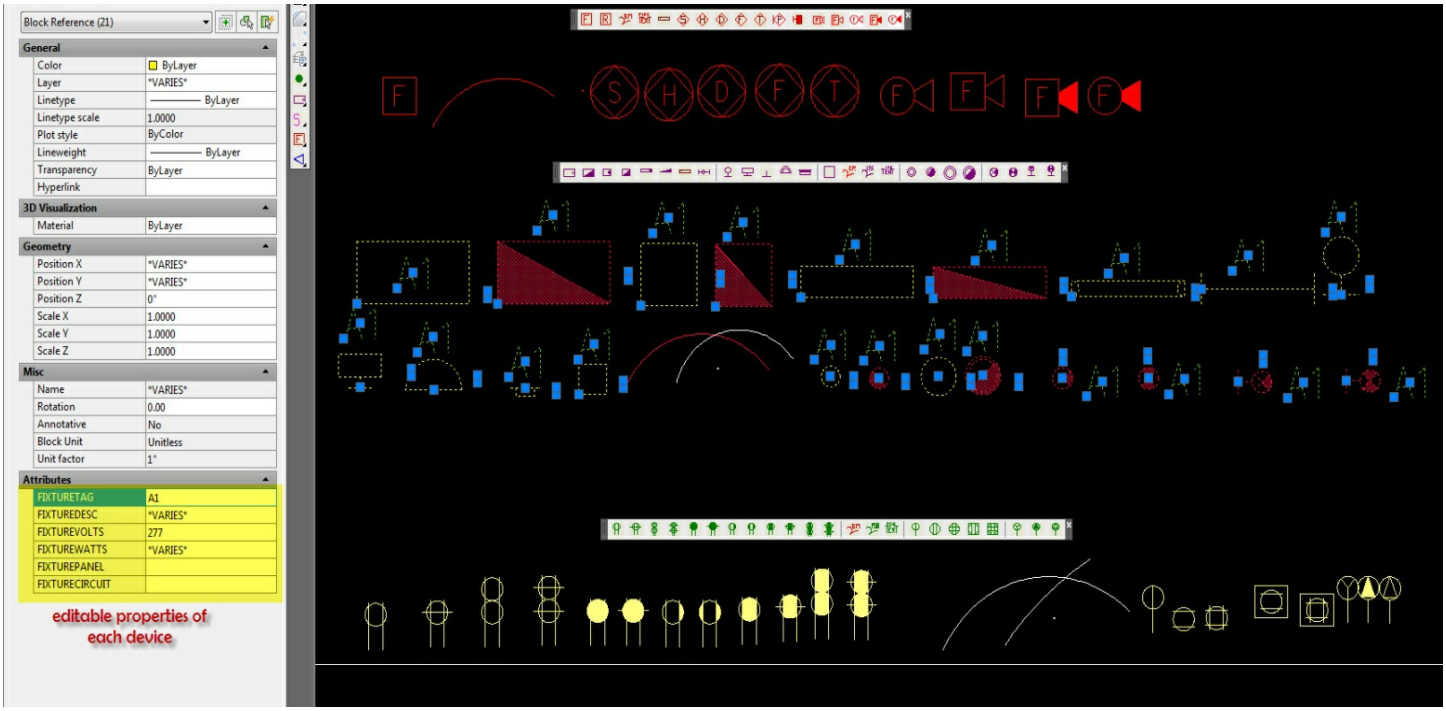
Starter toolbars and electrical icons will also be provided.

General Usage Instructions

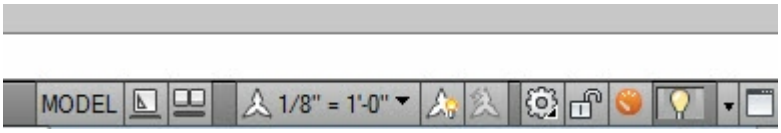
Before inserting blocks on a drawing using the toolbars, working annotation scales must be used to determine what the insert scale will be.

After placement each block can be edited for each property.

Note: All Contents/library files will be placed to %Public%/Documents/Autodesk/Downloaded Content/Eleader.content for windows 7 and %ALLUSERPROFILE%/Documents/Autodesk/Downloaded Content/Eleader.content for windows XP

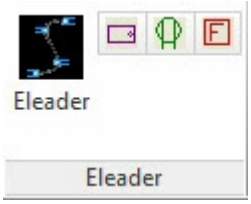


A screen shot of editing parameters and blocks and toolbars included in this package.



Make sure annotation scale is set prior to placing blocks using Eleader. Blocks are scaled accordingly, except for light fixtures, which must remain to scale.

Startup toolbars and electrical icons will also be provided and can be modified by experienced users as required.



Commands

Ribbon/Toolbar Icon	Command	Command Description
	-toolbar e-lighting show	Displays toolbar which contains lighting blocks
	-toolbar e-receptacles show	Displays toolbar which contains receptacles blocks
	-toolbar e-fire show	Displays toolbar which contains fire blocks

Installation/Uninstallation

The installer that ran when you downloaded this plug-in from Autodesk Exchange has already installed the plug-in. You may need to restart Autodesk® AutoCAD® to activate the plug-in. To uninstall this plug-in, click Control Panel > Programs > Programs and Features (Windows 7 /8) or Control Panel > Add or Remove Programs (Windows XP), and uninstall as you would any other application from your system.

Additional Information

This package includes three toolbars, 238 icons and 76 electrical light fixtures, receptacle and fire alarm blocks.

This window will display information based on minor or major program errors. It also displays a record of all panelboards that have been open and/or changed. This panel can be closed or opened at any time. This panel can be toggled to display on or off by pressing the miimize button. This will collapse the panel so it will not be visible. EPS is designed to let users know when errors occur by displaying this button as red. The user must click the button at least once to deactivate this colored button, so you will be ensured to see those warnings. in the messages window.

Electrical Panelboard Scheduler AutoCAD

This external application EPSA is used primarily for calculating electrical wattage from a block inserted in AutoCAD with specific attribute tag labels. There are three modules included in this application. Displaying selection sets calculated total wattage, displaying the selection set into a table so it can be exported to Excel or simply viewed and finally taking selection sets and sizing those loads to a schedule which can be scheduled into AutoCAD.

First, when used in conjunction with another app (Eleader from the AutoDESK Exchange Apps Store), based on inserting blocks with specific attributes, this program will determine each block selected, whether a light fixture or receptacle, and add a wattage data field within the block then sum those values to determine load, in watts, of a selection set.

Second, a function that will sort a selection set of light fixtures and/or receptacles based on its visible tag and export that list to Excel which also counts the number of devices per tag. This function is great for ASHRA determinations of light fixture plans since it counts the number of lights and calculates the total wattage for each fixture type then totals building load.

Thirdly, another function will size a selection set (a group of receptacles representing a circuit) into a panelboard schedule and size wire and voltage drops based on the furthest length. This is the most useful function because once a selection set of devices is selected; clicking a circuit from the schedule is all that is required to both put a circuit number beside a receptacle or light block while simultaneously loading the circuiting information into a schedule. Wiring a receptacle plan with four panels for a 20,000 sq. ft. building can be done in less than 30 minutes including exporting the panel schedule back into AutoCAD (with EPS Pro only - see below), once all the prep work has been done. Each device must have a wattage associated with its proper use. In other words, a refrigerator can be 700 to 1500 watts. Attributes fields must be filled for each device to properly hold this data.

This is where the external application comes in. There is a free version and a professional version which has to be used to create and edit the panel schedules that the plug-in for AutoCAD requires. The free version allows users to create and modify circuit to and from AutoCAD, but does not have the linking power or export capabilities as the Pro version.

Getting Started

Electrical Panelboard Scheduler AutoCAD (EPSA)

The purpose of this app is to provide electrical designers a very easy method for determining loads of electrical devices (light and receptacle blocks), exporting those devices to a table which can be exported to Excel, then displaying and including the data in a panel schedule. Users will have to include a set of attributes based on their own block library in them which will hold the data from the electrical schedule and load information as well as descriptions. EPSA will ask users for selections of blocks to determine load and other characteristics of the electrical block and display a panel schedule which the user can assign circuits too and which will size wiring characteristics to.

Electrical blocks must have the following attribute properties in order to use EPSA.

```
POWERTAG                RECEPTACLES (GROUP)
DEVICEDESC              DESCRIPTION OF THIS DEVICE TYPE
DEVICEVOLTS             VOLTAGE OF THIS DEVICE
DEVICEWATTS             WATTS FOR THIS DEVICE
DEVICEPANEL             PANEL NAME
DEVICECIRCUIT           CIRCUIT #
        TEXT    E-POWR-REC-CKT          POWER CIRCUIT TAG
LAYER
        COLOR   72
        WEIGHT .25
        HEIGHT  12
        JUST.   MIDDLE CENTER

FIXTURETAG              FIXTURE TYPE
FIXTUREDESC             DESCRIPTION OF THIS DEVICE TYPE
FIXTUREVOLTS            VOLTAGE OF THIS DEVICE
FIXTUREWATTS            WATTS FOR THIS DEVICE
FIXTUREPANEL            PANEL NAME
FIXTURECIRCUIT          CIRCUIT #
        TEXT    E-LITE-FIX-TEXT         FIXTURE TAG LAYER
        COLOR   72
        WEIGHT .25
        HEIGHT  12
        JUST.   MIDDLE CENTER
        TEXT    E-LITE-FIX-CKT          CIRCUIT TAG LAYER
        COLOR   97
        WEIGHT .25
        HEIGHT  6
        JUST.   MIDDLE CENTER
```

Electrical plans and determining loads based on attribute fields within a block that the user has assigned. The block library is not provided with this app but an attribute field is, which the users will have to include in the blocks library.

Usage

The purpose of this AutoCAD plugin is to provide electrical designers a very easy method for sizing devices on electrical plans with block with specific attributes.

The ribbon bar will attempt to load a .NET app if it is not loaded. The app must be in a search path or specify directory before the file name.

```
(if (findfile "epselec.dll")(prong (princ " epselec.dll
loaded.\n")(command "._NETLOAD" "epselec.dll"))(princ "
epselec.dll NOT found!\n"))
```

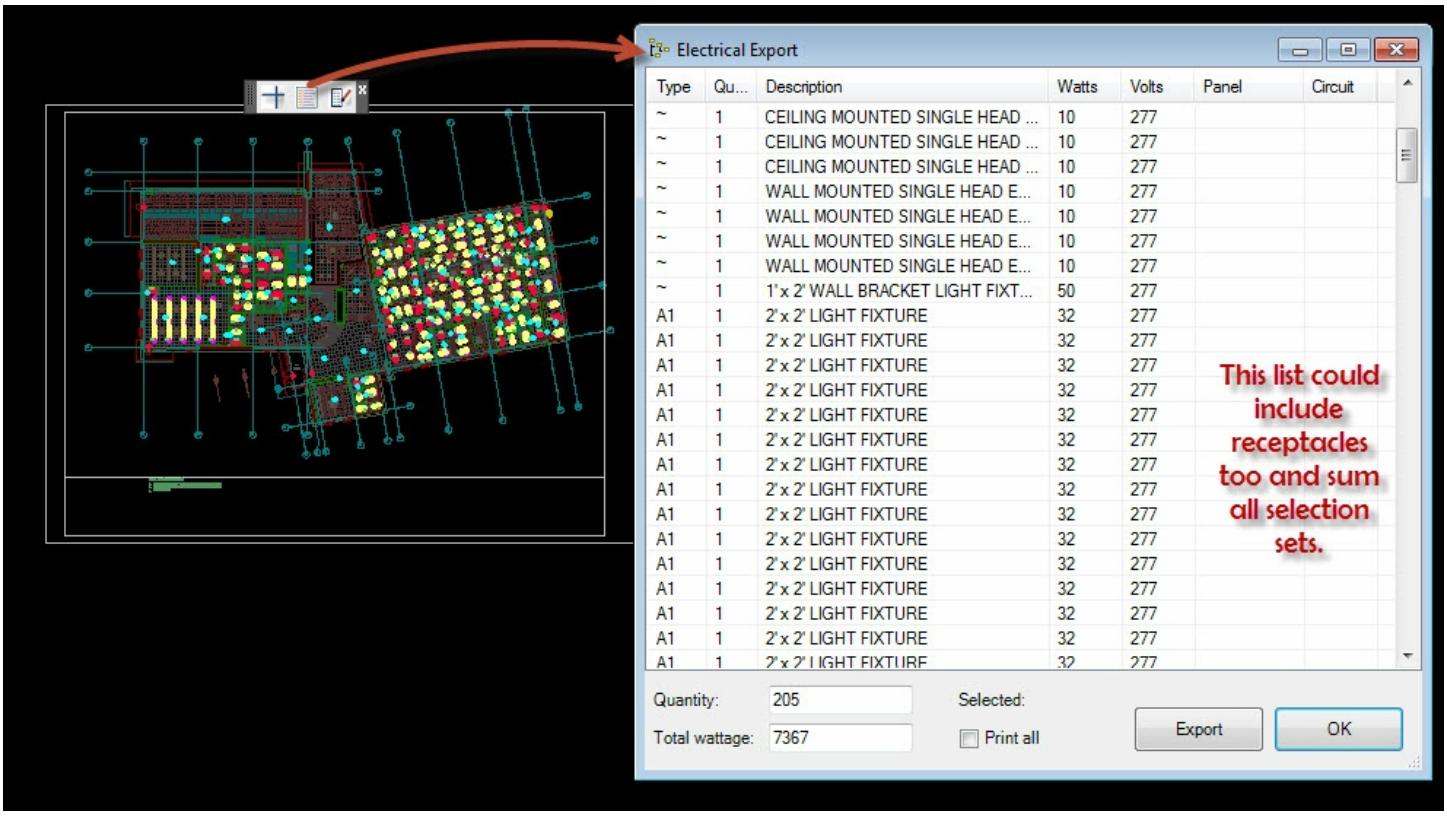
There are two separate dll's included with this project. Do not attempt to load the EPSLoad.dll as this is only used for capturing the data files required but they must reside together along with the icons.

Once loaded a toolbar will appear:

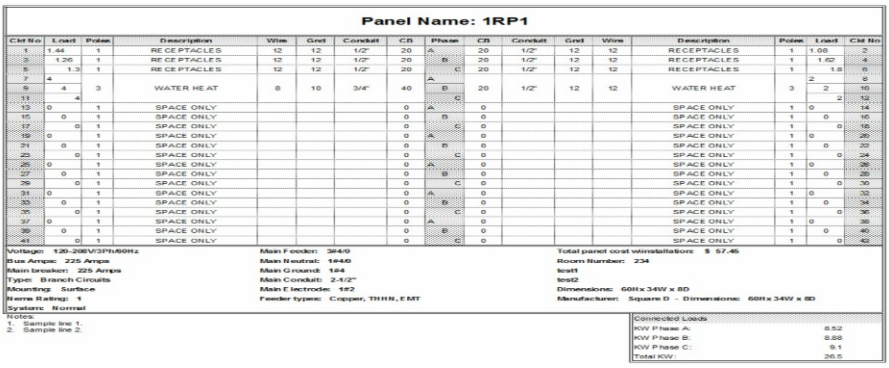
There are three commands and a toolbar associated with this app.

EPSSUM – When used in conjunction with another app (Eleader from the Autodesk Exchange Apps Store), which is based on inserting blocks with specific attributes, this program will determine each block selected, whether a light fixture or receptacle, and add a wattage data field within the block then sum those values to determine load, in watts, of a selection set.

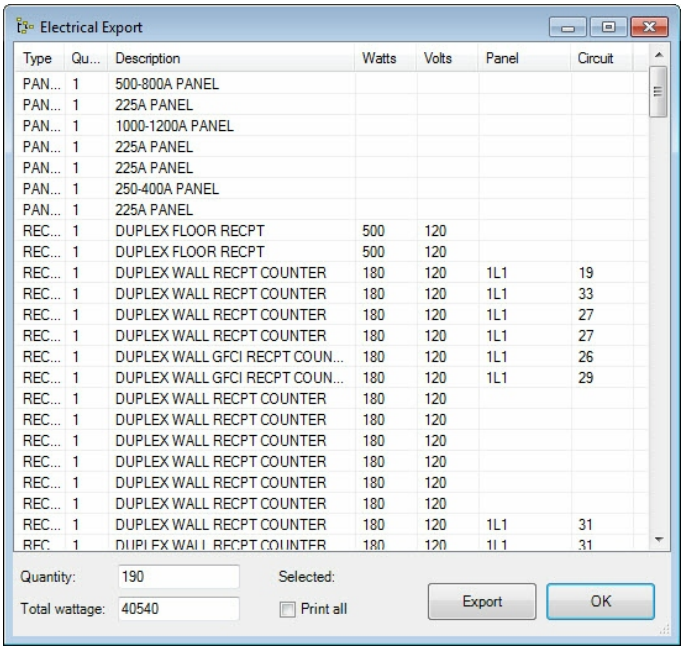
```
Command:
Command: _EPSSum
Select block references: Specify opposite corner: 289 found

Select block references:

Total wattage - 7367;  Lts(205) - 7367

Command:
```



EPSLIST – This function will sort a selection set of light fixtures and/or receptacles based on its visible tag and export that list to Excel which also counts the number of devices per tag. This function is great for ASHRA determinations of light fixture plans since it counts the number of lights and calculates the total wattage for each fixture type then totals building load.



When exporting, Excel (which is required) will print the list so users can see and count the number of lights by type. The tilde (~) designates that not all types are the same or there is more than one. Descriptions are shown as the last one loaded, but could have other names.



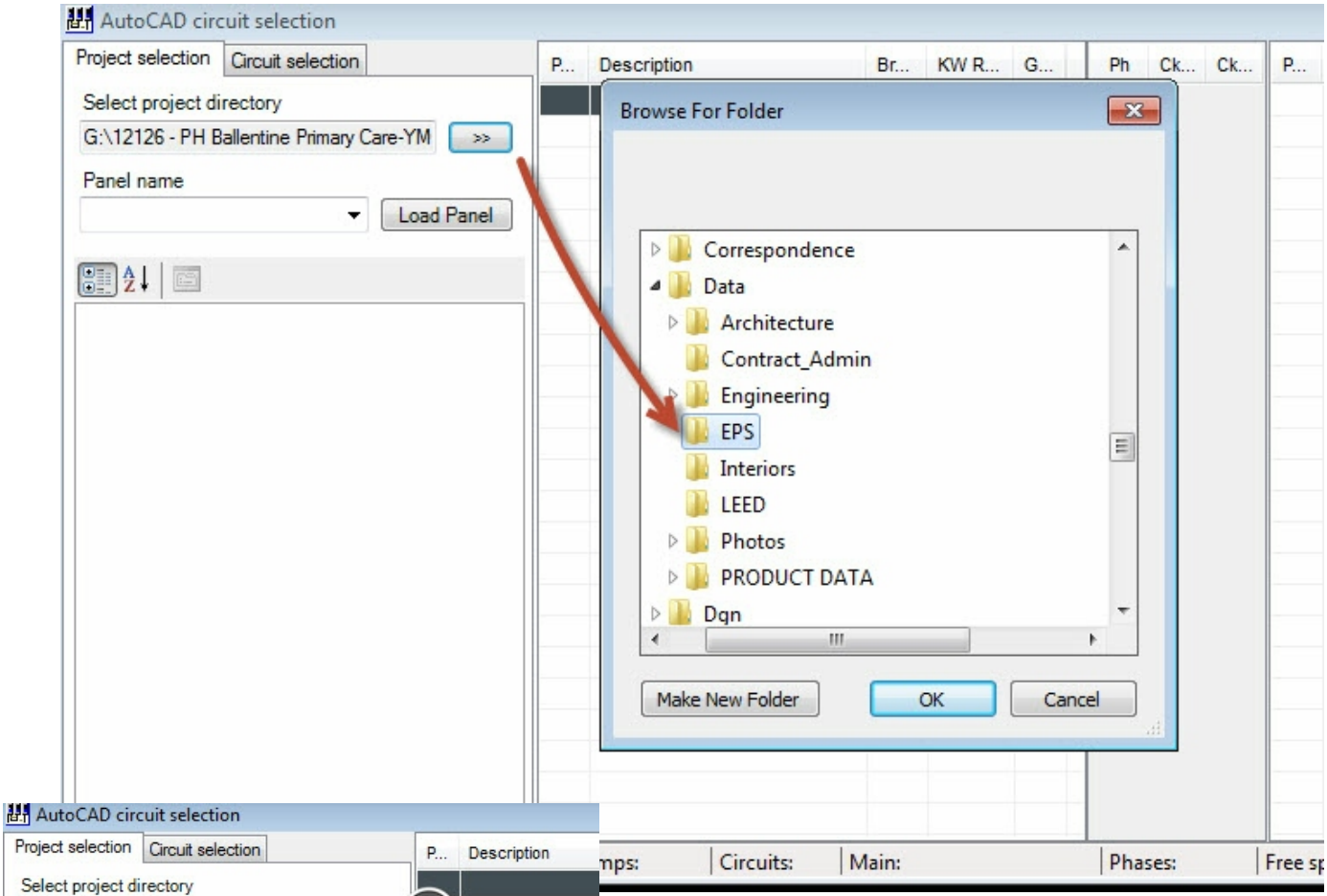
Receptacle list can look different from fixtures but certainly be shown in the same schedule provided the plans reside in the same drawing.

EPSPANEL – This function will size a selection set (a group of receptacles representing a circuit) into a panelboard schedule and size wire and voltage drops based on the furthest length. This is the most useful function because once a selection set of devices is selected; clicking a circuit from the schedule is all that is required to both put a circuit number beside a receptacle or light block while simultaneously loading the circuiting information into a schedule. Wiring a receptacle plan with four panels for a 20,000 sq. ft. building can be done in less than 30 minutes including exporting the panel schedule back into AutoCAD (with EPS Pro only - see below), once all the prep work has been done. Each device must have a wattage associated with its proper use. In other words, a refrigerator can be 700 to 1500 watts. Attributes fields must be filled for each device to properly hold this data.

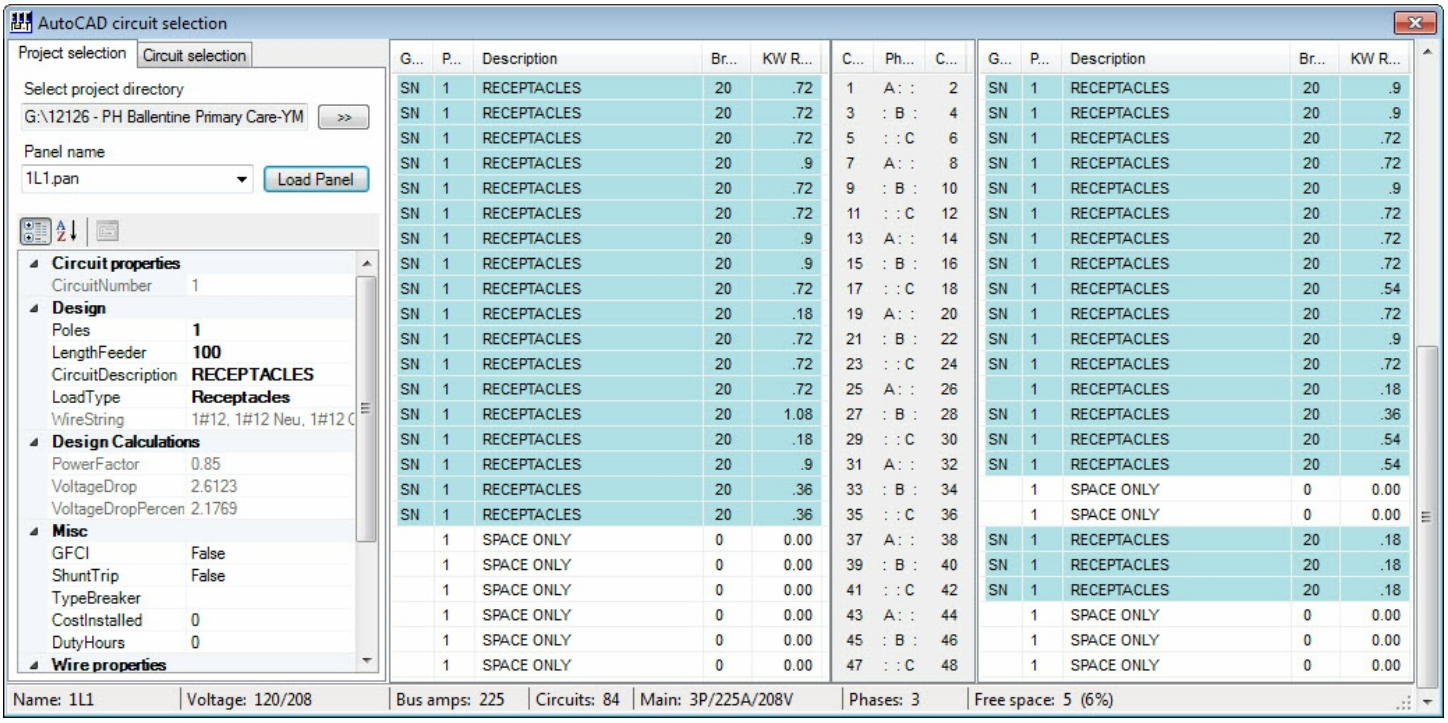
In order to use this portion a user must also get a free program from our web site called EPS 2013 Lite. These data files must be present before using these functions for creating schedules and is limited in it functions as opposed to the outside program which can be called to determine which circuits are sharing neutrals, sizing main feeders and other panelboard functions.

http://www.powersofteng.com/eps2010/download.html

Locate a directory where EPS schedule data files exists.



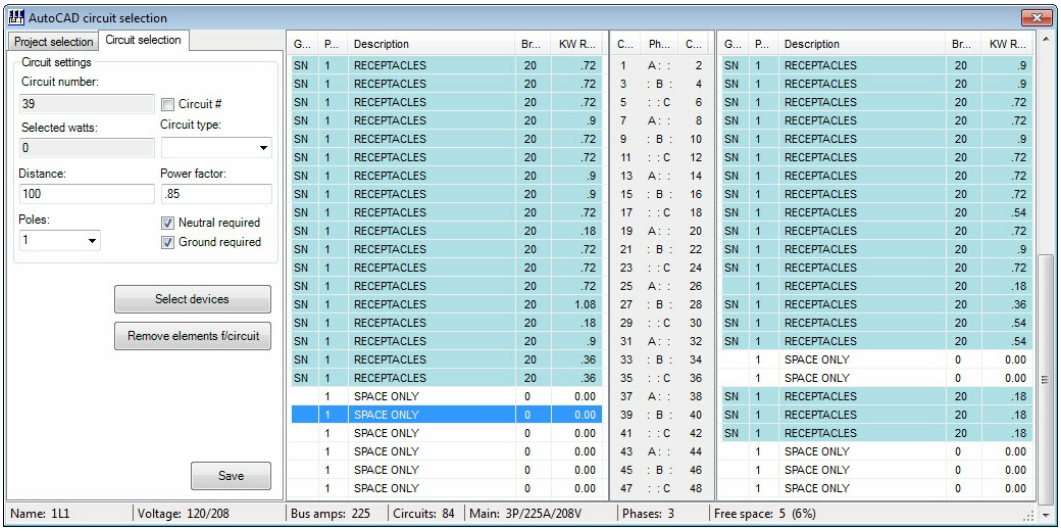
After pressing the load panel button the circuits are shown. This window will remain open and on top for the duration of your acad session, or till it is closed. This works best on dual monitors.



In order to start circuiting, select some electrical devices from acad beforehand. If there is no selection set, EPSA will wait for a selection before committing to a circuit, but the circuit type and other fields must be filled in prior to committing the circuit.

Make sure the proper circuit number is shown in the circuit number box. If the user wants to display a panelname prefix ahead of the circuit number, press the check box next to the circuit number. The total watts is shown as a collective of devices selected. Make sure the type, distance, power factors and number of poles are shown correctly before committing. Now with devices selected, press select devices button and instantly, EPSA add the circuit number to each device along with the panel name (while rotating the text to zero degrees, size breaker, wire, load, amps and finally totals the loads within the panel load summary. A yellow background will be displayed in the EPSA window if there is a voltage drop warning. EPS Lite must be used to review this load summary and be sure there is a balanced load, assigned shared neutral circuits, fine tune any circuit, ensure bus size is correct and other display minor panelboard warnings. All schedules should be reviewed by an experienced engineer to make sure all sizing is correct.

After saving the panel with save button, the panel schedule may be immediately be edited with EPS Lite to review additional circuiting, but must be reloaded by AutoCAD to review the changes that were made with EPS Lite. If any circuit that was mistakenly circuited may be removed by selecting the desired circuit, right click and select delete circuit. Each individual circuit must be selected to remove each.



Text will always be at zero degrees when assigning circuit numbers to devices. This layer can be turned off so it isn't visible if the user chooses to do so. A circuit without the panel name prefix and rotated circuit text.

This screenshot shows a circuit applied with panel name prefix applied and properties for one quad receptacle block. Notice schedule background was turned to cyan color denoting that this was an automation step. To change color of these circuits, go into the EPS Lite or Pro version and change them manually. See the user guide for panelboard specifics and how those groups are circuited.

Installation and Uninstallation

The installer that ran when you downloaded this plug-in from Autodesk Exchange has already installed the plug-in. You may need to restart AutoCAD to activate the plug-in.

To uninstall this plug-in, click Control Panel > Programs > Programs and Features (Windows 7 /8) or Control Panel > Add or Remove Programs (Windows XP), and uninstall as you would any other application from your system.

Additional Information

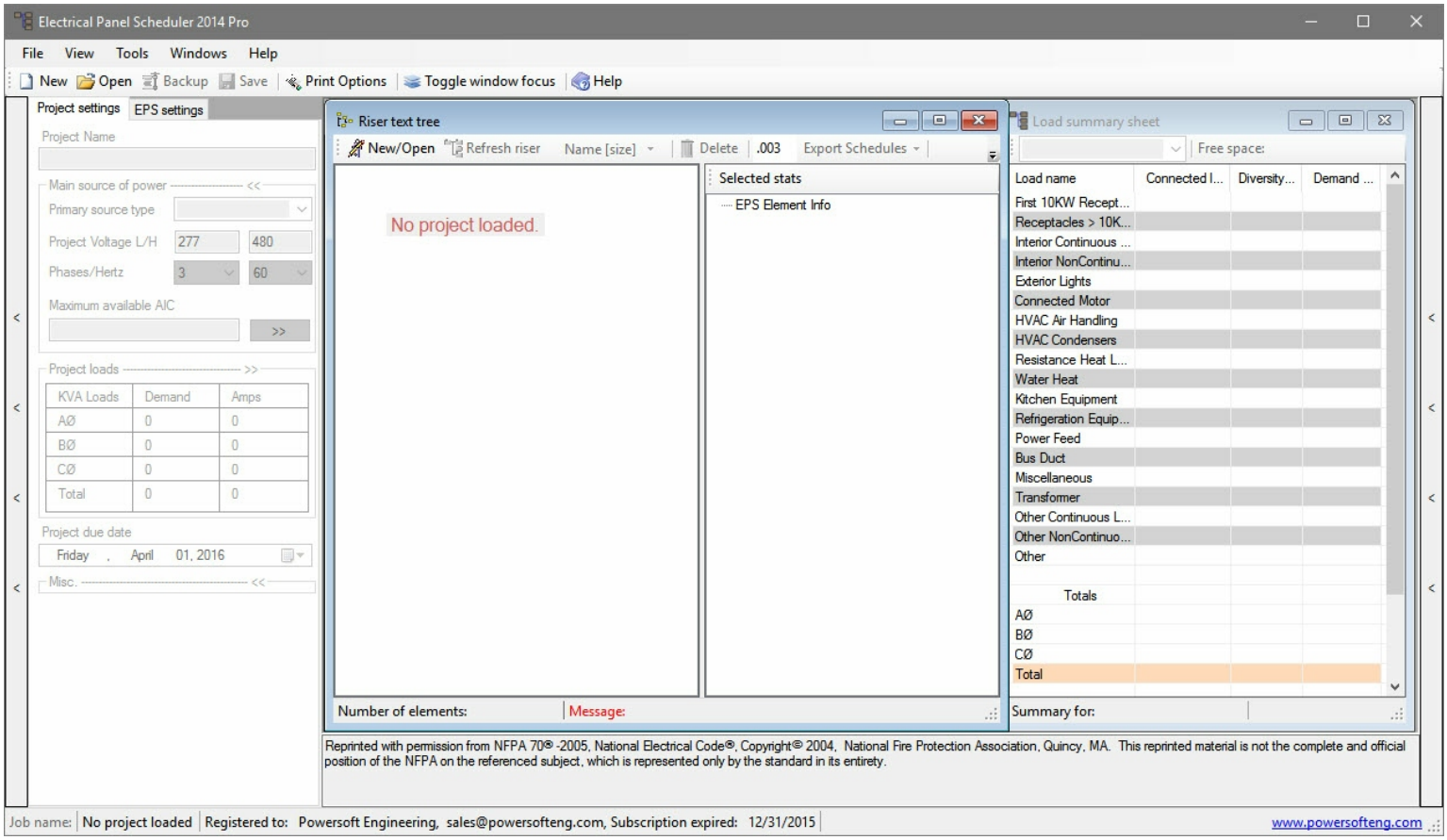
This app is part of a larger project that includes sizing panelboards and linking them together under the professional version of Electrical Panelboard Scheduler 2013. You can find more information about this and other Powersoft Engineering programs here. http://www.powersofteng.com/products.html

The EPS Lite 2013 version is free and can be used to create and size panelboards but is not designed to interlink and calculate riser characteristics like the professional version. The 2013 version of Lite and Pro can share data files, so users can choose which solution is right for them.

You may download the free version here (download the 2013 version):
http://www.powersofteng.com/eps2010/download.html

Chapter 4

Tutorial



EPS Main Screen

Before beginning, ensure that all the settings are correct under the Project Settings tab. You may select any of these fields to get some hints on what they do or what their purpose is. For this exercise, ensure all the settings are similar to the ones shown.

For this tutorial we will be using a garage building and you will be required to have a good working knowledge of how to design electrical systems and know the inner-workings of building design contract concepts. The design for this sample project is dynamic and will change along the way as it comes to final construction documents.

The time to complete these task's is dependent on how long it takes to coordinate all equipment that will used be in a building. The architect shows locations of the equipment and placed them on the drawings with his coordination with the owner. The only thing the architect does not know is the loads each of these items will require. This must be gathered from other disciplines or from the owner.

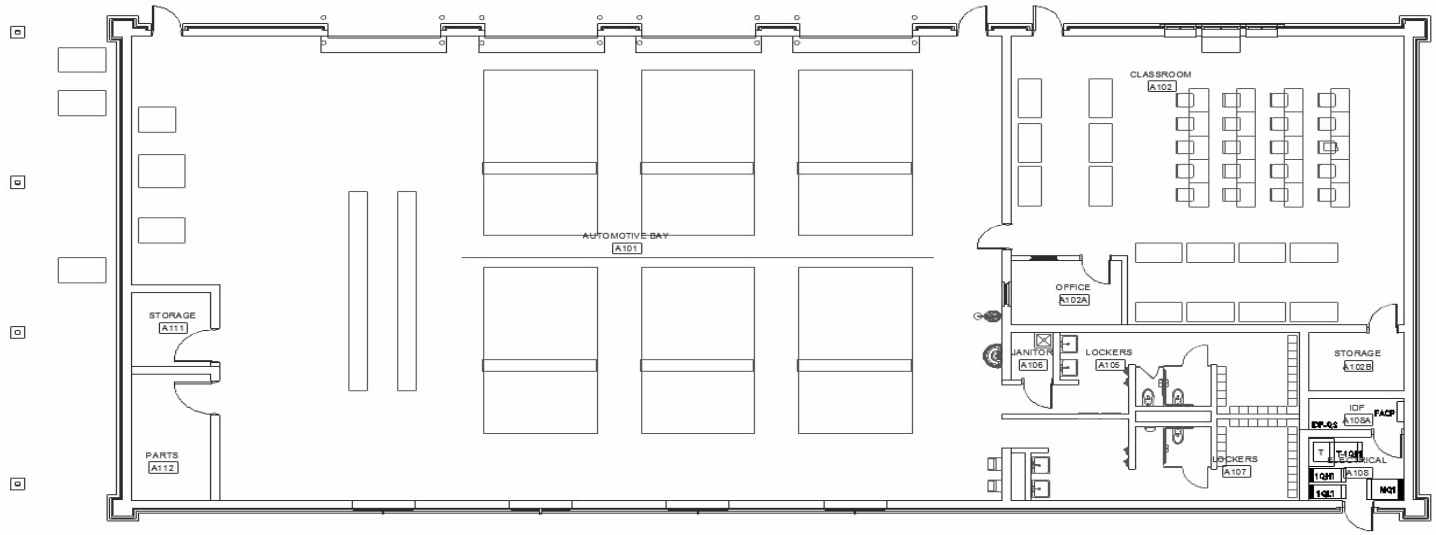


Figure 1

Overview of design

Before beginning EPS, layout all devices in CAD where you think the a device might go and experience tells you they should. Make sure all the coordination studies are done and all devices, locations and loads have been approved. If there is mechanical equipment as shown here, make sure you have cut sheets from the mechanical engineer or designer. Once you have these sheets, I would suggests storing cut sheets in your project directory, in case shops drawings come back as something they were not designed for. Gathering this could information could take days or weeks depending on complexity of the building.

Once this information is gathered, it will take only a couple of hours to complete the circuiting design. If changes to the floor plan do occur, as they often do, that will not be a problem. Hopefully this workflow will cover that or at least point you in the right direction.

For the firs step in design process, the first phase is conceptual (Design Development) so the owner can review and approve any device placement locations. This tutorial demonstrates the process of placing devices on a drawing during a long period of time, often days, weeks or even months, depending on schedules. If there is a design question along the way about an item placement or load, normally we will make notes on the drawing in a non-plotting layer and remove it when it gets answered. Usually this text will be in an obvious place and color. When we address the question or that information comes available then we remove the note. This is the part that takes years of experience and can only be improved by learning from past mistakes.

Panel location and names are also important at this point. Although a service load size may not be determined at this point, an approximation size can. Certainly knowing what voltage system and emergency electrical building requirements will be required to be known at the contract date. Speaking with local utility service providers will give designers available voltage and phase requirements.

Once all the approvals have been made for placement and loads we are almost ready to begin circuiting. The layout in figure 2 shows where circuits will be placed in a building and be wired.

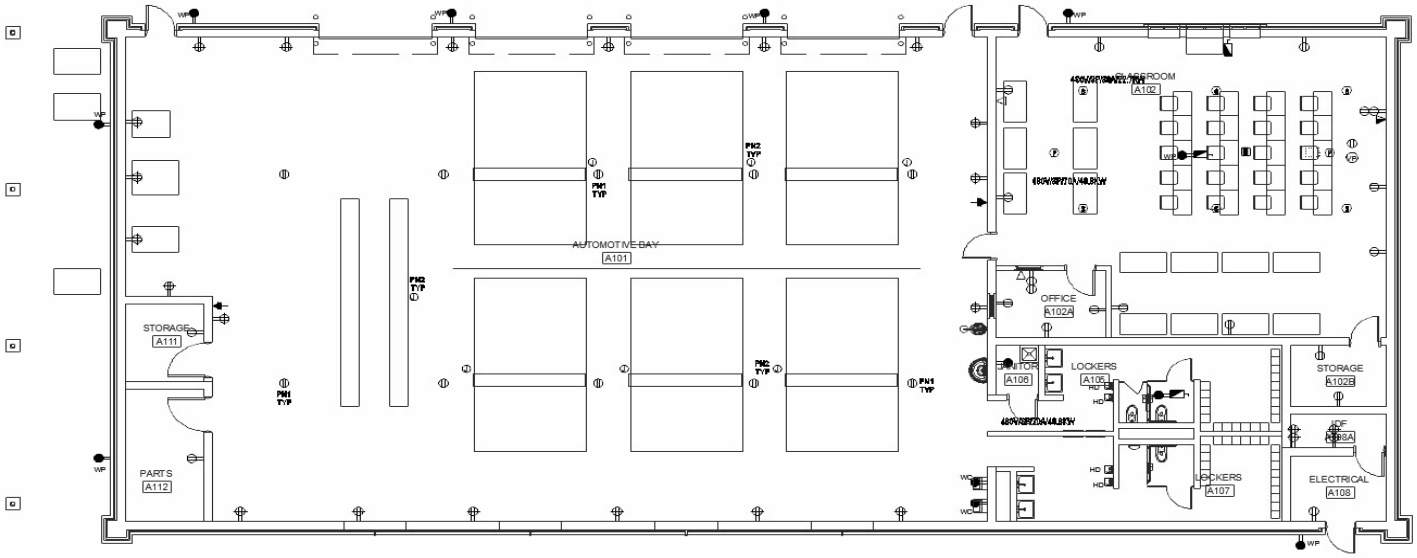


Figure 2

Begin design

Begin the next steps by determining which receptacle will be on what circuit (figure 4) by putting circuiting loops on each device. Do not skip any device so we can make sure all will have a circuit.

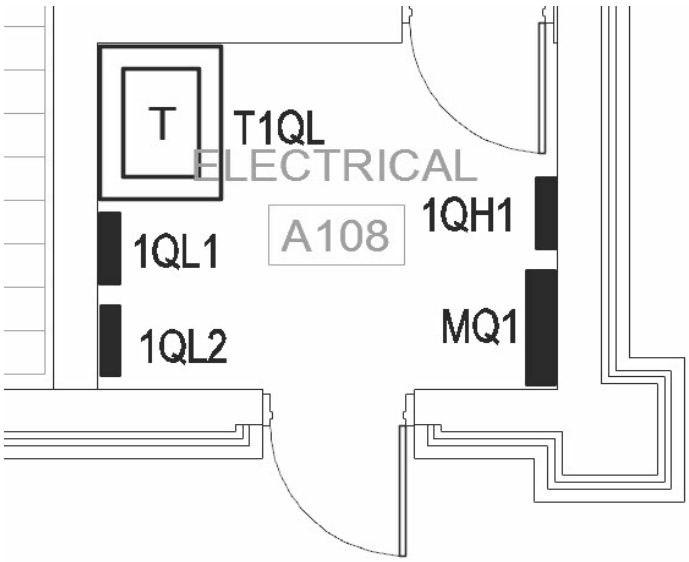


Figure 3

Tip: When circuiting, make sure all devices further from the power panels is loaded the least (perhaps only 5 receptacles as opposed to 8) because of voltage drops. EPS will determine this exact drop. The building shown is 140' x 65' This is a 480-208V/3Ph. We guestimated a 800A service with a 75KVA xfmr, shown if figure 3.

MQ1 is for mains and mechanical loads (service entrance rated).

1QH1 is lighting panel.

1QL1 is receptacles.

Dashed lines are non-plotting and represent working clearances.

All references to shared neutrals shown below shall comply with NEC 210.4(B). There are commonly two methods of dealing with this code and should be planned with discretion or to local codes and ordinances.

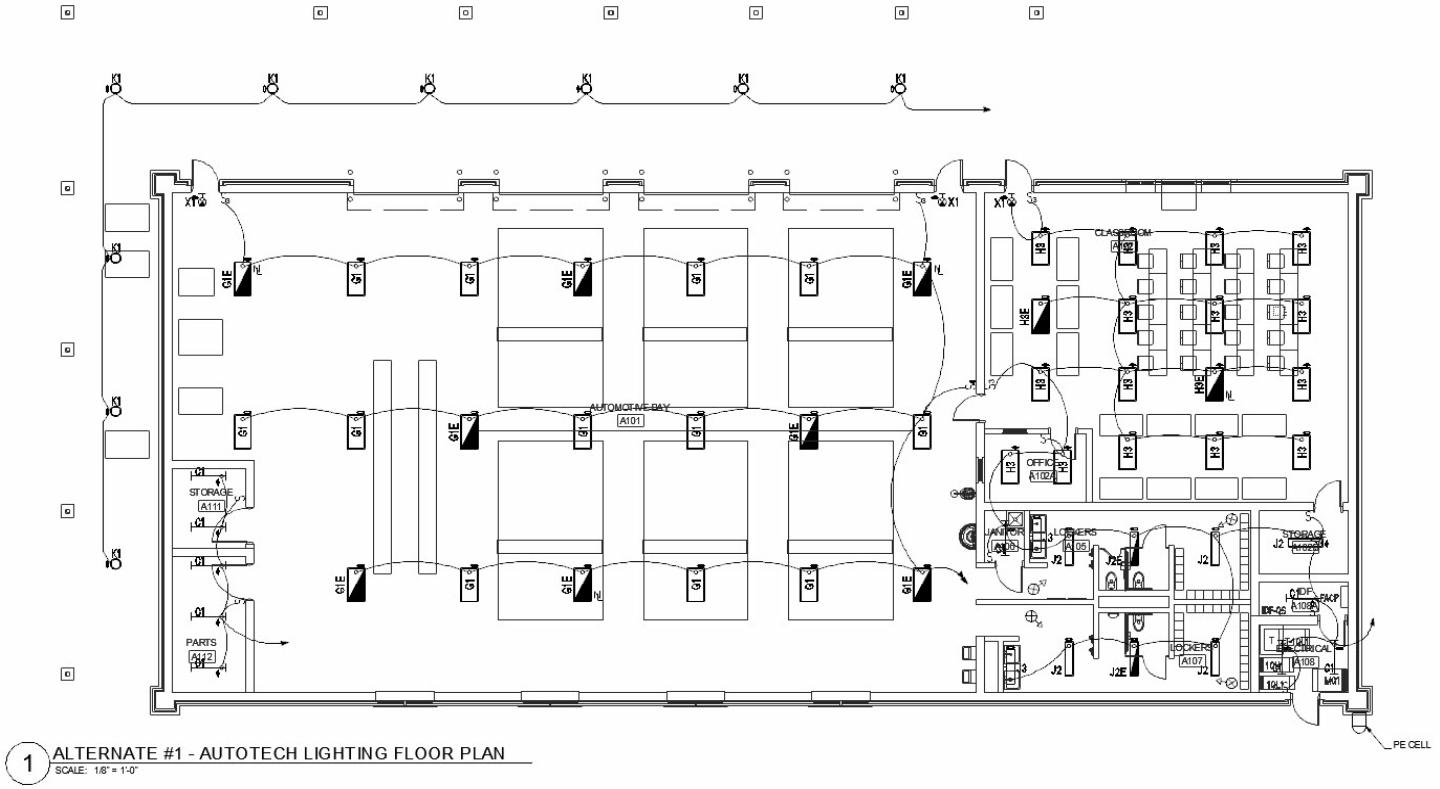


Figure 4

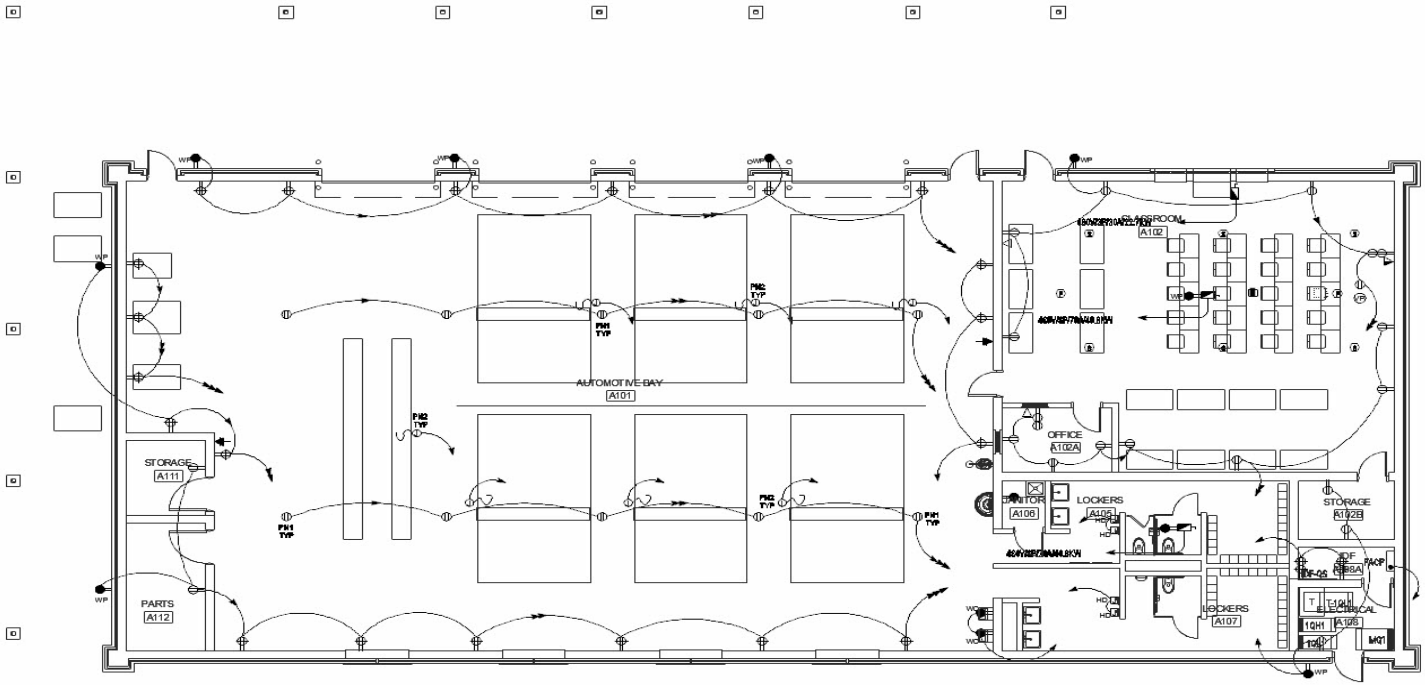


Figure 5

For circuiting, it doesn't matter if you start with lights or receptacles.
For simplicity, we have shown loops on wire to keep wiring as efficient as possible. If you don't use "spaghetti" wiring, delete them at a later time.
Important thing is to know which receptacles will be wired on a circuit. Nothing is written in stone and can easily be changed if EPS says voltage drop is too large to cover the load of a length of wire. It is very important to know how the wire will be circuited, and only field experience could tell you how this is done. This also depends a lot of the construction of the building. Metal studs versus CMU's (concrete masonry units)

The method for lighting is shown in figure 4.
G1 is a 6 lamps (F32T8 – rated 200W each).
H3 is a 3 lamps (F32T8 - rated 100W each)
K1 is undetermined, but we will rate them for 125W each.

