CODE HELP

Always know that you can contact Lee Jolley (Supervisor of Electrical Inspections for Baltimore County Government) at 717-779-5869 or Marty Schumacher (Electrical Training Instructor) at 410-790-8993, as they have developed some special computer courses that can help you with the calculations listed below. In addition, there are programs and code change books that can further explain topics listed below and can be obtained from Mike Holt by calling 1-888-632-2633 or 1-800-786-4234 (IAEI).

After reviewing some previously shared material from a few years ago, I decided to provide some information that might prove helpful in solving everyday workplace problems. You will find formulas, wire, raceway, ampacity charts, and a few commonly asked questions below.

Additionally, you might wish to examine Chapter 9 (Tables and Annexes) carefully. Pay particular attention to the notes and headings, as you will find guidance on: percent of fill for conduit, tubing, etc.; ampacity and properties of conductors; examples to use for load calculations of various equipment and occupancies; materials used for construction types; critical operation systems; tightening torque; and handicap or accessible design diagrams. Chapter 9 of the Code is often overlooked or not reviewed, but it is a very important part of the NEC.

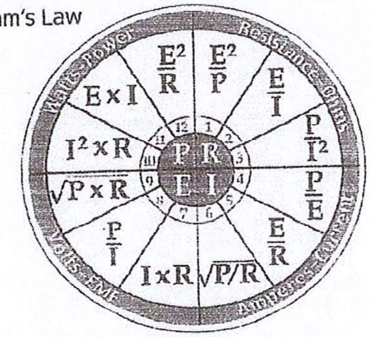
Commercial Wire and Raceway Chart

Overcurrent Protection Size	Copper [1] Wire 60°C Terminal	Copper [2] Wire 75°C Terminal	Maximum [3] Continuous Ampere Load	Raceway [4]	Copper [5] Ground Wire	Max. Continuous 1-Phase VA Load [3]					Max. Continuous 3-Phase VA Load [3]		
						120 V	208 V	240 V	277 V	480 V	208 V	240 V	480 V
15	14	14	12	1/2"	14	1,440	2,496	2,880	3,324	5,760	4,323	4,988	9,976
20	12	12	16	1/2"	12	1,920	3,328	3,840	4,432	7,680	5,764	6,651	13,302
25	10	10	20	3/4"	10	2,400	4,160	4,800	5,540	9,600	7,205	8,314	16,627
30	10	10	24	3/4"	10	2,880	4,992	5,760	6,648	11,520	8,646	9,976	19,953
35	8	8	28	1"	10	3,360	5,824	6,720	7,756	13,440	10,087	11,639	23,278
40	8	8	32	1"	10	3,840	6,656	7,680	8,864	15,360	11,528	13,302	26,604
45	6	8	36	1"	10	4,320	7,488	8,640	9,972	17,280	12,969	14,964	29,929
50	6	8	40	1"	10	4,800	8,320	9,600	11,080	19,200	14,410	16,627	33,254
60	4	6	48	1"	10	5,760	9,984	11,520	13,296	23,040	17,292	19,953	39,905
70	4	4	56	1 1/4"	8	6,720	11,648	13,440	15,512	26,880	20,174	23,278	46,556
80	3	4	64	1 1/4"	8	7,680	13,312	15,360	17,728	30,720	23,056	26,604	53,207
90	2 (1 1/2")	3	72	1 1/4" [7]	8	8,640	14,976	17,280	19,944	34,560	25,938	29,929	59,858
100	1 (2")	3	80	1 1/4" [7]	8	9,600	16,640	19,200	22,160	38,400	28,820	33,254	66,509
110		2	88	1 1/2"	6	10,560	18,304	21,120	24,376	42,240	31,703	36,580	73,160
125		1	100	2"	6	12,000	20,800	24,000	27,700	48,000	36,026	41,568	83,136
150		1/0	120	2"	6	14,400	24,960	28,800	33,240	57,600	43,231	49,882	99,763
175		2/0	140	2"	6	16,800	29,120	33,600	38,780	67,200	50,436	58,195	116,390
200		3/0	160	2 1/2"	6	19,200	33,280	38,400	44,320	76,800	57,641	66,509	133,018
225		4/0	180	2 1/2"	4	21,600	37,440	43,200	49,860	86,400	64,846	74,822	149,645
250		250 kcmil	200	3"	4	24,000	41,600	48,000	55,400	96,000	72,051	83,136	166,272
300		350 kcmil	240	3 1/2"	4	28,800	49,920	57,600	66,480	115,200	86,461	99,763	199,526
350		400 kcmil	268 [6]	3 1/2"	3	32,160	55,744	64,320	74,236	128,640	96,549	111,402	222,804
400		500 kcmil	304 [6]	4"	3	36,480	63,232	72,960	84,208	145,920	109,518	126,367	252,733
400		600 kcmil	320	4"	3	38,400	66,560	76,800	88,640	153,600	115,282	133,108	266,035

(1) Conductor size based on 60°C terminal rating. Ampacity based on four 90°C THHN current-carrying conductors [110.14(C), 310.15, Table 310.16].
(2) Conductor size based on 75°C terminal rating. Ampacity based on four 90°C THHN current-carrying conductors [110.14(C), 310.15, Table 310.16].
(3) Maximum continuous nonlinear load in an ambient temperature of 30°C limited to 80 percent of the overcurrent device rating [210.19(A), 240.6(A)].
(4) To ensure ease of installation, raceways are sized to six THHN conductors (based on 75°C column, Note 3) in rigid nonmetallic conduit [Annex C10].
(5) Copper equipment grounding conductor is sized in accordance with Table 250.122.
(6) Maximum continuous load limited to 80 percent of 75°C conductor ampacity, because conductor ampacity is lower than the overcurrent protection device rating.
(7) Raceway size is based on 75°C conductor size, not the 60°C conductor size.

Question No. 3

- Ohm's Law



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Formulas

Conversion Formulas

Area of Circle = πr^2
Breakeven Dollars = Overhead Cost \$/Gross Profit %
Busbar Ampacity AL = 700A Sq. in. and CU = 1000A Sq. in.
Centimeters = Inches x 2.54
Inch = 0.0254 Meters
Inch = 2.54 Centimeters
Inch = 25.4 Millimeters
Kilometer = 0.6213 Miles
Length of Coiled Wire = Diameter of Coil (average) x Number of Coils x π
Lightning Distance in Miles = Seconds between flash and