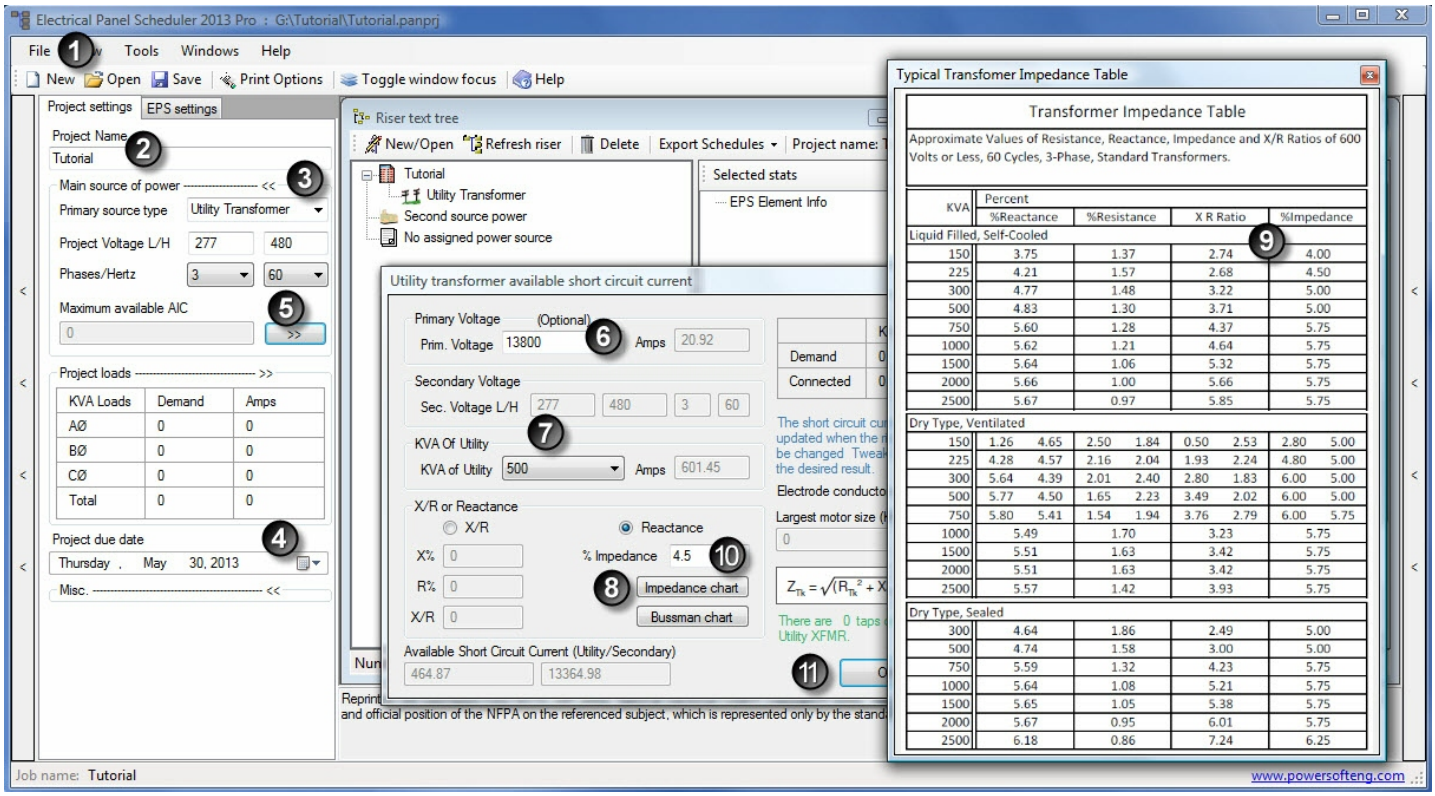


Figure 6

Getting started

With all the loads preparation completed, begin circuiting in EPS.

Open EPS (EPS Main Screen)

Start a new EPS Pro project by creating a specific directory. This EPS project directory could usually be under your CAD files or in some data directory but keep in mind that EPS does not like to share files with any other data which is not specific to EPS. If you are working with CAD files, please keep those and any other files separate from EPS directory. Each panelboard ("*.pan", "*.panbak" is a backup), transformer ("*.xfm", "*.xfmbak" is a backup), project event log ("EPS project log.txt", keeps track of operations in EPS), EPS project file ("*.panprj") and panelboard Excel files ("*.xls" which would be the same file name as the panelboard it is associated with).

Project log file stores all messages that occurred in the messages panel. It records how much time was spent in each panelboard data file, who opened the project along with time and date, riser updates, riser errors. See user guide under messages tab for information on how to display these messages.

The procedures for starting a new project are labeled in the illustration in figure 6.

1. New > assign a filename, directory.
2. Give project a name.
3. Assign a utility type, in this case it comes from a utility transformer.
4. Adjust project due date.
5. Open utility assignment window.
6. Enter utility high voltage if known. This is optional.
7. Assign a transformer KVA.
8 Open the impedance chart and look at the proper
(9) impedance value for AIC ratings on the riser.
10 Enter the impedance, but this may vary depending on which transformer is delivered. Call the utility company to confirm this value.
11 Press OK to get back to the main screen.

Panelboard settings

Before beginning, ensure that all the settings are correct under the EPS Settings tab.

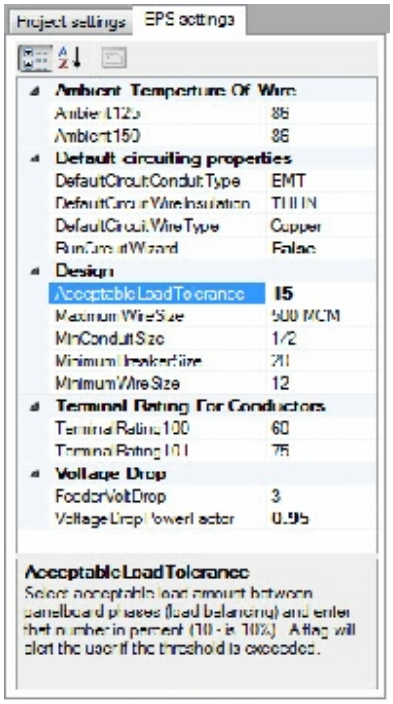


Figure 7

Refer to user guide for each specific items in the EPS setting tab.

For this exercise, ensure all the settings are similar to the ones shown except make sure the run circuit wizard is set for true, for now. This switch can be turned off or on during the design process, depending on the types of circuits encountered. The switch means that each time we select a load type on the panelboard schedule window, the wizard will run. Otherwise a circuit apply window will open. This is the preferred window for more experienced users so a load and wire assignments can be made more accurately.

Start a new panelboard schedule.

1. Press the New/Open button on the riser window.
2. Enter a new panelboard name “1QL1”. Make sure the panelboard type is named ‘Panelboard’.
3. Make sure the voltage is set properly. Use 120-208V/3P/60 hertz for this example. Press the enter key or press the OK button.
5. The panelboard name is already entered by default. Naming the file to something else is not advisable. Press enter key or hit save button.

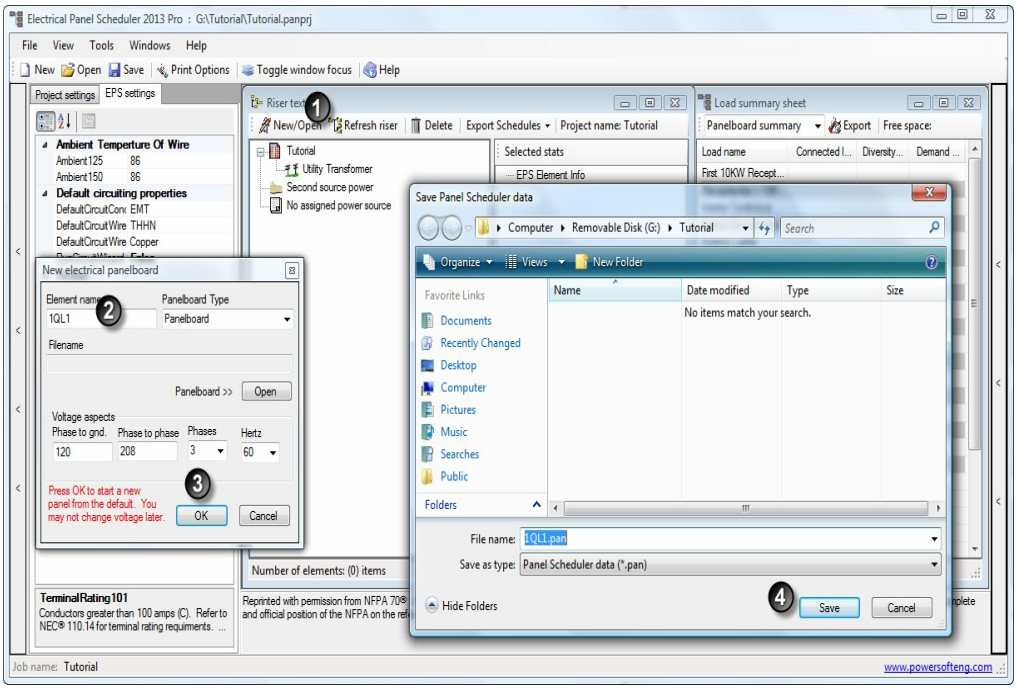


Figure 8

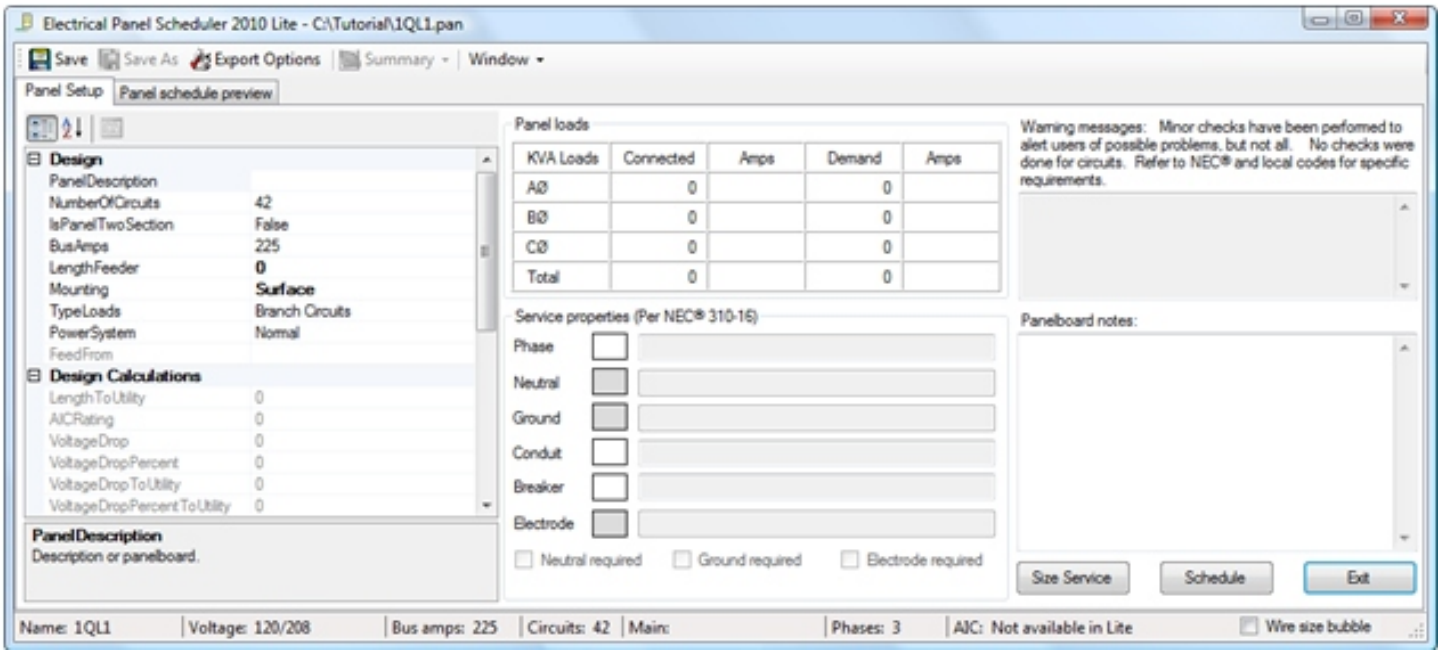


Figure 9

Figure 9. The schedule will display as blank and of course there will not be any loads in it. Notice the path display is shown in the title bar, so you know where you are at all times.

EPS can be maximized or resized for a larger work area. Screen shot is default size.

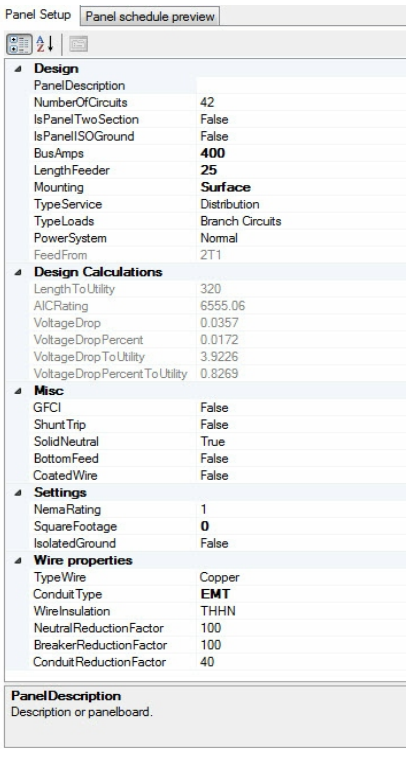


Figure 10

Set the bus amps in this panel for 225Amps, 10' feeder length, copper wire and PVC schedule 40 conduit.

Panel can be labeled for multiple system types such as Normal, Emergency, Life Safety, etc. Panel may also be labeled for load types, mounting and many other settings which will be saved in the data file.

EPS also stores the area served in square footage in the settings pull out. EPS does not make any calculations based on this setting but may be recorded for use on specially designed systems.

EPS has begun displaying some warning messages and the panel name has turned yellow on the status line so we can see there is a warning when we go to the next tab. These are minor checks so please check everything before you leave the scheduler.

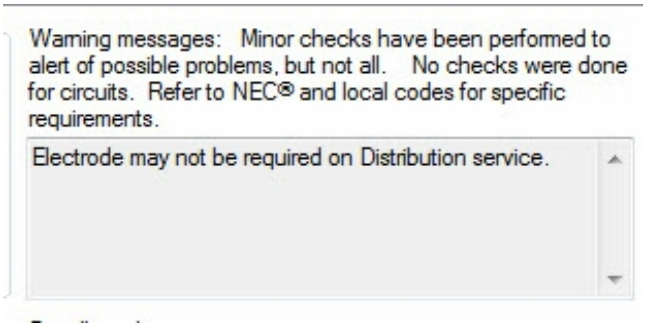


Figure 11

Based on which service and load type is selected, will automatically default to required neutral, and electrode. Of course, electrodes are only required for service entrance cases, but there may be circumstances where that may have to be changed. Refer to NEC 250 for requirements of grounds and electrodes. In this case, distribution is used for service type and branch circuits is used for load type so a neutral is required and an electrode is not. This is default for that distribution type. It may be changed at any time.

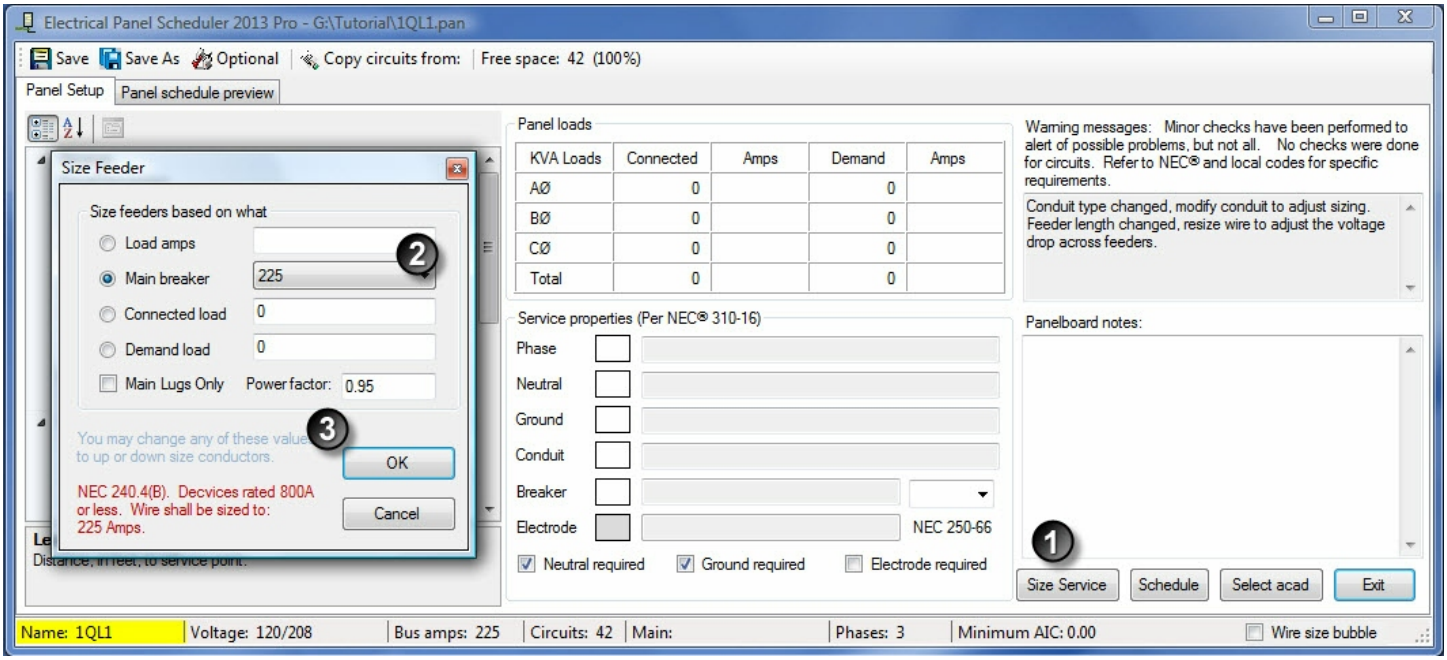


Figure 12

1. Press Size Service button
2. Make sure Main breaker of 225 Amps is selected.
3. Press OK button.

Figure 13

If voltage drop warning is turned on, a warning will display to let users know that without loads in the panel, there can be no voltage drop. It may be turned off, never to be shown again by selecting the switch under the message

EPS sizes all wires regardless if they are needed or not but will size conduit based on only what is required. In this case, the electrode is not required for branch circuit loads, so the text box is dimmed out. If this were a service entrance panel (TypeLoads), the electrode would have been required and not dimmed. Of course the electrode is not routed in the same conduit as service conductors, so no calculations or conduit is shown for it. Usually this is routed in separate conduit to a ground field, water pipe, building steel or ground ring depending on soil conditions, or may be run bare, depending on building codes.

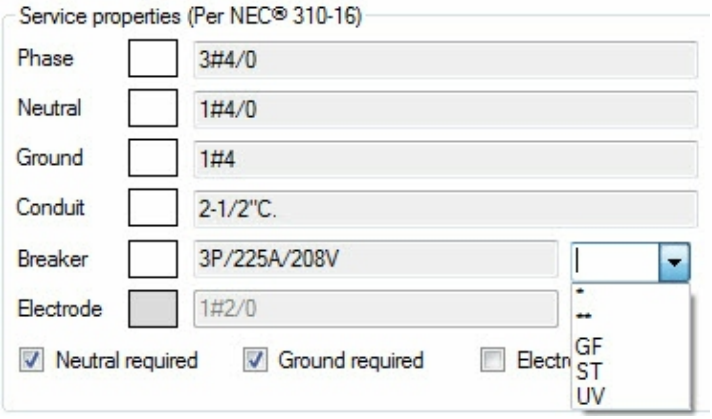


Figure 14

In some cases, a lighting contactor, a shunt trip (usually reserved for equipment under hood fans in kitchens) or under voltage trip and most commonly GFCI breakers will be required for main breakers. A pulldown box shown here beside the breaker is intended to give users an opportunity to provide a suffix and at breakers when exporting documents. This is the case for each circuit too. If using this extra feature, be sure to record notes in the panelboard notes box to let end users know what the suffix means, sort of like a footnote. This will make it evident on final construction documents which breakers will have special properties.

Now we are ready to begin inputting loads on circuits. For most people with a one monitor system, you can choose to have the window always on top as the default and/or dimmed so we can partially see through it will working on our cad file.

Adjusting scheduler visibility to about 75% is sufficient to see through the window and still see what is going on inside cad.

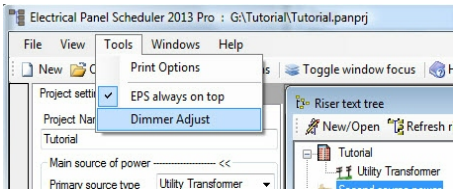


Figure 15

Setting the dimmer to 0% will barely make EPS visible. The dimmer control can stay on the screen to adjust it as needed. It updates in real time.

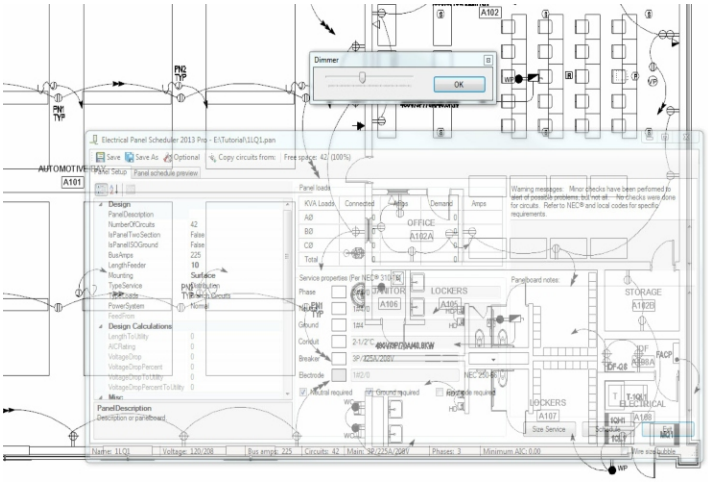


Figure 16

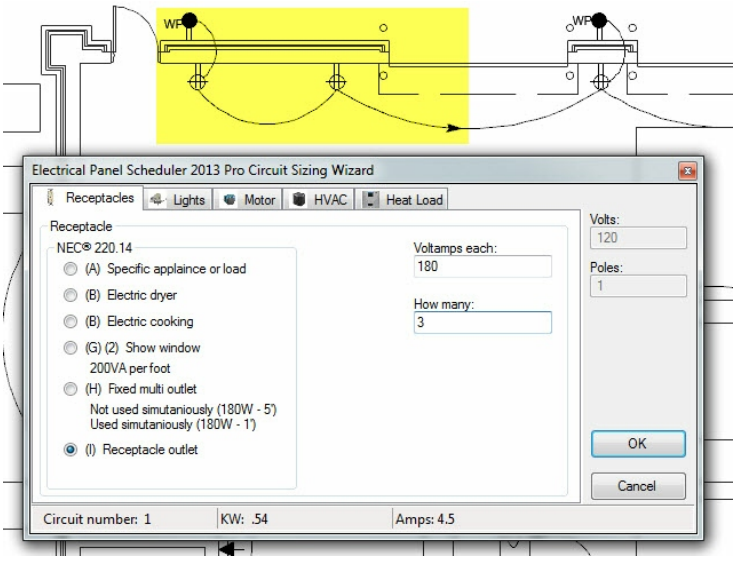


Figure 17

Now let's begin circuiting. Before we begin it is important to note that the default circuit properties for wire, conduit and insulation is carried over from the EPS settings tab. It can be changed at any time if the need arises, usually when there are underground verses overhead wire conditions that need to be meet which mainly affects voltage drop and conduit fill calculations.

Where to start circuiting is a matter of personal preference and will not affect how a building operates. Some engineers may even go as far as specifying which homerun gets circuited first, but that too does not affect how a building operates. In this case, we are using the last circuit on the homerun to be the "first" circuit on a shared neutral. The loops from one outlet to another shown in figure 17 is a "circuit" but when multiple "circuits" are looped together, they designation is for a shared neutral with a maximum of three circuits. We will demonstrate how this displays in the EPS scheduler.

The wizard is shown here when circuiting. There are multiple tabs that perform a specific circuiting application. In this case, select the applicable situation from NEC 220.14 and the program will plug-in the appropriate voltamps each. This first circuit is 195' length. A general use receptacle shall have a minimum of 180 voltamps, but can be more depending on its use. Since this is a simple circuit, pressing OK will load the total watts in the scheduler and preview the result.

G...	P...	Description	Br...	KW R...	C...	Ph...
	1	RECEPTACLES	20	.54	1	A :
	1	SPACE ONLY	0	0	3	: B
	1	SPACE ONLY	0	0	5	: : C
	1	SPACE ONLY	0	0	7	A :
	1	SPACE ONLY	0	0	9	: B
	1	SPACE ONLY	0	0	11	: : C

Begin circuiting

Since the wizard is not set to on by default, in the EPS settings tab, I will spend a moment to explain it since most users will not need it. It is important to show sometimes forgotten *NEC*® codes and where to find them. Press the Wizard button. The EPS window minimizes. We can see that receptacles may be found in *NEC* 220.14 along with a few other references.

Normally we round all receptacles to 200W for simple adding and unknown loads. This prevents loading circuits to maximum capacity too. Start anywhere you want in the building. I like to work my way from a location furthermost from the panel to nearest. By default the watts for a receptacle is 180W. Press OK. EPS will ask for the number of feet to the outlet. Enter 190' since we have to measure perpendicular to walls and usually add 10% of distance fluff to furtherest outlet. Enter circuit 1 beside the arrowhead leader.

Work your way down the panel and choose circuit since this is a shared neutral circuit. Follow the procedure above and label the leader 1,3. This circuit is 170' in length.

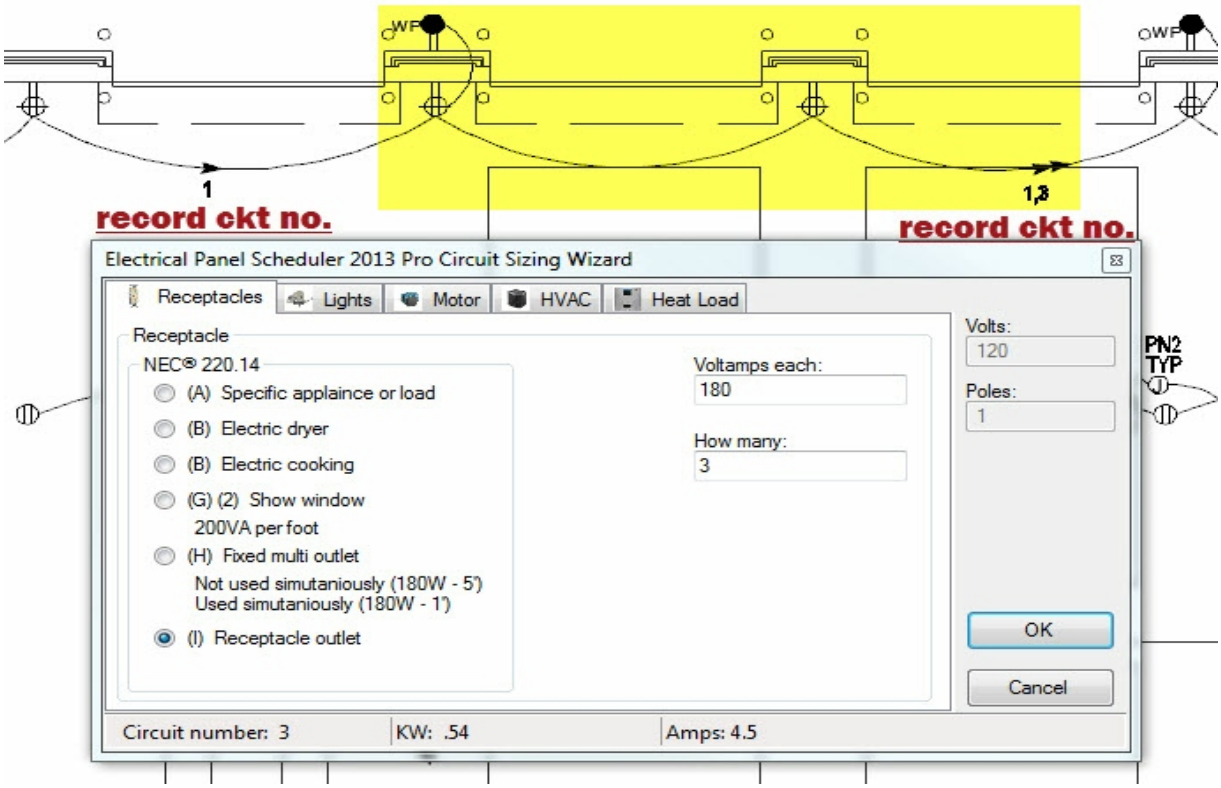


Figure 18

Finish up the circuit with the homerun of 140'.

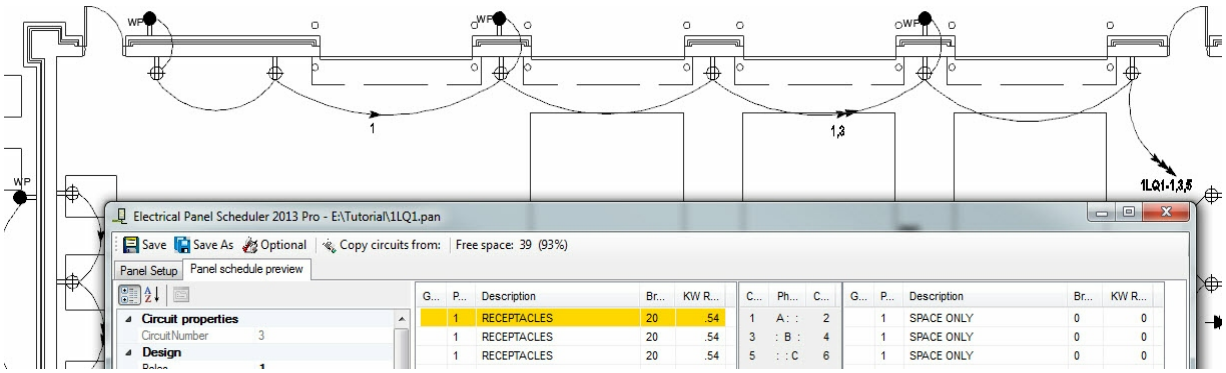


Figure 19

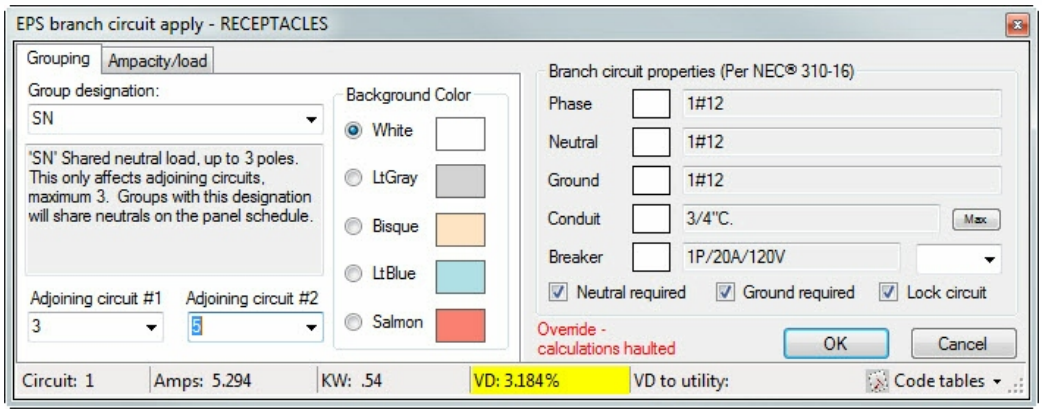


Figure 20

Notice that one of these circuits are yellow as shown in figure 19. This is an indication that there is a problem with the circuit, usually voltage drop. To correct this problem we need to edit the first circuit but first we need to assign a shared neutral to all three circuits. If a group is not assigned to a circuit, we come into circuit apply window on the grouping tab. This is where we tell EPS which circuits have shared conduits which can include shared neutrals, two pole or three pole breakers. Rarely is one pole used because it doesn't serve any purpose except make the schedule harder to read, but it is provided non the less.

Here we share a conduit with circuit number 3 and 5 so record those in the adjoining circuit #1 and 2. It is very important to make sure the numbering is in proper order or errors will occur when calculating panel loads. This automatically assigns those two circuits with the correct circuit numbers so this only has to be done once.

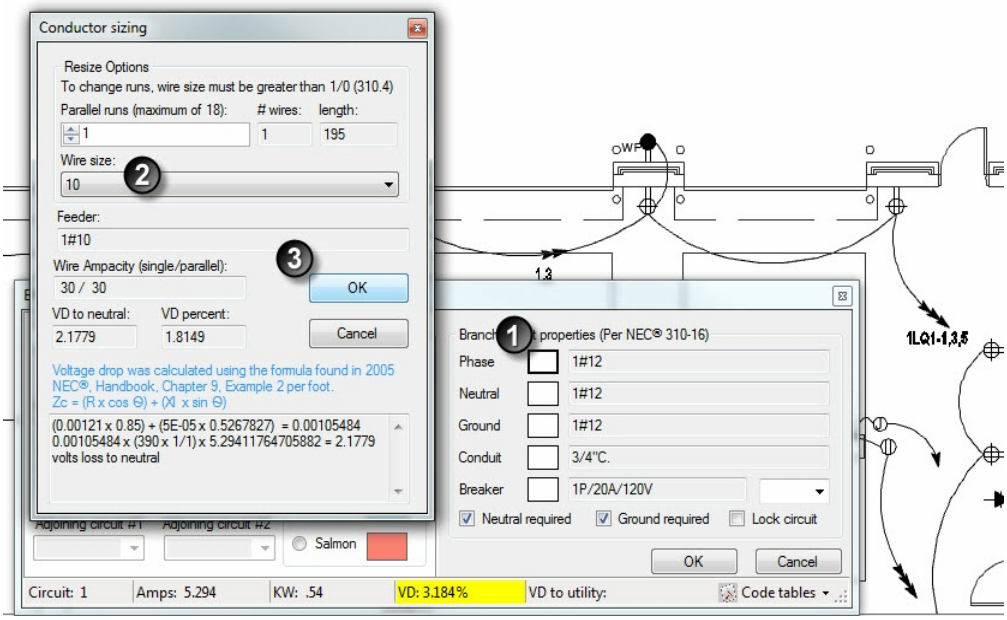


Figure 21

Refer to figure 21. To modify the bad voltage drop, select the phase conductor button and increase wire AWG to next highest size. Change it to a #10 conductor. Note the voltage drop is below the project setting of 3% so now it should be good. Click the ok button on wire size window. The yellow highlight has now cleared in the circuit apply window.

Pressing the OK button at this point will warn the user that a shared neutral is being used and the conductors do not match shown in figure 22.

Pressing yes here will leave the neutral as-is and continue processing the circuit with the smaller conductor. Pressing no will upsize the neutral to whichever size as the feeder is and continue processing the circuit.

In either case, EPS will always size the neutral conductor as the current circuit being edited. In other words, if circuit 1 were using a #8 neutral, the other two links, 3 and 5 would use this same neutral as circuit 1, #8. A yes would pick up the #10 feeder and use that for the neutral.

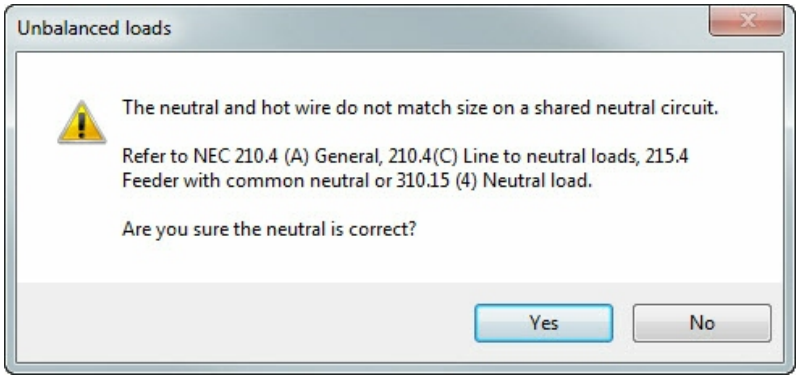


Figure 22

When designating voltage drops for circuits EPS does not account for service feeders since the loads are being added or deleted in the design process.

Voltage drop is a result of load on a circuit. Obviously if these loads are turned off or on during the day in circuits, the voltage drops on the panelboard varies. EPS gives worst scenario for a circuit at a point in time with everything turned on. When calculating voltage drops for circuits, EPS will only use load calculations from the bus to the end of circuit. Connections and wire conditions will also affect final results on the construction site. It is up to the user to determine if or when a wire will need to be up-sized based on those circumstances. To compensate for some of those factors the length of feeders can be

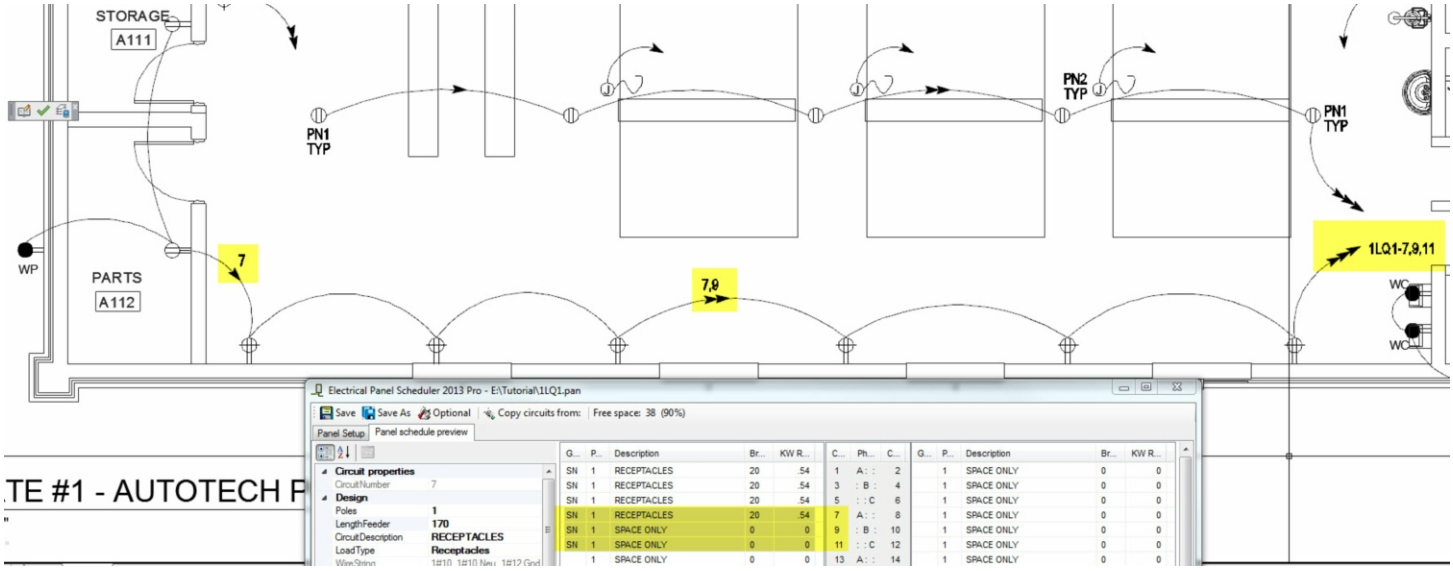


Figure 23

Since the next grouping circuits was similar to 1,3,5, most users may like to discontinue using the circuit wizard since drag and drop is more efficient. Select circuit 1 and drag and drop it to circuit 7. Select copy. If you know from the plan you will have 3 shared neutrals again on the next 3 circuits, go ahead and group the next 3. Double click circuit 7.

Follow the procedure as above except make the group color LtGray. From the scheduler in figure 23 we can see that the circuits can be very easy to read sine we have groups. Dragging from one color will not affect a group but will if it is single. Drag 7 to 9 and 7 to 11. Change the length of ckt 7 to 170', ckt 9 to 130' and ckt 11 to 95'. Make sure to record the circuits on the drawing.

Since the first circuit we copied from was a #10 feeder, the other circuits in this group will also have a #10, so if dragging, be careful to look for all modifications from dragged circuits.

Continue by dragging and dropping circuit from 7 to 9 and 9 to 11 by making all the circuits on the bottom wall in the next shared neutral group. That completes this homerun. The only thing that needs to be changed is the length of feeder of each run from the circuit properties window since each circuit has the same 3 receptacles. If they were each different we could double click to edit the load of each.

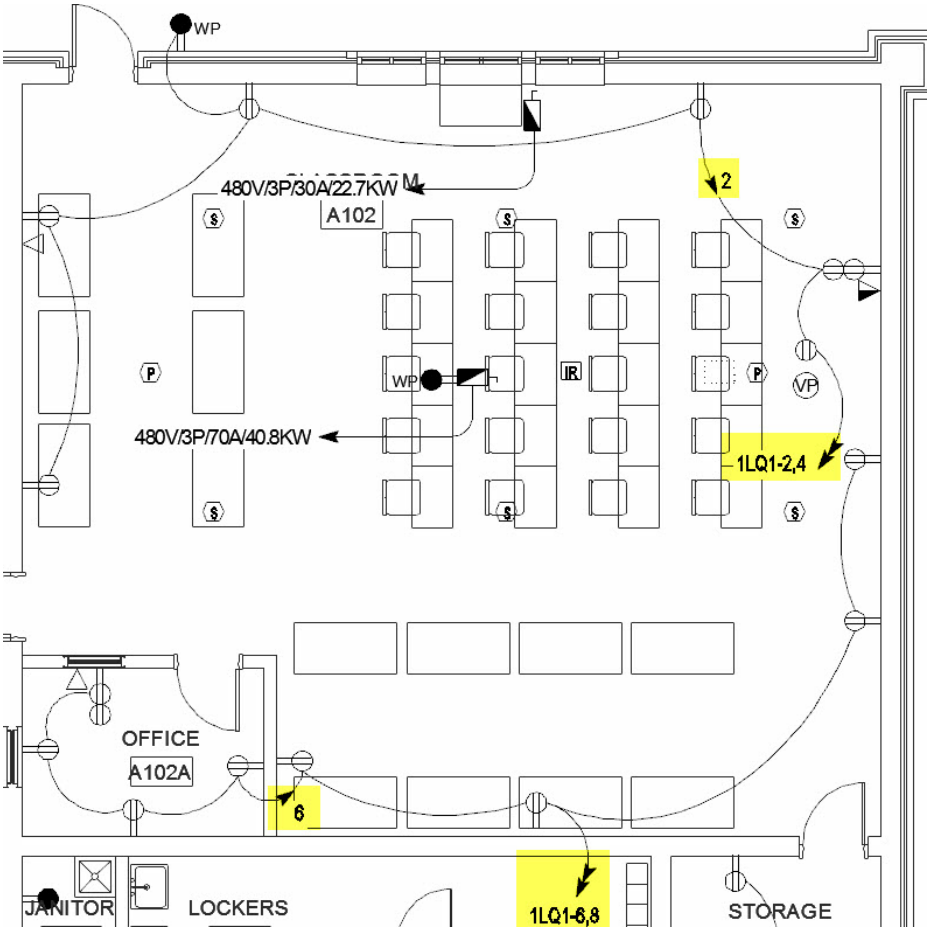


Figure 24

Circuit the two shared neutral groups in the classroom. Only thing unusual is the ceiling mounted receptacle is rated at 600W for an overhead projector. Of course, quad receptacles are rated at 2 X 200W or 400W. This will go onto circuit 4.

Under load type select Receptacles. Feeder length is 140'. EPS will minimize and circuit apply will open. Make sure KW is selected as the input method and enter a 1 (1KW = 5 receptacles x 200 watts each) in input value box. Pressing the apply button will show the user that the load on this circuit is to much. Select wire size and make it one size greater.

Without using #10 wire, if this circuit were any longer, it could not be used because of voltage drop. We would have to drop out some receptacles to reduce the load. This is why we reduce the number of receptacles when routing lengths greater that 70 feet.

Play around with circuit apply window to see what the maximum length or load will accept a grouping of loads. In this case, we will increase the wire size.

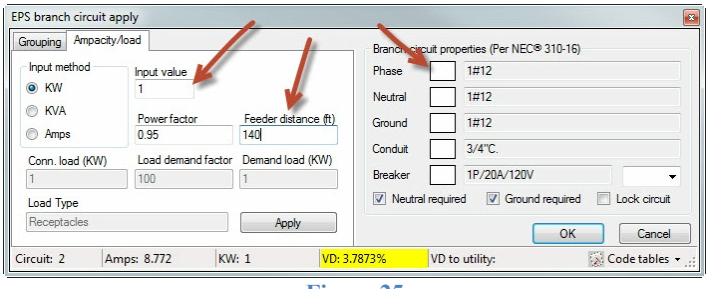


Figure 25

Press enter key. If the circuit is not locked (switch above the cancel key), the enter key will now size the wires and conduits and close this box. The load is applied to the panel. Drag and drop circuit 2 to 4. Double click 4 and change load to 1.2KW. Make sure the group is set to "SN" and 2 in adjoining circuit box.

As long as the user selects a valid circuit, the links can be used but it will cause unpredictable results if they are not valid linked numbers, as with any valid breaker in a panel. Feeder length for ckt. is 55' Press enter key.

Continue for the other 2 circuits in this space. Ckt. 6 is 1KW at 75' and ckt. 8 is .8KW at 50'. When finished it should look similar to figure 23 & 25.

C...	G...	P...	Description	Br...	KW R...
2	SN	1	RECEPTACLES	20	1
4	SN	1	RECEPTACLES	20	1.2
6	SN	1	RECEPTACLES	20	1
8	SN	1	RECEPTACLES	20	.8
10		1	SPACE ONLY	0	0

Figure 26

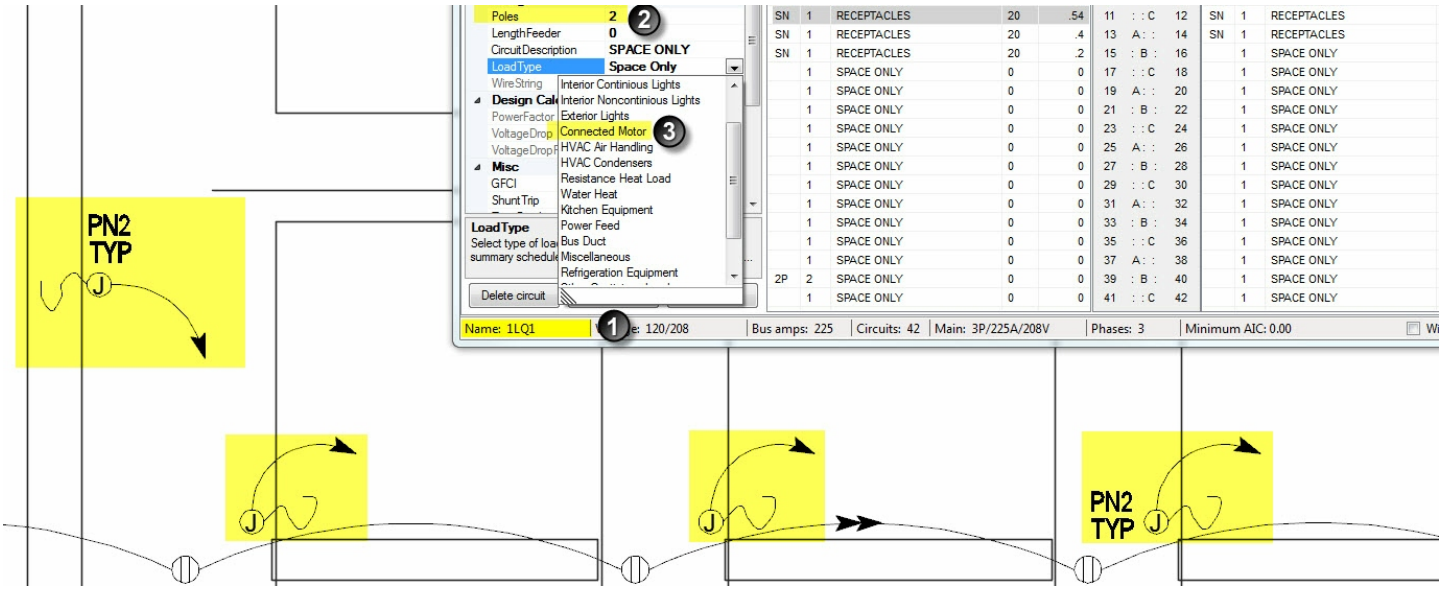


Figure 27

Refer to figure 26. We can see that we have errors in the panel as shown by yellow highlighting under the panel name. If you look at the warning message on the panel setup tab, we can see that is because of load tolerances. Refer to figure 29 and footnotes for an explanation of what is going on and how to correct it. It becomes more prevalent in the early stages on panel design and layout. Ignore this problem for now.

There are some lifts rated for 208V/1Ph/30A feed from overhead. Those lifts are tagged with PN2 (or power note #2). Since this is general load information the load for the lift will not be exact but we can size a circuit based on what we have. To proceed, select circuit 39. When sizing more than one pole breaker, you must start with the first link pole and EPS will automatically assign the next two links. Select the number of poles as 2. Select the load type as connected motor.

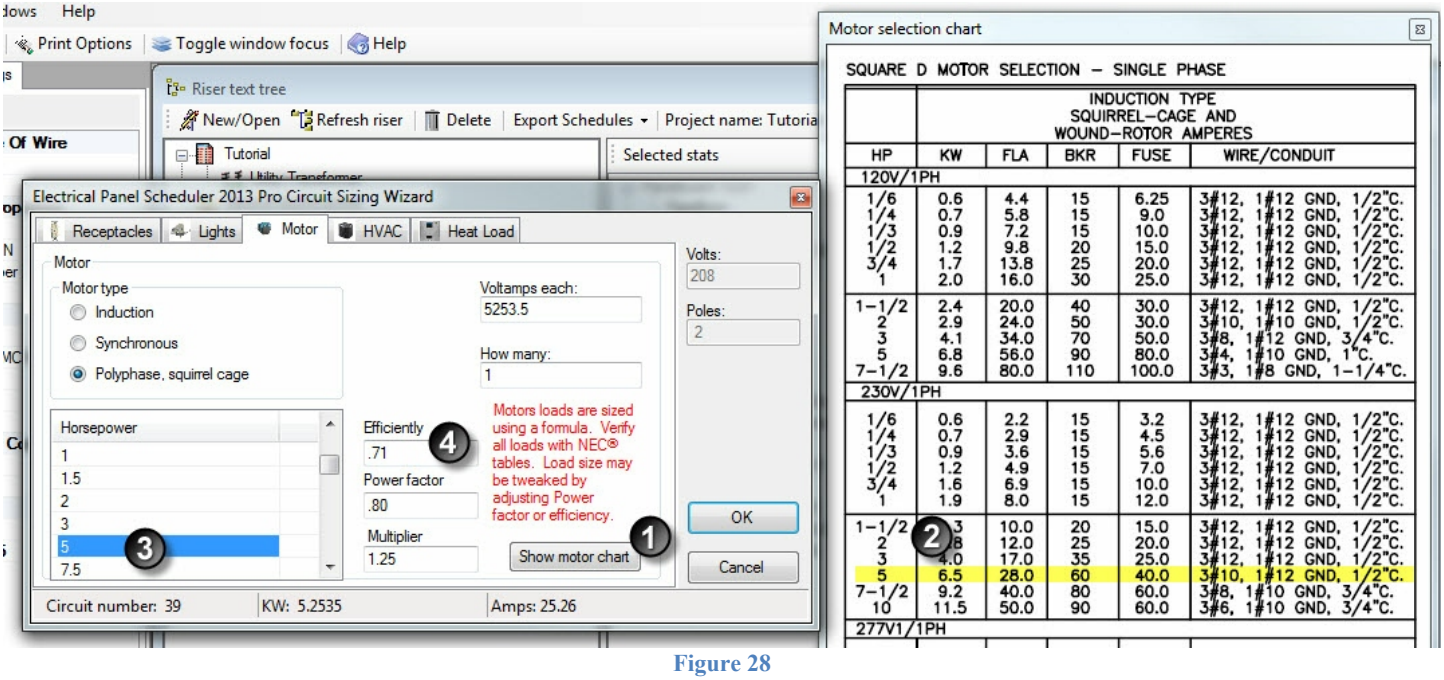


Figure 28

Since we told the wizard to run on the EPS setting window, the window shown in figure 27 should be displayed. This function uses math to determine final load for a motor. If we press show motor chart button, we can see a chart that displays a lot of motors we will make a determination on what the approximate load will be. Tweak efficiency to .65 to get us close to 28 amps as the chart shows. Press the OK button.

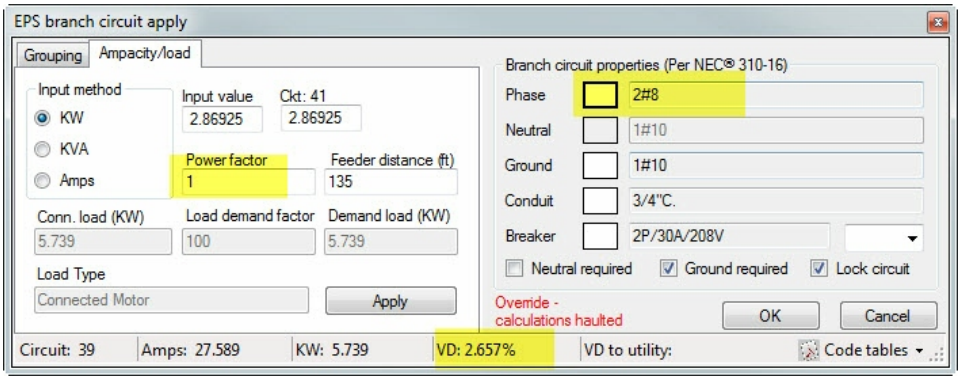


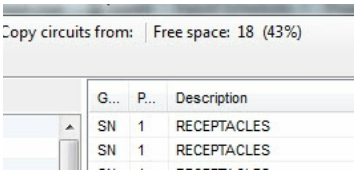
Figure 29

The voltage drop is to much for this circuit and the load was over 30 amps. To resolve this issue, make the power factor equal to 1 and increase wire size by one.

Press ok and change the name of the connected motor to car lift.

Continue wiring car lifts for the building as noted. There are seven car lifts total.

The circuits thus far are filling up the panelboard quickly so we need to determine what to do about completing circuits in the remainder of the building. With the car lifts, there are 18 spaces left, or 43% shown on the toolbar. Counting the remaining arrowheads, there are many more which need to be circuited.



In this case we will have to add a new panel board, so since we sized breakers for the car lifts, it would probably be best if those were in another panel.

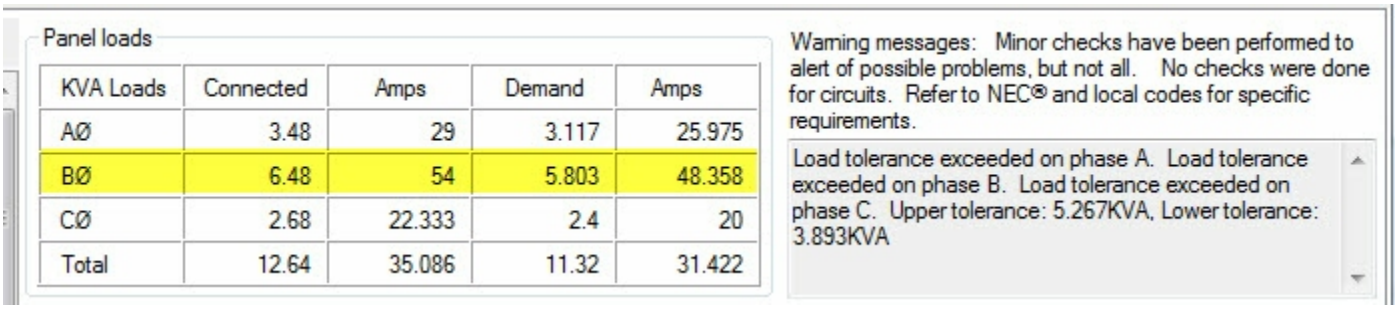


Figure 30

Save files periodically. Figure 29 shows a load balance that is unacceptable according to a 15% load tolerance we had assigned on the EPS main window settings tab. The loads assigned in this panel is unbalanced and needs to be adjusted. Take some of the loads on circuiting and drag and move them till these loads are more balanced.

Of course in the real world, circuits will have varying loads throughout the day or week like the car lifts in the previous step which will operate only a short time each day. It is somewhat important to try and determine which circuits will be used throughout the day and assign them accordingly some loads remain balanced.

Since the number of spaces is reaching near the maximum of capacity, lets add a new panelboard and tap the transformer, T1QL.

To do this there are two methods, to either create a new panel from the new menu or to use save as in the EPS window. For this exercise, lets use the save as and modify as required. Keep in mind that we only wish to copy in the car lifts created in the previous example.

Press the save button to save the current work.

Press the save as button and give the panel the name of 1QL2. There will be a message box telling you that you are working on the new saved panel and the file name is present on the title bar. It is now exactly the same as the 1QL1 except the name.

For the sake of showing some examples of what we can do in EPS, delete every circuit in the new panel so every circuit breaker is marked space only, otherwise we would have left the car lift breakers alone.

Notice that deleting a shared neutral that will delete each circuit that is linked together. If you don't wish to delete one or two of the breakers, those circuit

should be copied to another space then moved back after the deletion is complete. Another window will open which looks similar to the schedule preview but will not have any editing features like the main.

At this point we want to start copying all the car lift breakers into the 1QL2 panel before we just start deleting the ones in 1QL1. Drag and drop those breakers from 1QL1 to 1QL2 as shown ion figure 30. Close 1QL2 and save changes.

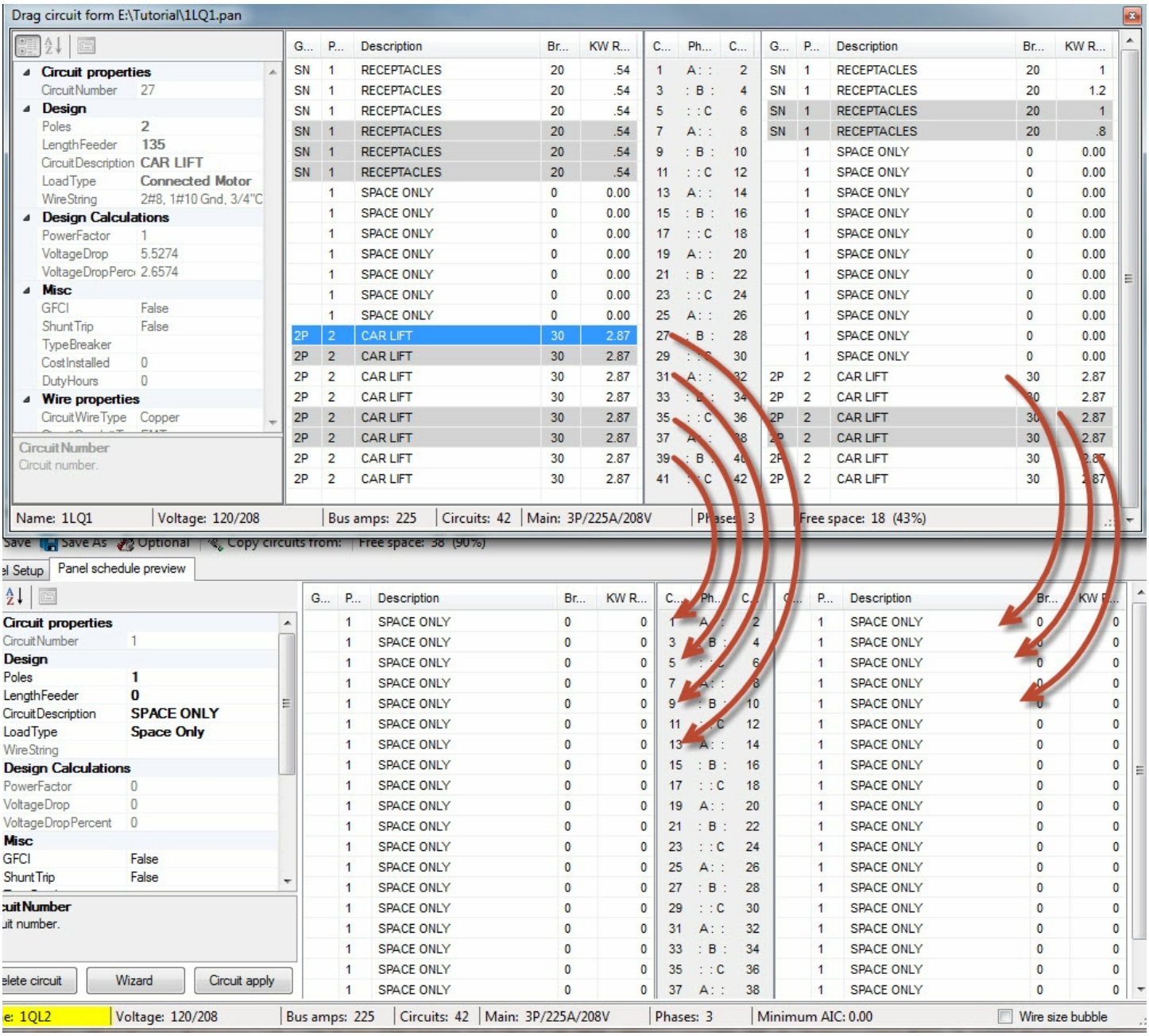


Figure 31

On the riser tree window, select the refresh riser button and the two panels we created now appear. Open panel 1QL1 by double clicking it in the riser and now delete the breakers we moved in the previous step.

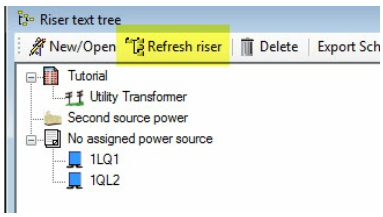


Figure 32

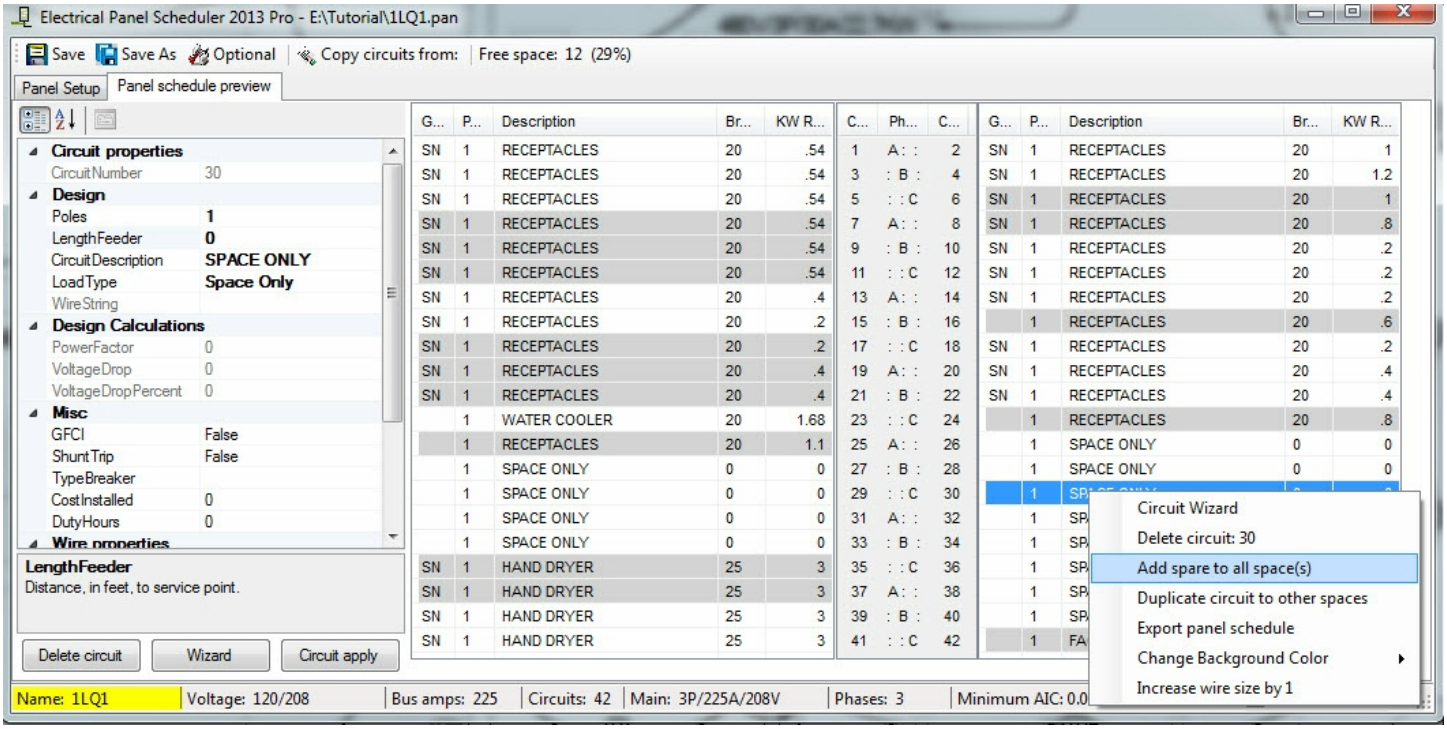


Figure 33

Hopefully we have given good direction up to this point and will not continue for each circuit in the building. We will fast forward to finish up all 120 volt circuit in the schedule. Keep in mind that a receptacle can be sized anything as long as it is over 180 watts, according to the NEC.

The hand dryers in the toilet we normally rate for 25A. We put this on a miscellaneous load type so the diversity factor is 100%. Rename this circuit for hand dryer after you apply the load.

Next we need to fill this panelboard with spare breakers in case the owner wants to add loads in the future. To do this, select the first starting circuit. We used circuit 30 to show how adding spares to panelboards works. Right click and select add spares to spaces. You will see a box that will ask for the final circuit number, shown as the last breaker space in this 42 circuit panel. Enter that number of 42 and press enter. Don't worry if there are breakers being used within that range because this function only writes to spare or space only poles. EPS has now filled the panel with spare breakers from 30 to 42 and the background color is unique for automatic functions but those can be changed by the user. Go back and copy any spare breaker to the remaining spaces to fill the panelboard.

This panelboard is now complete and we can look at the loads to see what our panel size will be.

Notice the hand dryers are causing the panel to balance improperly, but because these are temporary loads, it will be nothing to worry about, especially in a shop building.

Because we build risers from the bottom up we can begin to start looking at sizing the components of the transformer and feeders. To do this, determine the maximum size or load on the panelboard, whether demand or connected. Size the bus amps accordingly and press size feeders again to correct the wire size. Make a determination based on the next highest panelboard available and what the user determines future load may be but also keep in mind the next sized transformer because costs for those can be significant for larger sizes.

In this case we determined the size of panelboards for 1QL1 and 1QL2 should both be set to 150 amps each.

We will now create a transformer to serve those panels.

Adding transformers

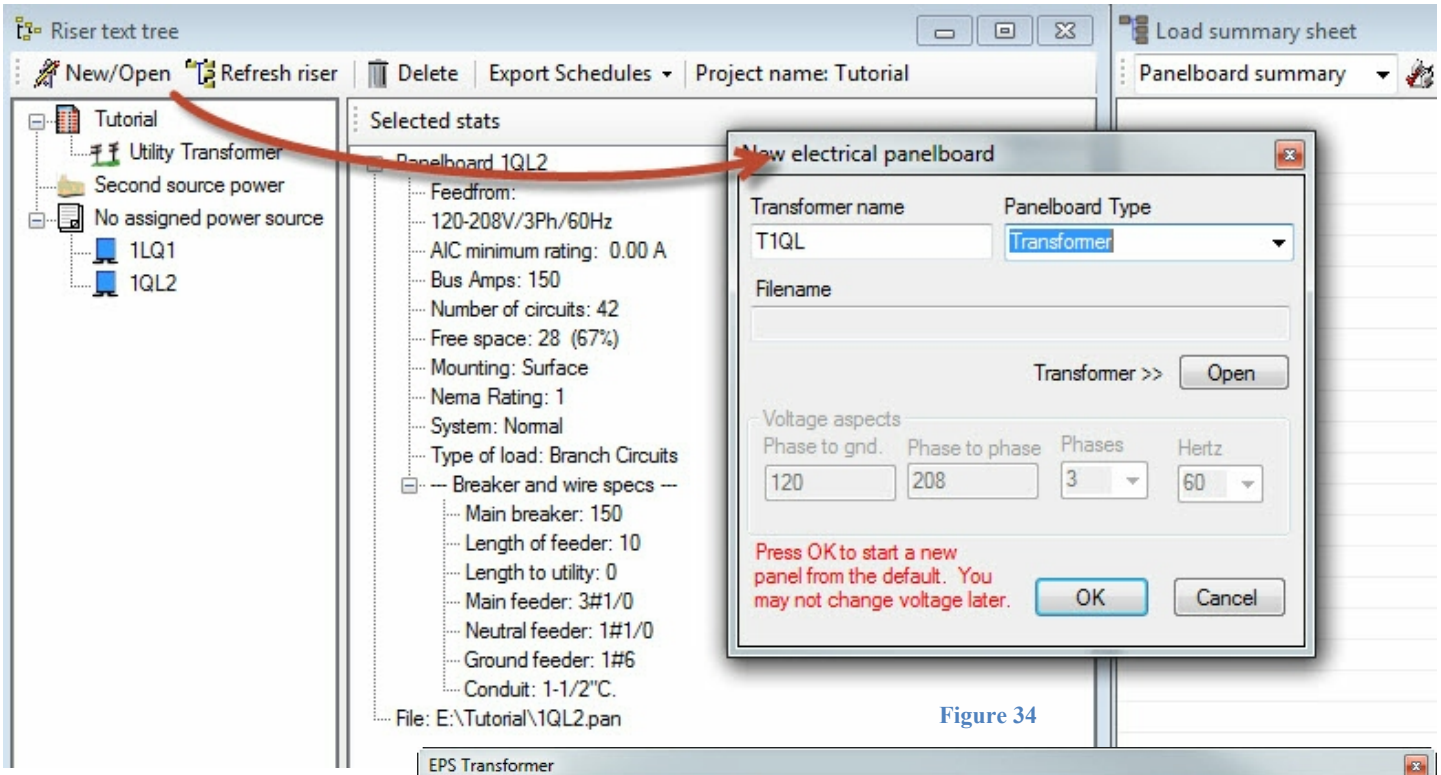


Figure 34

Start a new transformer called T1QL, press ok then save. Those files automatically go into the project directory as long as one is open.

When selecting transformers, look for the secondary amps requirement for serving both panel 1QL1 and 1QL2 which sum to nearly 150 amps maximum load, but keep in mind there should always be room for expansion.

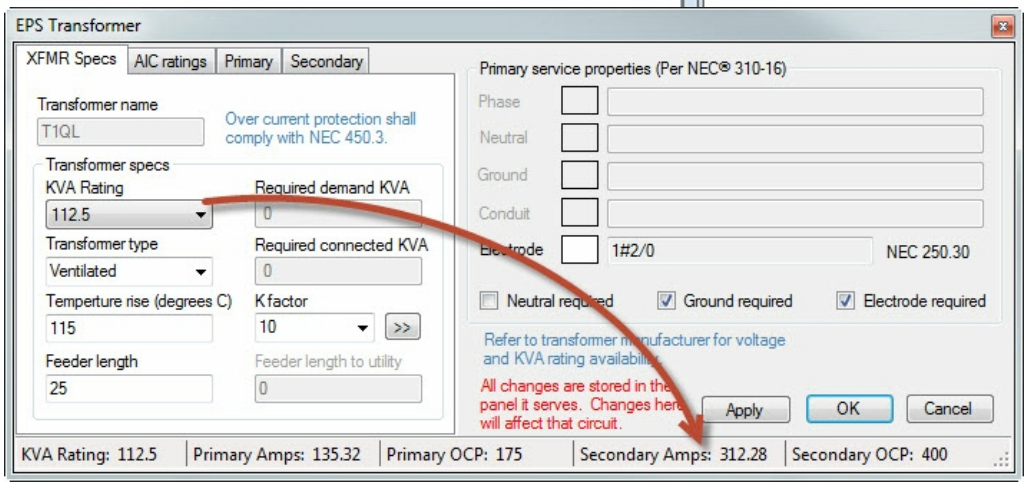


Figure 35

In order to determine AIC ratings for transformers and downstream panels, there must be a an X/R ratio to calculate these values. There is an impedance chart to aid designers with general acceptance guide. Actual transformers may vary according to manufacturer, but this will give an acceptable example. Enter values as shown in figure 34.

Press ok on transformer window then refresh riser button to make the new electrical elements visible on the riser.

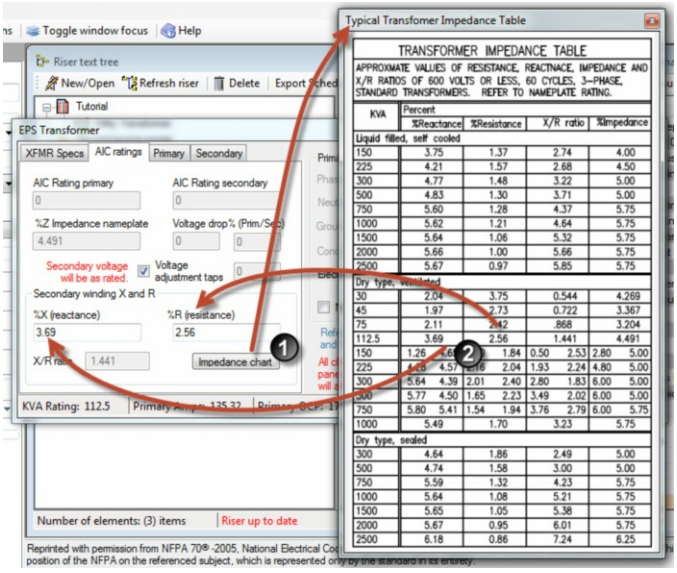


Figure 36

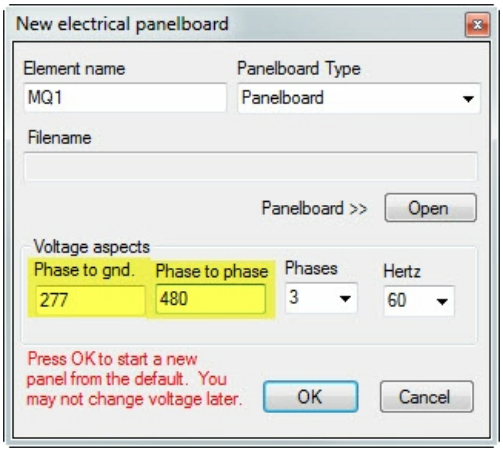


Figure 37

To complete the riser, we need to create a new 480-277V panel named MQ1.

Make sure to change the voltage as shown since this is not default.

Feeder length will be 40', bus size will be 400A and type service with be service entrance. It is important to make sure these fields are set before proceding any further because EPS will make default determinations which wires to set for conduit from utility company or from what ever source is called for. Select size service button in EPS window and use the 400 main breaker.

Once created exit scheduler and refresh riser to show this new element on riser.

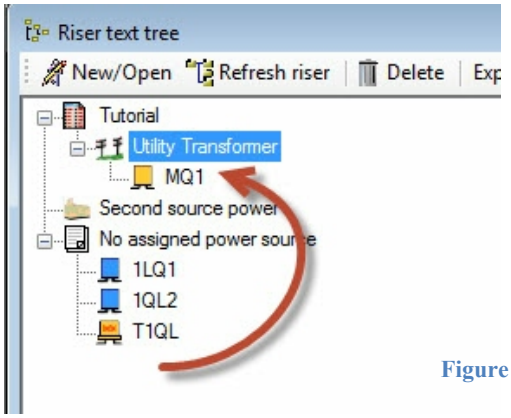


Figure 38

Drag and drop this element to on top of the utility transformer. You will be asked if you want to tap the utility with this panelboard. Press yes. The new panel is now attached to the utility and AIC rating will start calculating once the refresh riser button is pressed. There are no loads yet so displaying project loads is zero.

Drag and drop the transformer T1QL on top of MQ1. This will open a preview of the panelboard MQ1 for breaker and circuit number selection.

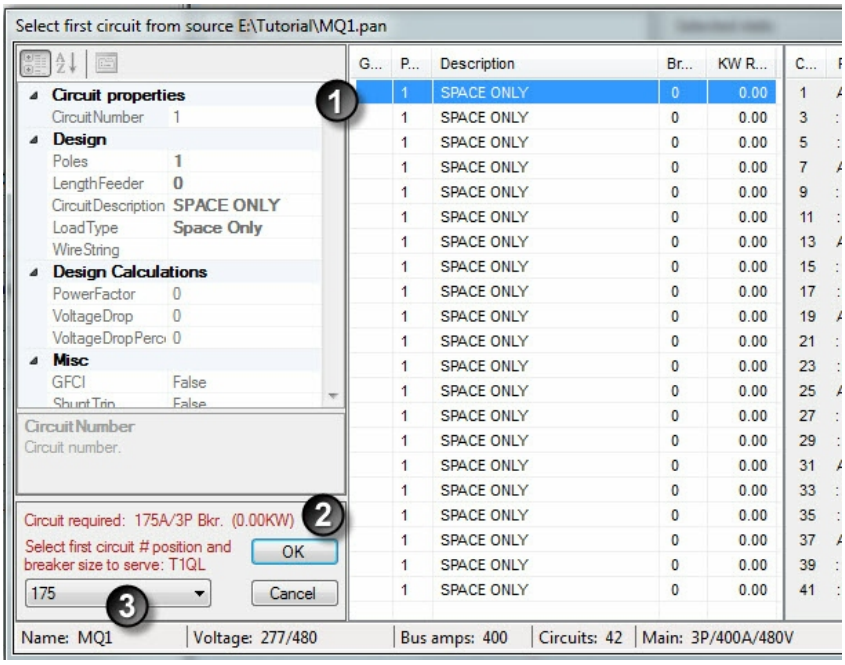


Figure 39

Select the first circuit of the three poles required because the linking is automatic.

A breaker is already selected (no. 3 in figure 37) which makes this process very simple. Press ok.

There are still no loads for the project yet so refreshing riser would have no affect except for sizing AIC ratings.

For now, lets combine the last two panels to the transformer T1QL. Drag and drop 1LQ1 and 1LQ2 onto T1QL and say yes when it ask for tapping.

Press refer riser and now look at the results.

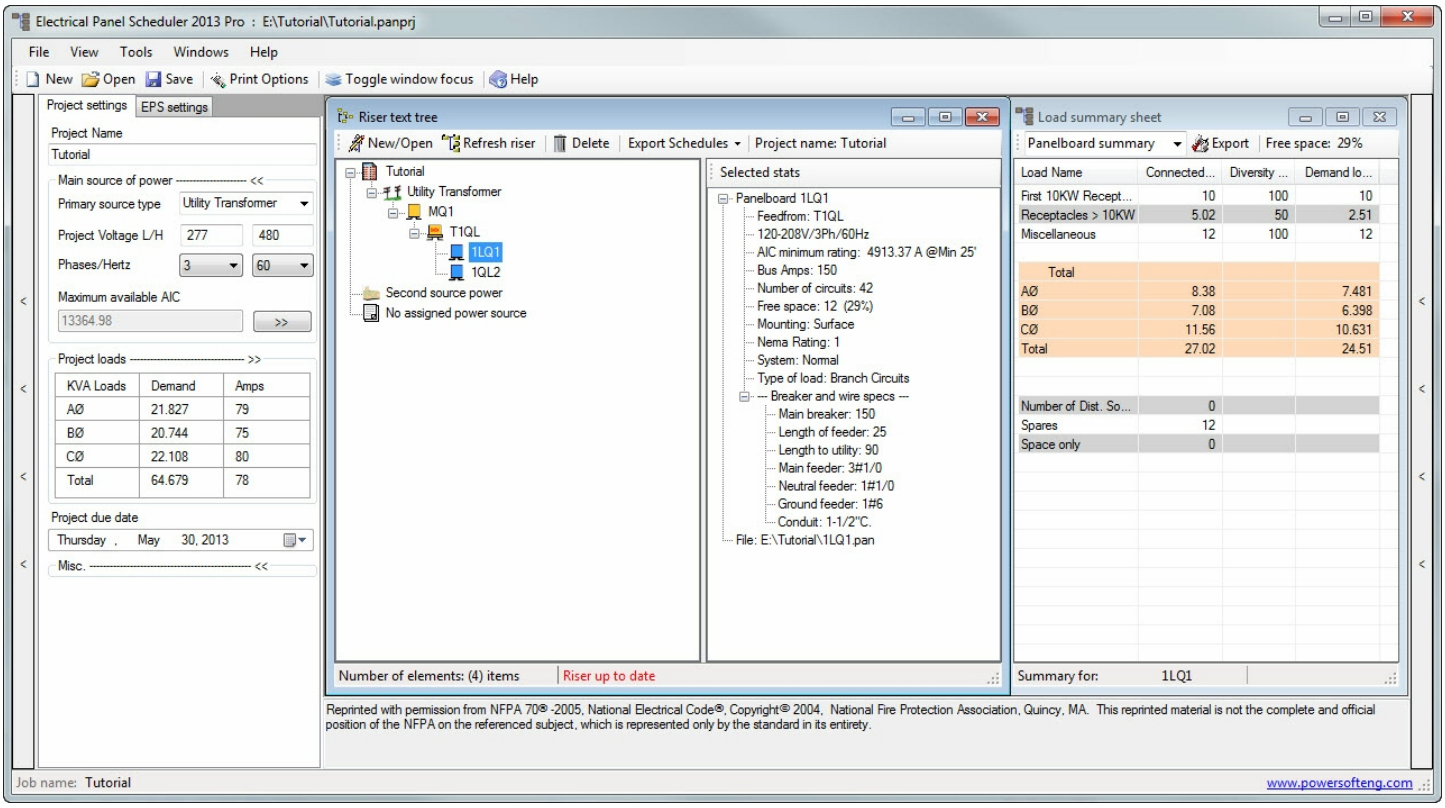
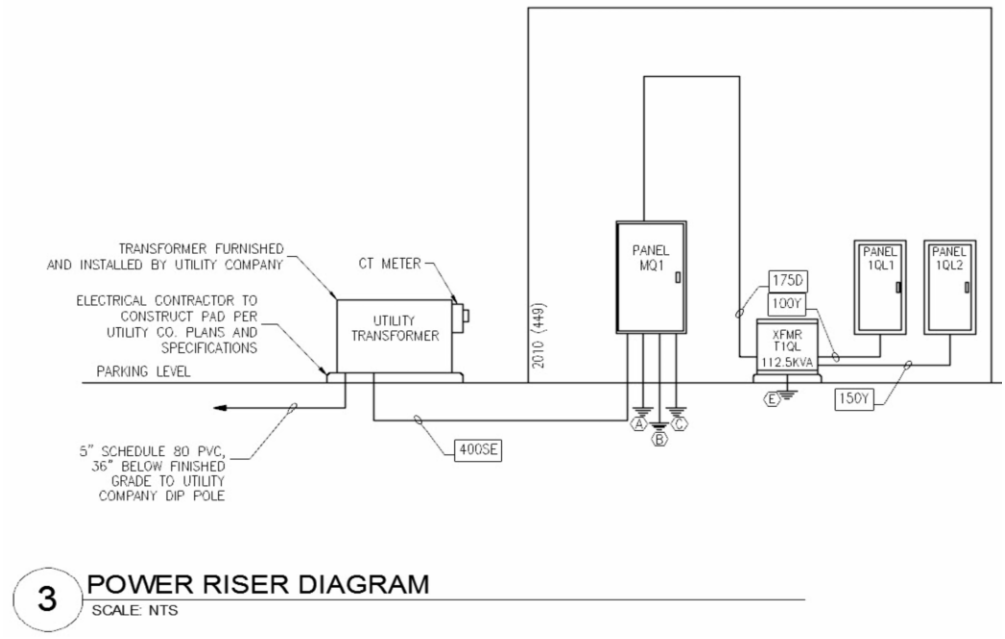


Figure 40

Select the panel 1LQ1 and look at the result in the selected stats window. Notice the AIC rating is 4913.37 A at minimum of 25'. Shortening this distance will increase AIC rating since resistance and reactance will change. Also notice that feeder length to utility is marked as 90' just below feeder length to attachment point of 25'. Loads are also now visible in projects loads are so the designer has immediate access to a lot of information in one screen.

Selecting other elements in the riser will display stats for each of those elements except for transformers. If we select the utility transformer, we can see demand and connected loads for each panel in the riser.

This is certainly a very small project and is capable of a lot more as our testing over the years has proved.



Typically our AutoCAD riser diagrams will look similar to the one shown in figure 39. There are more loads to complete before the riser is finalized but it should be very close. We will certainly have to confirm the loads in MQ1 with HVAC, lights and viewing finished loads from 208 volt panels.

Figure 41

Mechanical load schedules for tutorial project

Some columns may be have been deleted to show pertinent information

RE-CIRCULATOR PUMP SCHEDULE									
TAG	MFGR	MODEL	TYPE	GPM	HEAD (FT)	HP	RPM	WATER HEATER SERVED	NOTES
RCP-03	TACO	0014-BFI	CARTRIDGE CIRCULATOR	5	15	1/8	3250	WH-01	1,2,3
NOTES:	1. PROVIDE WITH MEANS OF DISCONNECT.								
	2. FURNISH WITH BRONZE BODY & CIRCULATOR.								
	3. PUMP SHALL BE CONTROLLED BY THE BMS. PUMP SHALL BE ON DURING WARM-UP, OCCUPIED AND OVERRIDE PERIODS.								

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DOMESTIC WATER HEATER SCHEDULE								
SYMBOL	MFGR	MODEL	RECOVERY (GPH) @ 100 DEG. F. RISE	STORAGE (GAL)	ACCESSORIES		KW	NOTES
					RECIRC. PUMP	MIXING VALVE		
WH-03	BRADFORD WHITE	M-II-50	37	50	RCP-03	MV-03	12	1,2,3
NOTES:	1. FURNISH W/HEAT TRAPS & MANUFACTURER'S RECOMMENDED ASME EXPANSION TANK							
	2. WATER SHALL BE STORED AT A MINIMUM OF 140 DEG. F.							
	3. PROVIDE WITH MEANS OF DISCONNECT.							

THROUGH THE WALL HEAT PUMP SCHEDULE									
UNIT TAG	MFGR	OUTDOOR AIR	EXHAUST AIR	SUPPLY AIR	ELECTRIC HEAT		ELECTRICAL SERVICE		NOTES
		CFM	CFM	CFM	KW	STAGES	VOLTAGE	PHASE	
TWHP-01	MARVAIR	420	370	1550	10	2	460	3	1
NOTES	1. ELECTRIC HEAT SHALL CAPABLE OF CONCURRENT OPERATION WITH COMPRESSORS DURING HEATING OR DEFROST MODES.								

DEDICATED OUTDOOR AIR SYSTEM (DOAS) SCHEDULE									
UNIT TAG	MFGR.	SUPPLY FAN	EXHAUST FAN	ELECTRIC HEAT	ELECTRICAL				NOTES
		HP	HP	INPUT KW	VOLTAGE	PHASE	MCA	MOP	
MAU-02	ANNEX AIR	5	3	32	460	3	54	70	123
MAU-03	ANNEX AIR	5	3	32	460	3	54	70	123
NOTES:	1. PROVIDE WITH UNIT MOUNTED DISCONNECT & CONVENIENCE OUTLET.								
	2. FURNISH WITH VFD'S ON ALL FANS & EBTRON AIRFLOW MONITORING STATION ON SUPPLY & EXHAUST DUCT AT UNIT CONNECTION.								
	3. FURNISH WITH SCR CONTROLS ON ELECTRIC HEAT.								

FAN SCHEDULE							
SYMBOL	MFGR.	MODEL	CFM	HP	DRIVE	VOLT/PH	NOTES
EF-06	GREENHECK	G-170-C	1500	1/4	DIRECT	115/1	123456
NOTES:	1. FURNISH WITH 24-VOLT MOTOR OPERATED DAMPER.						
	2. FURNISH WITH INTEGRAL DISCONNECT SWITCH.						
	3. FURNISH WITH THERMOSTAT.						
	4. FURNISH WALL SWITCH. LABEL WALL SWITCH.						
	5. INTERLOCK WITH LIGHTS.						
	6. FURNISH WITH WC-8 HOODED WALL CAP.						
	7. FURNISH WITH DECORATIVE STAINLESS STEEL GRILLE.						

DUCTLESS SPLIT SYSTEM AIR CONDITIONERS						
MFGR.	AIR HANDLER		OUTDOOR UNIT		SEER	NOTES:
	SYMBOL	MODEL	SYMBOL	MODEL		
MITSUBISHI	IU-06	PLA-A18	OU-06	PUY-A18	14.2	12
NOTES:	1. PROVIDE INDOOR AND OUTDOOR UNIT WITH DISCONNECT.					
	2. PROVIDE INDOOR UNIT WITH MANUFACTURER'S CONDENSATE PUMP (30" LIFT MINIMUM). PROVIDE SEPARATE CONDENSATE PUMP IF LIFT IS NOT AVAILABLE. ROUTE CONDENSATE IN A 1" LINE TO THE NEAREST MOP SINK OR DRY WELL.					

With this new information we can begin to circuit bigger loads in the building which can be more critical since the feeders are bigger and cost more as well as typically the largest loads in a building.

Open the MQ1 by double clicking the panel in the riser window.

Since MAU-02 and MAU-03 are the same, if we size one we can copy this to serve the other circuit and change the name. Select circuit 2. Make it a 3 pole and give it a length ot 75'. Select HVAC condensors since it an outdoor unit. The diversity factor for both HVAC is the same but for the sake of definition.

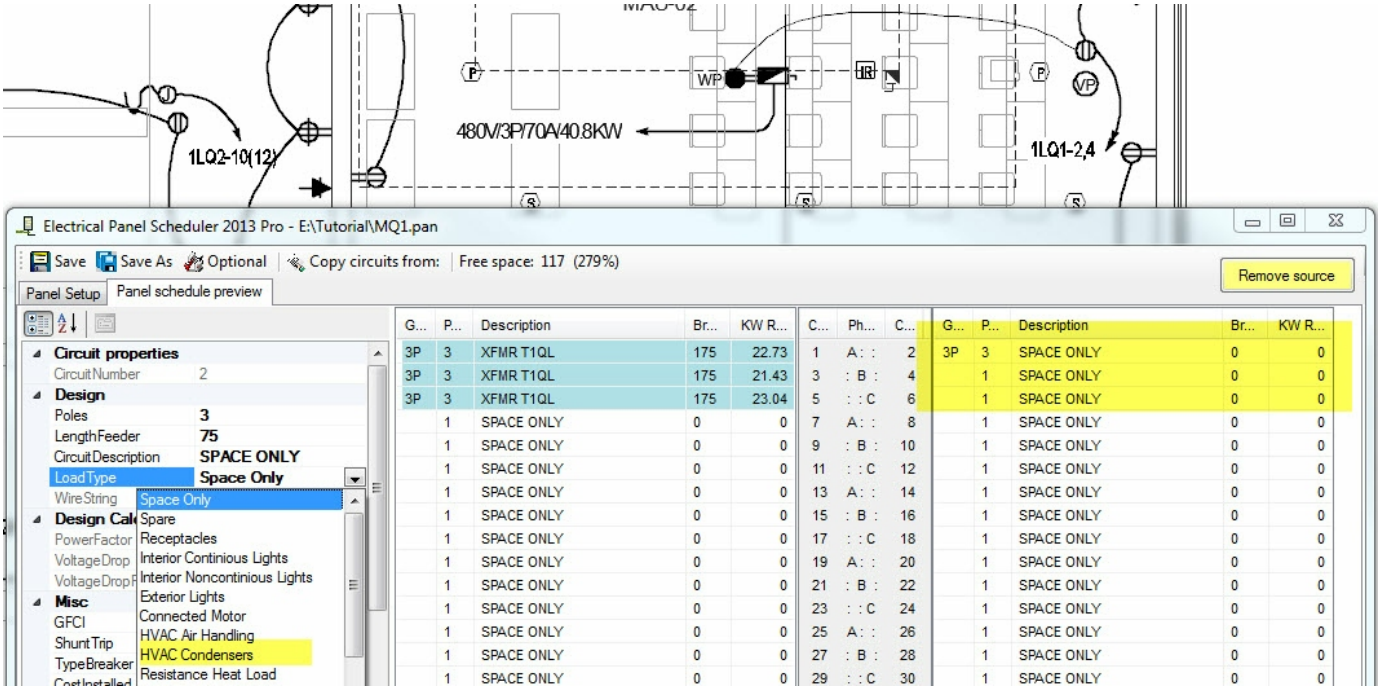


Figure 42

Since the run circuit wizard is still turned on in the EPS settings panel, the wizard window should still open.

We prefer to use circuit wizard for sizing HVAC equipment since there are three separate operations when determining conductors, loads and breakers. Step 1 is to enter minimum circuit amps (MCA). Refer to electrical, MCA column in the table, this is 54 amps. Step 2 is to enter maximum over-current protection (MOCP). Refer to MOP column at the table, this is 70 amps. Step 3 is a bit more complicated since there are actually 3 pieces of information that need to be entered. This information is for a 5HP supply and 3HP exhaust fan motor and also a heat 32KW strip.

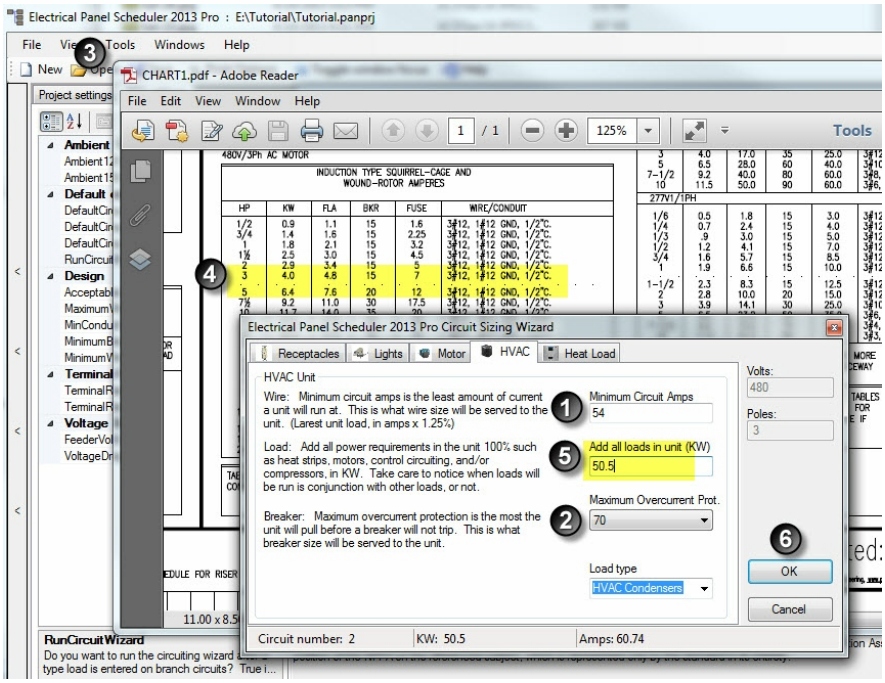


Figure 43

Because of heat strips, they have to be rated for 125% in addition to each fan at 100%. In order to enter the value of load we have to enter the total of combined loads in the table. There is a chart to help determine motor load KW. On the main window select view > sizing chart. Lookup load on the proper voltage chart for a 3HP and 5HP and sum the total which is 4 + 6.4 = 10.4. Next multiply the heat strip KW of 32KW times 125%. 32 x 1.25 = 40. Add the motor and heat strip load together and enter in load box. 10.4 + 40 = 50.4.

Press ok. This will open the circuit apply window so we can see loads that got applied in the previous steps. Notice the lock circuit switch was automatically set. This will prevent the circuit from being changed by pressing the ok button. Do not press the apply button the wire, conduit and breaker will be overwritten and the lock circuit will switch to off. Changing any of the branch circuit properties will also lock the circuit automatically.

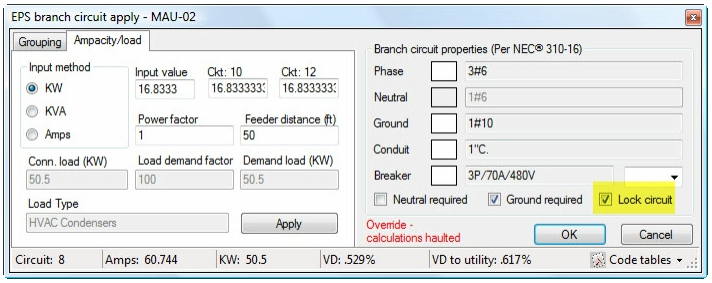


Figure 44

Rename the newly created circuit to MAU-02 and press enter. This will change all three circuits positions.

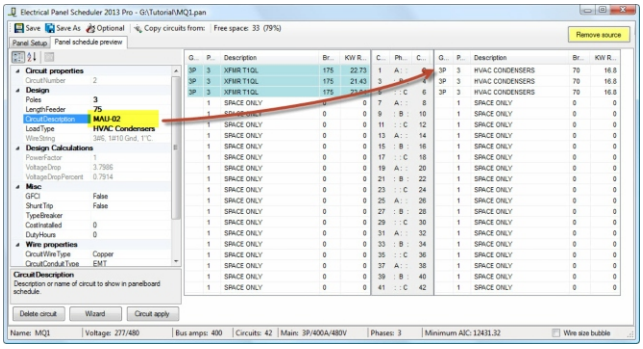


Figure 45

Now with one of the two identical units created we can simply copy the one we just created to a new breaker location. Select circuit 2, hold the left button down and move the mouse to circuit 8 and release the mouse button.

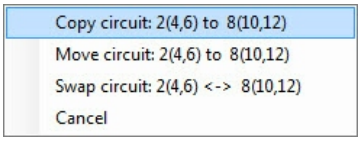


Figure 46

Choose the first selection of copy 2(4,6) to 8(10,12). Notice that for 2 pole breakers and above in EPS uses a special designation for denoting circuits to distinguish between it and a shared neutral which will be denoted as 2,4,6, for instance. A new circuit will be created to the position as indicated.

It is simple to designate a background color to breakers or conduit groups inside EPS. To do this select the circuit we created in the previous step and circuit 8 and right click.

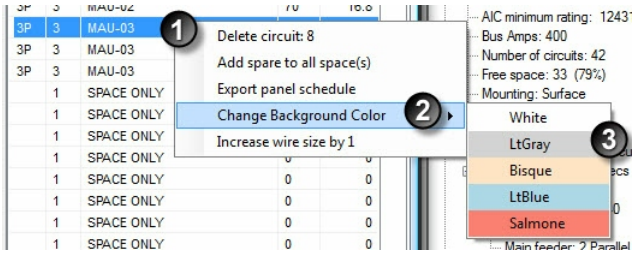


Figure 47

There are many selections in the menu but the one we want to use is change background color. Select LtGray. This will make groups inside schedules much easier to read and work with as you will discover.

There is a 12KW water heater that needs to be wired for our next step. Select circuit 7. Make it 3 poles and a feeder length of 50'. Press the wizard button. Since no load was selected, we are at the first tab. Select the tab that mentions heat load. The RCP-03 mentioned in the table with this equipment is not actually a load onto the water heater but a separate motor and must be wired to 120 volts. For this instance, only one box has to be filled out since there is no additional load in this water heater. Enter 12 into the resistance load box. Notice this is multiplying 125 percent to the load. If there were additional load, it would add 100 percent to it and calculate the breaker and wire size based on that.

Press ok again once you see the circuit apply window. Rename the circuit to WH-03.

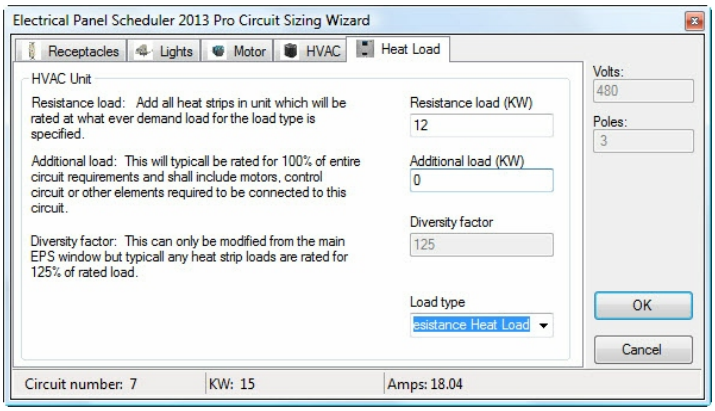


Figure 48

The TWHP unit is a little tricky since is claims to have some air flow in it labeled as CFM (volume of air flow in cubic feet per minute). Since the room is sort of large, is is hard to determine the size of motor, but if we include a 1HP motor it should be fine. Select circuit 13. Make it 3 pole and a length of 60'. Select the wizard button then the heat load tab in the wizard window. This time include 10 in the resistance load box and 1.8 for additional load since that is the load on a 1HP motor. Press ok.

Press ok again once you see the circuit apply window. Rename the circuit to TWHP-01.

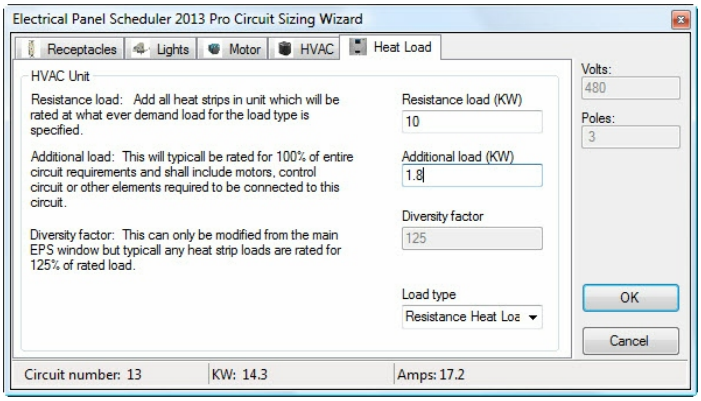


Figure 49

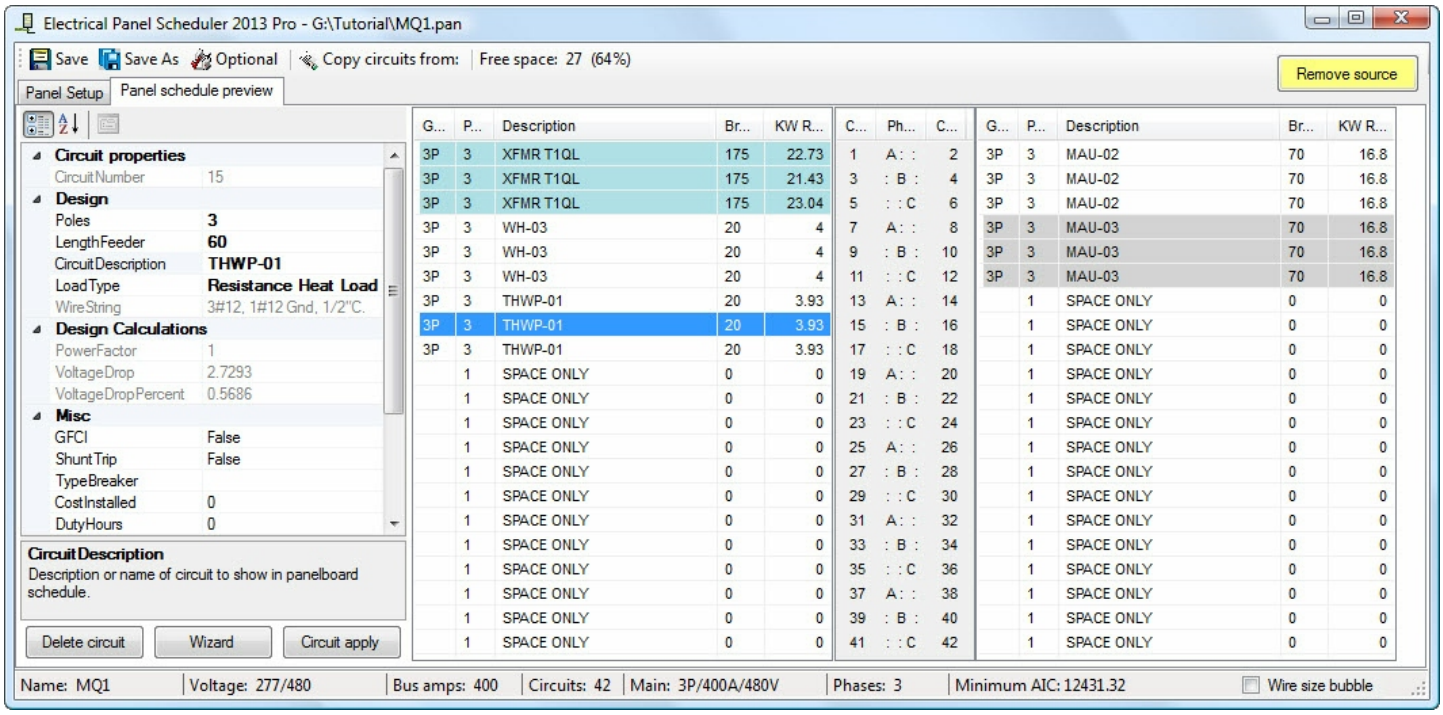


Figure 50

Realistically we will probably not have a 175 amp breaker sharing an adjacent space of a panelboard frame with another breaker less than 125 amps, in this case, but couldn't really say for sure till shop drawings came back from the manufacturer. For the sake of argument, lets move the circuit breakers around in the panel to fix this problem. Make sure the circuits shown on the CAD file are updated after this procedure.

Select circuit 8 and drag it it to circuit 14. Use the move menu selection. Continue using the same procedure on circuit 2 to 8. Now the panel is more in line with realistic values. With breaker 100 amps and less sharing the same frame areas.

Close MQ1 and open 1QL2.

Lets finish wiring the building in this panel. First take care of unit OU-06 and IU-06 part of a very small split HVAC unit shown on mechanical loads tables. For this unit we have to serve the rooftop unit and it serves the indoor unit. Although the table does not show the loads, it is a 208V/1Ph/1940W unit.

Delete circuit 14 and 16 spare breakers. Those may have caused problems when linking a two pole breaker. Make circuit 14 a 2 pole and assign a length of 30'. Give a load of HVAC condensors. The wizard should display.

Enter a MCA of 20 load of 1.94 (this is KW slot) and MOCP of 20.

Press ok then ok again at the circuit apply window. Rename the circuit to OU-06.

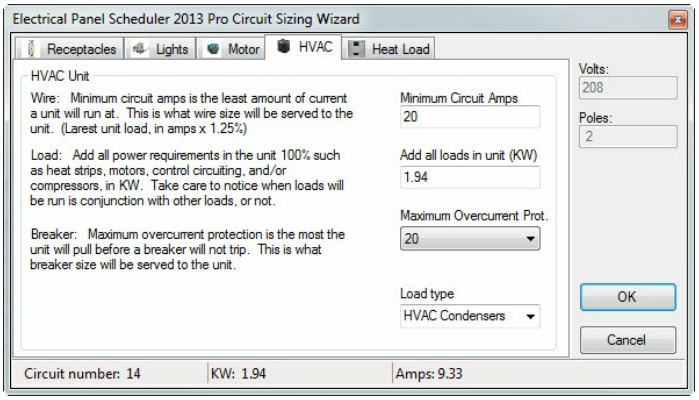


Figure 51

Be sure to record all the circuits mentioned thus far in CAD.

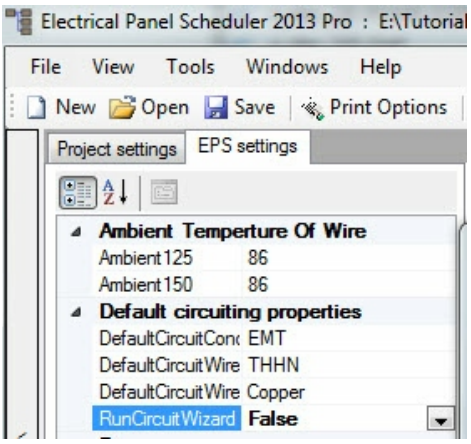


Figure 52

One more load we need to add from the HVAC tables. EF-06 which is a 1/4HP exhaust fan. For this, turn off the circuit wizard on the EPS settings tab in the main window.

Anything we do now will not display the wizard, so switching back to it, you will have to turn the switch to true.

Select circuit 17. This should be a spare circuit. Make the length 20'. Make the type a connected motor. This time, the circuit apply window opened and is waiting for a load.

Since we don't know what the KW rating a 1/4HP motor is, we can display a table from inside the circuit apply window that lets us see many tables which are helpful to sizing circuits. Select the code tables pulldown and select wire sizing chart. Find the location in the tables where 120V/1Ph motors are located. Find the load for a 1/4HP motor which is .7KW. Enter this into the input value box. Press ok button.

In the scheduler window, change the backcolor to light gray and change the name to EF-06.

Close the panel schedule and press the refersh riser button on the riser tree window so we can update all the loads in the riser.

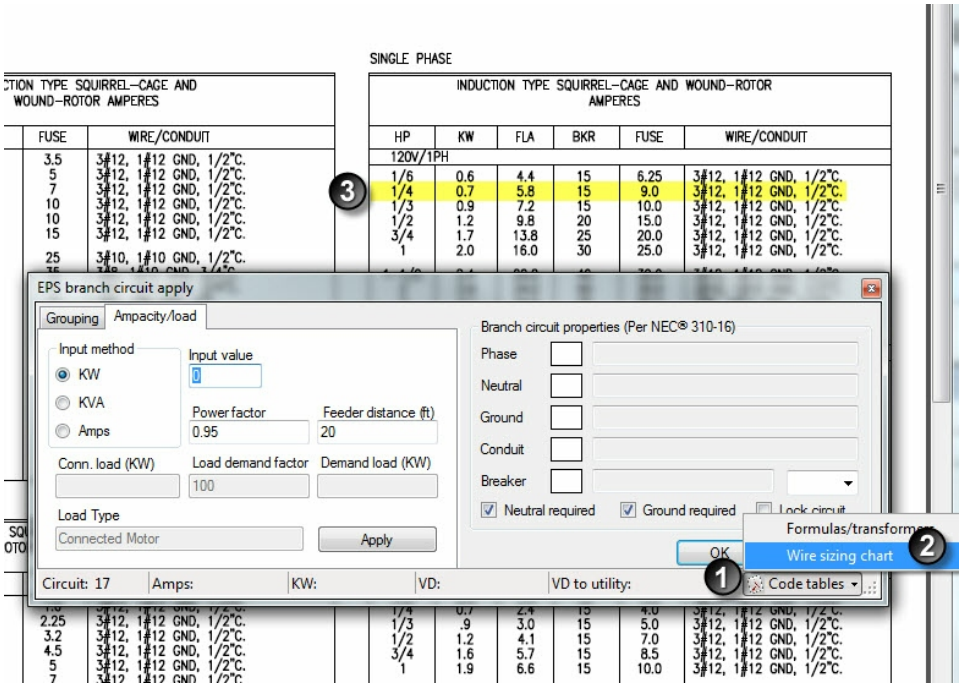


Figure 53

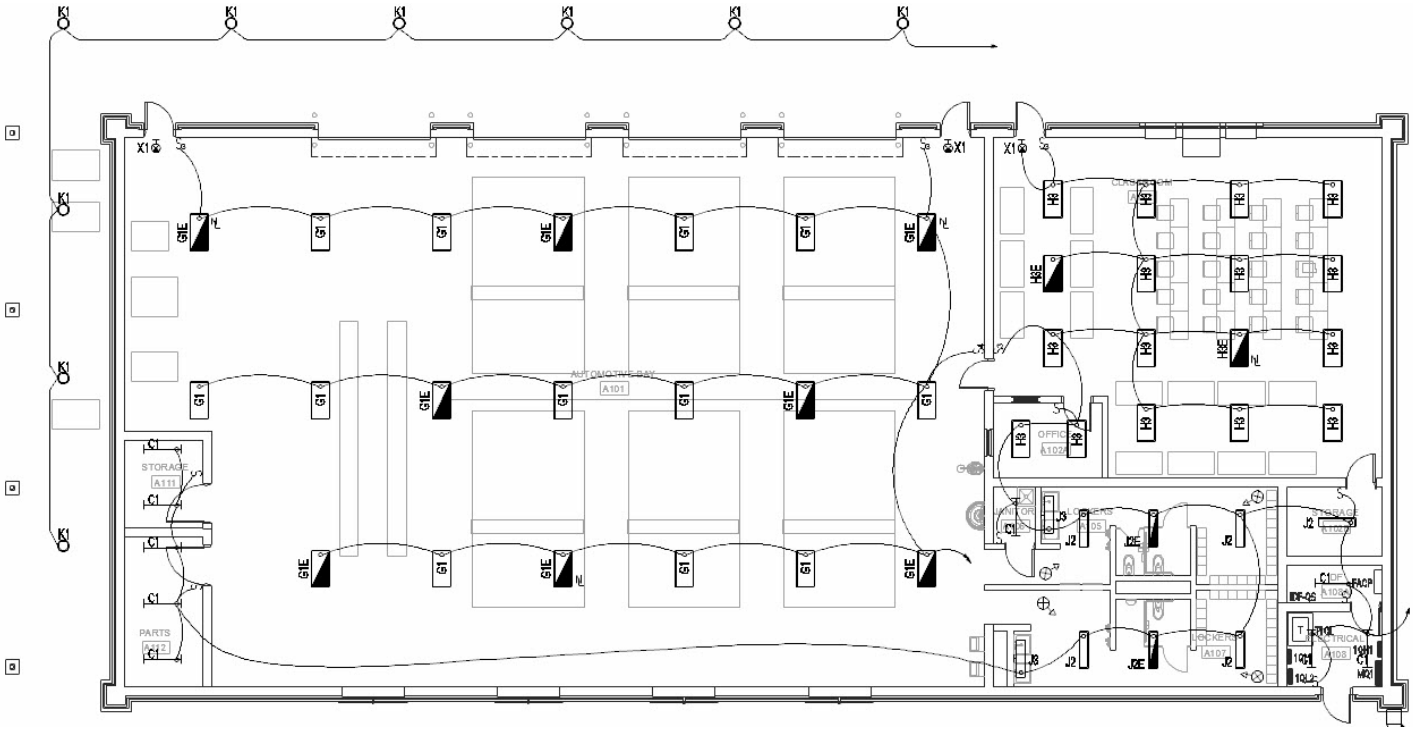


Figure 54

Wiring lights is based on the number and type of lamps in each fixture. For design purposes, a good rule of thumb is to add each lamp wattage in each fixture and add 10% to determine the load of each fixture. For a commercial building, typically they should be considered continuous duty.

The fixtures shown here are sized per the table shown:

Fixture type	Description	Watts
C1	Strip	65
G1	2x4 surface 6 lamp	195
H3	2x4 3 lamp	100
J2	Surface mount	65
J3	Wall mount	65
K1	HID Pendant	130

Sum all lights associated with a desired circuit. Starting with K1. 9 x 130 = 1170W. We do not like to exceed 3500 watts for a 277 volt circuit although 4400 watts is acceptable. Since K1 is an exterior light and on a time clock, we want to make sure this keep the circuit in a conduit not shared with other loads.

(20)-G1 fixtures x 195 watts = 3900 watts. To large for one circuit, so we have to split this out to two. 10 x 195 = 1950 watts. Since this is the case, we can do one of two things. Alternate circuit numbers or double switch fixtures. Because 6 lamp fixtures are not usually served with one ballast, we can can call for (2) 3 lamps ballast in each fixture.

There is 17 H3 fixtures (100 watts each) which is 1700 watts and 18 other fixtures which are 65 watts each equals 1170 watts. This totals 2870 watts, enough for one circuit provided the voltage drop is not to bad. The worst case of distance for the remaining lights is 160’ which out to be 2.33%.

This completes circuiting for this building.

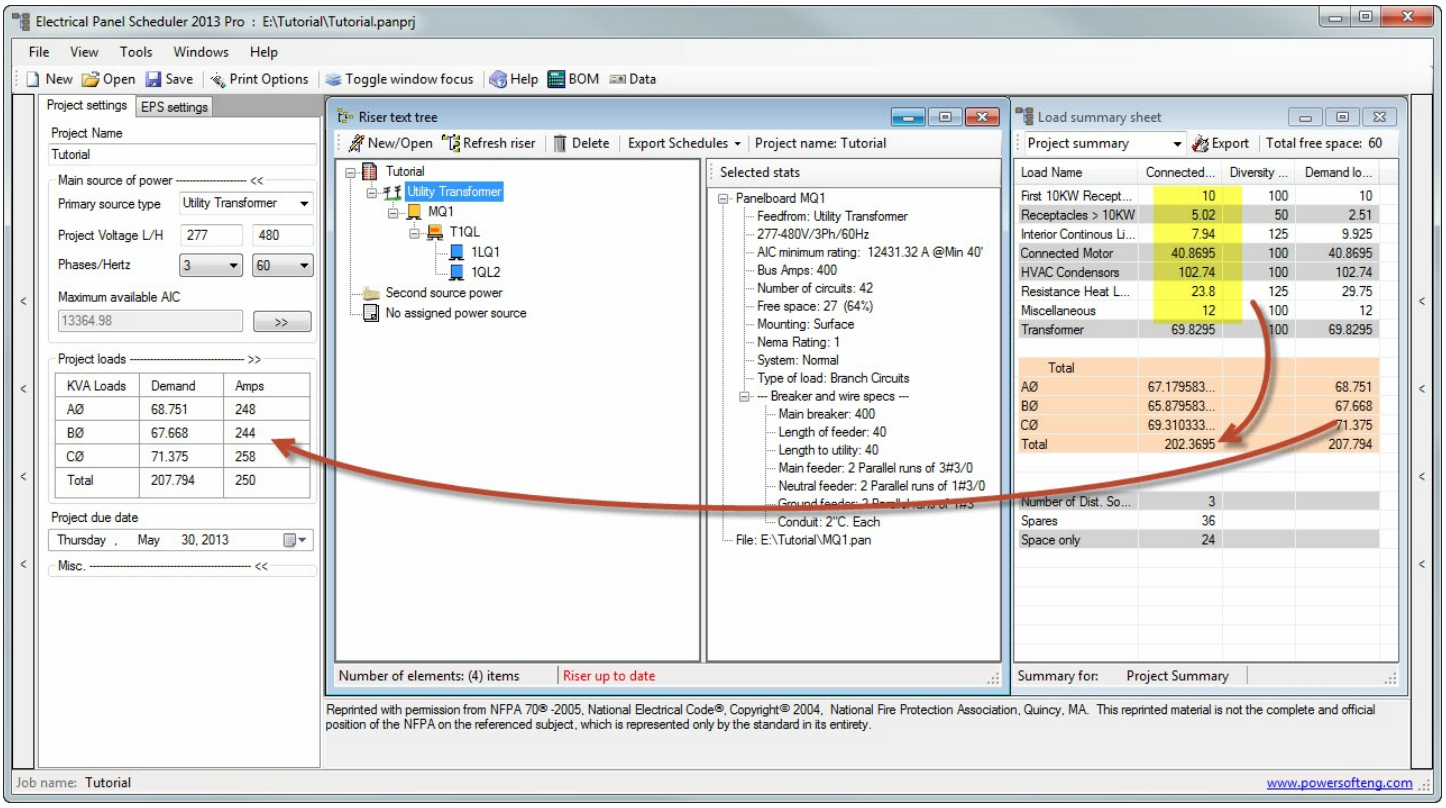


Figure 55

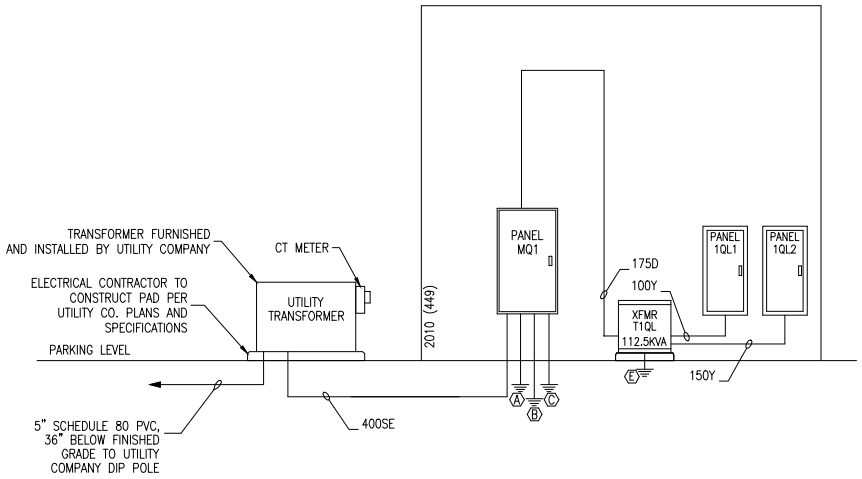
For an understanding of the loads on the displayed on the riser, select the utility transformer icon so project loads are displayed in the load summary window. When selecting the utility source, EPS goes through each panel and transformer in the riser and calculates the total of each load type. They are summed and displayed pertinent to what is used or not. We can see from figure 50 that even though a transformer is displayed, it doe not contribute to the load summery. Only fields highlighted in yellow will be summed.

We can also see that our main panel of 400 amps is well within the bounds of what we had sized, but there must space for future capacity because we never know what the future holds for commercial buildings. In this case, there could also be welders and other equipment.

Each time EPS is opened, it saves a copy of itself, in case the program ever crashes. If you ever enter any bad data and you close the scheduler you can always recover from the last closed session. There is not an autosave in the program. You will need to save often.

POWER/LIGHTING SYMBOL SCHEDULE

SYMBOL	DESCRIPTION	SYMBOL	DESCRIPTION
GLA–1	CIRCUIT HOMERUN TO PANELBOARD SHOWN LABELED WITH PANELBOARD DESIGNATION AND CIRCUIT NUMBER. UNLESS OTHERWISE NOTED, CONDUIT SHALL BE MINIMUM ¾" WITH #12 WIRING FOR THE NUMBER OF CIRCUITS INDICATED.		PANELBOARD. SEE SCHEDULE FOR REQUIREMENTS
	RACEWAY CONCEALED IN WALLS, CEILINGS, BELOW SLAB, CHASES OR OTHER BUILDING ELEMENTS.		DISCONNECT SWITCH. SEE DETAIL ON SHEET E0.3 FOR SWITCH CHARACTERISTICS. (MF= PER MANUFACTURERS REQUIREMENTS, NF = NON-FUSED, /SN = SOLID NEUTRAL/ NEMA ENCLOSURE TYPE). REFER TO SPECIFICATIONS FOR ADDITIONAL REQUIREMENTS.
AA AL AR	FLUORESCENT LIGHTING FIXTURE, LETTER INDICATES FIXTURE TYPE. (TYP.) SEE SPECIFICATIONS SECTION 16500 FOR DESCRIPTION. SUBSCRIPT "UNS" DENOTES THE FIXTURE TO BE WIRED UNSWITCHED.		DISCONNECT SWITCH FURNISHED WITH EQUIPMENT
			JUNCTION BOX, WALL MOUNTED.
EA	WALL MOUNTED INCANDESCENT, COMPACT FLUORESCENT OR HID LIGHT FIXTURE. SEE SPECIFICATIONS SECTION 16500 FOR DESCRIPTION.		JUNCTION BOX, CEILING MOUNTED.
CA	CEILING MOUNTED INCANDESCENT, COMPACT FLUORESCENT OR HID LIGHT FIXTURE. SEE SPECIFICATION SECTION 16500 FOR DESCRIPTION.		DUPLEX RECEPTACLE, FLUSH MOUNTED, SUBSCRIPT "SP" DENOTES SURGE PROTECTOR TYPE, "WP" DENOTES WEATHERPROOF COVER.
	EXIT LIGHT, CEILING MOUNTED, SHADED REGION INDICATES FACE(S) REQUIRED. PROVIDE DIRECTIONAL ARROW(S) AS INDICATED. ALL EXIT LIGHTS SHALL BE CONNECTED UNSWITCHED.		DUPLEX RECEPTACLE, FLUSH MOUNTED 6" ABOVE COUNTERTOP BACKSPLASH OR 42" AFF IF NO COUNTER.
			GFCI DUPLEX RECEPTACLE, FLUSH MOUNTED.
N	DIAGONAL SHADING DENOTES THAT LIGHT FIXTURE SHALL BE PROVIDED WITH EMERGENCY BATTERY BALLAST. SUBSCRIPT "UNS" DENOTES THE FIXTURE TO BE WIRED UNSWITCHED. "NL" SHALL DENOTE FIXTURE TO HAVE MINIMUM ONE UNSWITCHED LAMP TO OPERATE 24/7.		GFCI DUPLEX RECEPTACLE, FLUSH MOUNTED 6" ABOVE COUNTERTOP BACKSPLASH OR 42" AFF IF NO COUNTER.
			DOUBLE DUPLEX RECEPTACLE, FLUSH MOUNTED.
	EMERGENCY WALL PACK LIGHT FIXTURE.TO BE WIRED UNSWITCHED.		DOUBLE DUPLEX RECEPTACLE, FLUSH MOUNTED 6" ABOVE COUNTERTOP BACKSPLASH OR 42" AFF IF NO COUNTER.
S_b	TOGGLE SWITCH, SPST ["b" DENOTES FIXTURE CONTROLLED (TYPICAL FOR ALL SWITCHES AND DIMMERS)].		GFCI DOUBLE DUPLEX RECEPTACLE, FLUSH MOUNTED.
S_3	TOGGLE SWITCH, 3-WAY.		GFCI DOUBLE DUPLEX RECEPTACLE, FLUSH MOUNTED 6" ABOVE COUNTERTOP BACKSPLASH OR 42" AFF IF NO COUNTER.
S_4	TOGGLE SWITCH, 4-WAY.		DUPLEX RECEPTACLE FLUSH MOUNTED IN CEILING.
SM	MOTOR RATED TOGGLE SWITCH.		
	OCCUPANCY SENSOR, DUAL TECHNOLOGY, CEILING/WALL MOUNTED. WATTSTOPPER #DT-200.		
	OCCUPANCY SENSOR, DUAL TECHNOLOGY, CEILING MOUNTED. WATTSTOPPER #DT-300.		



1 POWER RISER DIAGRAM
SCALE: NTS

POWER NOTES (PN):

1. RETRACTIBLE POWER CORD REEL. EXACT LOCATION TO BE DETERMINED BY OWNER.
2. POWER FOR LIFT. COORDINATE EXACT LOCATION WITH OWNER.

POWER RISER FEEDER SCHEDULE

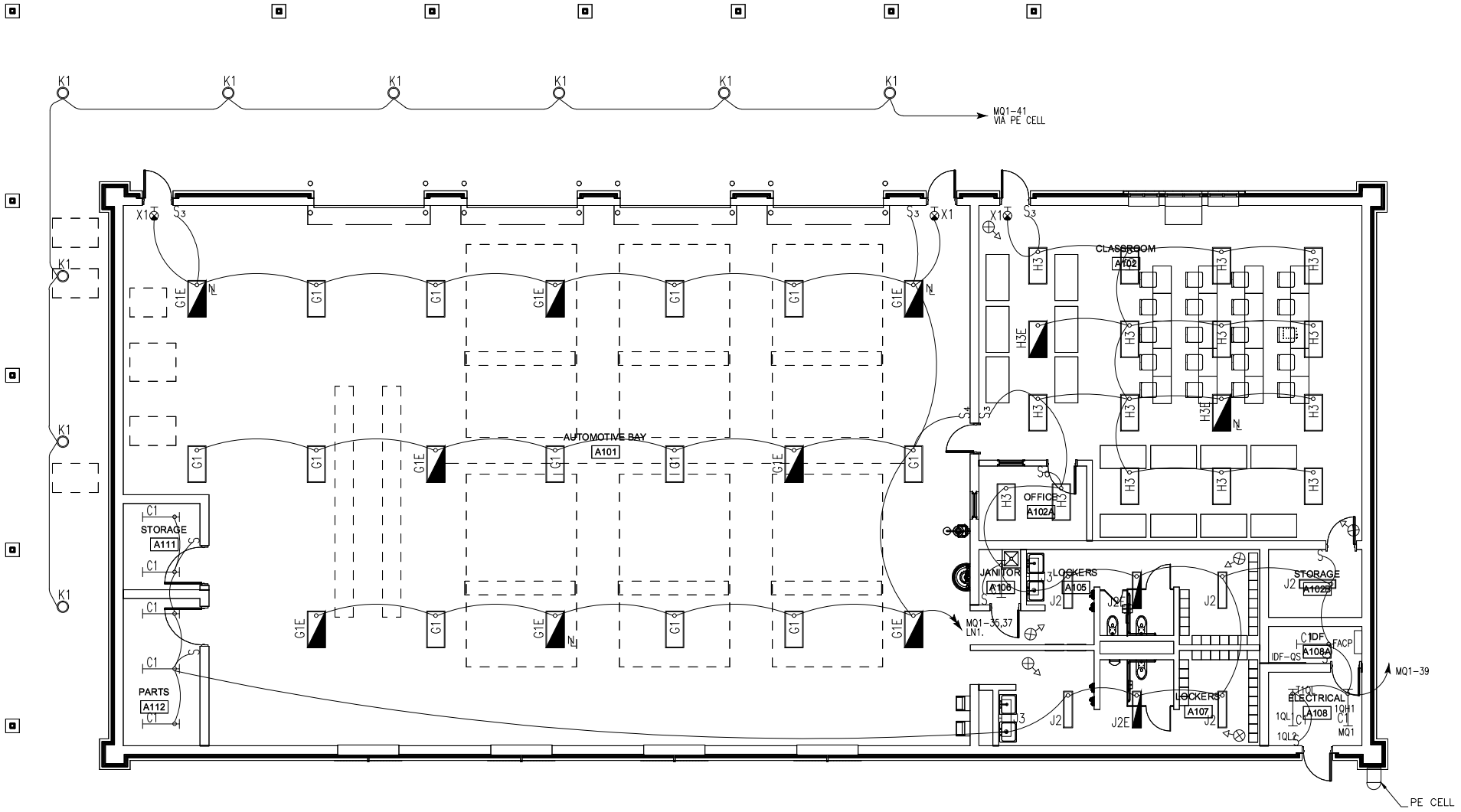
FEEDER	PANELBOARD FEEDER SCHEDULE
100Y	1–1/2" WITH 4#1 & 1#4 GND.
150Y	2"C WITH 4#1/0 & 1#4 GND
175D	2"C WITH 3#2/0 & 1#6 GND
400SE	3"C WITH 4#500 MCM

GROUNDING SCHEDULE

A	1#2"C. WITH (1) #250MCM GROUND TO GROUND RING. SEE DETAIL 1/E0.4.
B	1#2"C. WITH (1) #250MCM GROUND TO METALLIC COLD WATER PIPE. SEE DETAIL 2/E0.4.
C	1#2"C. WITH (1) #250MCM GROUND TO BUILDING STEEL. SEE DETAIL 3/E0.4.
D	1#2"C. WITH (1) #250MCM GROUND TO CONCRETE ENCASED ELECTRODE.
E	1"C. WITH (1) #2/0 GROUND TO BUILDING STEEL.

EQUIPMENT SCHEDULE

ALL TRANSFORMERS EXCEPT UTILITY	DRY TYPE TRANSFORMER – PRIMARY: 480V, 3 PHASE, 3 WIRE, DELTA, SECONDARY: 208/120V, 3 PHASE, 4 WIRE WYE. "K" FACTOR = 14. NEMA TP-1-2002 COMPLIANT.

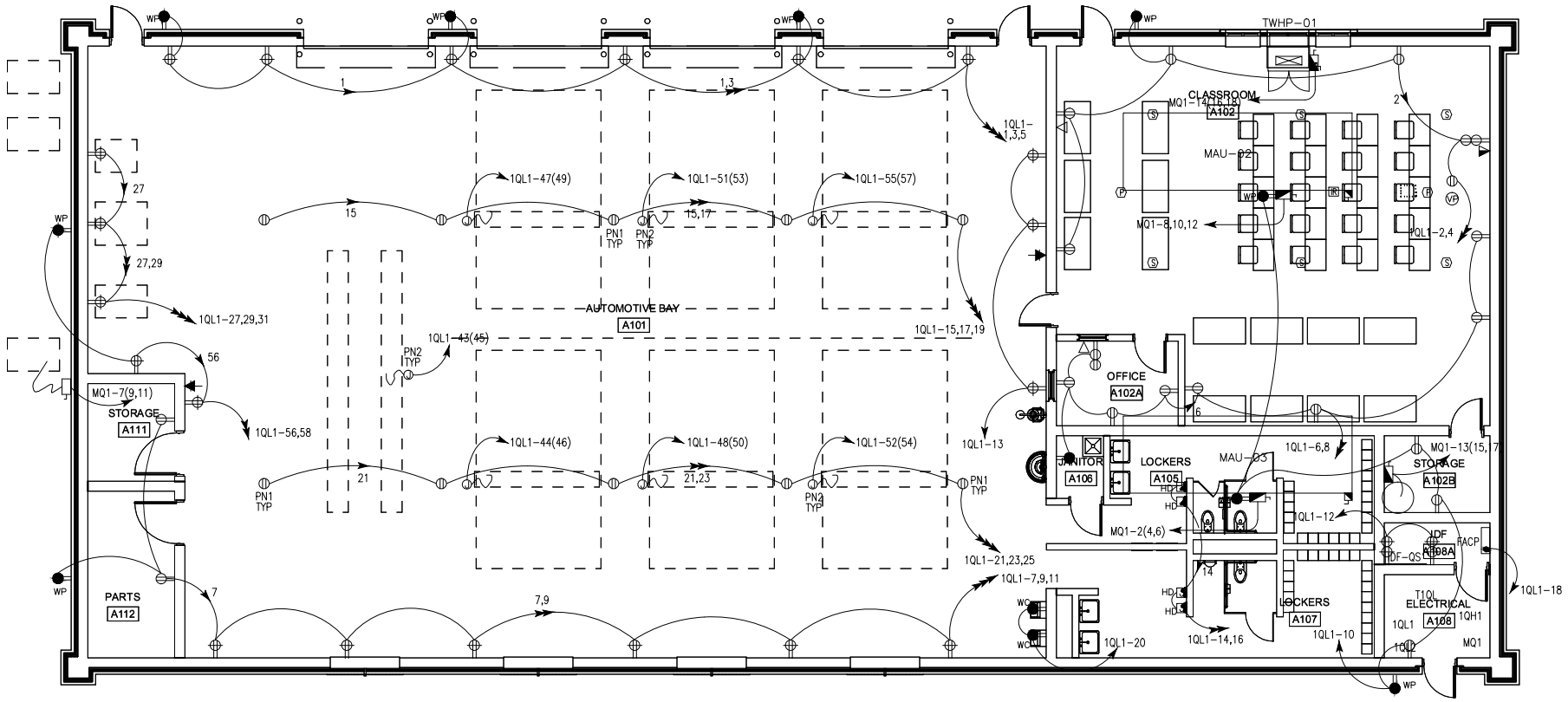


1 ALTERNATE #1 - AUTOTECH LIGHTING FLOOR PLAN

SCALE: 1/8" = 1'-0"

LIGHTING NOTES (LN):

1. ONLY ONE EMERGENCY BALLAST SHALL REMAIN ON FOR NIGHT LIGHT.
2. CIRCUIT 35 SHALL SERVE THE 2 LAMP BALLASTS AND CIRCUIT 37 SHALL SERVE THE 4 LAMP BALLASTS. EMERGENCY BALLASTS SHALL BE CIRCUITED THROUGH CIRCUIT 35.



1 ALTERNATE #1 - AUTOTECH POWER FLOOR PLAN

SCALE: 1/8" = 1'-0"

POWER NOTES (PN):

1. RETRACTIBLE POWER CORD REEL. EXACT LOCATION TO BE DETERMINED BY OWNER.
2. POWER FOR LIFT. COORDINATE EXACT LOCATION WITH OWNER.

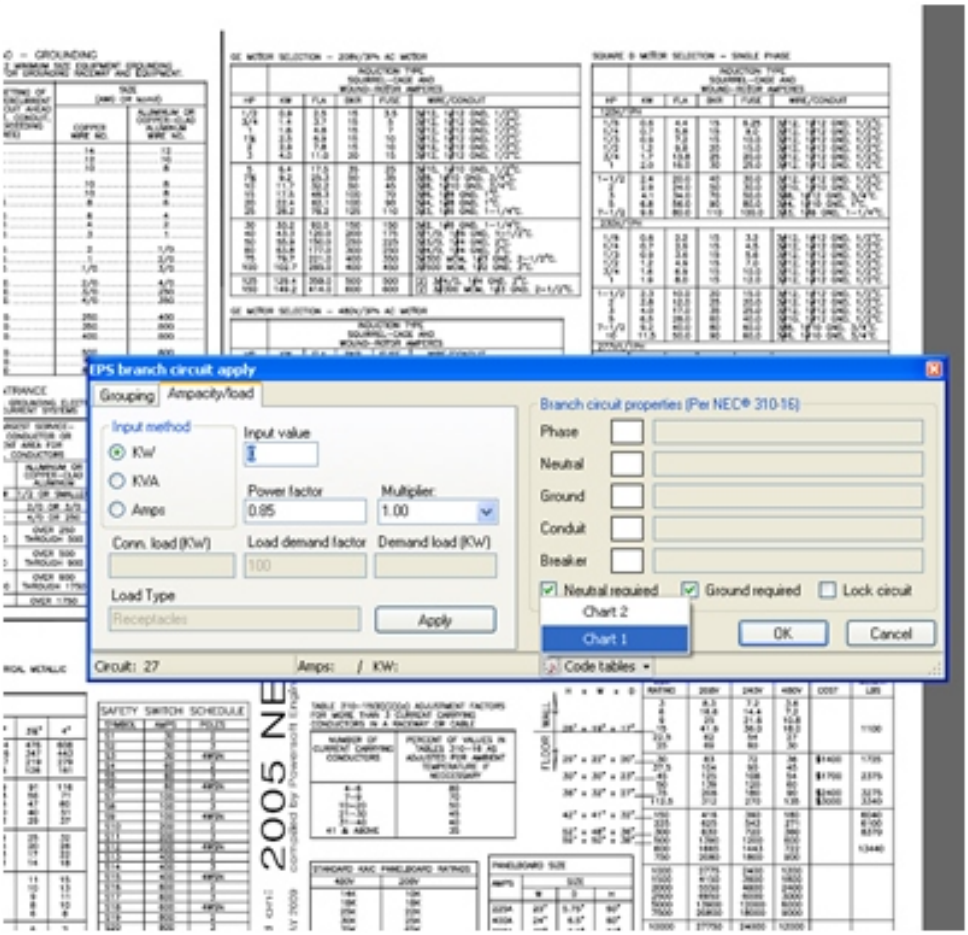


Figure 1

Hints and tricks

Opening charts inside the circuit apply window

Inside the circuit apply window there is a pulldown menu which will show some charts useful for helping to solve motor, or other loads which can be entered, associated with electrical design which you can print out and used on your desk as a quick reference. I have a laminate sleeve that I print out both charts and put them back to back and use.

Changing a breaker/wire size of a circuit

When applying a circuit it sizes a 20A breaker since the project settings say a 20A should be minimum. Press the button next to the breaker and it will bring up a box that we can adjust the breaker. Select the size of 15A from the drop down menu. A user may bump up the wire to #10 because of distance. Now press OK.

Notice that this has displayed a warning that the circuit is locked so when we press the ok button it will not override the wire or breakers we just set. Locking a circuit will not override any wire, breaker or conduit sizes. All sizes will have to be manually entered once it is locked or press apply button to automatically size all settings.

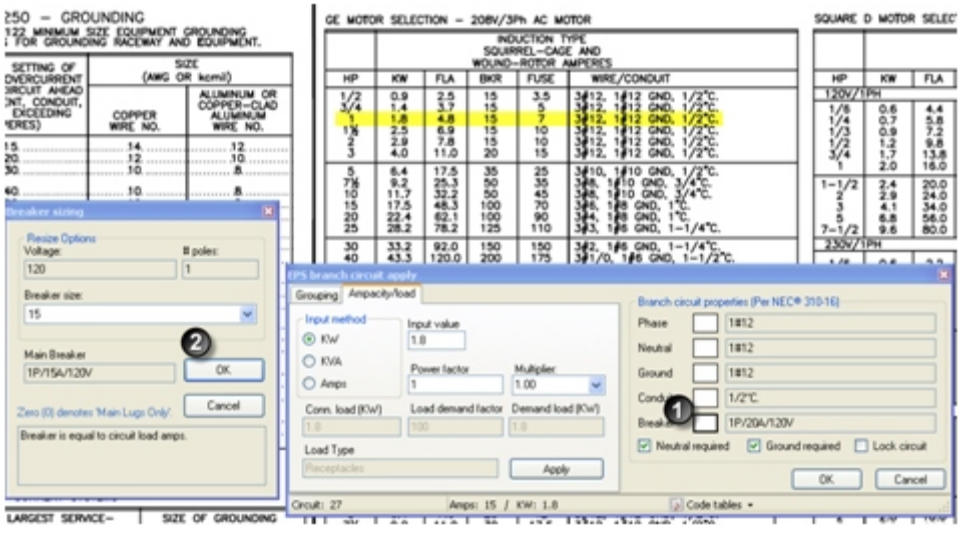


Figure 2

Making a panel two section

To do this, go back to the panel setup tab. Make the number of circuits 84. Make the switch for IsPanelTwoSection as true (this would not be pressed if the panel contained 84 circuits).

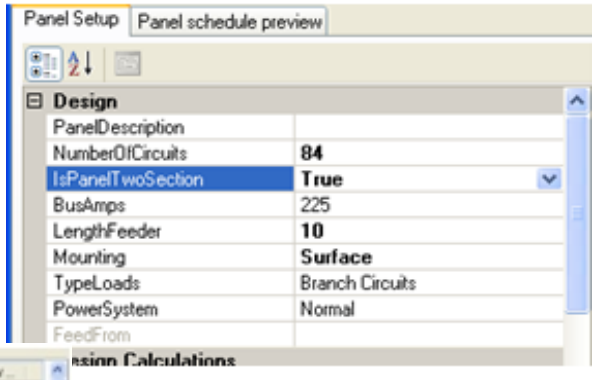


Figure 3

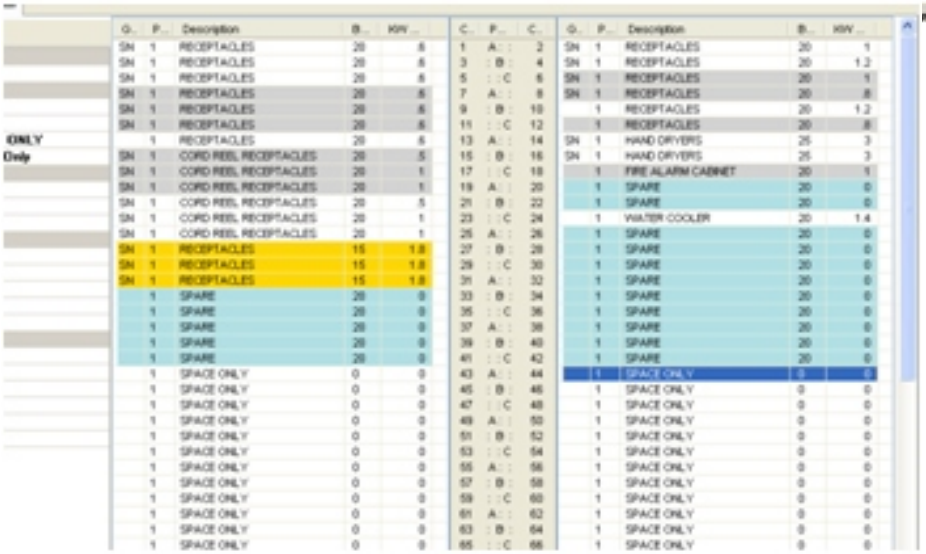


Figure 4

The result is now that we have added another 42 circuits to the panel and since we made the spares before we added the additional, we now have 42 circuits of space only and the ability to add more spares when needed. The circuit shading on panelboard preview makes circuiting overview highly effective to visualize which breakers have shared neutrals, have problems that need to be addressed and which are spares or spaces.

Setting up new paneloards

EPS will perform some minor checks to ensure neutrals and wires are setup properly. In this case, on service entrance panels, if the electrode is not checked, EPS will warn the user that it needs to be included and sized properly. Anytime there is a yellow background marker under the panelboard name there imay be a potential problem and you should look under the message to see what the message is.

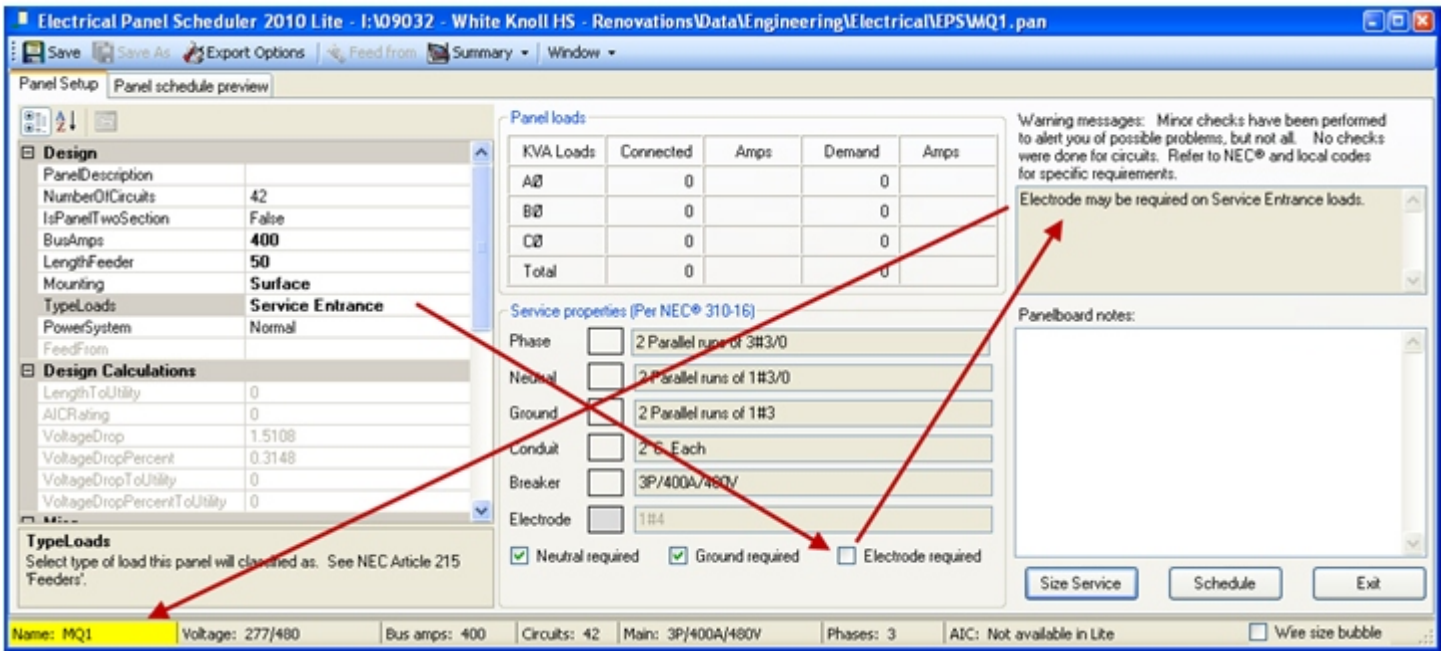


Figure 5

Panelboards may be sized based on many factors

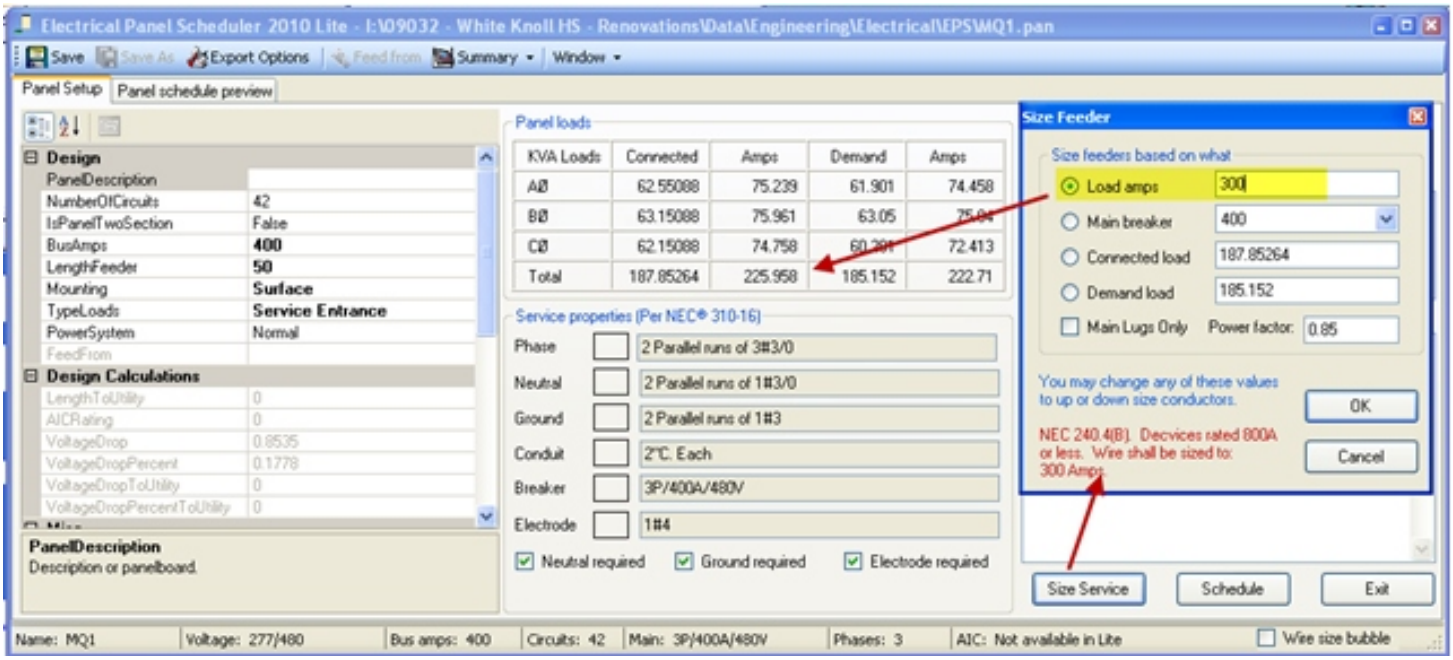


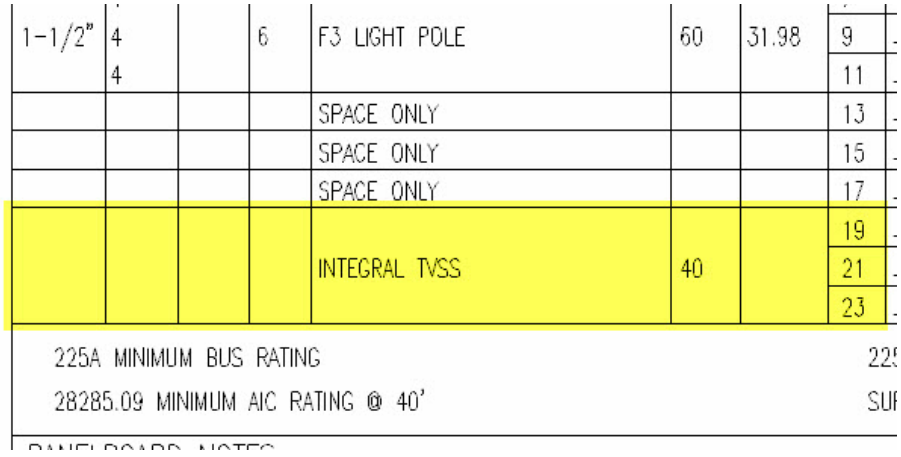
Figure 6

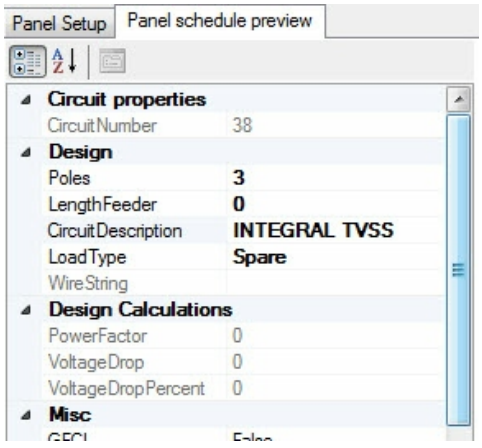
When sizing wire for panelboards, based on load amps, main breaker, connected load, demand load or buss amps. Make sure the panelboard is finalized before settings these things so they are not capable of future expansion. This only sizes wire and not the factors selected.

Create a breaker when a circuit is existing or used with unknown loads

In many cases we have to create breakers in panels when loads or wire sizes are not required such as transient voltage surge suppressor or existing breakers in a panelboard, so we can show trip rating and circuit numbers. To accomplish this, we can create a spare breaker. This can be up to 3 poles and of course labeled anything. In the EPS window assign a spare breaker and the name may be anything. Be sure to size the breaker size as required.

There is a known bug because now this circuit is labeled as a spare and spare circuit counts will be not technically accurate when looking and project summaries, so be aware of this drawback. Plans are in the works to correct this problem.



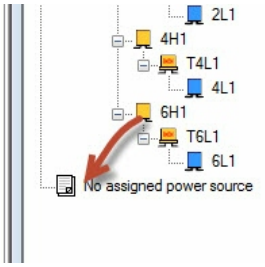


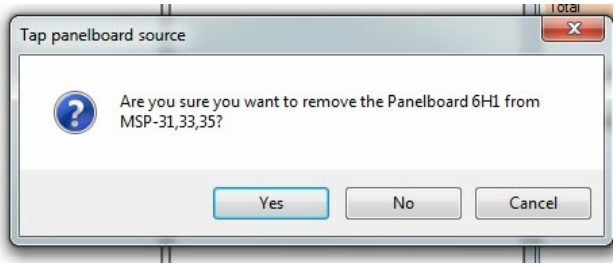
Removing a connection from any riser elements

EPS automatically assigns breakers and load information when users drag and drop electrical elements from 'No assigned power source' to any legal specified element. Like wise those elements can be removed in the same manner.

Dragging an element from one panel to another is not designed to work and will cause errors when updating the riser. Any elements must first be disconnected in the aforementioned procedure first before connecting from one element to another.

Dragging an element back to 'no assigned power source' will remove both the source feeding the panel you no longer want serving this element but will also remove the breaker and appropriate load requirements in the source panel.





Exporting panelboard elements

Do not interrupt the process, especially AutoCAD. Control will be given once all EPS processes are finished.

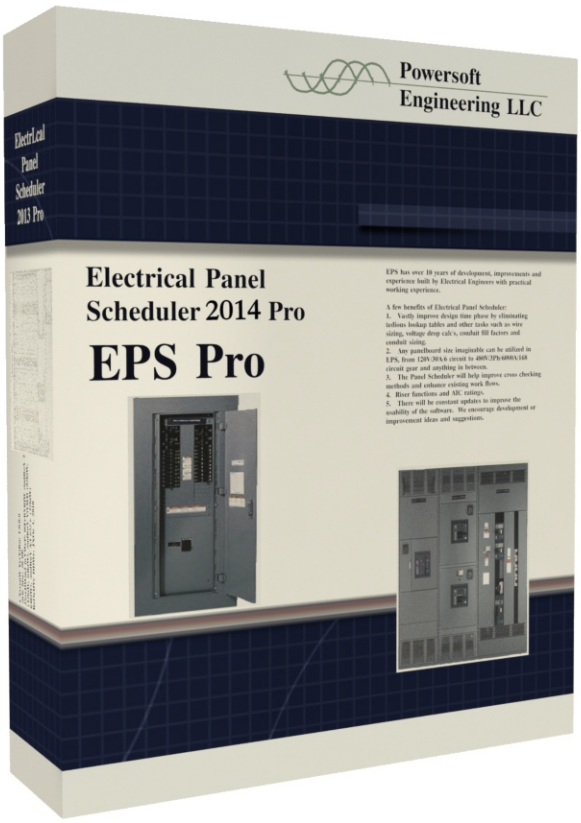
Create a breaker when a circuit is existing or used with unknown loads

In many cases we have to create breakers in panels when loads or wire sizes are not required such as transient voltage surge suppressor or existing breakers in a panelboard, so we can show trip rating and circuit numbers. To accomplish this, we can create a spare breaker. This can be up to 3 poles and of course labeled anything. In the EPS window assign a spare breaker and the name may be anything. Be sure to size the breaker size as required.

There is a known bug because now this circuit is labeled as a spare and spare circuit counts will be not technically accurate when looking and project summaries, so be aware of this drawback. Plans are in the works to correct this problem.

Chapter 5

Notes:



Sales Options

Electrical Panel Scheduler 2014 Pro

EPS has a full range of design features such as voltage drop; wire; conduit; breaker sizing and load summaries with demand/connected categorized loads. The professional version also offers electrical projects for storing multiple panelboard schedules used in a system and an easily visible riser diagram tree for which users can connect together by drag and drop operations. This offers users the ability to connect and size branch circuits from one source to another and track circuit parameters automatically throughout the riser. EPS will calculate short circuit, voltage drops and wire lengths throughout the branches. Branch circuits can also be copied from other panelboards making the entire design process as effortless as possible and very efficient. EPS Pro can be purchased with three licensing options.

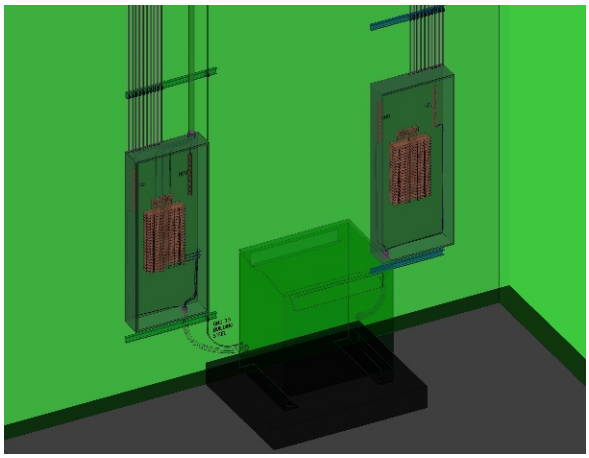
Option 1. Stand alone. The licensing will never expire.

Option 2. Same as option 1 and includes a one year subscription. Any updates that come available for one year will be free of charge.

Please review all documentation to determine which option fits the needs of your firm. Users may also test drive the program for a period of 15 days.

Please make all purchases from our web site at:

http://www.powersofteng.com/cart/page2.html



Thank you for your support and for using EPS. Please help spread the word.

Voltage drop examples

Voltage-drop calculations using the dc-resistance formula are not always accurate for ac circuits, especially for those with a less-than-unity power factor or for those that use conductors larger than 2 AWG. Table 9 allows Code users to perform simple ac voltage-drop calculations. Table 9 was compiled using the Neher-McGrath ac-resistance calculation method, and the values presented are both reliable and conservative. This table contains completed calculations of effective impedance (Z) for the average ac circuit with an 85 percent power factor (see Example 1). If calculations with a different power factor are necessary, Table 9 also contains the appropriate values of inductive reactance and ac resistance (see Example 2).
The basic assumptions and the limitations of Table 9 are as follows:

1. Capacitive reactance is ignored.
2. There are three conductors in a raceway.
3. The calculated voltage-drop values are approximate.
4. For circuits with other parameters, the Neher-McGrath ac-resistance calculation method is used.

Example 1

A feeder has a 100-ampere continuous load. The system source is 240 volts, 3 phase, and the supplying circuit breaker is 125 amperes. The feeder is in a trade size 1 1/ 4 aluminum conduit with three 1 AWG THHN copper conductors operating at their maximum temperature rating of 75°C. The circuit length is 150 ft, and the power factor is 85 percent. Using Table 9, determine the approximate voltage drop of this circuit.
Solution
Step 1. Find the approximate line-to-neutral voltage drop. Using the Table 9 column ``Effective Z at 0.85 PF for Uncoated Copper Wires," select aluminum conduit and size 1 AWG copper wire. Use the given value of 0.16 ohm per 1000 ft in the following formula:

Voltage drop $_{\text{(line to neutral)}}$ = table value X (circuit length / 1000 ft)
X circuit load
= 0.16 ohm X (150ft / 1000ft) X 100A
= 2.40V

Step 2. Find the line-to-line voltage drop.

Voltage drop $_{\text{(line to line)}}$ = voltage drop $_{\text{(line to neutral)}}$ X √3
= 2.40V X 1.732
= 4.157V

Step 3. Find the voltage drop expressed as a percentage of the circuit voltage.

Percentage voltage drop $_{\text{(line to line)}}$ = (4.157V / 240V) X 100
= 1.73% VD

Step 4. Find the voltage present at the load end of the circuit.
240V – 4.157V = 235.84V

Example 2

A 270-ampere continuous load is present on a feeder. The circuit consists of a single 4 in. PVC conduit with three 600 kcmil XHHW/USE aluminum conductors fed from a 480-volt, 3-phase, 3-wire source. The conductors are operating at their maximum rated temperature of 75°C. If the power factor is 0.7 and the circuit length is 250 ft, is the voltage drop excessive?
Solution

Step 1. Using the Table 9 column ``X L (Reactance) for All Wires," select PVC conduit and the row for size 600 kcmil. A value of 0.039 ohm per 1000 ft is given as this X L. Next, using the column ``Alternating-Current Resistance for Aluminum Wires," select PVC conduit and the row for size 600 kcmil. A value of 0.036 ohm per 1000 ft is given as this *R*.

Step 2. Find the angle representing a power factor of 0.7. Using a calculator with trigonometric functions or a trigonometric function table, find the arccosine ($\cos^{-1}$) of 0.7, which is 45.57 degrees. For this example, call this angle . Use the table or a calculator to find the sine of 45.57 degrees, which is 0.7141.

Step 3. Find the impedance (Z_C) corrected to 0.7 power factor (Z_C).

$Z_c = (R \text{ X } \cos\theta) + (X_L \text{ X } \sin\theta)$
= (0.036 X 0.7) + (0.039 X 0.7141)
= 0.0252 X 0.0279
= 0.0531 ohm to neutral

Step 4. As in Example 1, find the approximate line-to-neutral voltage drop.

Voltage drop $_{\text{(line to line)}}$ = Z_C X (circuit length / 1000ft) X circuit load
= 0.0530 X (250ft/1000ft) X 270A
= 3.577V

Step 5. Find the approximate line-to-line voltage drop.

Voltage drop $_{\text{(line to line)}}$ = voltage drop $_{\text{(line to neutral)}}$ X √3
= 3.577V x 1.732
= 6.196 V

Step 6. Find the approximate voltage drop expressed as a percentage of the circuit voltage.

Percentage voltage drop $_{\text{(line to line)}}$ = (6.196V / 480V) X 100
= 1.29%

Step 7. Find the voltage present at the load end of the circuit.
480 volts – 6.196V = 473.8V

Conclusion: According to 210.19(A)(1), FPN No. 4, this voltage drop does not appear to be excessive.

Table 9 Alternating-Current Resistance and Reactance for 600-Volt Cables, 3-Phase, 60 Hz, 75°C (167° F) - Three single conductors in Conduit

Ohms to neutral per killometter
Ohms to neutral per 1000 feet

	XL (Reactance) for AL Wires		Alternating-Current Resistance for Uncoated Copper Wires			Alternating-Current Resistance for Uncoated Aluminum Wires			Effective Z at 0.85 PF for Uncoated Copper Wires			Effective Z at 0.85 PF for Uncoated Aluminum Wires			
Size (AWG or kcmil)	PVC, Aluminum Conduits	Steel Conduit	PVC Conduit	Aluminum Conduit	Steel Conduit	PVC Conduit	Aluminum Conduit	Steel Conduit	PVC Conduit	Aluminum Conduit	Steel Conduit	PVC Conduit	Aluminum Conduit	Steel Conduit	Size (AWG or kcmil)
	0.190	0.240	10.200	10.200	10.200	---	---	---	8.900	8.900	8.900	---	---	---	
14	0.058	0.073	3.100	3.100	3.100	---	---	---	2.700	2.700	2.700	---	---	---	14
	0.177	0.223	6.600	6.600	6.600	10.500	10.500	10.500	5.600	5.600	5.600	9.200	9.200	9.200	
12	0.054	0.068	2.000	2.000	2.000	3.200	3.200	3.200	1.700	1.700	1.7	2.800	2.800	2.800	12
	0.164	0.207	3.900	3.900	3.900	6.600	6.600	6.600	3.600	3.600	3.600	5.900	5.900	5.900	
10	0.050	0.063	1.200	1.200	1.200	2.000	2.000	2.000	1.100	1.100	1.100	1.800	1.800	1.800	10
	0.171	0.213	2.560	2.560	2.560	4.300	4.300	4.300	2.260	2.260	2.300	3.600	3.600	3.600	
8	0.052	0.065	0.780	0.780	0.780	1.300	1.300	1.300	0.690	0.690	0.700	1.100	1.100	1.100	8
	0.167	0.210	1.610	1.610	1.610	2.660	2.660	2.660	1.440	1.480	1.480	2.330	2.360	2.360	
6	0.051	0.064	0.490	0.490	0.490	0.810	0.810	0.810	0.440	0.450	0.450	0.710	0.720	0.720	6
	0.157	0.197	1.020	1.020	1.020	1.670	1.670	1.670	0.950	0.950	0.980	1.510	1.510	1.510	
4	0.048	0.060	0.310	0.310	0.310	0.510	0.510	0.510	0.290	0.290	0.300	0.460	0.460	0.460	4
	0.154	0.194	0.820	0.820	0.820	1.310	1.350	1.310	0.750	0.790	0.790	1.210	1.210	1.210	
3	0.047	0.059	0.250	0.250	0.250	0.400	0.410	0.400	0.230	0.240	0.240	0.370	0.370	0.370	3
	0.148	0.187	0.620	0.660	0.660	1.050	1.050	1.050	0.620	0.620	0.660	0.980	0.980	0.980	
2	0.045	0.057	0.190	0.200	0.200	0.320	0.320	0.320	0.190	0.190	0.200	0.300	0.300	0.300	2
	0.151	0.187	0.490	0.520	0.520	0.820	0.850	0.820	0.520	0.520	0.520	0.790	0.790	0.820	
1	0.046	0.057	0.150	0.160	0.160	0.250	0.260	0.250	0.160	0.160	0.160	0.240	0.240	0.250	1
	0.144	0.180	0.390	0.430	0.390	0.660	0.690	0.660	0.430	0.430	0.430	0.620	0.660	0.660	
1/0	0.044	0.055	0.120	0.130	0.120	0.200	0.210	0.200	0.130	0.130	0.130	0.190	0.200	0.200	1/0
	0.141	0.177	0.330	0.330	0.330	0.520	0.520	0.520	0.360	0.360	0.360	0.520	0.520	0.520	
2/0	0.043	0.054	0.100	0.100	0.100	0.160	0.160	0.160	0.110	0.110	0.110	0.160	0.160	0.160	2/0
	0.138	0.171	0.253	0.269	0.259	0.430	0.430	0.430	0.289	0.302	0.308	0.430	0.430	0.460	
3/0	0.042	0.052	0.077	0.082	0.079	0.130	0.130	0.130	0.088	0.092	0.094	0.130	0.130	0.140	3/0
	0.135	0.167	0.203	0.220	0.207	0.330	0.360	0.330	0.243	0.256	0.262	0.360	0.360	0.360	
4/0	0.041	0.051	0.062	0.067	0.063	0.100	0.110	0.100	0.074	0.078	0.080	0.110	0.110	0.110	4/0
	0.135	0.171	0.171	0.187	0.177	0.279	0.295	0.282	0.217	0.230	0.240	0.308	0.322	0.330	
250	0.041	0.052	0.052	0.057	0.054	0.085	0.090	0.086	0.066	0.070	0.073	0.094	0.098	0.100	250
	0.135	0.167	0.144	0.161	0.148	0.233	0.249	0.236	0.194	0.207	0.213	0.269	0.282	0.289	
300	0.041	0.051	0.044	0.049	0.045	0.071	0.076	0.072	0.059	0.063	0.065	0.082	0.086	0.088	300
	0.131	0.164	0.125	0.141	0.128	0.200	0.217	0.207	0.174	0.190	0.197	0.240	0.253	0.262	
350	0.040	0.050	0.038	0.043	0.039	0.061	0.066	0.063	,053	0.058	0.060	0.073	0.077	0.080	350
	0.131	0.161	0.108	0.125	0.115	0.177	0.194	0.180	0.161	0.174	0.184	0.217	0.233	0.240	
400	0.040	0.049	0.033	0.038	0.035	0.054	0.059	0.055	0.049	0.053	0.056	0.066	0.071	0.073	400
	0.128	0.157	0.089	0.105	0.095	0.141	0.157	0.148	0.141	0.157	0.164	0.187	0.200	0.210	
500	0.039	0.048	0.027	0.032	0.029	0.043	0.048	0.045	0.043	0.048	0.050	0.057	0.061	0.064	500
	0.128	0.157	0.075	0.092	0.082	0.118	0.135	0.125	0.131	0.144	0.154	0.167	0.180	0.190	
600	0.039	0.048	0.023	0.028	0.025	0.036	0.041	0.038	0.040	0.044	0.047	0.051	0.055	0.058	600
	0.125	0.157	0.062	0.079	0.069	0.095	0.112	0.102	0.118	0.131	0.141	0.148	0.161	0.171	
750	0.038	0.048	0.019	0.024	0.021	0.029	0.034	0.031	0.036	0.040	0.043	0.045	0.049	0.052	750
	0.121	0.151	0.049	0.062	0.059	0.075	0.089	0.082	0.105	0.118	0.131	0.128	0.138	0.151	
1000	0.037	0.046	0.015	0.019	0.018	0.023	0.027	0.025	0.032	0.036	0.040	0.039	0.042	0.046	1000

Notes:

1. These values are based on the following constants: UL-Type RHH wires with Class B stranding, in cradled configuration. Wire conductivities are 100 percent IACS copper and 61 percent IACS aluminum, and aluminum conduit is 45 percent IACS. Capacitive reactance is ignored, since it is negligible at these voltages. These resistance values are valid only at 75°C (167°F) and for the parameters as given, but are representative for 600-volt wire types operating at 60 Hz.

2. Effective Z is defined as R cos (Ø) + X sin (Ø), where Ø is the power factor angle of the circuit. Multiplying current by effective impedance gives a good approximation for line-to-neutral voltage drop. Effective impedance values shown in this table are valid only at 0.85 power factor. For another circuit power factor (PF), effective impedance (Ze) can be calculated from R and XL values given in this table as follows: *Ze = R x PF + XL sin[arccos(PF)]*.

ELEVATOR TYPICAL CONDITIONS

	TRAVEL HEIGHT MAX	MAX STOPS	SPEED FT/MIN
HOLELESS HYDRAULIC	20"	3	100,125
TELESCOPIC HOLELESS HYDROLIC	44'1"	5	100,125
ROPED HOLELESS HYDROLIC	60'	7	100,125,150
HOLED HYDROLIC	60'	7	100,125,150
MACHINE ROOMLESS	196'@200'/MIN 300'@350'/MIN	30	200,350,400

OTIS ELEVATOR
HYDRAULIC HORSEPOWERS CAN RANGE FROM 15 TO 60

2500lb 17hp – 60hp
3000lb 21hp – 60hp
3500lb 24hp – 60hp
4000lb 28hp – 60hp
4500lb 31hp – 60hp
5000lb 35hp – 60hp

EMERGENCY POWER IF AVAILABLE AND SHUNT TRIP.

75–80KVA GENERATOR

FUEL CONSUMPTION Cfh (Cubic feet hour) – LP (NATURAL)			
100% LOAD	75% LOAD	50% LOAD	25% LOAD
325 (826)	244 (622)	166 (424)	?? (??)

DIMENSIONS OF A 400KW GENSET: 226" X 87"

230–250KVA GENERATOR

FUEL CONSUMPTION (GPH)			
100% LOAD	75% LOAD	50% LOAD	25% LOAD
16 – 19	12 – 14	8 – 9	4.5 – 5.2

WITH A 400 GALLON TANK, MINIMUM RUNNING TIME WILL BE 21 HOURS. MAX = 88 HOURS. AT 100% LOAD DIESEL FUEL WOULD COST $67(HR) BASED ON $3.50 A GALLON. $1400 FILLUP.

SAFETY SWITCH SCHEDULE

SYMBOL	AMPS	POLES
S1	30	2
S2	30	3
S3	30	4WSN
S4	60	2
S5	60	3
S6	60	4WSN
S7	100	2
S8	100	3
S9	100	4WSN
S10	200	2
S11	200	3
S12	200	4WSN
S13	400	2
S14	400	3
S15	400	4WSN
S16	600	2
S17	600	3
S18	600	4WSN
S19	800	2
S20	800	3
S21	800	4WSN
S22	1200	2
S23	1200	3
S24	1200	4WSN

ALL SWITCHES FUSIBLE UNLESS NOTED ON DRAWINGS.

STANDARD KAIC PANELBOARD RATINGS

480V	208V
14K	10K
18K	18K
25K	22K
30K	25K
35K	65K
50K	–
65K	–
100K	–
200K	–

AVERAGE PANELBOARD SIZE (<60AIC)

AMPS	SIZE		
	W	D	H
225A	20"	5.75"	60"
400A	24"	6.5"	60"
600A	30"	6.5"	74"
800A	32"	8.25"	80"
1200A	42"	10"	90"
1600A	46"	13"	90"

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326 Integrated Gas Spacer Cable: Type IGS
328 Medium Voltage Cable: Type MV
330 Metal–Clad Cable: Type MC
332 Mineral–Insulated, Metal–Sheathed Cable:
334 Nonmetallic–Sheathed Cable: Types NM,
336 Power and Control Tray Cable: Type TC
338 Service–Entrance Cable: Types SE and
340 Underground Feeder and Branch–Circuit
342 Intermediate Metal Conduit: Type IMC
344 Rigid Metal Conduit: Type RMC
348 Flexible Metal Conduit: Type FMC
350 Liquidtight Flexible Metal Conduit: Type LFMC
352 Rigid Polyvinyl Chloride Conduit: Type PVC
353 High Density Polyethylene Conduit: Type HDPE Conduit
354 Nonmetallic Underground Conduit with Conductors: Type NUCC
355 Reinforced Thermosetting Resin Conduit: Type RTRC
356 Liquidtight Flexible Nonmetallic Conduit: Type LFNC
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362 Electrical Nonmetallic Tubing: Type ENT
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370 Cablebus
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374 Cellular Metal Floor Raceways
376 Metal Wireways
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Chapter 9 Tables
TABLES
Conductors in Conduit

"Intumescent" means that the material expands when exposed to fire or heat to fill a void in the penetration caused by the deformation or combustion of the penetration item. An "endothermic" product blocks heat by chemical absorption and moisture release. "Elastomeric" products are flexible and prevent passage of heat and gasses while permitting movement of the assembly.

Firestopping systems are typically categorized by through–penetration of:
- F–rating, Flame Ratings (flames) opening shall also withstand a hose stream test.
- T–rating, Thermal Ratings (temperature)
- L–rating, Smoke Ratings (smoke)
  - L–rating is tested under a differential pressure of 0.30 inches water column (75 Pa) at 75°F and at 400°F.

UL NUMBERING SYSTEM

The first alpha component is an F, W or C.
F ..... signifies a floor is being penetrated
W ..... signifies a wall is being penetrated
C ..... signifies either a floor or a wall is being penetrated.

The second alpha component may be any letter. The significance of the letter used is:

Letter	Description
A	Concrete floors with a minimum thickness less than or equal to 5 in.
B	Concrete floors with a minimum thickness greater than 5 in.
C	Framed floors
D	Steel decks in marine vessels
E	Floor–ceiling assemblies consisting of concrete with membrane protection
F – I	Not used at present time
J	Concrete or masonry walls with a minimum thickness less than or equal to 8 in.
K	Concrete or masonry walls with a minimum thickness greater than 8 in.
L	Framed walls
M	Bulkheads in marine vessels
N	Composite panel walls
O – Z	Not used at present time

The numeric component uses sequential numbers to identify the penetrating item. The significance of the number used is:

No. Range	Description
0000–0999	No penetrating items
1000–1999	Metallic pipe, conduit or tubing
2000–2999	Nonmetallic pipe, conduit or tubing
3000–3999	Electrical cable
4000–4999	Cable trays with electrical cable
5000–5999	Insulated pipe
6000–6999	Miscellaneous electrical penetrants, such as busducts
7000–7999	Miscellaneous mechanical penetrants, such as air ducts
8000–8999	Groupings of penetrations, including any combination of items listed above
9000–9999	Not used at present time

ELECTRICAL FORMULAE

	ALTERNATING CURRENT	
TO OBTAIN	SINGLE PHASE	THREE PHASE
KILOWATTS	$\frac{V \times I \times P.F.}{1000}$	$\frac{1.732 \times V \times I \times P.F.}{1000}$
KVA	$\frac{V \times I}{1000}$	$\frac{1.732 \times V \times I}{1000}$
AMPERES	$\frac{HP \times 746}{V \times P.F. \times EFF.}$	$\frac{HP \times 746}{1.732 \times V \times EFF. \times P.F.}$
AMPERES	$\frac{KW \times 1000}{V \times P.F.}$	$\frac{KW \times 1000}{1.732 \times V \times P.F.}$
AMPERES	$\frac{KWA \times 1000}{V}$	$\frac{KWA \times 1000}{1.732 \times V}$
P.F.	$\frac{INPUT\ WATTS}{V \times I}$	$\frac{INPUT\ WATTS}{1.732 \times V \times I}$

CONDUIT TABLE

CONDUIT SIZE	MIN BEND RADIUS*	OUTSIDE DIAMETER TYPE/SUPPORT MAX*** EMT/3'**	IMC/3'**	RMC/3'**	PVC/3'**
1/2"	4"	0.71/10'	0.82/10'	0.84/10'	0.84/3'
3/4"	4–1/2"	0.92/10'	1.03/10'	1.05/10'	1.05/3'
1"	5–3/4"	1.16/10'	1.29/10'	1.32/12'	1.32/3'
1–1/4"	7–1/4"	1.51/10'	1.64/10'	1.66/14'	1.66/3'
1–1/2"	8–1/4"	1.74/10'	1.88/10'	1.90/14'	1.90/5'
2"	9–1/2"	2.20/10'	2.36/10'	2.38/16'	2.38/5'
2–1/2"	10–1/2"	2.88/10'	2.86/10'	2.88/20'	2.88/6'
3"	13"	3.50/10'	3.48/10'	3.50/20'	3.50/6'
3–1/2"	15"	4.00/10'	3.97/10'	4.00/20'	4.00/7'
4"	16"	4.50/10'	4.47/10'	4.50/20'	4.50/7'
5"	24"			5.56/20'	5.56/7'
6"	30"				6.63/8'

* – TABLE 2, CHAPTER 9, ** – MAX SUPPORT DISTANCE FROM BOX,
*** – BASED ON NEC (EMT) 358, (IMC) 342, (RIGID) 344, (PVC) 352
SCHEDULE 40 AND 80 PVC HAVE SAME O.D. SO CONNECTORS FIT EACH.

POWER FACTOR Φ cos = .95

NOMINAL (kW)	DEMAND LOAD (A) 120V/1ø	208V/1ø	277V/1ø	208V/3ø	480V/3ø
0.1	0.88	0.51	0.38	0.10	0.13
0.2	1.76	1.01	0.76	0.58	0.25
0.5	4.39	2.53	1.90	1.46	0.63
1.0	8.77	5.06	3.80	2.90	1.25
1.5	13.16	7.60	5.70	4.38	1.90
2.0	17.54	10.12	7.60	4.67	2.51
2.5	21.93	12.65	9.50	7.30	3.16
3.0	26.32	15.18	11.40	8.77	3.80
3.5	30.70	17.71	13.30	10.22	4.43
4.0	35.09	20.24	15.20	11.69	5.05
4.5	39.48	22.78	17.10	13.15	5.70
5.0	43.86	25.30	19.00	14.55	6.31
6.0	52.63	30.36	22.80	17.53	7.60
7.0	61.40	35.43	26.60	20.42	8.85
8.0	70.18	40.49	30.40	23.32	10.10
9.0	78.95	45.55	34.20	26.30	11.40
10.0	87.72	50.61	38.00	29.19	12.65

AVERAGE POWER FACTOR VALUES

LOAD	P.F.%
RECEPTACLES	80–95
INDUCTION MOTOR	70–90
SPEED DRIVE	90–98
MAGNETIC BALLAST	70–80
ELECTRONIC BALLAST	90–95
ARC WELDERS	35–80
RESISTANCE HEATING	100
INDUCTION MOTORS	
LOAD 25%	55
LOAD 50%	73
LOAD 75%	80
LOAD 100%	85
FACTIONAL HP	55–75
1–10	75–85
SQUIRREL CAGE MOTOR	
HIGH SPEED	75–90
LOW SPEED	85–92
WOUND ROTOR	80–90
SYNCHRONOUS MOTOR	80–100
POWER CONVERTER	50–90

(J) SURFACE/CONCEALED [J] FLUSH FLOOR/CEIL/WALL

CEILING	WALL
30' X 30' = 30cd	30' X 30' = 34cd
50' x 50' = 110cd	50' X 50' = 94cd

SIGNAL – MAXIMUM DISTANCE 100' IN CORRIDOR NFPA 72 23.8.6.2

OPTIMAL TONE FOR WAKING SOMEONE OUT OF SLEEP IS 520Hz (SLEEP: 70–90 MINUTE CYCLE)

COPIERS – 120V/20A – W/DATA
WATER COOLER, 750W@, GFCI, (2) COOLERS, 1 CIR WASHER/DRYER COMBO, 240V/30A W/NEU
HAND DRYER 120V/25A

NEC 210.8(B) OTHER THAN DWELLINGS – RECEPTACLE GFCI PROTECTION REQUIRED IN (1)BATHROOM, (2)KITCHENS, (3)ROOFTOPS & (4)OUTDOORS REGARDLESS OF WHERE IT IS, AND (5)SINKS WITHIN 6' OF OUTSIDE EDGE IN ALL OTHER SPACES. NEC 422.51 VENDING MACHINES SHALL BE GFCI PROTECTED.

based on 2014 NEC edited: AUG 2015
MATH/EQUIPMENT/NEC®
REFER TO NATIONAL, STATE, LOCAL AND AHJ FOR CODES AND EXACT REQUIREMENTS.

DESIGNERS GUIDE

II. 600 Volts, Nominal, or Less
110.26 Spaces About Electrical Equipment.
(1) Depth of Working Space. The depth of the working space in the direction of live parts shall not be less than that specified in Table 110.26(A)(1) unless the requirements of 110.26(A)(1)(a), (A)(1)(b), or (A)(1)(c) are met. Distances shall be measured from the exposed live parts or from the enclosure or opening if the live parts are enclosed.
Note: Where the conditions are as follows:
Condition 1 – Exposed live parts on one side of the working space and no live or grounded parts on the other side of the working space, or exposed live parts on both sides of the working space that are effectively guarded by insulating materials.
Condition 2 – Exposed live parts on one side of the working space and grounded parts on the other side of the working space. Concrete, brick, or tile walls shall be considered as grounded.
Condition 3 – Exposed live parts on both sides of the working space.
...
110.26(C)(2) LARGE EQUIPMENT 1200 AMPS AND ABOVE...
(2) Large Equipment. For equipment rated 1200 amperes or more and over 1.8 m (6 ft) wide that contains overcurrent devices, switching devices, or control devices, there shall be one entrance to and egress from the required working space not less than 610 mm (24 in.) wide and 2.0 m (6½ ft) high at each end of the working space. A single entrance to and egress from the required working space shall be permitted where either of the conditions in 110.26(C)(2)(a) or (C)(2)(b) is met.
Unobstructed Egress. Where the location permits a continuous and unobstructed way of egress travel, a single entrance to the working space shall be permitted. Extra Working Space. Where the depth of the working space is twice that required by 110.26(A)(1), a single entrance shall be permitted. It shall be located such that the distance from the equipment to the nearest edge of the entrance is not less than the minimum clear distance specified in Table 110.26(A)(1) for equipment operating at that voltage and in that condition.
(1) Personnel Doors. Where equipment rated 800 A or more that contains overcurrent devices, switching devices, or control devices is installed and there is a personnel door(s) intended for entrance to and egress from the working space less than 7.6 m (25 ft) from the nearest edge of the working space, the door(s) shall open in the direction of egress and be equipped with listed panic hardware.
(A) Illumination. Illumination shall be provided for all working spaces about service equipment, switchboards, switchgear, panelboards, or motor control centers installed indoors and shall not be controlled by automatic means only. Additional lighting outlets shall not be required where the work space is illuminated by an adjacent light source or as permitted by 10.70(A)(1), Exception No. 1, for switched receptacles.

2014 NEC – Table 310.15(B)(2)(b) Ambient Temperature Correction Factors Based on 40°C (104°F)

For ambient temperatures other than 40°C (104°F), multiply the allowable ampacities specified in the ampacity tables by the appropriate correction factor shown below.

AMBIENT TEMPERATURE CELSIUS	RATING OF CONDUCTOR 60°	75°	90°	150°	200°	250°	AMBIENT TEMPERATURE FAHRENHEIT
10 or less	1.58	1.36	1.26	1.13	1.09	1.07	50 or less
11–15	1.5	1.31	1.22	1.11	1.08	1.06	51–59
16–20	1.41	1.25	1.18	1.09	1.06	1.05	60–68
21–25	1.32	1.2	1.14	1.07	1.05	1.04	69–77
26–30	1.22	1.13	1.1	1.04	1.03	1.02	78–86
31–35	1.12	1.07	1.05	1.02	1.02	1.01	87–95
36–40	1.00	1.00	1.00	1.00	1.00	1.00	96–104
41–45	0.87	0.93	0.95	0.98	0.98	0.99	105–113
46–50	0.71	0.85	0.89	0.95	0.97	0.98	114–122
51–55	0.5	0.76	0.84	0.93	0.95	0.96	123–131
56–60	–	0.65	0.77	0.9	0.94	0.95	132–140
61–65	–	0.53	0.71	0.88	0.92	0.94	141–149
66–70	–	0.38	0.63	0.85	0.9	0.93	150–158
71–75	–	–	0.55	0.83	0.88	0.91	159–167
76–80	–	–	0.45	0.8	0.87	0.9	168–176
81–90	–	–	–	0.74	0.83	0.87	177–194
91–100	–	–	–	0.67	0.79	0.85	195–212
101–110	–	–	–	0.6	0.75	0.82	213–230
111–120	–	–	–	0.52	0.71	0.79	231–248
121–130	–	–	–	0.43	0.66	0.76	249–266
131–140	–	–	–	0.3	0.61	0.72	267–284
141–160	–	–	–	–	0.5	0.65	285–320
161–180	–	–	–	–	0.35	0.58	321–356
181–200	–	–	–	–	–	0.49	357–392
201–225	–	–	–	–	–	0.35	393–437

NEC 110.26(A)(1) WORKING SPACES

Nominal Voltage to Ground	Minimum Clear Distance Condition 1	Condition 2	Condition 3
0–150	914 mm (3 ft)	914 mm (3 ft)	914 mm (3 ft)
151–600	914 mm (3 ft)	1.07 m (3 ft 6 in.)	1.22 m (4 ft)

TABLE 430–150 FULL–LOAD CURRENT THREE PHASE ALTERNATING CURRENT MOTORS.

HP	INDUCTION TYPE SQUIRREL–CAGE AND WOUND–ROTOR AMPERES 208V	230V	460V	575V
1/2	2.4	2.2	1.1	0.9
3/4	3.5	3.2	1.6	1.3
1	4.6	4.2	2.1	1.7
1½	6.6	6.0	3.0	2.4
2	7.5	6.8	3.4	2.7
3	10.6	9.6	4.8	3.9
5	16.7	15.2	7.6	6.1
7½	24.2	22	11	9
10	30.8	28	14	11
15	46.2	42	21	17
20	59.4	54	27	22
25	74.8	68	34	27
30	88	80	40	32
40	114	104	52	41
50	143	130	65	52
60	169	154	77	62
75	211	192	96	77
100	273	248	124	99
125	343	312	156	125
150	396	360	180	144
200	528	480	240	192
250	–	–	302	242
300	–	–	361	289

TABLE 430–148 FULL–LOAD CURRENT SINGLE PHASE ALTERNATING CURRENT MOTORS.

HP	115V	200V	208V	230V
1/6	4.4	2.5	2.4	2.2
1/4	5.8	3.3	3.2	2.9
1/3	7.2	4.1	4.0	3.6
1/2	9.8	5.6	5.4	4.9
3/4	13.8	7.9	7.6	6.9
1	16	9.2	8.8	8.0
1–1/2	20.0	11.5	11.0	10.0
2	24.0	13.8	13.2	12.0
3	34.0	19.6	18.7	17.0
5	56.0	32.3	30.8	28.0
7–1/2	80.0	46.0	44.0	40.0
10	100.0	57.5	55.0	50.0

NEC 310–15(B)(16)

SIZE	TEMPERATURE RATING OF CONDUCTOR		
	60° (140°F)	75° (167°F)	90° (194°F)
AWG	TYPE: TW, UF	TYPE: FEPW, RH, RHW, THHW, THW, THWN, XHHW, USE, ZW	TYPE: TBS, SA, SIS, FEP, FEPB, MI, RHH, RHW–2, THHN, THHW, THW–2, THWN–2, USE–2, XHH, XHHW, XHHW–2, ZW–2
	COPPER		
18	–	–	14
16	–	–	18
14*	15	20	25
12*	20	25	30
10*	30	35	40
8	40	50	55
6	55	65	75
4	70	85	95
3	85	100	115
2	95	115	130
1	110	130	145
1/0	125	150	170
2/0	145	175	195
3/0	165	200	225
4/0	195	230	260
250	215	255	290
300	240	285	320
350	260	310	350
400	280	335	380
500	320	380	430
600	350	420	475
700	385	460	520
750	400	475	535
800	410	490	555
900	435	520	585

* SEE 240.4(D) SMALL CONDUCTORS

MAXIMUM NUMBER OF CABLES BASED UPON ALLOWABLE FILL

CONDUIT SIZE	CABLE OUTSIDE DIAMETER (IN./CAT DESIGNATION)						
	.18/5E	.22/6	.24/6	.29/6	.31/6A	.37/6A	.53
3/4"	5	4	3	2	2	1	0
1"	8	7	6	3	3	2	1
1¼"	14	12	10	6	4	3	1
1½"	18	16	15	7	6	4	
2"	26	22	20	14	12	7	4
2½"	40	36	30	17	14	12	6
3"	60	50	40	20	20	17	7
3½"	–	–	–	–	–	22	12
4"	–	–	–	–	–	30	14
2"x6" CT	111	~72	–	45	~35	–	–
4"x8" CT	298	~192	–	121	~93	–	–
6"x20" CT	1116	~722	–	454	~350	–	–

MAX 295' & MAXIMUM CONDUIT FILL OF 40% | JBOX'S ARE SIZED PER BEND RADIUS & SHOULD EXCEED 4x OD FOR UTP AND SHIELDED CABLE.

ARTICLE 250 – GROUNDING

CIRCUITS

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 WIRE NO.	ALUMINUM OR COPPER–CLAD ALUMINUM WIRE NO.
15	14	12
20	12	10
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	750
5000	700	1200
6000	800	1200

SERVICE ENTRANCE

TABLE 250–66 GROUNDING ELECTRODE CONDUCTOR FOR ALTERNATING–CURRENT SYSTEMS

SIZE OF LARGEST SERVICE–ENTRANCE CONDUCTOR OR EQUIVALENT AREA FOR PARALLEL CONDUCTORS		SIZE OF GROUNDING ELECTRODE CONDUCTOR	
COPPER	ALUMINUM OR COPPER–CLAD ALUMINUM	COPPER	ALUMINUM OR COPPER–CLAD ALUMINUM
2 OR SMALLER	1/0 OR SMALLER	8	6
1 OR 1/0	2/0 OR 3/0	6	4
2/0 OR 3/0	4/0 OR 250	4	2
OVER 3/0 THROUGH 350	OVER 250 THROUGH 500	2	1/0
OVER 350 THROUGH 600	OVER 500 THROUGH 900	1/0	3/0
OVER 600 THROUGH 1100	OVER 900 THROUGH 1750	2/0	4/0
OVER 1100	OVER 1750	3/0	250

RECOMMENDED: ¾ HP & ABOVE 480V/3ø
½ HP & BELOW 120V/1ø

MOTORS

208V/3Ph AC MOTOR

INDUCTION TYPE SQUIRREL–CAGE AND WOUND–ROTOR AMPERES					
HP	KW	FLA	BKR	FUSE	WIRE/CONDUIT
1/2	0.9	2.5	15	3.5	3#12, 1#12 GND, 1/2"C.
3/4	1.4	3.7	15	5	3#12, 1#12 GND, 1/2"C.
1	1.8	4.8	15	7	3#12, 1#12 GND, 1/2"C.
1½	2.5	6.9	15	10	3#12, 1#12 GND, 1/2"C.
2	2.9	7.8	15	10	3#12, 1#12 GND, 1/2"C.
3	4.0	11.0	20	15	3#12, 1#12 GND, 1/2"C.
5	6.4	17.5	35	25	3#10, 1#10 GND, 1/2"C.
7½	9.2	25.3	50	35	3#8, 1#10 GND, 3/4"C.
10	11.7	32.2	50	45	3#8, 1#10 GND, 3/4"C.
15	17.5	48.3	100	70	3#6, 1#8 GND, 1"C.
20	22.4	62.1	100	90	3#4, 1#8 GND, 1"C.
25	28.2	78.2	125	110	3#3, 1#6 GND, 1–1/4"C.
30	33.2	92.0	150	150	3#2, 1#6 GND, 1–1/4"C.
40	43.3	120.0	200	175	3#1/0, 1#6 GND, 1–1/2"C.
50	55.9	150.0	250	225	3#3/0, 1#4 GND, 2"C.
60	63.8	177.0	300	250	3#4/0, 1#4 GND, 2"C.
75	79.7	221.0	400	350	3#300 MCM, 1#3 GND, 2–1/2"C.
100	102.7	285.0	400	450	3#500 MCM, 1#2 GND, 3"C.
125	129.4	359.0	500	500	(2) 3#4/0, 1#4 GND, 2"C.
150	149.2	414.0	600	600	(2) 3#300 MCM, 1#3 GND, 2–1/2"C.

480V/3Ph AC MOTOR

INDUCTION TYPE SQUIRREL–CAGE AND WOUND–ROTOR AMPERES					
HP	KW	FLA	BKR	FUSE	WIRE/CONDUIT
1/2	0.9	1.1	15	1.6	3#12, 1#12 GND, 1/2"C.
3/4	1.4	1.6	15	2.25	3#12, 1#12 GND, 1/2"C.
1	1.8	2.1	15	3.2	3#12, 1#12 GND, 1/2"C.
1½	2.5	3.0	15	4.5	3#12, 1#12 GND, 1/2"C.
2	2.9	3.4	15	5	3#12, 1#12 GND, 1/2"C.
3	4.0	4.8	15	7	3#12, 1#12 GND, 1/2"C.
5	6.4	7.6	20	12	3#12, 1#12 GND, 1/2"C.
7½	9.2	11.0	30	17.5	3#12, 1#12 GND, 1/2"C.
10	11.7	14.0	35	20	3#12, 1#12 GND, 1/2"C.
15	17.5	21.0	50	30	3#10, 1#10 GND, 1/2"C.
20	22.5	27.0	50	40	3#10, 1#10 GND, 1/2"C.
25	28.3	34.0	70	50	3#8, 1#10 GND, 3/4"C.
30	33.3	40.0	100	60	3#8, 1#10 GND, 3/4"C.
40	43.3	52.0	100	80	3#6, 1#6 GND, 3/4"C.
50	54.1	65.0	100	100	3#4, 1#8 GND, 1"C.
60	64.1	77.0	125	125	3#3, 1#6 GND, 1–1/4"C.
75	79.9	96.0	150	150	3#1, 1#6 GND, 1–1/4"C.
100	103.1	124.0	200	200	3#2/0, 1#6 GND, 2"C.
125	129.7	156.0	250	225	3#3/0, 1#4 GND, 2"C.
150	149.7	180.0	300	250	3#4/0, 1#4 GND, 2"C.
200	199.6	240.0	400	350	3#350 MCM, 1#3 GND, 2–1/2"C.

TABLE 1 PERCENT OF CROSS SECTION OF CONDUIT AND TUBING FOR CONDUCTORS	NUMBER OF C.C.C.	ALL CONDUCTOR TYPES
	1	53%
	2	31%
C.C.C. – CURRENT CARRYING CONDUCTORS	OVER 2	40%

SINGLE PHASE

INDUCTION TYPE SQUIRREL–CAGE AND WOUND–ROTOR AMPERES					
HP	KW	FLA	BKR	FUSE	WIRE/CONDUIT
120V/1PH					
1/6	0.6	4.4	15	6.25	3#12, 1#12 GND, 1/2"C.
1/4	0.7	5.8	15	9.0	3#12, 1#12 GND, 1/2"C.
1/3	0.9	7.2	15	10.0	3#12, 1#12 GND, 1/2"C.
1/2	1.2	9.8	20	15.0	3#12, 1#12 GND, 1/2"C.
3/4	1.7	13.8	25	20.0	3#12, 1#12 GND, 1/2"C.
1	2.0	16.0	30	25.0	3#12, 1#12 GND, 1/2"C.
1–1/2	2.4	20.0	40	30.0	3#12, 1#12 GND, 1/2"C.
2	2.9	24.0	50	30.0	3#10, 1#10 GND, 1/2"C.
3	4.1	34.0	70	50.0	3#8, 1#12 GND, 3/4"C.
5	6.8	56.0	90	80.0	3#4, 1#10 GND, 1"C.
7–1/2	9.6	80.0	110	100.0	3#3, 1#8 GND, 1–1/4"C.
230V/1PH					
1/6	0.6	2.2	15	3.2	3#12, 1#12 GND, 1/2"C.
1/4	0.7	2.9	15	4.5	3#12, 1#12 GND, 1/2"C.
1/3	0.9	3.6	15	5.6	3#12, 1#12 GND, 1/2"C.
1/2	1.2	4.9	15	7.0	3#12, 1#12 GND, 1/2"C.
3/4	1.6	6.9	15	10.0	3#12, 1#12 GND, 1/2"C.
1	1.9	8.0	15	12.0	3#12, 1#12 GND, 1/2"C.
1½	2.3	10.0	20	15.0	3#12, 1#12 GND, 1/2"C.
2	2.8	12.0	25	20.0	3#12, 1#12 GND, 1/2"C.
3	4.0	17.0	35	25.0	3#12, 1#12 GND, 1/2"C.
5	6.5	28.0	60	40.0	3#10, 1#12 GND, 1/2"C.
7½	9.2	40.0	80	60.0	3#8, 1#10 GND, 3/4"C.
10	11.5	50.0	90	60.0	3#6, 1#10 GND, 3/4"C.
277V1/1PH					
1/6	0.5	1.8	15	3.0	3#12, 1#12 GND, 1/2"C.
1/4	0.7	2.4	15	4.0	3#12, 1#12 GND, 1/2"C.
1/3	.9	3.0	15	5.0	3#12, 1#12 GND, 1/2"C.
1/2	1.2	4.1	15	7.0	3#12, 1#12 GND, 1/2"C.
3/4	1.6	5.7	15	8.5	3#12, 1#12 GND, 1/2"C.
1	1.9	6.6	15	10.0	3#12, 1#12 GND, 1/2"C.
1½	2.3	8.3	15	12.5	3#12, 1#12 GND, 1/2"C.
2	2.8	10.0	20	15.0	3#12, 1#12 GND, 1/2"C.
3	3.9	14.1	30	25.0	3#10, 1#10 GND, 1/2"C.
5	6.5	23.2	50	35.0	3#6, 1#10 GND, 3/4"C.
7½	9.2	33.2	70	50.0	3#4, 1#8 GND, 1"C.
10	11.5	41.5	80	50.0	3#3, 1#8 GND, 1–1/4"C.

TABLE 310–15(B)(3)(a) ADJUSTMENT FACTORS FOR MORE THAN 3 CURRENT CARRYING CONDUCTORS IN A RACEWAY OR CABLE

TOTAL NUMBER OF CONDUCTORS	PERCENT OF VALUES IN TABLES 315(B)... AS ADJUSTED FOR AMBIENT TEMPERATURE IF NECESSARY
4–6	80
7–9	70
10–20	50
21–30	45
31–40	40
41 & ABOVE	35

RECEPTACLE LOADS @180 WATTS/A EACH	
# REC.	WATTS/A
1	180/1.6
2	360/3.2
3	540/4.7
4	720/5.3
5	900/7.9
6	1080/9.5
7	1260/11.0
8	1440/12.6
9	1620/14.2
10	1800/15.8
11	1980/17.3

APPENDIX C

TABLE C1, C4, C8, C9 & C10. – DESIGNER CONSOLIDATION (WORST CASE C9) NUMBER OF CONDUCTORS AND FIXTURE WIRES IN EMT, IMC, RIGID AND PVC (SCHD 40 & 80), BASED ON CONDUIT FILL TABLES, CHAPTER 9

TYPE	CONDUCTOR SIZE (AWG/kcmil)	CONDUCTORS TRADE SIZE (IN.)										
		1/2"	3/4"	1"	1¼"	1½"	2"	2½"	3"	3½"	4"	5"	6"
THHN, THWN, THWN–2	14	9	17	28	51	70	118	170	265	358	464	736	1055
	12	6	12	20	37	51	86	124	193	261	338	537	770
	10	4	7	13	23	32	54	78	122	164	213	338	485
	8	2	4	7	13	18	31	45	70	95	123	195	279
	6	1	3	5	9	13	22	32	51	68	89	141	202
	4	1	1	3	6	8	14	20	31	42	54	86	134
	3	1	1	3	5	7	12	17	26	35	46	73	105
	2	1	1	2	4	6	10	14	22	30	39	61	88
	1	0	1	1	3	4	7	10	16	22	29	45	65
	1/0	0	1	1	2	3	6	9	14	18	24	38	55
	2/0	0	1	1	1	3	5	7	11	15	20	32	46
	3/0	0	1	1	1	2	4	6	9	13	17	26	38
	4/0	0	0	1	1	1	3	5	8	10	14	22	31
	250	0	0	1	1	1	3	4	6	8	11	18	25
	300	0	0	0	1	1	2	3	5	7	9	15	22
	350	0	0	0	1	1	1	3	5	6	8	13	19
	400	0	0	0	1	1	1	3	4	5	7	12	17
	500	0	0	0	0	1	1	2	3	4	6	10	14
	600	0	0	0	0	1	1	1	3	3	5	6	12
	700	0	0	0	0	1	1	1	2	3	4	7	10
	750	0	0	0	0	1	1	1	2	3	4	7	9
	800	0	0	0	0	1	1	1	2	3	4	6	9
	900	0	0	0	0	0	1	1	1	3	3	6	8
	1000	0	0	0	0	0	1	1	1	2	3	5	7

GROUNDING SCHEDULE FOR RISER DIAGRAM.

GROUNDING SCHEDULE	
Ⓐ	1"C. WITH (1) 3/0 GROUND TO METALLIC COLD WATER PIPE (TO MDP)
Ⓑ	1"C. WITH (1) 3/0 GROUND TO BUILDING STEEL (TO MDP)
Ⓒ	1"C. WITH (1) 3/0 GROUND TO GROUND RING (TO MDP)
Ⓓ	1–1/4"C. WITH (1) #250 MCM, UTILITY XFMR GND FIELD (TO MDP)
Ⓔ	1"C. WITH (1) #2/0 GROUND TO BUILDING STEEL (TO XFMR)
Ⓕ	3/4"C. WITH (1) #1 GROUND TO COMM GROUND BUSES (TO TELE BRD)

NEC 240.4 (B) & (C) PROTECTION OF CONDUCTORS

CIRCUIT TYPES
- BRANCH
- POWER
- RECEPTACLE
- LIGHTING
- DISTRIBUTION

DISTRIBUTION TYPES
- SERVICE ENTRANCE
- DISTRIBUTION
- DISTRIBUTION 3ø ONLY

DESIGNERS GUIDE

based on 2011 NEC edited: JUN 2014

WIRE/CONDUIT/MOTOR

REFER TO NATIONAL, STATE, LOCAL AND AHJ FOR CODES AND EXACT REQUIREMENTS.

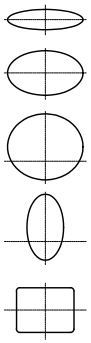
POWER RISER FEEDER SCHEDULE

FEEDER	PANELBOARD FEEDER SCHEDULE	FEEDER	PANELBOARD FEEDER SCHEDULE
30Y	1"C WITH 4#10 & 1#10 GND	30D	3/4"C WITH 3#10 & 1#10 GND.....(15KVA)
60Y	1–1/4"C WITH 4#4 &1#10 GND.....(15KVA)	50D	1"C WITH 3#6 & 1#10 GND.....(30KVA)
90Y	1–1/2" WITH 4#2 & 1#8 GND	70D	1–1/4"C WITH 3#4 & 1#8 GND.....(45KVA)
100Y	2" WITH 4#1 & 1#4 GND	100D	1–1/4"C WITH 3#1 & 1#8 GND
110Y	2" WITH 4#1 & 1#4 GND.....(30KVA)	110D	1–1/4"C WITH 3#1 & 1#6 GND
150Y	2"C WITH 4#1/0 & 1#4 GND	125D	1–1/4"C WITH 3#1 & 1#6 GND.....(75KVA)
175Y	2"C WITH 4#2/0 & 1#4 GND.....(45KVA)	150D	2"C WITH 3#1/0 & 1#6 GND
200Y	2–1/2"C WITH 4#3/0 & 1#6 GND	175D	2"C WITH 3#2/0 & 1#6 GND.....(112.5KVA)
200YG	2–1/2"C WITH 4#3/0 & 1#6 GND & 1#6 ISOLATED GND	200D	2"C WITH 3#3/0 & 1#6 GND
225Y	2–1/2"C WITH 4#4/0 & 1#4 GND	225D	2–1/2"C WITH 3#4/0 & 1#4 GND
250Y	3"C WITH 4#250MCM & 1#4 GND	80SE	1–1/4"C WITH 4#3
300Y	3"C WITH 4#350MCM & 1#4 GND.....(75KVA)	200SE	2–1/2"C WITH 4#4/0
400Y	3–1/2"C WITH 4#500MCM & 1#1/0 GND.....(112.5KVA)	600SE	(2) PARALLEL RUNS, EACH WITH 3"C & 4#350MCM
500Y	(2) PARALLEL RUNS, EACH WITH 2–1/2"C, 4#250MCM & 1#2 GND	1000SE	(3) PARALLEL RUNS, EACH WITH 3"C & 4#400MCM
600Y	(2) PARALLEL RUNS, EACH WITH 3"C, 4#350MCM & 1#1 GND	1200SE	(4) PARALLEL RUNS, EACH WITH 3"C & 4#350MCM
800Y	(3) PARALLEL RUNS, EACH WITH 3"C, 4#300MCM & 1#1/0 GND	2000SE	(5) PARALLEL RUNS, EACH WITH 4"C & 4#600MCM
1000Y	(3) PARALLEL RUNS, EACH WITH 3–1/2"C, 4#400MCM & 1#2/0 GND	2400SE	(6) PARALLEL RUNS, EACH WITH 4"C & 4#600MCM

TRANSFORMER SECONDARY

TRANSFORMER PRIMARY

AREA LIGHTING CLASSIFICATIONS



TYPE 1 IS VERY LINEAL AND INTENDED FOR 1 OR 2 LANE ROADWAYS.

TYPE 2 IS STILL LINEAL BUT WIDER IN THE FRONT TO ACCOMMODATE 4 LANE ROADWAYS, OR WIDER DRIVE LANES.

TYPE 3 (COMMONLY KNOWN AS A "BAT-WING") IS SUITABLE FOR PERIMETERS, OFTEN WHERE OTHER INTERIOR POLE PLACEMENTS FILL THE SITE.

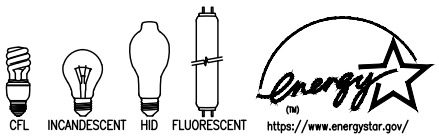
TYPE 4 (COMMONLY KNOWN AS A "FORWARD THROW" OR" ASYMMETRIC) IS BEST ALONG PERIMETERS WHERE SPILL LIGHT IS A CONCERN OR THERE ARE NO PLACE TO ADD POLES WITHIN A SITE.

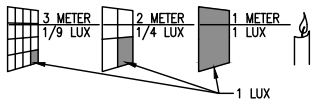
TYPE 5 – IS AVAILABLE IN A ROUND OR SQUARE PATTERN. BEST SUITED FOR INTERIOR AREAS WITHIN A SITE OR ON THE MEDIAN OF 4–6 LANE ROADWAYS.

DESPITE THESE STANDARD 5 CLASSIFICATIONS, MANUFACTURERS WILL STRETCH THOSE PARAMETERS AND DEVELOP UNIQUE DISTRIBUTIONS AND NOMENCLATURE IN SOME CASES. FOR ACUITY BRANDS LIGHTING EXTERIOR PRODUCTS, DISTRIBUTIONS ARE CLASSIFIED AS R2 THRU R5 WITH SOME SPECIALTY DISTRIBUTIONS SUCH AS R4W, R4SC, SYM, ASY, AND VFA FOR POLE MOUNTED LUMINARIES. ALL OF THESE STILL FALLS WITHIN THE 5 BASIC CLASSIFICATIONS BUT THEIR UNIQUE PATTERNS ALLOW THE PRODUCT TO SERVE FOR SPECIFIC SITE CONDITIONS.

R4W – IS A PATTERN THAT IS A WIDER PATTERN THAN A NORMAL TYPE 4. GREAT FOR PERIMETERS AND IN SOME CASES CAN BE USED ON AN INTERIOR LOCATION WITH A TWIN CONFIGURATION. GREAT FOR A ONE REFLECTOR DOES ALL OPTION.

R4SC – STILL A TYPE 4 WITH VERY SHARP CUTOFF. THIS OPTIC EXCELS WHERE THERE ARE STRICT LOCAL ORDINANCES FOR SPILL LIGHT OR SEEKING LEED CREDITS.



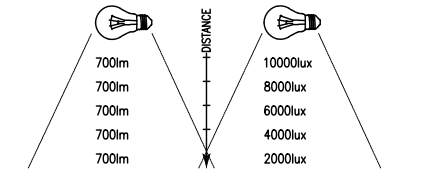


$E = \frac{I}{d^2}$

E= ILLUMINATION [1 LUMEN/FT² OR 1 FOOTCANDLE (1 LUMEN/m² OR 1 LUX OR 0.0926 FOOTCANDLE)]
I= INTENSITY OF SOURCE (1 CD OR 12.57 LUMENS)
d= DISTANCE FROM SOURCE TO OBJECT (FT OR M)

LUX (lx) = LUMENS PER SQUARE METER
1 CANDLE POWER = 12.57 LUMENS.
ONE FOOT CANDLE (fc) = 10.764lx
A COMMON CANDLE EMITS LIGHTS ROUGHLY 1 CANDELA (cd) LUMINOUS INTENSITY MEASURED AT 540 X 10^{12} HERTZ.
FOOT CANDLE (fc) = EQUAL THE AMOUNT OF LUMENS PER SQft OF AREA.

DIFFERENCE BETWEEN LUX AND LUMEN



LUMENS is the total number of "packets of light" (or quality of light outlet) produced by a light source. IE: A 100W incandescent lamp emits about 1300 lumens.

LUX is a ratio of illumination (or lumens) over a distance: 1 lux = 1 lumen per square meter. ILLUMINATION ON A SURFACE

ELECTRONIC BALLAST LAMP WATTS X 10%
MAGNETIC BALLAST LAMP WATTS X 25%

FLOURESCENT LAMPS LOAD
2 LAMP F32T8 – ~65 WATTS
3 LAMP F32T8 – ~100 WATTS
4 LAMP F32T8 – ~120 WATTS

FLUORESCENT FIXTURE
1 LAMP = 32W
2 LAMP = 60W
3 LAMP = 100W
4 LAMP = 120W

TRACK LIGHTS – 75 WATTS PER FOOT

$LEF = \frac{\text{TOTAL LAMP LUMENS X LIGHT OUTPUT RATIO}}{\text{TOTAL CIRCUIT POWER}}$

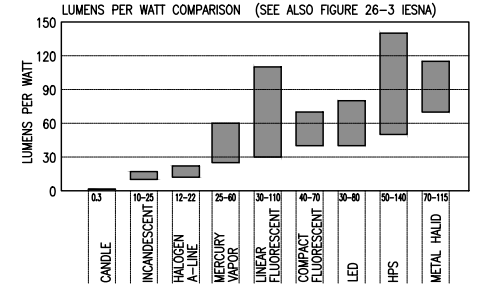
LEF = LUMINARIE EFFICIENCY FACTOR

$\text{LUMENS PER WATT} = \frac{\text{LUMENS}}{\text{WATTS}}$

Watts			(Brightness)	WATTS	~LUMENS
Incandescent	CFL	LED	Lumens		
40	8 – 12	6 – 9	400 – 500	150W	2600lm
60	13 – 18	8 – 12.5	650 – 900	100W	1600lm
75 – 100	18 – 22	13+	1100 – 1750	75W	1100lm
100	23 –30	16 – 20	1800+	60W	800lm
150	30 – 55	25 – 28	2780	40W	450lm

	DIMMER			BRIGHTER
LUMENS	450	800	1100	1600
STANDARD INCANDESCENT	40W	60W	75W	100W
HALOGEN INCANDESCENT	29W	43W	53W	72W
CFL	9W	14W	19W	23W
LED	9W	13W	17W	N/A

LUMENS PER WATT COMPARISON (SEE ALSO FIGURE 26–3 IESNA)



LIGHT TYPE	TYPICAL LUMINOUS EFFICACY (LUMENS/WATT)
TUNGSTEN INCANDESCENT LIGHT BULB	10–25 LM/W
HALOGEN LAMP	12–22 LM/W
LED LAMP	30–80 LM/W
FLUORESCENT LAMP	30–110 LM/W
MERCURY VAPOR LAMP	25–60 LM/W
METAL HALIDE LAMP	70–115 LM/W
HIGH PRESSURE SODIUM VAPOR LAMP	50–140 LM/W
LOW PRESSURE SODIUM VAPOR LAMP	100–200 LM/W

Color	Wavelength	Frequency	Photon energy
violet	380–450 nm	668–789 THz	2.75–3.26 eV
blue	450–495 nm	606–668 THz	2.50–2.75 eV
green	495–570 nm	526–606 THz	2.17–2.50 eV
yellow	570–590 nm	508–526 THz	2.10–2.17 eV
orange	590–620 nm	484–508 THz	2.00–2.10 eV
red	620–750 nm	400–484 THz	1.65–2.00 eV

LUX AND LOW LIGHTING CHART

CONDITION	ILLUMINATION		DETAILS
	fc	LUX	
SUNLIGHT	10,000	107,527	DAYLIGHT
FULL DAYLIGHT	1,000	10,752	RANGE
OVERCAST DAY	100	1,075	
VERY DARK DAY	10	107	
TWILIGHT	1	10	
DEEP TWILIGHT	.1	1	
FULL MOON	.01	.108	LOW LIGHT
QUARTER MOON	.001	.0108	LEVEL RANGE
STARLIGHT	.0001	.0011	
OVERCAST NIGHT	.00001	.0001	

LIGHT SPECTRUM		
COLOR	WAVELENGTH	FREQUENCY
VIOLET	~380–440nm	~790–680THz
BLUE	~440–485nm	~680–620THz
CYAN	~485–500nm	~620–600THz
GREEN	~500–565nm	~600–530THz
YELLOW	~565–590nm	~530–510THz
ORANGE	~590–625nm	~510–480THz
RED	~625–740nm	~480–405THz
PEACH	~	~
BROWN	~	~
BLACK	~	~

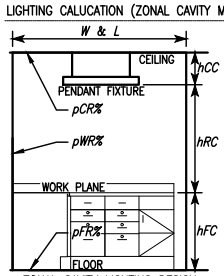
BULB COMPARISON						
FEATURES	Incandescent	CFL	HID	LED	Halogen	Fluorescent
Rated Avg. Life	755–1200	10,000	20,000	50,000	3,000	3,000
Life Span	Low	Long	Very Long	Very Long	Medium	Medium
Watts	3 – 500	3 – 120	35 – 1500	2.5 – 16	5 – 500	5 – 500
Cost per bulb	1.25	3.95		39.95		
Cost to Operate	High	Low	Lowest	Low	Medium	Medium
Price to Product	Low	Medium	High	High	Medium	Medium
Lumens per Watt (LPW)	15LPW	60LPW	Up to 120LPW	45LPW	25LPW	25LPW
Color Temperature (in Kelvin)	2700K	2700K – 6500K	1700K – 6500K	2700K – 6500K	3000K	4000K

REFLECTANCE TABLE			
COLORS	%	MATERIALS	%
WHITE	70–80	PLASTER – WHITE	80
LIGHT CREAM	70–80	WHITE PORCELAIN	65–75
LIGHT YELLOW	55–65	GLAZED WHITE TILE	60–75
LIGHT GREEN	45–50	LIMESTONE	35–70
PINK	45–50	MARBLE	30–70
SKY–BLUE	40–50	SANDSTONE	20–40
LIGHT GRAY	40–45	BRICK – RED	10–20
BEIGE	25–35	CARBON – BLACK	2–10
YELLOW OCHER	25–35		
LIGHT BROWN	25–35	MIRROR	95
OLIVE GREEN	25–35	CLEAR GLASS	6–8
ORANGE	20–25		
VERMILLION RED	20–25	MAPLE (NATURAL)	60
MEDIUM GRAY	20–25	BIRCH (NATURAL)	35–50
		OAK – LIGHT	15–35
DARK GREEN	10–15	CHERRY (NATURAL)	15–30
DARK BLUE	10–15	OAK – DARK	10–15
DARK RED	10–15	MAHOGANY	6–12
DARK GRAY	10–15	WALNUT – DARK	5–10
IDEAL CEILING	60–90	TIN	67–72
IDEAL WALLS	35–60	STAINLESS STEEL	50–60
IDEAL COUNTERTOPS	30–50	ALUMINUM	55–58
DEFAULT: CEILING = 80, WALL = 50, FLOOR = 20			

Overall performance of a lamp over its life

LAMP LUMEN DEPRECIATION (LLD)		
	GROUP REPLACEMENT	REPLACEMENT OR BURNOUT
INCANDESCENT	0.94	0.88
TUNGSTON–HALOGEN	0.98	0.94
FLUORESCENT	0.90	0.85
MERCURY	0.82	0.74
METAL–HALID	0.87	0.80
HPS	0.94	0.88

LIGHTING CALUCATION (ZONAL CAVITY METHOD) DOE



ZONAL CAVITY LIGHTING DESIGN

CALCULATION TERMS	
APL	AREA PER LUMINAIRE (Sqft)
FIX	NUMBER OF FIXTURES REQD.
LF	LAMPS PER FIXTURE
lum	LUMENS PER LUMINAIRE
CU	COEFFICIENT OF UTILIZATION (FOUND WITH FIXTURE CUT SHEET)
LLF	LIGHT LOSS FACTOR
BF	BALLAST FACTOR
MF	MAINTENANCE FACTOR (CLEANLINESS OF SPACE, .9)
LLD	LAMP LUMEN DEPRECIATION
LU	LUMENS PER FIXTURE
Mfc	MAINTAINED FOOTCANDLES DESIRED
Afc	AVERAGE MAINTAINED ILLUMINATION (FOOTCANDLES)
hCC	FIXTURE TO CEILING (ft)
hRC	WORK PLANE TO FIXTURE (ft)
hFC	FLOOR TO WORK PLANE (ft)
CCR	CEILING CAVITY RATIO
RCR	ROOM CAVITY RATIO
FCR	FLOOR CAVITY RATIO
pCR	CEILING REFLECTANCE VALUE (80)
pWR	WALL REFLECTANCE VALUE (50)
pFR	FLOOR REFLECTANCE VALUE (20)
L	LENGTH OF ROOM (ft)
W	WIDTH OF ROOM (ft)
A = L X W	

$RCR = 5 \times hRC \times \left(\frac{L + W}{L \times W}\right)$

$APL = \frac{lum \times CU \times MF}{Mfc}$

$FIX = \frac{A}{APL}$

$Afc = \frac{FIX \times lum \times CU \times MF}{A}$

WATTS/FIXTURE = _____

WATTS/ROOM = _____

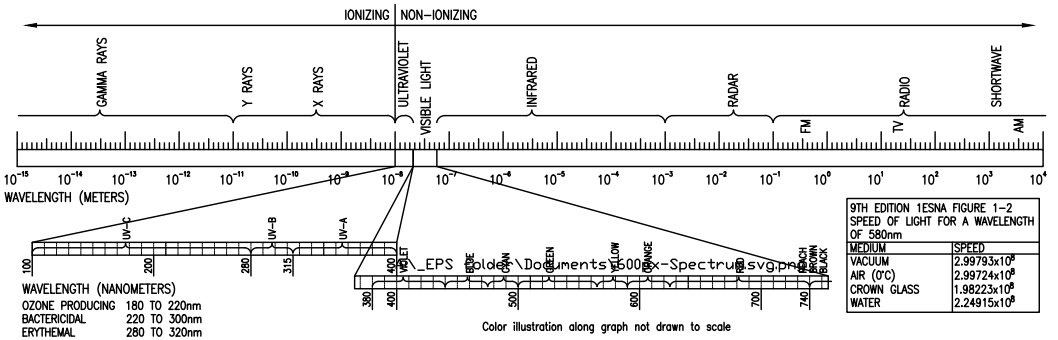
WATTS/Sqft = _____

COST OF LIGHT (CHAPTER 25 IESNA)

$U = \frac{10}{Q}\left(\frac{P + h}{L} + WR\right)$

U = UNIT COST OF LIGHT FOR A LAMP (DOLLARS/10^6 lm x h)
Q = MEAN LAMP FLUX (LUMENS)
P = LAMP PRICE (CENTS)
h = LABOR COST TO REPLACE ONE LAMP (CENTS)
L = AVERAGE RATED LAMP LIFE (THOUSANDS OF HOURS)
W = MEAN INPUT POWER PER LAMP (LAMP AND LOSSES) (WATTS)
R = ENERGY COST (CENTS/KILOWATT–HOUR)

Lighting designers knowledgebase edited: JUN 2015
LIGHTING OVERALL
DESIGNERS GUIDE



OZONE PRODUCING	180 TO 220nm
BACTERICIDAL	220 TO 300nm
ERYTHEMAL	280 TO 320nm
BLACK LIGHT	320 TO 400nm

Color illustration along graph not drawn to scale

9TH EDITION 1ESNA FIGURE 1–2
SPEED OF LIGHT FOR A WAVELENGTH OF 580nm

MEDIUM	SPEED
VACUUM	2.99793×10^8
AIR (0°C)	2.99724×10^8
CROWN GLASS	1.98223×10^8
WATER	2.24915×10^8

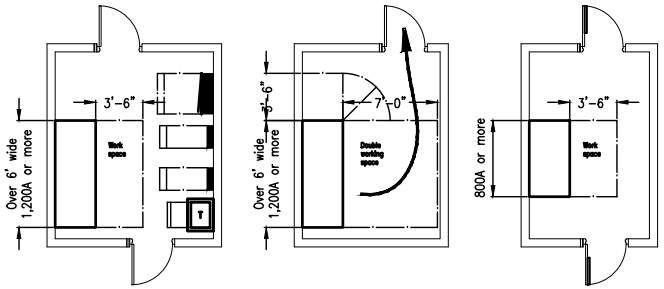
COLOR TEMPERATURE SPECTRUM	
DEGREES KELVIN	TYPE OF LIGHT SOURCE
1700–1800K	MATCH FLAME
1850–1930K	CANDLE FLAME
2000–3000K	SUN: AT SUNRISE/SUNSET
2500–2900K	HOUSEHOLD TUNGSTEN BULBS
3000K	TUNGSTEN LAMP
3200–3500K	QUARTZ LIGHTS
3200–7500K	FLUORESCENT LIGHTS
3275K	TUNGSTEN LAMP
3380K	TUNGSTEN LAMP
5000–5400K	SUN: DIRECT AT NOON
5500–6500K	DAYLIGHT (SUN & SKY)
5500–6500K	SUN: THROUGH CLUDS/HAZE
6000–7500K	SKY: OVERCAST
6500K	RGB MONITOR (WHITE PT.)
7000–8000K	OUTDOOR SHADE AREAS
8000–10000K	SKY: PARTLY CLOUDY

COLOR TEMPERATURE IS A MEASUREMENT IN DEGREES KELVIN THAT INDICATES THE HUE OF A SPECIFIC TYPE OF LIGHT SOURCE. YOU CAN USE A COLOR TEMPERATURE (AS SHOWN IN THE COLOR TEMPERATURE CHART) TO SUGGEST REALISTIC COLORS FOR THE LIGHTS IN A 3D SCENE.

VISIBLE COLORS ARE RELATIVE TO THE COLOR BALANCE (OR WHITE BALANCE) OF A FILM STOCK OR VIDEO CAMERA, WITH THE TWO MOST COMMON FIXED SETTINGS BEING 3200K INDOOR COLOR BALANCE, AND 5500K OUTDOOR (DAYLIGHT) COLOR BALANCE. TO PICK AN RGB VALUE FROM THE CHART BELOW, FIRST CHOOSE WHETHER YOUR SCENE WOULD BE SHOT WITH INDOOR OR OUTDOOR FILM (USUALLY CHOSEN BASED ON THE DOMINANT LIGHTING), THEN FIND THE COLOR CORRESPONDING TO THE TYPE OF LIGHT SOURCE AT THAT COLOR TEMPERATURE.

SO, WHY DO WE MEASURE THE HUE OF THE LIGHT AS A "TEMPERATURE"? THIS WAS STARTED IN THE LATE 1800S, WHEN THE BRITISH PHYSICIST WILLIAM KELVIN HEATED A BLOCK OF CARBON. IT GLOWED IN THE HEAT, PRODUCING A RANGE OF DIFFERENT COLORS AT DIFFERENT TEMPERATURES. THE BLACK CUBE FIRST PRODUCED A DIM RED LIGHT, INCREASING TO A BRIGHTER YELLOW AS THE TEMPERATURE WENT UP, AND EVENTUALLY PRODUCED A BRIGHT BLUE–WHITE GLOW AT THE HIGHEST TEMPERATURES. IN HIS HONOR, COLOR TEMPERATURES ARE MEASURED IN DEGREES KELVIN, WHICH ARE A VARIATION ON CENTIGRADE DEGREES. INSTEAD OF STARTING AT THE TEMPERATURE WATER FREEZES, THE KELVIN SCALE STARTS AT "ABSOLUTE ZERO," WHICH IS –273 CENTIGRADE. (SUBTRACT 273 FROM A KELVIN TEMPERATURE, AND YOU GET THE EQUIVALENT IN CENTIGRADE.) HOWEVER, THE COLOR TEMPERATURES ATTRIBUTED TO DIFFERENT TYPES OF LIGHTS ARE CORRELATED BASED ON VISIBLE COLORS MATCHING A STANDARD BLACK BODY, AND ARE NOT THE ACTUAL TEMPERATURE AT WHICH A FILAMENT BURNS.

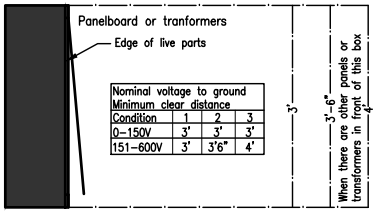
WORKING CLEARANCE



NEC 110.26(C)(2)
For equipment rated 1,200A or more and over 6' wide, an entrance to and egress from (2' wide x 6-1/2' high) is required at each end of the working space.

NEC 110.26(C)(2)(a)
Only one entrance is required where the location permits a continuous and unobstructed way of egress travel.

NEC 110.26(C)(3)
For equipment rated 800A or more, personel door(s) located less than 25' from the nearest edge of the working space must open in the direction of egress and have listed panic harware.



Nominal voltage to ground Minimum clear distance			
Condition	1	2	3
0-150V	3'	3'	3'
151-600V	3'	3'6"	4'

NEC 110.26(A)(1) - WORKING SPACE
Note: Where the conditions are as follows:
Condition 1 - Exposed live parts on one side of the working space and no live or grounded parts on the other side of the working space, or exposed live parts on both sides of the working space that are effectively guarded by insulating materials.
Condition 2 - Exposed live parts on one side of the working space and grounded parts on the other side of the working space. Concrete, brick, or tile walls shall be considered as grounded.
Condition 3 - Exposed live parts on both sides of the working space.

NEMA ratings enclosure types	
NEMA Type	Definition
1	General-purpose. Protects against dust, light, and indirect splashing but is not dust-tight; primarily prevents contact with live parts; used indoors and under normal atmospheric conditions.
2	Drip-tight. Similar to Type 1 but with addition of drip shields; used where condensation may be severe (as in cooling and laundry rooms).
3, 3S, 3X	Weather-resistant. Protects against weather hazards such as rain and sleet; used outdoors on ship docks, in construction work, and in tunnels and subways. X (as 3X) indicates additional corrosion resistance.
3R	Intended for outdoor use. Provides a degree of protection against falling rain and ice formation. Meets rod entry, rain, external icing, and rust-resistance design tests.
4 and 4X	Watertight. Must exclude at least 65 GPM of water from 1-in. nozzle delivered from a distance not less than 10 ft for 5 min. Used outdoors on ship docks, in dairies, and in breweries. X (as 4X) indicates additional corrosion resistance.
5	Dust-tight. Provided with gaskets or equivalent to exclude dust; used in steel mills and cement plants.
6 and 6P	Submersible. Design depends on specified conditions of pressure and time; submersible in water or oil; used in quarries, mines, and manholes.
7	Certified and labeled for use in areas with specific hazardous conditions: for indoor use in Class I, Groups A, B, C, and D environments as defined in NFPA standards such as the NEC.
8	Certified and labeled for use in areas with specific hazardous conditions: for indoor and outdoor use in locations classified as Class I, Groups A, B, C, and D as defined in NFPA standards such as the NEC.
9	Certified and labeled for use in areas with specific hazardous conditions: for indoor and outdoor use in locations classified as Class II, Groups E, F, or G as defined in NFPA standards such as the NEC.
10	MSHA. Meets the requirements of the Mine Safety and Health Administration, 30 CFR Part 18 (1978).
11	General-purpose. Protects against the corrosive effects of liquids and gases. Meets drip and corrosion-resistance tests.
12 and 12K	General-purpose. Intended for indoor use, provides some protection against dust, falling dirt, and dripping noncorrosive liquids. Meets drip, dust, and rust resistance tests.
13	General-purpose. Primarily used to provide protection against dust, spraying of water and noncorrosive coolants. Meets oil exclusion and rust resistance design tests.

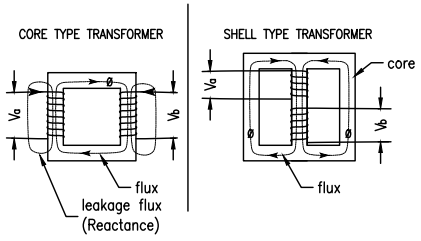
A transformer transfers electrical energy from one electric circuit to another through inductively coupled conductors. When the current in the primary1 circuit changes, a changing magnetic field will induce a changing voltage in the secondary circuit.
For an ideal transformer the induced voltage and current can be expressed as:
V1 / V2 = N1 / N2 = I2 / I1
where
V = potential difference (Voltage)
N = number of turns of wire
I = current (Amps)

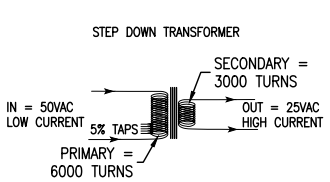
Example - Secondary Voltage in a Transformer
The secondary voltage in a transformer with 500 primary turns, 3000 secondary turns and 230 V alternating primary current can be calculated as:
V2 = V1 N2 / N1
= (230 V) 3000 / 500
= 1380 V
= 1.38 kV

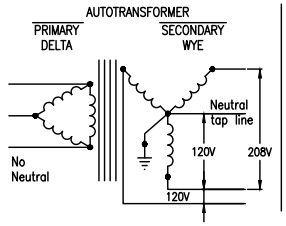
Transformer Configurations:	Transformer types:	Transformer Losses:
Single-phase Power	Power Transformer	Winding resistance
Three-phase Power	Distribution Transformer	Eddy currents
Delta and Wye Defined	Autotransformer	Stray losses
Three-phase Transformers	Isolation Transformer	Hysteresis losses
	Instrument Transformer	Mechanical losses
	Current Transformer	Magnetostriction
	Potential Transformer	Cooling system

$$\frac{\#\text{ of Primary turns } N_p}{\#\text{ of Secondary turns } N_s} = \frac{\text{Primary Voltage } V_p}{\text{Secondary Voltage } V_s}$$

$$\frac{\#\text{ of Secondary turns } N_s}{\#\text{ of Primary turns } N_p} = \frac{\text{Primary Current } I_p}{\text{Secondary Current } I_s}$$







FULL- LOAD CURRENTS
SINGLE-PHASE TRANSFORMERS

VOLTAGE

KVA RATING	120V	208V	240V	480V	600V	2400V
1	8.3	4.8	4.2	2.1	1.7	.42
1.5	12.5	7.2	6.2	3.1	2.5	.62
2	16.7	9.6	8.3	4.2	3.3	.83
3	25	14.4	12.5	6.2	5.0	1.25
5	41.7	24	20.8	10.4	8.3	2.1
7.5	62.5	36.1	31.2	15.6	12.5	3.1
10	83.4	48	41.6	20.8	16.7	4.16
15	125	72	62.5	31.2	25	6.25
25	208	120	104	52	41.7	10.4
37.5	312	180	156	78	62.5	15.6
50	417	240	208	104	83.5	20.8
75	625	361	312	156	125	31.2
100	834	480	416	208	167	41.6
125	1042	600	520	260	208	50.0
167.5	1396	805	698	349	279	70.0
200	1666	960	833	416	333	83.3
250	2080	1200	1040	520	417	104
333	2776	1600	1388	694	555	139
500	4170	2400	2080	1040	835	208

kVA Rating	Sound Level
15 to 50 kVA	45 dB
51 to 150 kVA	50 dB
151 to 300 kVA	55 dB
301 to 500 kVA	60 dB
501 to 700 kVA	62 dB
701 to 1000 kVA	64 dB
1001 to 1500 kVA	65 dB
1501 to 2000 kVA	66 dB

K-Factor transformers are designed to reduce the heating effects of harmonic currents created by loads like those shown in Chart A. The K-Factor rating is an index of the transformer's ability to withstand harmonic content while operating within the temperature limits of its insulating system. SolaHD K-Factor transformers have UL ratings of K-4, K-13, and K-20.
- Conductors capable of carrying the harmonic currents of non-linear loads without exceeding the temperature rating of the insulation system.
- A transformer design that takes into account the increase in naturally occurring 'stray' losses caused by non-linear loads. These losses cause standard transformers to dramatically overheat and substantially shorten design life.
- A core and coil design that manages the DC flux caused by triplen harmonics. As these harmonics increase, they cause additional current to circulate in the delta winding. This produces a DC flux in the core which leads to core saturation, voltage instability and overheating.

TRANSFORMER - SERVING LOAD RECOMMENDED KFACTOR	K-FACTOR
Electric discharge lighting	K-4
UPS with optional input filtering	K-4
Welders	K-4
Induction heating equipment	K-4
PLCs and solid state controls (other than variable speed drives)	K-4
Telecommunications equipment (e.g. PBX)	K-13
UPS without input filtering	K-13
Multiwire receptacle circuits in general care areas of health care facilities and classrooms of schools, etc.	K-13
Multiwire receptacle circuits supplying inspection or testing equipment on an assembly or production line	K-13
Mainframe computer loads	K-20
Solid state motor drives (variable speed drives)	K-20
Multiwire receptacle circuits in critical care areas and operating/recovery rooms of hospitals	K-20

based on 2014 NEC edited: MAR 2015
MATH/EQUIPMENT/NEC©
REFER TO NATIONAL STATE, LOCAL AND AHJ FOR CODES AND EXACT REQUIREMENTS.

DESIGNERS GUIDE

TRANSFORMER SIZING
NEC-450

FULL- LOAD CURRENTS THREE-PHASE TRANSFORMERS

VOLTAGE (LINE TO LINE)

AVERAGE SIZE H X W X D	KVA RATING		208V	240V	480V	COST$ APPOX.	WEIGHT LBS~	*PRI OCP	*SEC OCP	**GND ELECTD	(BTU) HEATLOSS
14" X 15" X 9"	3		8.3	7.2	3.6	-	120	15	15	8	563
	6		16.6	14.4	7.2	-	150	15	25	8	939
15" X 12" X 12"	9		25	21.6	10.8	-	175	15	35	8	1280
28" X 19" X 17"	15	115° RISE	41.6	36.0	18.0	1176	200	30	60	8	2270
	22.5		62	54	27	-	-	35	80	8	-
	25		69	60	30	-	-	40	90	8	-
29" X 22" X 20"	30		83	72	36	1252	250	50	110	6	6128
	37.5		104	90	45	-	-	60	150	6	-
30" X 30" X 23"	45		125	108	54	1507	360	70	175	4	5753
	50		139	120	60	-	-	80	175	4	-
38" X 32" X 27"	75		208	180	90	2271	540	125	300	2	8654
	112.5		312	270	135	38047	750	175	400	1/0	13076
42" X 41" X 32"	150		416	360	180	4656	917	200	600	2/0	15124
	225		625	542	271	8068	1250	350	800	2/0	19784
52" X 48" X 36"	300		830	720	360	32508	1574	500	1200	3/0	24120
59" X 50" X 38"	500		1390	1200	600	45463	2388	800	2000	3/0	23471
	600		1665	1443	722	-	-	1000	2400	3/0	-
56" X 56" X 56"	750		2080	1800	900	75516	3950	1200	3000	3/0	34447
	1000		2775	2400	1200	121263	6300	1600	4000	3/0	-
	1500		4150	3600	1800	-	-	2400	6000	3/0	-
	2000		5550	4800	2400	-	-	-	-	-	-
	2500		6950	6000	3000	-	-	-	-	-	-
	5000	80° RISE	13900	12000	6000	-	-	-	-	-	-
	7500		20800	18000	9000	-	-	-	-	-	-
	10000		27750	24000	12000	-	-	-	-	-	-

FLOOR WALL (TYPICAL)
NEC 450.21 SHALL BE INSTALLED IN A 1HR OR HIGHER FIRE RATED TRANSFORMER ROOM

* - REFER TO POWER RISER FEEDER SCHEDULE FOR WIRE SIZE.
** - SIZE PER 250-66 FROM SECONDARY.
*** - NEC 250-66.

TRANSFORMER IMPEDANCE $Z_{Tk} = \sqrt{(R_{Tk}^2 + X_{Tk}^2)}$

FOR OTHER KVA RATINGS OR VOLTAGES:
AMPERES = KVA x 1000 / VOLTS x 1.732

NEC-250.30(A)(3) GROUNDING ELECTRODE FOR A SEPARATELY DERIVED SYSTEM SHALL BE SIZED PER 250-66

TRANSFORMER SIZING FOR WIRE & BREAKER
PRIMARY SIDE 110.58, 240.21(B)(3) 125% OF VALUE IN TABLE VOLTAGE COLUMN
SECONDARY SIDE 240.4(F) NOT MORE THAN 125% OF VALUE IN VOLTAGE COLUMN

K-factor is a weighting of the harmonic load currents according to their effects on transformer heating, as derived from ANSI/IEEE C57.110. A K-factor of 1.0 indicates a linear load (no harmonics). The higher the K-factor, the greater the harmonic heating effects.

TRANSFORMER IMPEDANCE TABLE

Approxmate values of resistance, reactnace, impedance and X/R ratios of 600 volts or less, 60 cycles, 3-phase, standard transformers.

KVA	Percent %Reactance	%Resistance	X/R ratio	%Impedance
Liquid filled, self cooled				
150	3.75	1.37	2.74	4.00
225	4.21	1.57	2.68	4.50
300	4.77	1.48	3.22	5.00
500	4.83	1.30	3.71	5.00
750	5.60	1.28	4.37	5.75
1000	5.62	1.21	4.64	5.75
1500	5.64	1.06	5.32	5.75
2000	5.66	1.00	5.66	5.75
2500	5.67	0.97	5.85	5.75
Dry type, ventilated				
30	2.04	3.75	0.544	4.269
45	1.97	2.73	0.722	3.367
75	2.11	2.42	.868	3.204
112.5	3.69	2.56	1.441	4.491
150	1.26 4.65	2.50 1.84	0.50 2.53	2.80 5.00
225	4.28 4.57	2.16 2.04	1.93 2.24	4.80 5.00
300	5.64 4.39	2.01 2.40	2.80 1.83	6.00 5.00
500	5.77 4.50	1.65 2.23	3.49 2.02	6.00 5.00
750	5.80 5.41	1.54 1.94	3.76 2.79	6.00 5.75
1000	5.49	1.70	3.23	5.75
1500	5.51	1.63	3.42	5.75
2000	5.51	1.63	3.42	5.75
2500	5.57	1.42	3.93	5.75
Dry type, sealed				
300	4.64	1.86	2.49	5.00
500	4.74	1.58	3.00	5.00
750	5.59	1.32	4.23	5.75
1000	5.64	1.08	5.21	5.75
1500	5.65	1.05	5.38	5.75
2000	5.67	0.95	6.01	5.75
2500	6.18	0.86	7.24	6.25

Efficancy = Power out/Power in

based on 9th EDITION IESNA/2010 ASHRAE 90.1 edited: JUL 2014

LIGHTING DESIGN TABLES

DESIGNERS GUIDE

REFER TO NATIONAL, STATE, LOCAL AND AHJ FOR CODES AND EXACT REQUIREMENTS.

ASHRAE

IESNA

ASHRAE TABLE 9.4.3A EXTERIOR LIGHTING ZONES

LIGHTING ZONE	DESCRIPTION
0	UNDEVELOPED AREAS WITHIN PARKS, FOREST LAND RURAL AREAS AND UNDEVELOPED AREAS AS DEFINED BY THE AUTHORITY HAVING JURISDICTION.
1	DEVELOPED AREAS OF NATIONAL PARKS, FOREST LAND, AND RURAL AREAS.
2	AREA PREDOMINANTLY CONSISTING OF RESIDENTIAL ZONING, NEIGHBORHOOD BUSINESS DISTRICTS, LIGHT INDUSTRIAL WITH LIMITED NIGHTTIME AND RESIDENTIAL MIXED USE AREAS
3	ALL OTHER AREAS
4	HIGH ACTIVITY COMMERCIAL DISTRACTS IN MAJOR METROPOLITAN AREAS AS DESIGNATED BY LOCAL JURISDICTIONS.

ASHRAE TABLE 9.4.3B INDIVIDUAL LIGHTING POWER ALLOWANCES FOR BUILDING EXTERIORS

	ZONE 0	ZONE 1	ZONE 2	ZONE 3	ZONE 4
BASE SITE ALLOWANCE	–	500W	600W	750W	1300W
UNCOVERED PARKING AREA					
PARKING AREA & DRIVES	–	0.04W/ft²	0.06W/ft²	0.10W/ft²	0.13W/ft²
BUILDING GROUNDS					
WALKWAYS < THAN 10'	–	0.7lf	0.7lf	0.8lf	1.0lf
WALKWAYS > THAN 10'	–	0.14W/ft²	0.14W/ft²	0.16W/ft²	0.13W/ft²
PLAZA AREAS	–	0.14W/ft²	0.14W/ft²	0.16W/ft²	0.13W/ft²
SPECIAL FEATURE	–	0.14W/ft²	0.14W/ft²	0.16W/ft²	0.13W/ft²
STAIRWAYS	–	0.75W/ft²	1.0W/ft²	1.0W/ft²	1.0W/ft²
PEDESTRIAN TUNNELS	–	0.15W/ft²	0.15W/ft²	0.2W/ft²	0.3W/ft²
LANDSCAPING	–	0.04W/ft²	0.05W/ft²	0.05W/ft²	0.05W/ft²
BUILDING ENTRANCES AND EXITS					
MAIN ENTRIES	–	20lfD	20lfD	30lfD	30lfD
OTHER DOORS	–	20lfD	20lfD	20lfD	20lfD
ENTRY CANOPIES	–	.25W/ft²	0.25W/ft²	0.4W/ft²	0.4W/ft²
SALES CANOPIES					
FREE STANDING	–	0.6W/ft²	0.6W/ft²	0.8W/ft²	1.0W/ft²
NON TRADABLE SURFACES					
BUILDING FACADES	–	–	0.1(2.5)	0.15(3.75)	0.2(5.0)
ENTRANCES & INSPECTION	–	0.75*	0.75*	0.75*	0.75*
LOADING AREAS					
PARKING NEAR 24HOUR RETAIL	–	800W**	800W**	800W**	800W**

TRADABLE SURFACES

NONTRADABLE SURFACES

TRADABLE = IF THERE ARE WATTS LEFT OVER FROM CALCULATIONS, THEY MAY BE USED SOMEWHERE ELSE.
NONTRADABLE = IF THERE ARE WATTS LEFT OVER FROM CALCULATIONS, THEY MAY NOT USED ANYWHERE ELSE.
– = NO ALLOWANCE.
W/ft² = WATTS/ft²

lf = WATTS PER LINEAR FOOT.
lfD = WATTS PER LINEAR FOOT OF DOOR WIDTH.
0.15(3.75) = 0.15W/ft² FOR EACH ILLUMINATED WALL OF SURFACE OR 3.75lf FOR EACH ILLUMINATED WALL OR SURFACE LENGTH.
* = W/ft² OF UNCOVERED AREA.
** = WATTS PER MAIN ENTRY.

ASHRAE 8.4.2 AUTOMATIC RECEPTACLE CONTROL. AT LEAST 50% OF ALL 125 VOLT 15– AND 20– AMP RECEPTACLES, INCLUDING THOSE INSTALLED IN MODULAR PARTITIONS, INSTALLED IN THE FOLLOWING SPACE TYPES:

a. PRIVATE OFFICES
b. OPEN OFFICES
c. COMPUTER CLASSROOMS

SHALL BE CONTROLLED BY AN AUTOMATIC CONTROL DEVICE THAT SHALL FUNCTION ON:

a. A SCHEDULED BASIS USING A TIME OF DAY OPERATED CONTROL DEVICE THAT TURNS RECEPTACLES OFF AT SPECIFIC PROGRAMMED TIMES–AN INDEPENDENT PROGRAM SCHEDULE SHALL BE PROVIDED FOR AREAS NO MORE THAN 25,000ft² BUT NOT MORE THAN ONE FLOOR, OR
b. AN OCCUPANT SENSOR THAT SHALL TURN RECEPTACLES OFF WITHIN 30 MINUTES OF ALL OCCUPANTS LEAVING A SPACE, OR
c. A SIGNAL FROM ANOTHER CONTROL OR ALARM SYSTEM THAT INDICATES THE AREA IS UNOCCUPIED.

ASHRAE TABLE 9.6.1 LIGHTING POWER DENSITIES USING THE SPACE BY SPACE METHOD
SPACE BY SPACE METHOD

COMMON SPACE TYPE	LPD W/FT²	RCR THRESHOLD
ATRIUM FIRST 40' IN HEIGHT	0.03*	NA
ATRIUM HEIGHT ABOVE 40'	0.02*	NA
AUDIENCE/SEATING AREA AUDITORIUM	0.79	6
AUDIENCE/SEATING AREA FOR PERFORMING ARTS THEATER	2.43	8
AUDIENCE/SEATING AREA FOR MOTION PICTURE THEATER	1.14	4
CLASSROOM/LECTURE/TRAINING	1.24	4
CONFERANCE/MEETING/MULTIPURPOSE	1.23	6
CORRIDOR/TRASNITION	0.66	WIDTH<8'
DINING AREA	0.65	4
DINING AREA BAR/LOUNGE/LEISURE	1.31	4
DINING AREA FOR FAMILY DINING	0.89	4
DRESSING/FITTING (PERFORMING ARTS)	0.40	6
ELECTRICAL/MECHANICAL	0.95	6
FOOD PREPARATION	0.99	6
LABORATORY CLASSROOMS	1.28	6
LABORATORY MEDICAL/INDUSTRICAL/RESEARCH	1.81	6
LOBBY	0.90	4
LOBBY ELEVATOR	0.64	6
LOBBY PERFORMING ARTS THEATER	2.00	6
LOBBY MOTION PICTURE THEATER	0.52	4
LOCKER ROOM	0.75	6
LOUNGE RECREATION	0.73	4
OFFICE ENCLOSED	1.11	8
OFFICE OPEN PLAN	0.98	4
RESTROOMS	0.98	8
SALES AREA	1.68	6
(FOR ACCENT LIGHTING SEE 9.6.2(b)		
STAIRWAY	0.69	10
STORAGE	0.63	6
WORKSHOP	1.59	6

BUILDING SPECIFIC SPACE TYPES	LPD W/FT²	RCR THRESHOLD
AUTOMOTIVE FACILITY SERVICE/REPAIR	0.67	4
BANK OFFICE BANKING ACTIVITY AREA	1.38	6
CONVENTION CENTER AUDIENCE SEATING	0.82	4
CONVENTION CENTER EXHIBIT SPACE	1.45	4
COURT HOUSE COURTROOM	1.72	6
COURT HOUSE CONFINEMENT CELLS	1.10	6
COURT HOUSE JUDGES CHAMBERS	1.17	8
PENITENTIARY AUDIENCE SEATING	0.43	4
PENITENTIARY CLASSROOM	1.34	4
PENITENTIARY DINING	1.07	6
DORMITORY LIVING QUARTERS	0.38	8
FIRE STATIONS ENGINE ROOM	0.56	4
FIRE STATIONS SLEEPING QUARTERS	0.25	6
GYMNASIUM FITNESS AREA	0.72	4
GYMNASIUM AUDIENCE/SEATING AREA	0.43	6
GYMNASIUM PLAYING AREA	1.20	4

BUILDING SPECIFIC SPACE TYPES	LPD W/FT²	RCR THRESHOLD
HOSPITAL CORRIDOR/TRANSITION	0.89	WIDTH<8'
HOSPITAL EMERGENCY	2.26	6
HOSPITAL EXAM/TREATMENT	1.66	8
HOSPITAL LAUNDRY/WASHING	0.60	4
HOSPITAL LOUNGE/RECREATION	1.07	6
HOSPITAL MEDICAL SUPPLY	1.27	6
HOSPITAL NURSERY	0.88	6
HOSPITAL NURSE STATION	0.87	6
HOSPITAL OPERATING ROOM	1.89	6
HOSPITAL PATIENT ROOM	0.62	6
HOSPITAL PHARMACY	1.14	6
HOSPITAL PHYSICAL THERAPY	0.91	6
HOSPITAL RADIOLOGY/IMAGING	1.32	6
HOSPITAL RECOVERY	1.15	6
HOTEL/HIGHWAY LODGING DINING AREA	0.82	4
HOTEL/HIGHWAY LODGING GUEST ROOM	1.11	6
HOTEL/HIGHWAY LODGING LOBBY	1.06	4
HOTEL/HIGHWAY LODGING DINING	0.88	4
HOTEL/HIGHWAY LODGING GUEST ROOM	0.75	6
LIBRARY CARD FILE & CATALOGUING	0.72	4
LIBRARY READING AREA	0.93	4
LIBRARY STACKS	1.71	4
MANUFACTURING CORRIDOR/TRANSITION	0.41	WIDTH<8'
MANUFACTURING DETAILED MANUFACTURING	1.29	4
MANUFACTURING EQUIPMENT ROOM	0.95	6
MUSEUM EXTRA HIGH BAY (>50')**	1.05	4
MUSEUM HIGH BAY (25'–50')**	1.23	4
MUSEUM LOW BAY (<25')**	1.19	4
MUSEUM GENERAL EXHIBITION	1.05	6
MUSEUM RESTORATION	1.02	6
PARKING GARAGE GARAGE AREA	0.19	4
POST OFFICE SORTING AREA	0.94	4
RELIGIOUS BUILDING AUDIENCE SEATING	1.53	4
RELIGIOUS BUILDING FELLOWSHIP HALL	0.64	4
RELIGIOUS BUILDING WORESHIP/PULPIT/CHOIR	1.53	4
RETAIL DRESSING/FITTING ROOM	0.87	8
RETAIL MALL CONCOURSE	1.10	4
RETAIL SALES AREA	1.68	6
SPORTS ARENA AUDIENCE SEATING	0.43	4
SPORTS ARENA COURT SPORTS AREA–CLASS 4	0.72	4
SPORTS ARENA COURT SPORTS AREA–CLASS 3	1.20	4
SPORTS ARENA COURT SPORTS AREA–CLASS 2	1.92	4
SPORTS ARENA COURT SPORTS AREA–CLASS 1	3.01	4
SPORTS ARENA RING SPORTS ARENA	2.68	4
TRANSPORTATION		
TRANSPORTATION AIR/TRAIN/BUS – BAGGAGE AREA	0.76	4
TRANSPORTATION AIRPORT – CONCOURSE	0.36	4
TRANSPORTATION AUDIENCE/SEATING	0.54	4
TRANSPORTATION TERMINAL – TICKET COUNTER	1.08	4
WAREHOUSE FINE MATERIAL STORAGE	0.95	6
WAREHOUSE MEDIUM/BULKY MATERIAL	0.58	4

* – PER FOOT OF HEIGHT, ** = FLOOR TO CEILING HEIGHT
IN CASES WHERE BOTH A SPACE TYPE AND A BUILDING SPECIFIC TYPE ARE LISTED, THE BUILDING SPECIFIC SPACE TYPE SHALL BE USED.

ASHRAE TABLE 9.5.1 LIGHTING POWER DENSITIES USING THE BUILDING AREA METHOD

BUILDING AREA TYPE	LPD (W/ft²) 1*	LPD (W/ft²) 2*
AUTOMOTIVE FACILITY	0.82	.9
CONVENTION CENTER	1.08	1.2
COURTHOUSE	1.05	1.2
DINING: BAR LOUNGE LEISURE	0.99	1.3
DINING: CAFETERIA FAST FOOD	0.90	1.4
DINING: FAMILY	0.89	1.6
DORMITORY	0.61	1.0
EXERCISE CENTER	0.88	1.0
FIRE STATION	0.71	0.8
GYMNASIUM	1.00	1.1
HEALTH CARE CLINIC	0.87	1.0
HOSPITAL	1.21	1.2
HOTEL	1.00	1.0
LIBRARY	1.18	1.3
MANUFACTURING FACILITY	1.11	1.3
MOTEL	0.88	1.0
MOTION PICTURE THEATER	0.83	1.2
MULTIFAMILY	0.60	0.7
MUSEUM	1.06	1.1
OFFICE	0.90	0.8
PARKING GARAGE	0.25	0.3
PENITENTIARY	0.97	1.0
PERFORMING ARTS BUILDING	1.39	1.6
POLICE STATION	0.96	1.0
POST OFFICE	0.87	1.1
RELIGIOUS BUILDING	1.05	1.3
RETAIL	1.40	1.4
SCHOOL/UNIVERSITY	0.99	1.2
SPORTS ARENA	0.78	1.1
TOWN HALL	0.92	1.1
TRANSPORTATION	0.77	1.0
WAREHOUSE	0.66	0.6
WORKSHOP	1.20	1.4

1* – FROM ASHRAE TABLE 9.5.1 & 2012 IECC TABLE C406.3 REDUCED INTERIOR LIGHTING POWER.
2* – FROM 2012 IECC TABLE 405.5.2(1) INTERIOR LIGHTING, POWER ALLOWANCES: BUILDING AREA METHOD.

ALSO FOUND IN 2012 IECC TABLE C405.5.2(1), C406.3

IESNA/ASHRAE LIGHTING DESIGN GUIDE (OUTDOOR)

LOCATIONS AND TASKS	ILLUMINANCE* CATEGORY	LPD** (W/FT²)
BUILDING GENERAL	B/A	
BUILDING INACTIVE ENTRANCE	A/A	
BUILDING GARDENS	A–C/A	
HOSPITALITY	B/A	
LOADING PLATFORM	C/A	
PLAZAS	B/A	
RETAIL SPACE FAST FOOD	C/A	
RETAIL SPACE MALL	A/A	

REFER TO IES TABLES FOR SPECIFIC SPACE REQUIREMENTS.
* – HORIZONTAL/VERTICAL ILLUMINANCE (ILLUMINATING ENGINEERING SOCIETY OF NORTH AMERICA (IES) NINTH EDITION)
** – ASHRAE 90.1 2010 LPD RECOMMENDATIONS

ACCESSIBILITY LIGHTING LEVELS	ILUX	FIGURE 14–2 LLUMINANCE (fc)
AMBIENT LIGHTING	50 TO 300	5 TO 30
TEXT PANELS	100 TO 300	10 TO 30
CONTROLS	100	10
DIRECTIONAL SIGNAGE	200 TO 300	20 TO 30
RAMPS, STAIRS	100 TO 300	20 TO 30
VISITOR PATHWAYS	100 TO 300	10 TO 30

RECOMMENDED MAINTAINED ILLUMINANCE VALUES FOR:
THEATRE, FIGURE 15–2
PHOTOGRAPHY, FIGURE 15–7
CAR DEALERSHIP, FIGURE 17–18
SERVICE STATION, FIGURE 17–20
MALLS, FIGURE 17–21
RESIDENTIAL, FIGURE 18–2
SPORTS LIGHTING, FIGURE 20–2
FLOODLIGHTING & MONUMENTS, FIGURE 21–12

IESNA/ASHRAE LIGHTING DESIGN GUIDE

LOCATIONS AND TASKS	ILLUMINANCE* CATEGORY	LPD** (W/FT²)
AUDITORIUMS ASSEMBLY	C/–	0.79
AUDITORIUMS SOCIAL ACTIVITY	B/A	#
BANK LOBBY	C/A	1.38
COURT ROOM SEATING	C/A	1.72
COURT ROOM JUDGE/CLERK	E/C	1.72
COURT ROOM PODIUM	E/C	1.72
EDUCATIONAL BASKETBALL	F/D	0.72–3.01
EDUCATIONAL CORRIDOR	–/C	0.66
EDUCATIONAL GENERAL CLASS (OSF)	E/–	1.24
EDUCATIONAL SCIENCE LAB	E/D	1.24
EXHIBITION HALL	C/A	1.45
FOOD SERVICE DINING	C/A	1.31
FOOD SERVICE KITCHEN	E/A	0.99
GRAPHIC DESIGN COLOR	F/D	#
HEALTH CARE EXAM	F/D	1.66
HEALTH CARE NURSING	C/A	0.87
HEALTH CARE OPERATING	E/A	1.89
HEALTH CARE CRITICAL CARE GENERAL	B/A	2.26
HEALTH CARE CRITICAL CARE EXAM	E/C	1.66
HEALTH CARE RECOVERY	C/A	1.15
HEALTH CARE LINEN	D/A	#
HEALTH CARE PATIENT ROOM	B/A	0.62
HEALTH CARE WAITING ROOM	C/A	1.07
INDUSTRIAL COURSE	C***	#
INDUSTRIAL MEDIUM	D***	#
INDUSTRIAL FINE	E***	#
INDUSTRIAL VERY FINE	F***	#
LIBRARY STACKS	D/–	1.71
MERCHANDISING RETAIL	F/D	1.68
OFFICE PRIVATE	D–E/B	1.11
OFFICE OPEN	E/B	0.98
READING DATA PROCESSING	A/A	#
READING HANDWRITTEN	D–F/	#
READING PRINTED	D–E/	#
SERVICE SPACE GENERAL	B/A	0.95
SUPERMARKET ALL	E/C	1.68
TOILET ALL	B/A	0.98

REFER TO IES TABLES FOR SPECIFIC SPACE REQUIREMENTS.
* – HORIZONTAL/VERTICAL ILLUMINANCE (ILLUMINATING ENGINEERING SOCIETY OF NORTH AMERICA (IES) NINTH EDITION).
** – ASHRAE 90.1 2010 LPD RECOMMENDATIONS, TABLE 9.6.1.
*** – LIGHT AT TASK PLANE.
# – NUMEROUS SPECIFIC CATEGORIES, SEE IES BOOK.

RECOMMENDED MAINTAINED ILLUMINANCE FOR PARKING LOTS & GARAGES FIGURE 22–21 & 22–22

LOT	BASIC (fc)	ENHANCED SECURITY (fc)
MINIMUM HORIZONTAL	0.2	0.5
UNIFORMITY, MAX TO MIN	20:1	15:1
MINIMUM VERTICAL	0.1	0.25
GARAGE	MIN. HORIZON. (fc)	MIN. VERTICAL
BASIC	1.0	0.5
RAMPS DAY	2.0	1.0
RAMPS NIGHT	1.0	0.5
ENTRANCE AREAS DAY	50	25
ENTRANCE AREAS NIGHT	1.0	0.5
STAIRWAYS	2.0	1.0

FC=LUX/10 (APPROX.)

IES NINTH EDITION, ILLUMINANCE RECOMMENDATIONS FIGURE 10–9

CATEGORY	ACTIVITY	FOOT CANDLES
ORIENTATION AND SIMPLE VISUAL TASKS		
A	PUBLIC SPACES	3fc
B	SIMPLE ORIENTATION FOR SHORT VISITS	5fc
C	WORKING SPACES WHERE SIMPLE VISUAL TASKS ARE PERFORMED	10fc
COMMON VISUAL TASKS		
D	PERFORMANCE OF VISUAL TASKS OF HIGH CONTRAST AND LARGE SIZE	30fc
E	PERFORMANCE OF VISUAL TASKS OF HIGH CONTRAST AND SMALL SIZE OR VISUAL TASKS OF LOW CONTRAST AND LARGE SIZE	50fc
F	PERFORMANCE OF VISUAL TASKS OF LOW CONTRAST AND SMALL SIZE	100fc
SPECIAL VISUAL TASKS		
G	PERFORMANCE OF VISUAL TASKS NEAR THRESHOLD	300 TO 1000fc

RECOMMENDED AVERAGE ILLUMINANCES FOR SECURITY LIGHTING FIGURE 29–17

APPLICATION	ILLUMINANCE (fc)	NOTES
LARGE OPEN AREA	0.5 TO 2.0	THE GREATER THE BRIGHTNESS OF THE SURROUNDING AREA. THE HIGHER THE ILLUMINANCE REQUIRED TO BALANCE THE BRIGHTNESSES IN THE SPACES.
BUILDINGS	0.5 TO 2.0	VERTICAL ILLUMINANCE ON THE BUILDING FACADE. THE GREATER THE BRIGHTNESS OF THE SURROUNDING AREA, THE HIGHER THE ILLUMINANCE REQUIRED TO BALANCE THE BRIGHTNESSES IN THE SPACE.
PERIMETER FENCE	0.5	ILLUMINANCE ON THE GROUND ON EITHER SIDE OF THE FENCE.
ENTRANCE	10	ILLUMINANCE ON THE GROUND IN THE INSPECTION AREA.
GATEHOUSES	30	ILLUMINANCE ON THE WORKPLANE IN THE GATEHOUSE. THIS LIGHTING MUST BE DIMMABLE TO LOW LEVELS AT NIGHT SO THE GUARD CAN SEE OUTSIDE THE GATEHOUSE.

ELEVATOR MOTOR SIZING ESTIMATE

HYDRAULIC PUSH LIFT			
2 – 3 STORY	4 – 5 STORY	6 – 8 STORY	–
25HP	50HP	125HP	–
CABLE PULL LIFT			
2 – 3 STORY	4 – 5 STORY	6 – 8 STORY	–
??HP	??HP	??HP	–

EMERGENCY POWER IF AVAILABLE AND SHUNT TRIP.

TAP RULE
NEC 240.21(B) – READ TO MEET ALL CONDITIONS
(1) NOT OVER 10' – AMPACITY NOT LESS THAN COMBINED CALCULATED LOAD
(2) NOT OVER 25' – AMPACITY NOT LESS THAN 1/3 OF OVERCURRENT DEVICE
(3) TRANSFORMER – AMPACITY NOT LESS THAN 1/3 OF OVERCURRENT DEVICE
(4) OVER 25' – AMPACITY NOT LESS THAN 1/3 OF OVERCURRENT DEVICE
(5) UNLIMITED LENGTH –

UNDERVOLTAGE –VS– SHUNT TRIP FOR RECEPTACLES LOCATED UNDER A KITCHEN HOOD
UNDERVOLTAGE IS MORE FAIL SAFE IN THAT IT REQUIRES A 35% TO 70% OF CONTROL VOLTAGE TO STAY ON. IF USING AN ANSUL FIRE SUPPRESSION CONTROL, IT WOULD REQUIRE A N.C. CONTACT.
SHUNT TRIP REQUIRES A 120V SOURCE TO CLOSE THE BREAKER.
UNDERVOLTAGE TRIP IS WAS REQUIRED BY SC OFFICE OF SCHOOL FACILITIES (OSF). MEMO FROM OSF DATED OCT, 29 2003 SHOWED THIS SHORT COMING. 2010.3 IN 2012 CODE.

MCA – SIZE WIRE
MOP – SIZE BREAKER
MOP (ONLY KNOWN) – SIZE WIRE & BREAKER

$$KW = \frac{V}{1000} \times \sqrt{3} \times MCA$$

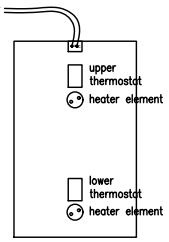
A TYPICAL GOLF COURSE IS 180 TO 220 ACRES

GE: A Series lighting panels were introduced in the late 1980's.
The lineup of A Series panels includes all of the following:
AQ, AL, AE, AD, and our newest is AS
The previous version panels were:
NLTQ, NLAB, NAB, and NHB
The power panels were changed in the same timeframe as well.
The current model is Spectra, and the previous version is CCB.

TEMPERATURE			
	KELVIN	CELSIUS	FAHRENHEIT
ABSOLUTE ZERO	0K	273.16°C	459.7°F
WATER FREEZES	273.16K	0°C	32°F
WATER BOILS	373.16K	100°C	212°F

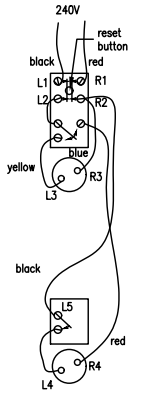
K=C° + 273.16
F=(9/5)C° + 32

ONLY QUALIFIED ELECTRICIANS SHOULD TROUBLESHOOT WATER HEATERS.



To check heater elements –
Make sure power is off and wires are removed. Should be between 8 to 18 ohms. If there is resistance is between 8 & 18 ohms, then elements are good. If it reads 0 or very high then the element is bad.

Check resistance from a ground on tank to each side of thermostat. If it is zero ohms, the element is bad.



To test thermostat, with power on, check voltage between L1 & R1 This should be 240V.

Now turn power off. Check ohms between R1 & R2. Check ohms between L1 & L2. If both read short then the reset is good.
Rotate top thermostat to higher temp. It may click to let you know it is now on. Check ohms between L2 & L3. It should read a short. Turn thermostat back to where it was previously. Check ohms between L2 & L3 again. It should not move.

Repeat for lower element and thermostat.

25% of 80 is 20
25% = 25/100
(25/100) x 80 = 20

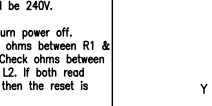
15% of 200 apples were bad. How many apples were bad?
(15/100) x 200 = 15 x 2 = 30 apples

If only 10 of the 200 apples were bad, what percent is that?
(10/200) = .05 (5%)

A Skateboard is reduced 25% in price in a sale. The old price was $120.
(25/100) x $120 = $30
$120 – $30 = $90

Prefix	Symbol	10^n
yotta	Y	10^{24}
zetta	Z	10^{21}
exa	E	10^{18}
peta	P	10^{15}
tera	T	10^{12}
giga	G	10^{9}
mega	M	10^{6}
kilo	k	10^{3}
hecto	h	10^{2}
deca	da	10^{1}
		10^{0}
deci	d	10^{-1}
centi	c	10^{-2}
milli	m	10^{-3}
micro	μ	10^{-6}
nano	n	10^{-9}
pico	p	10^{-12}
femto	f	10^{-15}
atto	a	10^{-18}
zepto	z	10^{-21}
yocto	y	10^{-24}

BREAKERS IN A PANEL MAY HAVE DIFFERENT SIZED AIC RATING BUT LOWEST RATED SHALL DESIGNATE SIZE FOR PROTECTION OF PANEL. IE: IF MOST ALL BREAKERS ARE 65K AND ONE IS RATED FOR 42K, THE PANEL SHALL BE DESIGNATED 42K AIC. ONLY WHEN ALL RATINGS ARE OVER 65AIC DOES THE SIZE OF THE BOX START TO BE CONSIDERED BECAUSE OF THE EXTRA SUPPORT REQUIRED TO MOUNT BREAKERS.



$$Y = \sqrt{Z^2 - X^2} \quad | \quad Z = \sqrt{Y^2 + X^2}$$

OHM'S LAW

1" x 25.4 = ___mm
mm x .03973 = ___"

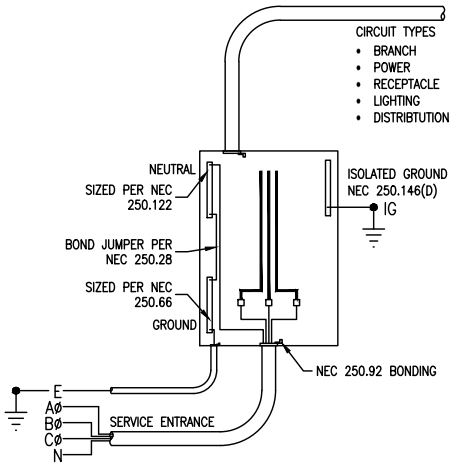
American	mm	mm (rounded)
8"	230	200
2'	610	600
4'	1220	1200
6'	1830	1800
8'	2438	2400
10'	3048	3000
12'	3658	3600

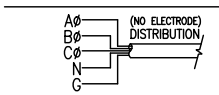
based on 2014 NEC edited: AUG 2015
MISC

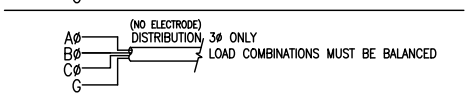
DESIGNERS GUIDE

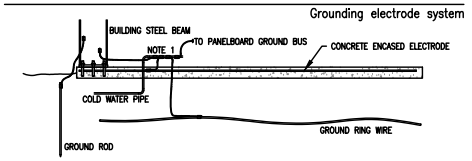
CURRENT CARRIERS IN CONDUIT RUNS				
ø	N	G	IG	NO. OF CCC* PER CONDUIT GROUP
12 12 12	12	12	12	(3)
12 12	12	12	12	(3)
12	12	12	12	(2)
12 12 12 12	12 12	12 12	12 12	(6)**
12 12 12	--	12	12	(3)
12 12	--	12	12	(3)
12 12 12 12	12 12	12 12		(6)**

*CURRENT CARRYING CONDUCTORS
**TABLE 310-15(B)(2)(a) ADJUSTMENT FACTORS FOR MORE THAN 3 CURRENT CARRYING CONDUCTORS IN A RACEWAY OR CABLE









NOTE 1: NEC 250.52(A)(1), CONNECTIONS SHALL BE MADE WITHIN 5 FEET OF POINT OF ENTRY OF WATER PIPE.

FOR INFORMATION ONLY. REFER TO NATIONAL, REGIONAL LOCAL & AHJ CODES FOR EXACT REQUIREMENTS OF GROUNDING, BONDING AND SERVICE CONNECTIONS.

Energy Comparison	
1 pound of wood	6,401 BTUs = 1.9 KWH
1 pound of coal	13,000 BTUs = 3.8 KWH
1,000 cubic foot of natural gas	1,000,021 BTUs = 299 KWH
1 gallon of oil	138,095 BTUs = 40.5 KWH
1 gallon of propane	91,500 BTUs 26.8 KWH

National Comparison Mix of Electric Generation Sources	
• Coal	52%
• Nuclear	19%
• Gas & Fuel Oil	18%
• Hydro	7%
• Wood/Biomass, Wind, Solar	4%
US Department of Energy, September, 2005	
National average cost of Electricity 8.83 cents per kilowatt hour	

Power Plant Type	Cost $/kW-hr
Coal	$0.10–0.14
Natural Gas	$0.07–0.13
Nuclear	$0.10
Wind	$0.08–0.20
Solar PV	$0.13
Solar Thermal	$0.24
Geothermal	$0.05
Biomass	$0.10
Hydro	$0.08

Fuel Energy Efficiency	
Wood	1.9 KWH per pound
Coal	3.8 KWH per pound
Natural Gas	6.9 KWH per pound (liquid and gas measures are calculated at 6.3 pounds per gallon)
Oil	6.4 KWH per pound
Propane	4.3 KWH per pound

When used as a unit of power for heating and cooling systems, BTU per hour (BTU/h) is the correct unit, though this is often abbreviated to just "BTU"
1 watt is approximately 3.412142 BTU/h[10]
1000 BTU/h is approximately 293.071 W
1 horsepower is approximately 2544 BTU/h

HEAT FROM LIGHTING SYSTEM = KW x 3.412142* x DUTY HOURS
* – MBtu/kWh

Covert 5000 watts to BTU per hour:
3.412142 x 5000 = 17060.71 BTU/hr.

Regional Variation in Levelized Costs of New Generation Resources, 2019			
Plant Type	Total System Levelized Costs (2010 USD/MWh)		
	Minimum	Average	Maximum
Conventional Coal	87.0	95.6	114.4
IGCC	106.4	112.2	131.5
IGCC with CCS	137.3	147.4	163.3
Natural Gas Fired			
Conventional Combined Cycle	61.1	66.3	75.8
Advanced Combined Cycle	59.6	64.4	73.6
Advanced CC with CCS	85.5	91.3	105.0
Conventional Combustion Turbine	106.0	128.4	149.4
Advanced Combustion Turbine	96.9	103.8	119.8
Advanced Nuclear	92.6	96.1	102.0
Geothermal	46.2	47.9	50.3
Biomass	92.3	102.6	122.9
Wind	71.3	80.3	90.3
Wind–Offshore	168.7	204.1	271.0
Solar PV	101.4	130.0	200.9
Solar Thermal	176.8	243.1	388.0
Hydro	61.6	84.5	137.7

O&M = operation and maintenance.
CC = combined cycle.
CCS = carbon capture and sequestration.
PV = photovoltaics.
GHG = greenhouse gas.

RADIOACTIVE DECAY			
ISOTOPE	HALF–LIFE	DECAY PRODUCT	HALF–LIFE
A. FISSIONABLE MATERIAL			
URANIUM–235	7.1×10^{8} yr.	THORIUM–231*	25.2 hr
URANIUM–238	4.5×10^{9} yr.	THORIUM–234*	24 days
URANIUM–239	2.4×10^{4} yr.	URANIUM–235*	7.1×10^{8} yr.
B. FISSION PRODUCTS			
LANTHANUM–140	40 hr.	CERIUM–140	STABLE
IODINE–131	8 days	XENON 131m	11.9 days
STONTIUM–90	28.9 yr.	YTTRIUM–90	64 hr
CESIUM–137	30.0 yr.	BARIUM–137m	2.5 min
C. OTHER RADIOISOTOPES			
RADON–222	3.8 days	PLONONIUM–218*	3 min
POTASSIUM–40	1.3×10^{9} yr.	CESIUM–40 OR ARGON–40	STABLE STABLE
SODIUM–24	15 hr.	MAGNESIUM–24	STABLE
HYDROGEN–3 (TRITIUM)	12.3 yr.	HELIUM–3	STABLE
* INCLUDES OTHER DAUGHTER RADIONUCLIDES.			

Material	Resistivity (nΩ m)	Density (g/cm^3)	MELTING POINT (°C)	Resistivity–density product Ω per m
Silver	15.87	10.49	960	1.591^{-08}
Copper	16.78	8.96	1083	1.664^{-08}
Gold	22.14	19.30	1064	2.349^{-08}
Aluminium	26.50	2.70	660	2.665^{-08}
Calcium	33.6	1.55	842	3.540^{-08}
Beryllium	35.6	1.85	1287	4.000^{-08}
Magnesium	43.90	1.74	650	4.467^{-08}
Bronze	50.0	8.70	950	7.184^{-08}
Sodium	47.7	0.97	97.72	??
Zinc	60	7.13	419.2	5.945^{-08}
Nickel	70	8.90	1455	6.842^{-08}
Brass	70	8.70	925	6.158^{-08}
Potassium	72.0	0.89	63.38	??
Lithium	92.8	0.53	180.5	8.535^{-08}
Iron	96.1	7.874	1538	9.579^{-08}
Tin	142	7.30	231.9	1.232^{-07}
Lead	207	11.34	327.5	1.567^{-07}
Nichrome	1000	~8.0	1400	1.250^{-06}

Specific Resistance
The Specific Resistance (K) of a material is the resistance offered by a wire of this material which is one foot long with a diameter of one MIL.

The resistance of a wire is directly proportional to the specific resistance of the material.

Material	"K"	Material	"K"
Brass	43.0	Aluminum	17.0
Constantan	295	Monel	253
Copper	10.8	Nichrome	600
German Silver 18 %	200	Nickel	947
Gold	14.7	Tantalum	93.3
Iron (Pure)	60.0	Tin	69.0
Magnesium	276	Tungsten	34.0
Manganin	265	Silver	9.7

Product	1 Gallon Pounds
Ale	8.33
Acid, Nitric	10.58
Acid, Sulphuric	15.42
Acid, Muriatic	10
Alcohol, Commerce	6.74
Alcohol, Proof Spirit	7.9375
Naphtha	7.08
Oil, Linseed	7.75
Oil of Turpentine	7.25
Oil, Whale	7.25
Petroleum	7.35
Vinegar	8.43
SaltWater	8.59
Tar	8.43
Distilled Water	8.33

Boiling Points and Heat of Vaporization			
Substance	Boiling point K	Boiling point °C	Heat of vaporization (103 J/kg)
Helium	4.216	–268.93	20.9
Hydrogen	20.26	–252.89	452
Nitrogen	77.34	–195.81	201
Oxygen	90.18	–182.97	213
Ethyl alcohol	351	78	854
Mercury	630	357	272
Water	373.15	100.00	2256
Sulfur	717.75	444.60	326
Lead	2023	1750	871
Antimony	1713	1440	561
Silver	2466	2193	2336
Gold	2933	2660	1578
Copper	2840	2567	5069

FIGURE 25.3 (IESNA) CONVERSION FACTORS FOR VARIOUS FUELS			
FUEL	FUEL EFFICIENCY	UNIT ENERGY	FUEL TO OBTAIN 1 MBtu
ELECTRIC HEAT	1.0	0.0034 MBtu/kWh	283 kWh
COAL	0.85	30 MBtu/TON	0.05 TON
NO. 2 FUEL OIL	0.70	0.14 MBtu/GAL	10 GAL
NATURAL GAS	0.70	1.0 MBtu/mCF	1.4 mCF/MBtu
MBtu – 1 THOUSAND BTU (1,000)			

WARNING SYMBOLS


RADIATION


BIO HAZARD


ELECTRIC SHOCK

SHOCK HAZARD

HIGH VOLTAGE

DESIGNERS GUIDE

PANELBOARD FIELD REPORT edited: JUN 2015

PANELBOARD NAME: _____ | SOURCE NAME: _____ |

SERVICE: 120–208V or 277/480V | PHASE: 1ø or 3ø | POWER SOURCE: (NORMAL) _____ |

BUS RATING: _____ | MAIN C.B.: _____ | NEUTRAL: YES or NO |

AIC RATING: _____ | MOUNTED: SURFACE or FLUSH | NEMA RATING: _____ | PROPER GROUNDING: YES or NO |

DISTRIBUTION TYPES
____ SERVICE ENTRANCE
____ DISTRIBUTION
____ DISTRIBUTION 3ø

CIRCUIT TYPES
____ BRANCH
____ POWER
____ RECEPTACLE
____ LIGHTING
____ DISTRIBUTION

(CIRCLE APPROPRIATE FIELD SPECS) INTENDED FOR DEMOLITION INVESTIGATIONS OR REMARKING AS BUILT CONDITIONS, COMPLETE APPROPRIATE FIELDS

LOAD SERVED	C.B. AMP	CKT#	_____	CKT#	C.B. AMP	LOAD SERVED
		1		2		
		3		4		
		5		6		
		7		8		
		9		10		
		11		12		
		13		14		
		15		16		
		17		18		
		19		20		
		21		22		
		23		24		
		25		26		
		27		28		
		29		30		
		31		32		
		33		34		
		35		36		
		37		38		
		39		40		
		41		42		

HAND DRAWN RISER

Table 220.42 Lighting Load Demand Factors		
Type of Occupancy	Portion of Lighting Load to Which Demand Factor Applies (Volt–Amperes)	Demand Factor (%)
Dwelling units	First 3000 or less at From 3001 to 120,000 at Remainder over 120,000 at	100 35 25
Hospitals*	First 50,000 or less at Remainder over 50,000 at	40 20
Hotels and motels, including apartment houses without provision for cooking by tenants*	First 20,000 or less at From 20,001 to 100,000 at Remainder over 100,000 at	50 40 30
Warehouses (storage)	First 12,500 or less at Remainder over 12,500 at	100 50
All others	Total volt–amperes	100

*The demand factors of this table shall not apply to the calculated load of feeders or services supplying areas in hospitals, hotels, and motels where the entire lighting is likely to be used at one time, as in operating rooms, ballrooms, or dining rooms.

Table 220.86 Optional Method – Demand Factors for Feeders and Service Conductors for Schools		
Connected Load		Demand Factor (Percent)
First 33 VA/m2 Plus,	(3 VA/ft2) at	100
Over 33 through 220 VA/m2 Plus,	(3 through 20 VA/ft2) at	75
Remainder over 220 VA/m2	(20 VA/ft2) at	25

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

based on 2014 NEC edited: OCT 2014

DEMAND LOAD

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Table 220.12 General Lighting Loads by Occupancy		
Type of Occupancy	Unit Load Volt–Amperes/ Square Meter	Volt–Amperes/ Square Foot
Armories and auditoriums	11	1
Banks	39[b]	3 1/2[b]
Barber shops and beauty parlors	33	3
Churches	11	1
Clubs	22	2
Court rooms	22	2
Dwelling units[a]	33	3
Garages – commercial (storage)	6	1/2
Hospitals	22	2
Hotels and motels, including apartment houses without provision for cooking by tenants	22	2
Industrial commercial (loft) buildings	22	2
Lodge rooms	17	1 1/2
Office buildings	39[b]	3 1/2[b]
Restaurants	22	2
Schools	33	3
Stores	33	3
Warehouses (storage) In any of the preceding occupancies except one–family dwellings and individual dwelling units of two–family and multifamily dwellings:	3	1/4
Assembly halls and auditoriums	11	1
Halls, corridors, closets, stairways	6	1/2
Storage spaces	3	1/4

[a]See 220.14(J).
[b]See 220.14(K).

Table 220.102 Method for Calculating Farm Loads for Other Than Dwelling Unit	
Ampere Load at 240 Volts Maximum	Demand Factor (%)
The greater of the following:	
All loads that are expected to operate simultaneously, or 125 percent of the full load current of the largest motor, or First 60 amperes of the load	100
Next 60 amperes of all other loads	50
Remainder of other loads	25

Table 220.103 Method for Calculating Total Farm Load	
Individual Loads Calculated in Accordance with Table 220.102	Demand Factor (%)
Largest load	100
Second largest load	75
Third largest load	65
Remaining loads	50

220.14 Other Loads – All Occupancies. In all occupancies, the minimum load for each outlet for general–use receptacles and outlets not used for general illumination shall not be less than that calculated in 220.14(A) through (L), the loads shown being based on nominal branch–circuit voltages.
Exception: The loads of outlets serving switchboards and switching frames in telephone exchanges shall be waived from the calculations.

(A) Specific Appliances or Loads. An outlet for a specific appliance or other load not covered in 220.14(B) through (L) shall be calculated based on the ampere rating of the appliance or load served.

...

(D) Luminaires. An outlet supplying luminaire(s) shall be calculated based on the maximum volt–ampere rating of the equipment and lamps for which the luminaire(s) is rated.

(E) Heavy–Duty Lampholders. Outlets for heavy–duty lampholders shall be calculated at a minimum of 600 voltamperes.

(F) Sign and Outline Lighting. Sign and outline lighting outlets shall be calculated at a minimum of 1200 voltamperes for each required branch circuit specified in 600.5(A).

(G) Show Windows. Show windows shall be calculated in accordance with either of the following:

(1) The unit load per outlet as required in other provisions of this section

(2) At 200 volt–amperes per 300 mm (1 ft) of show window

(H) Fixed Multioutlet Assemblies. Fixed multioutlet assemblies used in other than dwelling units or the guest rooms or guest suites of hotels or motels shall be calculated in accordance with (H)(1) or (H)(2). For the purposes of this section, the calculation shall be permitted to be based on the portion that contains receptacle outlets.

(1) Where appliances are unlikely to be used simultaneously, each 1.5 m (5 ft) or fraction thereof of each separate and continuous length shall be considered as one outlet of not less than 180 volt–amperes.

(2) Where appliances are likely to be used simultaneously, each 300 mm (1 ft) or fraction thereof shall be considered as an outlet of not less than 180 volt–amperes.

...

(K) Banks and Office Buildings. In banks or office buildings, the receptacle loads shall be calculated to be the larger of (1) or (2):

(1) The calculated load from 220.14(I)

(2) 11 volt–amperes/m2 or 1 volt–ampere/ft2

(L) Other Outlets. Other outlets not covered in 220.14(A) through (K) shall be calculated based on 180 volt–amperes per outlet.

Table 220.3 Additional Load Calculation References		
Calculation	Article	Section (or Part)
Air–conditioning and refrigerating equipment, branch–circuit conductor sizing	440	Part IV
Cranes and hoists, rating and size of conductors	610	610.14
Electric vehicle charging system branch–circuit and feeder calculations	625	625.41
Electric welders, ampacity calculations	630	630.11, 630.31
Electrically driven or controlled irrigation machines	675	675.7(A), 675.22(A)
Electrified truck parking space	626	
Electrolytic cell lines	668	668.3(C)
Electroplating, branch–circuit conductor sizing	669	669.5
Elevator feeder demand factors	620	620.14
Fire pumps, voltage drop (mandatory calculation)	695	695.7
Fixed electric heating equipment for pipelines and vessels, branch–circuit sizing	427	427.4
Fixed electric space–heating equipment, branch–circuit sizing	424	424.3
Fixed outdoor electric deicing and snow–melting equipment, branch–circuit sizing	426	426.4
Industrial machinery, supply conductor sizing	670	670.4(A)
Marinas and boatyards, feeder and service load calculations	555	555.12
Mobile homes, manufactured homes, and mobile home parks, total load for determining power supply	550	550.18(B)
Mobile homes, manufactured homes, and mobile home parks, allowable demand factors for park electrical wiring systems	550	550.31
Motion picture and television studios and similar locations – sizing of feeder conductors for television studio sets	530	530.19
Motors, feeder demand factor	430	430.26
Motors, multimotor and combination–load equipment	430	430.25
Motors, several motors or a motor(s) and other load(s)	430	430.24
Over 600–volt branch–circuit calculations	210	210.19(B)
Over 600–volt feeder calculations	215	215.2(B)
Phase converters, conductors	455	455.6
Recreational vehicle parks, basis of calculations	551	551.73(A)
Sensitive electrical equipment, voltage drop (mandatory calculation)	647	647.4(D)
Solar photovoltaic systems, circuit sizing and current	690	690.8
Storage–type water heaters	422	422.11(E)
Theaters, stage switchboard feeders	520	520.27

Table 220.86 Optional Method – Demand Factors for Feeders and Service Conductors for Schools		
	Connected Load	Demand Factor %
First	(3 VA/ft2)	100
Over	(3 through 20 VA/ft2)	75
Remainder over	(20 VA/ft2)	25

Table 220.3 Additional Load Calculation References

Calculation	Article	Section (or Part)
Air–conditioning and refrigerating equipment, branch–circuit conductor sizing	440	Part IV
Cranes and hoists, rating and size of conductors	610	610.14
Electric vehicle charging system branch–circuit and feeder calculations	625	625.41
Electric welders, ampacity calculations	630	630.11, 630.31
Electrically driven or controlled irrigation machines	675	675.7(A), 675.22(A)
Electrified truck parking space	626	
Electrolytic cell lines	668	668.3(C)
Electroplating, branch–circuit conductor sizing	669	669.5
Elevator feeder demand factors	620	620.14
Fire pumps, voltage drop (mandatory calculation)	695	695.7
Fixed electric heating equipment for pipelines and vessels, branch–circuit sizing	427	427.4
Fixed electric space–heating equipment, branch–circuit sizing	424	424.3
Fixed outdoor electric deicing and snow–melting equipment, branch–circuit sizing	426	426.4
Industrial machinery, supply conductor sizing	670	670.4(A)
Marinas and boatyards, feeder and service load calculations	555	555.12
Mobile homes, manufactured homes, and mobile home parks, total load for determining power supply	550	550.18(B)
Mobile homes, manufactured homes, and mobile home parks, allowable demand factors for park electrical wiring systems	550	550.31
Motion picture and television studios and similar locations – sizing of feeder conductors for television studio sets	530	530.19
Motors, feeder demand factor	430	430.26
Motors, multimotor and combination–load equipment	430	430.25
Motors, several motors or a motor(s) and other load(s)	430	430.24
Over 600–volt branch–circuit calculations	210	210.19(B)
Over 600–volt feeder calculations	215	215.2(B)
Phase converters, conductors	455	455.6
Recreational vehicle parks, basis of calculations	551	551.73(A)
Sensitive electrical equipment, voltage drop (mandatory calculation)	647	647.4(D)
Solar photovoltaic systems, circuit sizing and current	690	690.8
Storage–type water heaters	422	422.11(E)
Theaters, stage switchboard feeders	520	520.27

Table 220.55 Demand Factors and Loads for Household Electric Ranges, Wall–Mounted Ovens, Counter–Mounted Cooking Units, and Other Household Cooking Appliances over 13/4 kW Rating (Column C to be used in all cases except as otherwise permitted in Note 3.) Demand Factor (%) (See Notes)			
Number of Appliances	Column A (Less than 3–1/2 kW Rating)	Column B (3–1/2 kW through 8–3/4 kW Rating)	Column C Maximum Demand (kW) (See Notes) (Not over 12 kW Rating)
1	80	80	8
2	75	65	11
3	70	55	14
4	66	50	17
5	62	45	20
6	59	43	21
7	56	40	22
8	53	36	23
9	51	35	24
10	49	34	25
11	47	32	26
12	45	32	27
13	43	32	28
14	41	32	29
15	40	32	30
16	39	28	31
17	38	28	32
18	37	28	33
19	36	28	34
20	35	28	35
21	34	26	36
22	33	26	37
23	32	26	38
24	31	26	39
25	30	26	40
26–30	30	24	15 kW + 1 kW for each range
31–40	30	22	
41–50	30	20	25 kW + 3/4 kW for each range
51–60	30	18	
61 and over	30	16	

Notes:
1. Over 12 kW through 27 kW ranges all of same rating. For ranges individually rated more than 12 kW but not more than 27 kW, the maximum demand in Column C shall be increased 5 percent for each additional kilowatt of rating or major fraction thereof by which the rating of individual ranges exceeds 12 kW.
2. Over 8–3/4 kW through 27 kW ranges of unequal ratings. For ranges individually rated more than 8–3/4 kW and of different ratings, but none exceeding 27 kW, an average value of rating shall be calculated by adding together the ratings of all ranges to obtain the total connected load (using 12 kW for any range rated less than 12 kW) and dividing by the total number of ranges. Then the maximum demand in Column C shall be increased 5 percent for each kilowatt or major fraction thereof by which this average value exceeds 12 kW.
3. Over 1–3/4 kW through 8–3/4 kW. In lieu of the method provided in Column C, it shall be permissible to add the nameplate ratings of all household cooking appliances rated more than 1–3/4 kW but not more than 8–3/4 kW and multiply the sum by the demand factors specified in Column A or Column B for the given number of appliances. Where the rating of cooking appliances falls under both Column A and Column B, the demand factors for each column shall be applied to the appliances for that column, and the results added together.
4. Branch–Circuit Load. It shall be permissible to calculate the branch–circuit load for one range in accordance with Table 220.55. The branchcircuit load for one wall–mounted oven or one counter–mounted cooking unit shall be the nameplate rating of the appliance. The branch–circuit load for a counter–mounted cooking unit and not more than two wall–mounted ovens, all supplied from a single branch circuit and located in the same room, shall be calculated by adding the nameplate rating of the individual appliances and treating this total as equivalent to one range.
5. This table shall also apply to household cooking appliances rated over 1–3/4 kW and used in instructional programs.

Table 220.88 Optional Method – Permitted Load Calculations for Service and Feeder Conductors for New Restaurants		
Total Connected Load (kVA)	All Electric Restaurant Calculated Loads (kVA)	Not All Electric Restaurant Calculated Loads (kVA)
0–200	80%	100%
201–325	10% (amount over 200) + 160.0	50% (amount over 200) + 200.0
326–800	50% (amount over 325) + 172.5	45% (amount over 325) + 262.5
Over 800	50% (amount over 800) + 410.0	20% (amount over 800) + 476.3

Table 220.56 Demand Factors for Kitchen Equipment – Other Than Dwelling Unit(s)	
Number of Units of Equipment	Demand Factor (%)
1	100
2	100
3	90
4	80
5	70
6 and over	65

Table 220.54 Demand Factors for Household Electric Clothes Dryers	
Number of Dryers	Demand Factor (%)
1–4	100
5	85
6	75
7	65
8	60
9	55
10	50
11	47
12–23	47% minus 1% for each dryer exceeding 11
24–42	35% minus 0.5% for each dryer exceeding 23
43 and over	25%

Table 8 Conductor Properties

Size (AWG or kxmil)	Area		Conductors							Direct-Current Resistance at 75°C (167°F)					
			Stranding			Overall				Copper					
				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/
18	0.23	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	.8367	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
3001	52	–	37	2.29	0.090	16.00	0.630	201	0.312	0.1409	0.0429	0.1463	0.0446	0.2318	0.0707
3501	77	–	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	336	–	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	87	–	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

Notes:

1. These resistance values are valid only for the parameters as given. Using conductors having coated strands, different stranding type, and, especially, other temperatures changes the resistance.
2. EQUATION FOR TEMPERATURE CHANGE: R2 = R1 [1 + A (T2 - 75)] WHERE ACU = 0.00323, AAL = 0.00330 AT 75°C.
3. CONDUCTORS WITH COMPACT AND COMPRESSED STRANDING HAVE ABOUT 9 PERCENT AND 3 PERCENT, RESPECTIVELY, SMALLER BARE CONDUCTOR DIAMETERS THAN THOSE SHOWN. SEE TABLE 5A FOR ACTUAL COMPACT CABLE DIMENSIONS.
4. THE IACS CONDUCTIVITIES USED: BARE COPPER = 100%, ALUMINUM = 61%.
5. CLASS B STRANDING IS LISTED AS WELL AS SOLID FOR SOME SIZES. ITS OVERALL DIAMETER AND AREA ARE THOSE OF ITS CIRCUMSCRIBING CIRCLE.

INFORMATIONAL NOTE: THE CONSTRUCTION INFORMATION IS IN ACCORDANCE WITH NEMA WC/70–2009 OR ANSI/UL 1581–2011. THE RESISTANCE IS CALCULATED IN ACCORDANCE WITH NATIONAL BUREAU OF STANDARDS HANDBOOK 100, DATED 1966, AND HANDBOOK 109, DATED 1972.

SHORT CIRCUIT OCCURANCES:	
L – G	75 – 80%
L – L	5 – 7%
LLG	10 – 12%
3ØG	8 – 10%
L = LINE	
G = GROUND	

NEC TABLE 8, CONDUCTOR PROPRTIES edited: JUL 2015

2014 NEC CALCULATING CONDUCTORS

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NEC 310.15(B)(2) Ambient Temperature Correction Factors. Ampacities for ambient temperatures other than those shown in the ampacity tables shall be corrected in accordance with Table 310.15(B)(2)(a) or Table 310.15(B)(2)(b), or shall be permitted to be calculated using the following equation:

$$I' = I\sqrt{\frac{T_c - T_a'}{T_c - T_a}}$$

where:
I' = ampacity corrected for ambient temperature
I = ampacity shown in the tables
T/c = temperature rating of conductor (°C)
T/a' = new ambient temperature (°C)
T/a = ambient temperature used in the table (°C)

Table 310.15(B)(2)(a) Ambient Temperature Correction Factors Based on 30°C (86°F)

For ambient temperatures other than 30°C (86°F), multiply the allowable ampacities specified in the ampacity tables by the appropriate correction factor shown below.

Ambient Temperature (°C)	Temperature Rating of Conductor 60°C	75°C	90°C	Ambient Temperature (°F)
10 or less	1.29	1.20	1.15	50 or less
11–15	1.22	1.15	1.12	51–59
16–20	1.15	1.11	1.08	60–68
21–25	1.08	1.05	1.04	69–77
26–30	1.00	1.00	1.00	78–86
31–35	0.91	0.94	0.96	87–95
36–40	0.82	0.88	0.91	96–104
41–45	0.71	0.82	0.87	105–113
46–50	0.58	0.75	0.82	114–122
51–55	0.41	0.67	0.76	123–131
56–60	–	0.58	0.71	132–140
61–65	–	0.47	0.65	141–149
66–70	–	0.33	0.58	150–158
71–75	–	–	0.50	159–167
76–80	–	–	0.41	168–176
81–85	–	–	0.29	177–185

Table 65 IEEE 241 1990 9.5.7

Table 65–Approximate Impedance Data – Insulated Conductors – 60 Hz (W/1000 feet Each Conductor)

Size AWG or kCM	RESISTANCE (25 °C) Copper Metal	Copper Nonmet.	Aluminum Metal	Aluminum Nonmet.	REACTANCE – 600 V – THHN Several 1/C Mag.	Several 1/C Nonmag.	1 Multicond. Mag.	1 Multicond. Nonmag.
14	2.57	Same	4.22	Same	0.0493	0.03914	0.0351	0.0305
12	1.62	Same	2.66	Same	0.0468	0.0374	0.0333	0.029
10	1.018	Same	1.67	Same	0.0463	0.0371	0.0337	0.0293
8	0.6404	Same	1.05	Same	0.0475	0.038	0.0351	0.0305
6	0.41	Same	0.674	Same	0.0437	0.0349	0.0324	0.0282
4	0.259	Same	0.424	Same	0.0441	0.0353	0.0328	0.0285
2	0.164	0.162	0.266	Same	0.042	0.0336	0.0313	0.0273
1	0.1303	0.129	0.211	Same	0.0427	0.0342	0.0319	0.0277
1/0	0.104	0.102	0.168	Same	0.0417	0.0334	0.0312	0.0272
2/0	0.0835	0.0812	0.133	Same	0.0409	0.0327	0.0306	0.0266
3/0	0.0668	0.0643	0.106	0.105	0.04	0.032	0.03	0.0261
4/0	0.0534	0.0511	0.0844	0.0838	0.0393	0.0314	0.0295	0.0257
250	0.0457	0.0433	0.0722	0.0709	0.0399	0.0319	0.0299	0.0261
300	0.0385	0.0362	0.0602	0.0592	0.0393	0.0314	0.0295	0.0257
350	0.0333	0.0311	0.052	0.0507	0.0383	0.0311	0.0388	0.0311
400	0.0297	0.0273	0.046	0.0444	0.0385	0.0308	0.0286	0.0252
500	0.0244	0.022	0.0375	0.0356	0.0379	0.0303	0.0279	0.025
600	0.0209	0.0185	0.0319	0.0298	0.0382	0.0305	0.0278	0.0249
750	0.0174	0.0185	0.0264	0.0301	0.0376	0.0301	0.0271	0.0247
1000	0.014	0.0115	0.0211	0.0182	0.037	0.0296	0.026	0.0243

NOTE – Increased resistance of conductors in magnetic raceway is due to the effect of hysteresis losses. The increased resistance of conductors in metal nonmagnetic raceway is due to the effect of eddy current losses. The effect is essentially equal for steel and aluminum raceway. Resistance values are acceptable for 600 V, 5 kV, and 15 kV insulated conductors.

Table 9 Alternating-Current Resistance and Reactance for 600-Volt Cables, 3-Phase, 60 Hz, 75°C (167°F) — Three Single Conductors in Conduit

Ohms per kilometer
Ohms to neutral per 1000 feet

Size (AWG or kcmil)	XL (Reactance) for All Wires		Alternating-Current Resistance for Uncoated Copper Wires			Alternating-Current Resistance for Aluminum Wires			Effective Z at 0.85 PF or Uncoated Copper Wires			Effective Z at 0.85 PF for Aluminum Wires			Size (AWG or kcmil)
	PVC, Aluminum Conduits	Steel Conduit	PVC Conduit	Aluminum Conduit	Steel Conduit	PVC Conduit	Aluminum Conduit	Steel Conduit	PVC Conduit	Aluminum Conduit	Steel Conduit	PVC Conduit	Aluminum Conduit	Steel Conduit	
14	0.190	0.240	10.2	10.2	10.2	-	-	-	8.9	8.9	8.9	-	-	-	14
	0.058	0.073	3.1	3.1	3.1	-	-	-	2.7	2.7	2.7	-	-	-	
12	0.177	0.223	6.6	6.6	6.6	10.5	10.5	10.5	5.6	5.6	5.6	9.2	9.2	9.2	12
	0.054	0.068	2.0	2.0	2.0	3.2	3.2	3.2	1.7	1.7	1.7	2.8	2.8	2.8	
10	0.164	0.207	3.9	3.9	3.9	6.6	6.6	6.6	3.6	3.6	3.6	5.9	5.9	5.9	10
	0.050	0.063	1.2	1.2	1.2	2.0	2.0	2.0	1.1	1.1	1.1	1.8	1.8	1.8	
8	0.171	0.213	2.56	2.56	2.56	4.3	4.3	4.3	2.26	2.26	2.30	3.6	3.6	3.6	8
	0.052	0.065	0.78	0.78	0.78	1.3	1.3	1.3	0.69	0.69	0.70	1.1	1.1	1.1	
6	0.167	0.210	1.61	1.61	1.61	2.66	2.66	2.66	1.44	1.48	1.48	2.33	2.36	2.36	6
	0.051	0.064	0.49	0.49	0.49	0.81	0.81	0.81	0.44	0.45	0.45	0.71	0.72	0.72	
4	0.157	0.197	1.02	1.02	1.02	1.67	1.67	1.67	0.95	0.95	0.98	1.51	1.51	1.51	4
	0.048	0.060	0.31	0.31	0.31	0.51	0.51	0.51	0.29	0.29	0.30	0.46	0.46	0.46	
3	0.154	0.194	0.82	0.82	0.82	1.31	1.35	1.31	0.75	0.79	0.79	1.21	1.21	1.21	3
	0.047	0.059	0.25	0.25	0.25	0.40	0.41	0.40	0.23	0.24	0.24	0.37	0.37	0.37	
2	0.148	0.187	0.62	0.66	0.66	1.05	1.05	1.05	0.62	0.62	0.66	0.98	0.98	0.98	2
	0.045	0.057	0.19	0.20	0.20	0.32	0.32	0.32	0.19	0.19	0.20	0.30	0.30	0.30	
1	0.151	0.187	0.49	0.52	0.52	0.82	0.85	0.82	0.52	0.52	0.52	0.79	0.79	0.82	1
	0.046	0.057	0.15	0.16	0.16	0.25	0.26	0.25	0.16	0.16	0.16	0.24	0.24	0.25	
1/0	0.144	0.180	0.39	0.43	0.39	0.66	0.69	0.66	0.43	0.43	0.43	0.62	0.66	0.66	1/0
	0.044	0.055	0.12	0.13	0.12	0.20	0.21	0.20	0.13	0.13	0.13	0.19	0.20	0.20	
2/0	0.141	0.177	0.33	0.33	0.33	0.52	0.52	0.52	0.36	0.36	0.36	0.52	0.52	0.52	2/0
	0.043	0.054	0.10	0.10	0.10	0.16	0.16	0.16	0.11	0.11	0.11	0.16	0.16	0.16	
3/0	0.138	0.171	0.253	0.269	0.259	0.43	0.43	0.43	0.289	0.302	0.308	0.43	0.43	0.46	3/0
	0.042	0.052	0.077	0.082	0.079	0.13	0.13	0.13	0.088	0.092	0.094	0.13	0.13	0.14	
4/0	0.135	0.167	0.203	0.220	0.207	0.33	0.36	0.33	0.243	0.256	0.262	0.36	0.36	0.36	4/0
	0.041	0.051	0.062	0.067	0.063	0.10	0.11	0.10	0.074	0.078	0.080	0.11	0.11	0.11	
250	0.135	0.171	0.171	0.187	0.177	0.279	0.295	0.282	0.217	0.230	0.240	0.308	0.322	0.33	250
	0.041	0.052	0.052	0.057	0.054	0.085	0.090	0.086	0.066	0.070	0.073	0.094	0.098	0.10	
300	0.135	0.167	0.144	0.161	0.148	0.233	0.249	0.236	0.194	0.207	0.213	0.269	0.282	0.289	300
	0.041	0.051	0.044	0.049	0.045	0.071	0.076	0.072	0.059	0.063	0.065	0.082	0.086	0.088	
350	0.131	0.164	0.125	0.141	0.128	0.200	0.217	0.207	0.174	0.190	0.197	0.240	0.253	0.262	350
	0.040	0.050	0.038	0.043	0.039	0.061	0.066	0.063	0.053	0.058	0.060	0.073	0.077	0.080	
400	0.131	0.161	0.108	0.125	0.115	0.177	0.194	0.180	0.161	0.174	0.184	0.217	0.233	0.240	400
	0.040	0.049	0.033	0.038	0.035	0.054	0.059	0.055	0.049	0.053	0.056	0.066	0.071	0.073	
500	0.128	0.157	0.089	0.105	0.095	0.141	0.157	0.148	0.141	0.157	0.164	0.187	0.200	0.210	500
	0.039	0.048	0.027	0.032	0.029	0.043	0.048	0.045	0.043	0.048	0.050	0.057	0.061	0.064	
600	0.128	0.157	0.075	0.092	0.082	0.118	0.135	0.125	0.131	0.144	0.154	0.167	0.180	0.190	600
	0.039	0.048	0.023	0.028	0.025	0.036	0.041	0.038	0.040	0.044	0.047	0.051	0.055	0.058	
750	0.125	0.157	0.062	0.079	0.069	0.095	0.112	0.102	0.118	0.131	0.141	0.148	0.161	0.171	750
	0.038	0.048	0.019	0.024	0.021	0.029	0.034	0.031	0.036	0.040	0.043	0.045	0.049	0.052	
1000	0.121	0.151	0.049	0.062	0.059	0.075	0.089	0.082	0.105	0.118	0.131	0.128	0.138	0.151	1000
	0.037	0.046	0.015	0.019	0.018	0.023	0.027	0.025	0.032	0.036	0.040	0.039	0.042	0.046	

Voltage drop was calculated using the formula found in 2005 NEC®, Handbook, Chapter 9, Example 2. $Zc = (R \times \cos\Theta) + (Xl \times \sin\Theta)$

2014 National Electrical Code Handbook - Chapter 9 tables

Voltage-drop calculations using the dc-resistance formula are not always accurate for ac circuits, especially for those with a less-than-unity power factor or for those that use conductors larger than 2 AWG. Table 9 allows Code users to perform simple ac voltage-drop calculations. Table 9 was compiled using the Neher-McGrath ac-resistance calculation method, and the values presented are both reliable and conservative. This table contains completed calculations of effective impedance (Z) for the average ac circuit with an 85 percent power factor (see Example 1). If calculations with a different power factor are necessary, Table 9 also contains the appropriate values of inductive reactance and ac resistance (see Example 2).
The basic assumptions and the limitations of Table 9 are as follows:
1. Capacitive reactance is ignored.
2. There are three conductors in a raceway.
3. The calculated voltage-drop values are approximate.
4. For circuits with other parameters, the Neher-McGrath ac-resistance calculation method is used.

Example 1
A feeder has a 100-ampere continuous load. The system source is 240 volts, 3 phase, and the supplying circuit breaker is 125 amperes. The feeder is in a trade size 1 1/4 aluminum conduit with three 1 AWG THHN copper conductors operating at their maximum temperature rating of 75°C. The circuit length is 150 ft, and the power factor is 85 percent. Using Table 9, determine the approximate voltage drop of this circuit.
Solution
Step 1. Find the approximate line-to-neutral voltage drop. Using the Table 9 column "Effective Z at 0.85 PF for Uncoated Copper Wires," select aluminum conduit and size 1 AWG copper wire. Use the given value of 0.16 ohm per 1000 ft in the following formula:
Voltage drop (line to neutral)
= table value * (circuit length / 1000 ft) * circuit load
= 0.16 ohm * (150ft / 1000ft) * 100A
= 2.40V
Step 2. Find the line-to-line voltage drop:
Voltage drop (line to line)
= voltage drop (line to neutral) * √3
= 2.40V * 1.732
= 4.157V
Step 3. Find the voltage drop expressed as a percentage of the circuit voltage.
Percentage voltage drop (line to line)
= (4.157V / 240V) * 100
= 1.73% VD
Step 4. Find the voltage present at the load end of the circuit.
240V - 4.157V
= 235.84V

Calculation Example 2

A 270-ampere continuous load is present on a feeder. The circuit consists of a single 4 in. PVC conduit with three 600 kcmil XHHW/USE aluminum conductors fed from a 480-volt, 3-phase, 3-wire source. The conductors are operating at their maximum rated temperature of 75°C. If the power factor is 0.7 and the circuit length is 250 ft, is the voltage drop excessive?

Solution
Step 1. Using the Table 9 column "X_L (Reactance) for All Wires," select PVC conduit and the row for size 600 kcmil. A value of 0.039 ohm per 1000 ft is given as this X_L. Next, using the column "Alternating-Current Resistance for Aluminum Wires," select PVC conduit and the row for size 600 kcmil. A value of 0.036 ohm per 1000 ft is given as this R.
Step 2. Find the angle representing a power factor of 0.7. Using a calculator with trigonometric functions or a trigonometric function table, find the arccosine ($\cos^{-1}$) of 0.7, which is 45.57 degrees. For this example, call this angle Θ. Use the table or a calculator to find the sine of 45.57 degrees, which is 0.7141.
Step 3. Find the impedance (ZC) corrected to 0.7 power factor (ZC).
$Zc = (R * \cos\Theta) + (X_L * \sin\Theta)$
= (0.036 * 0.7) + (0.039 * 0.7141)
= 0.0252 * 0.0279
= 0.0531 ohm to neutral
Step 4. As in Example 1, find the approximate line-to-neutral voltage drop.
Voltage drop (line to line)
= Z_C * (circuit length / 1000ft) * circuit load
= 0.0530 * (250ft/1000ft) * 270A
= 3.577V
Step 5. Find the approximate line-to-line voltage drop.
Voltage drop (line to line)
= voltage drop (line to neutral) * √3
= 3.577V * 1.732
= 6.196 V
Step 6. Find the approximate voltage drop expressed as a percentage of the circuit voltage.
Percentage voltage drop (line to line)
= (6.196V / 480V) * 100
= 1.29%
Step 7. Find the voltage present at the load end of the circuit.
480 volts - 6.196V = 473.8V

Conclusion: According to 210.19(A)(1), FPN No. 4, this voltage drop does not appear to be excessive.

NEC TABLE 9, ENGINEERING SUPERVISED CIRCUIT edited: JUN 2015
2011 NEC VOLTAGE DROP SAMPLE
DESIGNERS GUIDE
VOLTAGE DROP

Conduit Trade Size (in)	Inside Diameter (inches)	Inside Diameter (mm)	Max Distance Between Supports Rigid Metal (Non Metal) (ft)
1/2	0.622	15.8	10 (3)
3/4	0.824	20.9	10 (3)
1	1.049	26.6	12 (3)
1 1/4	1.380	35	14 (5)
1 1/2	1.610	40.9	14 (5)
2	2.067	52.5	16 (5)
2 1/2	2.469	62.7	16 (6)
3	3.068	77.9	20 (6)
3 1/2	3.548	90.1	20 (7)
4	4.026	102.3	20 (7)
5	5.047	128.2	20 (7)

CHAPTER 9, Table 1 Percent of Cross Section of Conduit and Tubing for Conductors and Cables

Number of Conductors and/or Cables	Cross-Sectional Area (%)
1	53
2	31
Over 2	40

Derate more than 3 conductors in a raceway	
4 thru 6	80
7 thru 9	70
10 thru 20	50
21 thru 30	45
31 thru 40	40
41 and above	35

EMT Conduit Property Table

Trade Size	Interior Diameter	Exterior Diameter	Interior Area	Exterior Area	Interior Volume per 10ft	Exterior Volume per 10ft
1/2"	0.62 in	0.71 in	0.30 in^2	0.39 in^2	36.46 in^3	46.98 in^3
3/4"	0.82 in	0.92 in	0.53 in^2	0.67 in^2	63.99 in^3	80.12 in^3
1"	1.04 in	1.16 in	0.85 in^2	1.06 in^2	101.94 in^3	127.48 in^3
1 1/4"	1.38 in	1.51 in	1.50 in^2	1.79 in^2	179.49 in^3	214.89 in^3
1 1/2"	1.61 in	1.74 in	2.04 in^2	2.38 in^2	244.30 in^3	285.34 in^3
2"	2.07 in	2.20 in	3.36 in^2	3.79 in^2	402.67 in^3	454.92 in^3
2 1/2"	2.73 in	2.88 in	5.86 in^2	6.49 in^2	702.93 in^3	779.02 in^3
3"	3.36 in	3.50 in	8.85 in^2	9.62 in^2	1,061.49 in^3	1,154.54 in^3
3 1/2"	3.83 in	4.00 in	11.55 in^2	12.57 in^2	1,385.40 in^3	1,507.96 in^3
4"	4.33 in	4.50 in	14.75 in^2	15.90 in^2	1,770.31 in^3	1,908.52 in^3

RIGID Conduit Property Table

Trade Size	Interior Diameter	Exterior Diameter	Interior Area	Exterior Area	Interior Volume per 10ft	Exterior Volume per 10ft
1/2"	0.63 in	0.86 in	0.31 in^2	0.57 in^2	37.64 in^3	68.90 in^3
3/4"	0.84 in	1.07 in	0.55 in^2	0.89 in^2	65.87 in^3	107.10 in^3
1"	1.04 in	1.33 in	0.84 in^2	1.39 in^2	101.16 in^3	166.97 in^3
1 1/4"	1.39 in	1.68 in	1.53 in^2	2.21 in^2	183.15 in^3	264.74 in^3
1 1/2"	1.62 in	1.92 in	2.07 in^2	2.88 in^2	248.57 in^3	345.99 in^3
2"	2.08 in	2.40 in	3.41 in^2	4.52 in^2	408.93 in^3	542.41 in^3
2 1/2"	2.49 in	2.90 in	4.87 in^2	6.62 in^2	583.88 in^3	794.81 in^3
3"	3.09 in	3.54 in	7.50 in^2	9.81 in^2	899.89 in^3	1,177.74 in^3
3 1/2"	3.57 in	4.04 in	10.01 in^2	12.82 in^2	1,201.18 in^3	1,538.27 in^3
4"	4.05 in	4.55 in	12.88 in^2	16.22 in^2	1,545.90 in^3	1,946.88 in^3
5"	5.07 in	5.62 in	20.21 in^2	24.80 in^2	2,425.50 in^3	2,975.70 in^3
6"	6.09 in	6.69 in	29.16 in^2	35.16 in^2	3,498.92 in^3	4,219.42 in^3

Cooper Bussman® short circuit calculation table.

Table 4. "C" Values for conductors

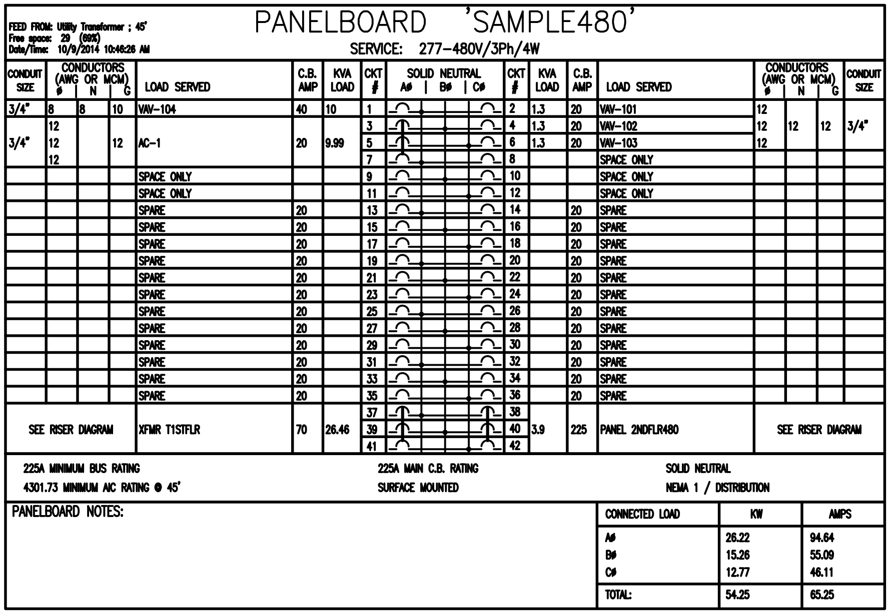
AWG or kcmil	Three single conductors						Three conductor cable					
	Steel			Nonmagnetic			Steel			Nonmagnetic		
	600V	5kV	15kV	600V	5kV	15kV	600V	5kV	15kV	600V	5kV	15kV
Copper												
14	389	–	–	389	–	–	389	–	–	389	–	–
12	617	–	–	617	–	–	617	–	–	617	–	–
10	981	–	–	982	–	–	982	–	–	982	–	–
8	1557	1551	–	1559	1555	–	1559	1557	–	1560	1558	–
6	2425	2406	2389	2430	2418	2407	2431	2425	2415	2433	2428	2421
4	3806	3751	3696	3826	3789	3753	3830	3812	3779	3838	3823	3798
3	4774	4674	4577	4811	4745	4679	4820	4785	4726	4833	4803	4762
2	5907	5736	5574	6044	5926	5809	5989	5930	5828	6087	6023	5958
1	7293	7029	6759	7493	7307	7109	7454	7365	7189	7579	7507	7364
1/0	8925	8544	7973	9317	9034	8590	9210	9086	8708	9473	9373	9053
2/0	10755	10062	9390	11424	10878	10319	11245	11045	10500	11703	11529	11053
3/0	12844	11804	11022	13923	13048	12360	13656	13333	12613	14410	14119	13462
4/0	15082	13606	12543	16673	15351	14347	16392	15890	14813	17483	17020	16013
250	16483	14925	13644	18594	17121	15866	18311	17851	16466	19779	19352	18001
300	18177	16293	14769	20868	18975	17409	20617	20052	18319	22525	21938	20163
350	19704	17385	15678	22737	20526	18672	22646	21914	19821	24904	24126	21982
400	20566	18235	16366	24297	21786	19731	24253	23372	21042	26916	26044	23518
500	22185	19172	17492	26706	23277	21330	26980	25449	23126	30096	28712	25916
600	22965	20567	17962	28033	25204	22097	28752	27975	24897	32154	31258	27766
750	24137	21387	18889	29735	26453	23408	31051	30024	26933	34605	33315	29735
1,000	25278	22539	19923	31491	28083	24887	33864	32689	29320	37197	35749	31959
Aluminum												
14	237	–	–	237	–	–	237	–	–	237	–	–
12	376	–	–	376	–	–	376	–	–	376	–	–
10	599	–	–	599	–	–	599	–	–	599	–	–
8	951	950	–	952	951	–	952	951	–	952	952	–
6	1481	1476	1472	1482	1479	1476	1482	1480	1478	1482	1481	1479
4	2346	2333	2319	2350	2342	2333	2351	2347	2339	2353	2350	2344
3	2952	2928	2904	2961	2945	2929	2963	2955	2941	2966	2959	2949
2	3713	3670	3626	3730	3702	3673	3734	3719	3693	3740	3725	3709
1	4645	4575	4498	4678	4632	4580	4686	4664	4618	4699	4682	4646
1/0	5777	5670	5493	5838	5766	5646	5852	5820	5717	5876	5852	5771
2/0	7187	6968	6733	7301	7153	6986	7327	7271	7109	7373	7329	7202
3/0	8826	8467	8163	9110	8851	8627	9077	8981	8751	9243	9164	8977
4/0	10741	10167	9700	11174	10749	10387	11185	11022	10642	11409	11277	10969
250	12122	11460	10849	12862	12343	11847	12797	12636	12115	13236	13106	12661
300	13910	13009	12193	14923	14183	13492	14917	14698	13973	15495	15300	14659
350	15484	14280	13288	16813	15858	14955	16795	16490	15541	17635	17352	16501
400	16671	15355	14188	18506	17321	16234	18462	18064	16921	19588	19244	18154
500	18756	16828	15657	21391	19503	18315	21395	20607	19314	23018	22381	20978
600	20093	18428	16484	23451	21718	19635	23633	23196	21349	25708	25244	23295
750	21766	19685	17686	25976	23702	21437	26432	25790	23750	29036	28262	25976
1,000	23478	21235	19006	28779	26109	23482	29865	29049	26608	32938	31920	29135

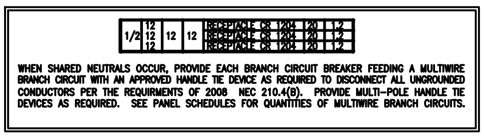
EPS SCHEDULES EXPORT

AUTOCAD AND EXCEL

edited: JUN 2015

DESIGNERS GUIDE





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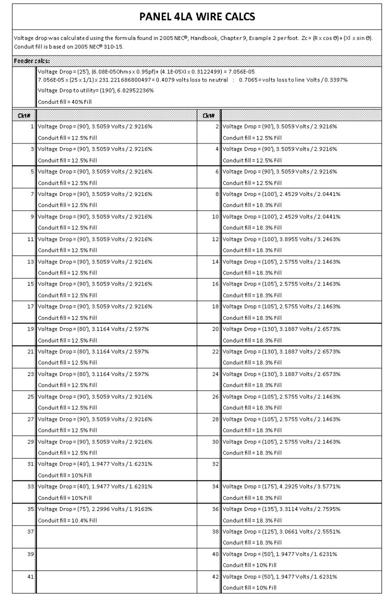

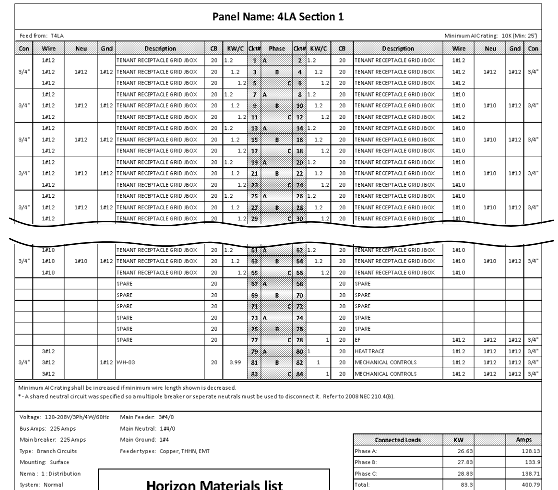

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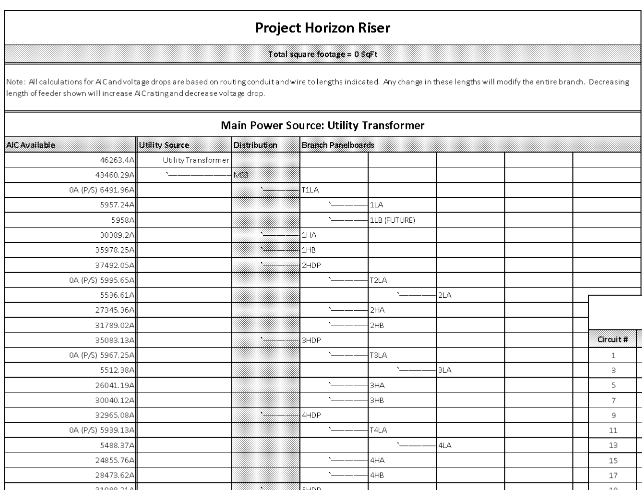
Within Electrical Panelboard Scheduler there are switches for showing many of export output options. The schedule shown is default switch options. Load, wire, riser elements wire, panel notes can also be included and remain till change by user preference.

← EXCEL

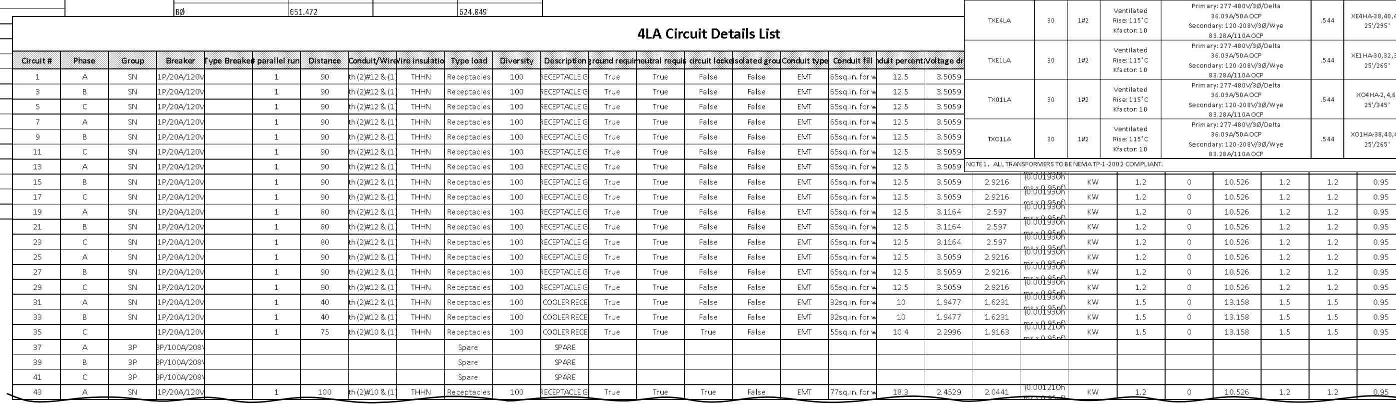
Horizon Materials list

Item	Type	Size
Conduit	EMT	3/4
Conduit	EMT	1
Conduit	EMT	1-1/4
Conduit	EMT	1-1/2
Conduit	EMT	2
Conduit	EMT	2-1/2
Conduit	EMT	3
Conduit	EMT	4
Copper Wire	THHN	12
Copper Wire	THHN	10
Copper Wire	THHN	8
Copper Wire	THHN	6
Copper Wire	THHN	4
Copper Wire	THHN	3
Copper Wire	THHN	1
Copper Wire	THHN	1/0
Copper Wire	THHN	2/0
Copper Wire	THHN	3/0
Copper Wire	THHN	4/0
Copper Wire	THHN	350MCM
Copper Wire	THHN	500MCM
Electrode	BARE	2
Electrode	BARE	1/0
Electrode	BARE	2/0
Electrode	BARE	3/0

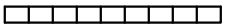
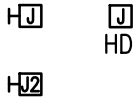
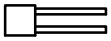
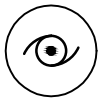


Project load summary

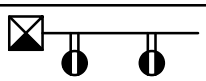
Load Type	Connected Load (KW)	Demand factor	Demand Load (KW)
First 10KW Recept.	10	100	10
Remaining Receptacles	347	50	173.5
Interior Cont. Lighting	169.5	125	211.875
Exterior Lighting	3	125	3.75
Air Handling HVAC	955.4	100	955.4
Condensors HVAC	166.44	100	166.44
Heat Load	124	125	155
Water Heater	11.997	125	14.996
Connected Motor	121.278	100	121.278
Power Feed	26	100	26
Miscellaneous	.5	100	.5
Other Loads	10	100	10
AØ	682.372		658.982
BØ	651.472		624.849



ELECTRICAL SYMBOL SCHEDULE

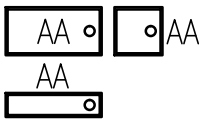
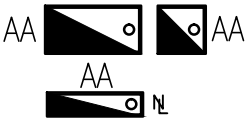
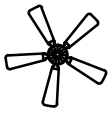
	EQUIPMENT AS NOTED.
	EQUIPMENT ID OR NOTE NUMBER.
	PANELBOARD. SEE SCHEDULE FOR SIZE.
	NEC–REQUIRED GROUNDING FOR SERVICE OR SEPARATELY DERIVED SYSTEM.
	CABLETRAY. SEE SPECIFICATION SECTION 260139.
	CIRCUIT HOMERUN TO PANELBOARD SHOWN LABELED WITH PANELBOARD DESIGNATION AND CIRCUIT NUMBER. UNLESS OTHERWISE NOTED, CONDUIT SHALL BE MINIMUM 3/4" WITH #12 WIRING FOR THE NUMBER OF CIRCUITS INDICATED. --- BOND THE EQUIPMENT GROUNDING CONDUCTOR TO EVERY PULL BOX AND TO EVERY JUNCTION BOX THROUGH WHICH IT PASSES.
	RACEWAY CONCEALED IN WALLS, CEILINGS, BELOW SLAB, CHASES OR OTHER BUILDING ELEMENTS.
	SURFACE WALL MOUNTED (STEM) OR ABOVE CEILING JUNCTION BOX. ALL BOX COVERS SHALL BE LABELED FOR CONTENTS OF PANEL NAME AND CIRCUIT NUMBER. SIZE PER NEC UNLESS NOTED OTHERWISE. SUBSCRIPT 'FH' DENOTES JUNCTION BOX AND CONNECTION TO FUME HOOD. SUBSCRIPT 'MS' DENOTES JUNCTION BOX AND CONNECTION TO MOTORIZED SCREEN. SUBSCRIPT 'DW' DENOTES CONNECTION TO DISH WASHER. SUBSCRIPT 'IM' DENOTES CONNECTION TO ICE MAKER.
	FLUSH WALL MOUNTED (STEM) OR IN FLOOR/CEILING JUNCTION BOX. ALL BOX COVERS SHALL BE LABELED IN THE INSIDE FOR CONTENTS OF PANEL NAME AND CIRCUIT NUMBER. SIZE PER NEC UNLESS NOTED OTHERWISE. NUMBER DENOTES GANG OF BOX COVER. SUBSCRIPT "HD" DENOTES CONNECTION HAND DRYER. FLUSH, WALL, COORDINATE MOUNTING HEIGHT.
	DISCONNECT SWITCH. SEE DETAIL 2 ON SHEET E005 FOR SWITCH CHARACTERISTICS. (MF= PER MANUFACTURERS REQUIREMENTS, NF = NON–FUSED, /SN = SOLID NEUTRAL/ NEMA ENCLOSURE TYPE). REFER TO SPECIFICATIONS FOR ADDITIONAL REQUIREMENTS.
	DISCONNECT SWITCH FURNISHED WITH EQUIPMENT
	FLOOR DUCT. POWER AND SIGNAL DUCTS UNDER FLOOR WITH FLUSH FLOOR JUNCTION BOX. SEE SPECIFICATIONS.
	ELECTRICAL CONNECTION TO MOTOR (DASHED CIRCLE DENOTES ROOF MOUNTED EQUIPMENT).
	ELECTRICAL EQUIPMENT GROUND BAR. REFER TO GROUNDING BAR DETAIL FOR MOUNTING HEIGHTS AND RISER DIAGRAM FOR SIZE OF CONDUCTORS, TYPICALLY MOUNTED IN ELECTRICAL AND TELECOMMUNICATIONS ROOMS.
	DOOR BELL BUZZER FOR DRIVER DELIVERY ENTRANCE TO KITCHEN STAFF.

RECEPTACLES SYMBOL SCHEDULE

15 +72" SP DW TP IM WP WC	ALL DEVICES: NUMBER BESIDE DEVICE DENOTES CIRCUIT NUMBER. SUBSCRIPT 'SP' DENOTES SURGE PROTECTOR TYPE. SUBSCRIPT 'TP' DENOTES TAMPER PROOF TYPE. SUBSCRIPT 'WP' DENOTES WEATHER PROOF WHILE IN USE COVER PLATE. SUBSCRIPT 'WC' DENOTES COORDINATE MOUNTING LOCATION BEHIND WATER COOLER. SUBSCRIPT +72" DENOTES MOUNTING HEIGHT, (72" AFF). SUBSCRIPT 'DW' DENOTES CONNECTION TO DISH WASHER. SUBSCRIPT 'IM' DENOTES CONNECTION TO ICE MAKER.
	DUPLEX RECEPTACLE, FLUSH MOUNTED. 18" AFF.
	DUPLEX RECEPTACLE, FLUSH MOUNTED 6" ABOVE COUNTERTOP BACKSPLASH OR 42" AFF IF NO COUNTER.
	GFCI DUPLEX RECEPTACLE, FLUSH MOUNTED. 18" AFF.
	GFCI DUPLEX RECEPTACLE, FLUSH MOUNTED 6" ABOVE COUNTERTOP BACKSPLASH OR 42" AFF IF NO COUNTER.
	DUPLEX ISOLATED GROUND, FLUSH MOUNTED. 18" AFF.
	DUPLEX RECEPTACLE, FLUSH MOUNTED, FOR CONNECTION OF INTERACTIVE WHITE BOARD. MOUNT RECEPTACLE 24" AFF.
	TAMPERPROOF DUPLEX RECEPTACLE, FLUSH MOUNTED. MOUNT RECEPTACLE 18" AFF.
	DOUBLE DUPLEX RECEPTACLE, FLUSH MOUNTED. 18" AFF.
	DOUBLE DUPLEX RECEPTACLE, FLUSH MOUNTED 6" ABOVE COUNTERTOP BACKSPLASH OR 42" AFF IF NO COUNTER.
	DUPLEX ISOLATED GROUND AT 18" AFF AND A DOUBLE DUPLEX ISOLATED GROUND RECEPTACLE AT 60" AFF, FLUSH MOUNTED RECEPTACLES. SEE DETAIL 6 ON SHEET E5.02.
	CEILING MOUNTED HEAVY DUTY CORD REEL ASSEMBLY WITH DUPLEX RECEPTACLE. 20A, 120V., 20'-0" CORD. HUBBELL #HBL45123R20 OR EQUAL.
	SPECIALTY OUTLET AS NOTED ON PLANS. A=NEMA 14-20R C=NEMA L18-20R E=NEMA 14-50R B=NEMA L6-20R D=NEMA L14-30R
	DUPLEX RECEPTACLE IN FLUSH FLOOR BOX.
	DUPLEX RECEPTACLE, FLUSH MOUNTED IN CEILING.
	SINGLE, SURFACE VERTICAL WIREMOLD #V700 RACEWAY WITH DEVICE SHOWN AS NOTED ON DRAWING, BACKBOX AS REQUIRED. SEE DETAILS ON DRAWINGS FOR MOUNTING INFORMATION.
	(2) SERVICE, SURFACE VERTICAL WIREMOLD #V4000 RACEWAY WITH DEVICE SHOWN AS NOTED ON DRAWING. ONE FOR POWER AND ONE FOR DATA OR AS DENOTED ON FLOOR PLAN. SEE DETAILS ON DRAWINGS FOR MOUNTING INFORMATION.
	SINGLE, SURFACE VERTICAL AND HORIZONTAL RUN WIREMOLD #V4000 RACEWAY WITH DEVICE SHOWN. DISTANCE AND DEVICE AS NOTED ON FLOOR PLAN. AS NOTED ON DRAWING. SEE DETAILS ON DRAWINGS FOR MOUNTING INFORMATION.
	WIREMOLD V700 , PROVIDE WITH DUPLEX RECEPTACLES 18" ON CENTER. ALTERNATE CIRCUITS TO WHICH RECEPTACLES ARE CONNECTED SO THAT THERE ARE NO MORE THAN THREE RECEPTACLES PER CIRCUIT.

LIGHT FIXTURE SYMBOL SCHEDULE

NOTE: FOR ALL LIGHTING FIXTURES, UPPERCASE LETTER INDICATES FIXTURE TYPE. (TYP.) SEE LIGHT FIXTURE SCHEDULE FOR DESCRIPTION. LOWERCASE LETTER INDICATES SWITCHING ARRANGEMENT. SUBSCRIPT ℄ DENOTES THE FIXTURE TO BE WIRED UNSWITCHED AND CONNECTED TO EMERGENCY CIRCUIT IF AVAILABLE.

	FLUORESCENT OR LED LIGHTING FIXTURE.
	WALL MOUNTED FLUORESCENT, LED, COMPACT FLUORESCENT OR HID LIGHT FIXTURE.
	CEILING MOUNTED LED, COMPACT FLUORESCENT OR HID LIGHT FIXTURE.
	EMERGENCY FLUORESCENT OR LED LIGHTING FIXTURE, CONNECT FIXTURE TO EMERGENCY CIRCUIT AS INDICATED.
	EMERGENCY WALL MOUNTED FLUORESCENT, LED, COMPACT FLUORESCENT OR HID LIGHT FIXTURE. CONNECT FIXTURE TO EMERGENCY CIRCUIT AS INDICATED.
	EMERGENCY CEILING MOUNTED LED, COMPACT FLUORESCENT OR HID LIGHT FIXTURE. CONNECT FIXTURE TO EMERGENCY CIRCUIT AS INDICATED.
	MOTORIZED CEILING FAN WITH RHEOSTAT MOTOR SWITCH AND LIGHTING CIRCUIT SWITCH. BACKBOX SHALL BE SECURED WITH MINIMUM 3 ALL–THREAD RODS OR TO A SECURED STRUCTURE MEMBER TO ELIMINATE ANY FAN WOBBLE WHEN OPERATING AT HIGH SPEED.
	EXIT LIGHT, CEILING MOUNTED, SHADED REGION INDICATES FACE(S) REQUIRED. PROVIDE DIRECTIONAL ARROW(S) AS INDICATED. ALL EXIT LIGHTS SHALL BE CONNECTED UNSWITCHED TO EMERGENCY CIRCUIT.
	EXIT LIGHT, WALL MOUNTED, SHADED REGION INDICATES FACE(S) REQUIRED. PROVIDE DIRECTIONAL ARROW(S) AS INDICATED. SUBSCRIPT 'WG' DENOTES FIXTURES TO BE PROVIDED WITH WIRE GUARDS. ALL EXIT LIGHTS SHALL BE CONNECTED UNSWITCHED TO EMERGENCY CIRCUIT.
	WALL MOUNTED EMERGENCY BATTERY PACK LIGHT FIXTURE. SEE LIGHT FIXTURE SCHEDULE FOR DESCRIPTION. EMERGENCY BATTERY PACK LIGHT FIXTURE SHALL BE CONNECTED TO UNSWITCHED NORMAL POWER CIRCUIT.
	POLE MOUNTED SITE AREA LIGHT FIXTURE. SEE LIGHT FIXTURE SCHEDULE FOR DESCRIPTION.

COMMUNICATIONS SYMBOL SCHEDULE

———	COMMUNICATION SYSTEM PLYWOOD BACKBOARD. PAINT WITH INTUMESCENT PAINT.
◀	VOICE–COMMUNICATIONS WALL OUTLET, FLUSH MOUNTED. PROVIDE 1"C FROM EACH OUTLET BOX TO THE NEAREST CABLE TRAY LOCATED IN THE ACCESSIBLE CEILING SPACE ON THE SAME FLOOR. EACH OUTLET BOX SHALL BE 4" x 4" x 2–5/8" WITH 1 GANG PLASTER RING.
◀	VOICE–COMMUNICATIONS WALL OUTLET, FLUSH MOUNTED 6" ABOVE COUNTERTOP BACKSPLASH OR 54"AFF. PROVIDE 1"C. FROM EACH OUTLET BOX TO THE NEAREST CABLE TRAY LOCATED IN THE ACCESSIBLE CEILING SPACE ON THE SAME FLOOR. EACH OUTLET BOX SHALL BE 4" x 4" x 2–5/8" WITH 1 GANG PLASTER RING.
◁	DATA–COMMUNICATIONS WALL OUTLET, FLUSH MOUNTED. PROVIDE 1"C FROM EACH OUTLET BOX TO THE NEAREST CABLE TRAY LOCATED IN THE ACCESSIBLE CEILING SPACE ON THE SAME FLOOR. EACH OUTLET BOX SHALL BE 4" x 4" x 2–5/8" WITH 1 GANG PLASTER RING.
◁	DATA–COMMUNICATIONS WALL OUTLET, FLUSH MOUNTED 6" ABOVE COUNTERTOP BACKSPLASH OR 54"AFF. PROVIDE 1"C FROM EACH OUTLET BOX TO THE NEAREST CABLE TRAY LOCATED IN THE ACCESSIBLE CEILING SPACE ON THE SAME FLOOR. EACH OUTLET BOX SHALL BE 4" x 4" x 2–5/8" WITH 1 GANG PLASTER RING.
◀	DATA–COMMUNICATIONS WALL OUTLET, FLUSH MOUNTED. PROVIDE 1–1/4"C FROM EACH OUTLET BOX TO THE NEAREST CABLE TRAY LOCATED IN THE ACCESSIBLE CEILING SPACE ON THE SAME FLOOR. EACH OUTLET BOX SHALL BE 4" x 4" x 4" WITH 2 GANG PLASTER RING.
◀	VOICE/DATA–COMMUNICATIONS WALL OUTLET, FLUSH MOUNTED 6" ABOVE COUNTERTOP BACKSPLASH OR 54"AFF. PROVIDE 1"C FROM EACH OUTLET BOX TO THE NEAREST CABLE TRAY LOCATED IN THE ACCESSIBLE CEILING SPACE ON THE SAME FLOOR. EACH OUTLET BOX SHALL BE 4" x 4" x 2–5/8" WITH 1 GANG PLASTER RING.
◀	VOICE/DATA – COMMUNICATIONS FLOOR OUTLET, FLUSH MOUNTED. PROVIDE 1"C FROM EACH OUTLET BOX TO THE NEAREST CABLETRAY OR TELECOMM ROOM ON THE SAME FLOOR. PROVIDE STEEL CITY #665 BOX.
◀	DATA–COMMUNICATIONS WALL OUTLET, FLUSH MOUNTED. PROVIDE 1–1/4"C FROM EACH OUTLET BOX TO THE NEAREST CABLE TRAY LOCATED IN THE ACCESSIBLE CEILING SPACE ON THE SAME FLOOR. EACH OUTLET BOX SHALL BE 4" x 4" x 4" WITH 3 GANG PLASTER RING.
(W)	WIRELESS DATA–COMMUNICATIONS OUTLET, MOUNTED ABOVE ACCESSIBLE CEILING. PROVIDE 1"C FROM JUNCTION BOX TO THE NEAREST CABLE TRAY LOCATED ABOVE ACCESSIBLE CEILING SPACE ON THE SAME FLOOR. EACH JUNCTION BOX SHALL BE 4" x 4" x 2–5/8" WITH 1 GANG REDUCER RING.
(W)	WIRELESS DATA–COMMUNICATIONS OUTLET, MOUNTED ABOVE ACCESSIBLE CEILING. PROVIDE 1"C FROM JUNCTION BOX TO THE NEAREST CABLE TRAY LOCATED ON THE ACCESSIBLE CEILING SPACE ON THE SAME FLOOR. EACH JUNCTION BOX SHALL BE 4" x 4" x 2–5/8" WITH 1 GANG REDUCER RING.
IB	INTERACTIVE SMARTBOARD WALL OUTLET, FLUSH MOUNTED. SEE DETAIL 2 ON DRAWING E007 FOR MORE INFORMATION. EACH OUTLET BOX SHALL BE 4" x 4" x 2–5/8" WITH 1GPR.
(S)	FLUSH, CEILING–MOUNTED PAGING SYSTEM SPEAKER. PROVIDE JUNCTION BOX WITH 3/4" CONDUIT STUBBED TO WITHIN 6" OF CABLETRAY. PROVIDE 5'–0" OF 3/4" FLEX FOR CONNECTION TO SPEAKER.
S	FLUSH, WALL–MOUNTED PAGING SYSTEM SPEAKER, BACKBOX & VANDLE–PROOF BAFFLE PROVIDED BY OWNER. SUBSCRIPT 'WP' DENOTES WEATHERPROOF SPEAKER. BACKBOX INSTALLED BY DIV.26. PROVIDE 3/4" CONDUIT TO NEAREST INTERIOR SPEAKER OR AS INDICATED ON PLANS.
IC	INTERCOM CALL–IN SWITCH, FLUSH MOUNTED. PROVIDE 3/4"C FROM EACH OUTLET BOX TO THE NEAREST CEILING SPEAKER IN THE SAME SPACE. EACH OUTLET BOX SHALL BE 4" x 4" x 2," WITH 1 GANG PLASTER RING.
	INTERCOM CALL–IN SWITCH WITH VOLUME CONTROL, FLUSH MOUNTED. PROVIDE 3/4"C FROM EACH OUTLET BOX TO THE NEAREST CEILING SPEAKER IN THE SAME SPACE. EACH OUTLET BOX SHALL BE 4" x 4" x 2," WITH 1 GANG PLASTER RING.
TV	INTEGRATED COMMUNICATIONS SYSTEM FLUSH, WALL–MOUNTED TELEVISION OUTLET.
(M)	FLUSH, WALL–MOUNTED MICROPHONE JACK.
M	FLUSH, FLOOR–MOUNTED MICROPHONE JACK.

FIRE ALARM SYMBOL SCHEDULE

(S)R	SMOKE DETECTOR SUBSCRIPT 'R' DENOTES RELAY BASE FOR DOOR HOLDER OPERATION.
(H)	HEAT DETECTOR.
(D)	DUCT MOUNTED SMOKE DETECTOR.
(F)	FLOW SWITCH
(T)	TAMPER SWITCH
(SD)	FIRE ALARM SMOKE DAMPER. PROVIDE A FIRE ALARM SYSTEM ADDRESSABLE INPUT MODULE FOR EACH. COORDINATE LOCATIONS WITH DIVISION 26 CONTRACTOR. PROVIDE 120 VOLT CONNECTIONS TO EACH.
[I]	FIRE ALARM ADDRESSABLE INPUT MODULE
[O]	FIRE ALARM ADDRESSABLE OUTPUT MODULE
[R] OAU-01	FIRE ALARM REMOTE ALARM INDICATOR FOR HVAC UNITS WITH DUCT DETECTORS. TEXT INDICATES THE UNIT IT SERVES.

FIRE ALARM	SOUND TYPE	SOUND	SOUND/VISUAL	VISUAL
FLUSH WALL MOUNTED	TONE	[F]<	[F]◁	[F]◀
	SPEAKER	[S]<	[S]◁	
	HORN	[H]<		
RECESSED CEILING MOUNTED	TONE	(F)<	(F)◁	(F)◀
	SPEAKER	(S)<	(S)◁	
	HORN	(H)<		
H▌	MAGNETIC DOOR HOLD OPEN DEVICE WITH INTEGRAL SMOKE DETECTOR (FURNISHED WITH DOOR HARDWARE) WIRED UNDER DIVISION 26.			
[F]	FIRE ALARM MANUAL PULLSTATION, SEMIFLUSH MOUNT TYPE, PULLSTATIONS SHALL BE PROVIDED WITH PROTECTOR GUARD.			
(R)	AREA OF REFUGE EMERGENCY CALL STATION.			
(AOR)	AREA OF REFUGE EMERGENCY CALL CONTROL PANEL			

[F] [S] [H] [I] [O] [R]

NOTIFICATION/ALERTS----------
F = FIRE I = INPUT
S = SPEAKER O = OUTPUT
H = HORN R = REMOTE

(T) (D) (H) (S) (F) (SD)

DETECTORS ----------
T = TAMPER S = SMOKE
D = DUCT F = FLOW
H = HEAT SD = SMOKE DAMPER

(F) ROUND = CEILING OR CONCEALED

[F] SQUARE = FLUSH WALL

◀ SOLID = LIGHT

< OPEN = SOUND

◁ CLOSED = LIGHT & SOUND

(R) REFUGE ASSISTANCE

(AOR) REFUGE ASSISTANCE CONTROL

SWITCHES SYMBOL SCHEDULE

ALL SWITCHES SHOWN IN THIS SCHEDULE SHALL BE MOUNTED AT 48" UNLESS NOTED OTHERWISE.

$b	120 VOLT	TOGGLE SWITCH, SPST {"b" DENOTES FIXTURE CONTROLLED (TYPICAL FOR ALL SWITCHES AND DIMMERS)}.
$3	120 VOLT	TOGGLE SWITCH, 3-WAY.
$4	120 VOLT	TOGGLE SWITCH, 4-WAY.
$M	120 VOLT	TOGGLE SWITCH, MOTOR RATED TOGGLE SWITCH, 16A.
$K	120 VOLT	TOGGLE SWITCH, KEY OPERATOR.
$OS2	120 VOLT	LINE VOLTAGE LIGHTING CONTROL OCCUPANCY SENSOR SWITCH, WALL MOUNTED. "OS" DENOTES ULTRASONIC TECHNOLOGY WATT STOPPER DW-200 OR EQUIVALENT. "TS" DENOTES DUAL TECHNOLOGY WATT STOPPER DW-200 OR EQUIVALENT. # AFTER DESIGNATION DENOTES NUMBER OF BUTTONS IN ONE SWITCH.
$OD	120 VOLT	ALL SWITCHES SUPPLIED BY RESPECTIVE MANUFACTURER AND INSTALLED BY ELECTRICAL CONTRACTOR. 'OD' DENOTES MOTORIZED DOOR OPERATOR SWITCH. 'PS' DENOTES PROJECTOR SCREEN SWITCH, 'GO' DENOTES GOAL SWITCH WITH CORRESPONDING NUMBER OF GOAL. 'SC' DENOTES GYM WINDOW SHADE CONTROL SWITCH.
Da	120 VOLT	DIMMER SWITCH, (2000W SLIDE TYPE) DO NOT GANG IN COMMON BOX. PROVIDE A SEPARATE BOX FOR EACH DIMMER. {"a" DENOTES FIXTURE CONTROLLED (TYPICAL FOR ALL SWITCHES AND DIMMERS)}.
$$	120 VOLT	INDICATION FOR MULTI-LEVEL SWITCHING. SEE DETAIL 2 ON SHEET E008 FOR WIRING REQUIREMENTS.
	120 VOLT	PHOTOCELL. WATT STOPPER #LS-190C OR EQUAL.
	120 VOLT	EPO - MOMENTARY PUSH BUTTON EMERGENCY POWER OFF SWITCH. WALL MOUNT 54" AFF.
	120 VOLT	UP-DOWN-STOP SWITCH PROVIDED BY DOOR MANUFACTURER AND INSTALLED BY ELECTRICAL CONTRACTOR.
	120 VOLT	UP-DOWN-STOP CONTROLLER FOR MOTORIZED SCREEN.
$DOS2 "D" DENOTES DIGITAL	24 VOLT	DIGITAL LIGHTING CONTROL OCCUPANCY SENSOR SWITCH, WALL MOUNTED. ROUTE 3/4"C. WITH WIRE PER LCP MANUFACTURER TO NEAREST PANEL. 'K' INDICATES SWITCH IN FLUSH WALL MOUNTED LOCKING ENCLOSURE. "OS" DENOTES ULTRASONIC TECHNOLOGY WATT STOPPER DW-200 OR EQUIVALENT. "TS" DENOTES DUAL TECHNOLOGY WATT STOPPER DW-200 OR EQUIVALENT. WATT STOPPER #HDLS2SS. WATT STOPPER #HDLS4SS. WATT STOPPER #HDLS8SS. # AFTER DESIGNATION DENOTES NUMBER OF BUTTONS IN ONE SWITCH.
	24 VOLT	DIGITAL LIGHTING CONTROL DUAL TECHNOLOGY OCCUPANCY SENSOR SWITCH WATT STOPPER DT-200 OR EQUIVALENT. WALL MOUNTED.
	24 VOLT	DIGITAL LIGHTING CONTROL DUAL TECHNOLOGY OCCUPANCY SENSOR SWITCH WATT STOPPER DT-300 OR EQUIVALENT. CEILING MOUNTED.
	24 VOLT	DIGITAL LIGHTING CONTROL ULTRASONIC TECHNOLOGY OCCUPANCY SENSOR SWITCH WATT STOPPER WT-2250 OR EQUIVALENT. CEILING MOUNTED.

SECURITY SYMBOL SCHEDULE

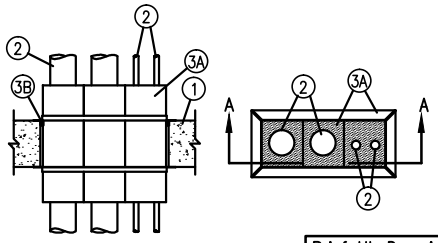
CAM PTZ	WALL MOUNTED SECURITY SYSTEM CCTV CAMERA. PROVIDE BACKBOX MOUNTED ADJACENT TO MOUNTING BRACKET AS REQUIRED. THE PTZ DENOTES A PAN/TILT/ZOOM OPTION FOR THE CAMERA AND SHALL HAVE A POWER BACKBOX MOUNTED ADJACENT TO THE MOUNTING BRACKET.
CAM	SEMI RECESSED CEILING MOUNTED SECURITY SYSTEM CCTV CAMERA. PROVIDE BACKBOX MOUNTED ADJACENT TO MOUNTING BRACKET AS REQUIRED. THE PTZ DENOTES A PAN/TILT/ZOOM OPTION FOR THE CAMERA AND SHALL HAVE A POWER BACKBOX MOUNTED ADJACENT TO THE MOUNTING BRACKET.
	SECURITY SYSTEM DOOR CONTACT – MAGNETIC TYPE – COORDINATE ROUGH–IN WITH DOOR HARDWARE.
	SECURITY SYSTEM CEILING OUTLET BOX, FLUSH MOUNTED. FOR USE WITH OWNER FURNISHED MOTION DETECTOR. EACH OUTLET SHALL BE A 4" OCTAGON BACKBOX.
IR	SECURITY SYSTEM WALL MOUNTED INFRARED DETECTOR. WALL MOUNT 3" DOWN FROM CEILING.
K	SECURITY SYSTEM KEYPAD. MOUNTED 54" AFF.
CR	SECURITY SYSTEM CARD READER. MOUNTED 54" AFF.
CP/PS	SECURITY SYSTEM 'CP' DENOTES CONTROL PANEL AND 'PS' DENOTES POWER SUPPLY.

	LOCATION	DESCRIPTION
	HEADWALL	NURSE CALL SYSTEM PATIENT CALL DOME LIGHT, WALL MOUNTED ABOVE ENTRY DOOR.
N	PATIENT TOILET/SHOWER	NURSE CALL PATIENT STATION OUTLET, WALL MOUNTED IN HEADWALL.
N	STORAGE, SOILED, BREAK ROOMS, CLEAN ROOMS, LOUNGE	NURSE CALL DUTY STATION OUTLET, WALL MOUNTED 54" AFF.
N	NURSE STATION AREA	NURSE CALL STAFF STATION OUTLET, WALL MOUNTED 54" AFF.
N	PATIENT BED	NURSE CALL MASTER STATION OUTLET, WALL MOUNTED 18"AFF.
N	CORRIDORS ABOVE PATIENT ENTRY DOOR	NURSE CALL EMERGENCY STATION, WALL MOUNTED WITH PULL CORD.
M		PHYSIOLOGICAL MONITOR SYSTEM MASTER MONITOR. PROVIDE JB WALL MOUNTED AT 18" AFF. WITH 1.25"C. RUN TO CABLETRAY. PROVIDE BLANK COVERPLATE.
M		PHYSIOLOGICAL MONITOR SYSTEM PATIENT MONITOR. PROVIDE JB MOUNTED ABOVE ACCESSIBLE CEILING WITH 1.25"C. RUN TO CABLETRAY. PROVIDE 1.25"C. FLEX FROM JB TO TOP OF PATIENT SERVICES COLUMN.
NPM		PHYSIOLOGICAL MONITOR SYSTEM NURSE MONITOR. PROVIDE JB WALL MOUNTED AT 18" AFF. WITH 1.25"C. RUN TO CABLETRAY. PROVIDE BLANK COVERPLATE, INTERCOM SYSTEM UNIT, FLUSH MOUNTED 54" AFF.
M		PATIENT SERVICES COLUMN DATA CONNECTION. PROVIDE JB MOUNTED ABOVE ACCESSIBLE CEILING WITH 1.25"C. RUN TO CABLETRAY. PROVIDE 1.25"C. FLEX FROM JB TO TOP OF PATIENT SERVICES COLUMN,
		CONTROLLER FOR POWER OPERATED DOORS. (FURNISHED WITH DOOR HARDWARE). SEE ARCHITECTURAL PLANS FOR EXACT LOCATIONS.

THROUGH PENETRATION FIRESTOP SYSTEMS DETAILS (UL CODE XHEZ)

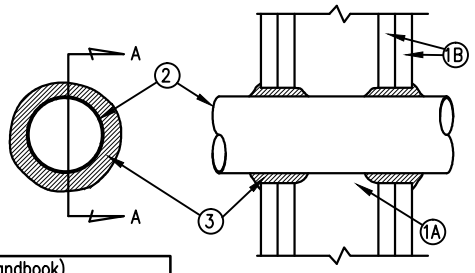
BACKING MATERIAL SHALL BE MINERAL WOOL WITH RED FIRE STOP MATERIAL AND TYPICAL FOR INSTALLATIONS WITH 3M PRODUCTS

System No. WL1540 F Rating – 2 AND 3 Hr T Rating – 0 Hr L Rating At Ambient – 1 CFM/sq ft (See Item 3B) L Rating At 400 F – less than 1 CFM/sq ft (See Item 3B)



SECTION A–A

System No. W–L–1001 F Rating – 1, 2, 3 and 4 Hr (See items 2 and 3) T Rating – 0, 1, 2, 3, and 4 Hr (See item 3) L Rating at Ambient – less than 1 CFM/sq. ft. L Rating at 400° F – less than 1 CFM/sq. ft.

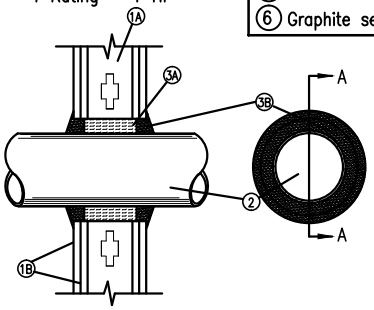


SECTION A–A

Brief UL Description (Refer to Handbook)

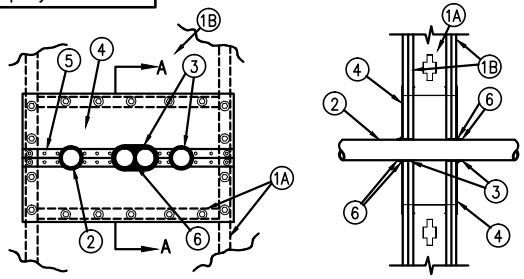
(1) (1A) (1B) Floor or Wall Assembly
(2) Through penetrant (pipe or conduit)
(3) (3A) (3B) Approved fill, void or cavity material
(4) Approved secondary fill, void or cavity material
(5) Steel cover strip
(6) Graphite seal, caulk sealant or putty

System No. WL1009
F Rating – 2 Hr
T Rating – 1 Hr



SECTION A–A

System No. WL1037
F Rating – 2 Hr
T Rating – 0 Hr



SECTION A–A

UL SYSTEMS SHOWN IN THIS DETAIL ARE TYPICAL FOR COMMON ELECTRICAL PENETRATION REQUIREMENTS AND SHALL BE USED ONLY FOR REFERENCE. EXACT FIELD CONDITIONS MAY VARY AND CONTRACTOR SHALL REFER TO UL MANUALS OR OTHER REFERENCE MATERIAL TO COMPLY WITH UL FIRESTOPPING REQUIREMENTS. ANY DEVIATION IN THE FIRE STOP SYSTEM METHODS MAY RESULT IN LOSS OF LIFE DUE TO FIRE/SMOKE PENETRATING DEFINED BARRIERS.

LIMITED EXAMPLES		CONCRETE FLOORS	CONCRETE/BLOCK WALLS	GYPSUM WALL ASSEMBLIES
TYPE OF PENETRANT	F–RATING (HR)	UL–CLASSIFIED SYSTEM	UL–CLASSIFIED SYSTEM	UL–CLASSIFIED SYSTEM
SINGLE METAL PIPES OR CONDUIT	1	C–AJ–2691, F–A–1019	C–AJ–1006, C–AJ–1058, C–AJ–1292	W–L–1001, W–L–1166, W–L–1299*
	2	C–AJ–2691, F–A–1019	C–AJ–1006, C–AJ–1058, C–AJ–1292	W–L–1001, W–L–1166, W–L–1299*
	3	C–AJ–1027, C–AJ–2691, F–A–1019	C–AJ–1006, C–AJ–1058, C–AJ–1292	W–L–1001, W–L–1202, W–L–8069*
	4	C–AJ–1044, C–BJ–1020*, F–A–1019	C–AJ–1044	W–L–1202, W–L–8069*
SINGLE NON–METALLIC PIPE OR COUNDUIT	1	C–AJ–2161, C–AJ–2216, C–AJ–2299	C–AJ–2226, C–AJ–2428, C–BJ–2002	W–L–2002, W–L–2397, W–L–2162
	2	C–AJ–2228, C–AJ–2313*, F–A–2167	C–AJ–2228, C–AJ–2428, C–BJ–2002	W–L–2002, W–L–2397, W–L–2162
	3	C–AJ–2228, F–A–2098, F–A–2167	C–AJ–2228, C–AJ–2244, C–BJ–2002	W–L–2162, W–L–8069*
	4	C–BJ–2002	C–BJ–2002, W–K–2001	W–L–2184, W–L–8069*
MIXED PENETRANTS	1	F–A–8015*, F–A–8041*, C–AJ–8013*	C–AJ–8001*	W–L–8002, W–L–8100, W–L–8069*
	2	F–A–8041*, C–AJ–8013*	C–AJ–8001*	W–L–8002, W–L–8100, W–L–8069*
	3	F–A–1064*, F–A–8041*, C–AJ–8013*	C–AJ–8001*	W–L–8069*
	4	–	–	W–L–8069*

UL NUMBERING SYSTEM

The first alpha component is an F, W or C.
F ..... signifies a floor is being penetrated
W ..... signifies a wall is being penetrated
C ..... signifies either a floor or a wall is being penetrated.

Firestopping systems are typically categorized by through–penetrations of:
- F–rating, Flame Ratings (flames) opening shall also withstand a hose stream test.
- T–rating, Thermal Ratings (temperature)
- L–rating, Smoke Ratings (smoke) L–rating is tested under a differential ressure of 0.30 inches water column (75 Pa) at 75°F and at 400°F.

The second alpha component may be any letter. The significance of the letter used is:

Letter	Description
A	Concrete floors with a minimum thickness less than or equal to 5 in.
B	Concrete floors with a minimum thickness greater than 5 in.
C	Framed floors
D	Steel decks in marine vessels
E	Floor–ceiling assemblies consisting of concrete with membrane protection
F – I	Not used at present time
J	Concrete or masonry walls with a minimum thickness less than or equal to 8 in.
K	Concrete or masonry walls with a minimum thickness greater than 8 in.
L	Framed walls
M	Bulkheads in marine vessels
N	Composite panel walls
O – Z	Not used at present time

The numeric component uses sequential numbers to identify the penetrating item. The significance of the number used is:

No. Range	Description
0000–0999	No penetrating items
1000–1999	Metallic pipe, conduit or tubing
2000–2999	Nonmetallic pipe, conduit or tubing
3000–3999	Electrical cable
4000–4999	Cable trays with electrical cable
5000–5999	Insulated pipe
6000–6999	Miscellaneous electrical penetrants, such as busducts
7000–7999	Miscellaneous mechanical penetrants, such as air ducts
8000–8999	Groupings of penetrations, including any combination of items listed above
9000–9999	Not used at present time

* – LARGE SCALE OPENING

NOTES:
1. JOBSITE CONDITIONS OF EACH THROUGH–PENETRATION FIRESTOP SYSTEM MUST MEET ALL DETAILS OF THE UL–CLASSIFIED SYSTEM SELECTED.
2. IF JOBSITE CONDITIONS DO NOT MATCH ANY UL–CLASSIFIED SYSTEMS IN THE SCHEDULES ABOVE, CONTACT FIRESTOP MANUFACTURER FOR ALTERNATIVE SYSTEMS OR ENGINEER JUDGEMENT DRAWINGS.
3. WHERE MORE THAN ONE APPLICABLE UL–CLASSIFIED SYSTEM IS LISTED IN THE SCHEDULES ABOVE, CHOOSE THE UL SYSTEM WHICH IS MOST ECONOMICAL FOR EACH THROUGH–PENETRATION FIRESTOP SYSTEM.
4. COORDINATE WORK WITH OTHER TRADES TO ASSURE THE PENETRATION OPENING SIZES ARE APPROPRIATE FOR PENETRATE LOCATIONS, AND VICE VERSA.

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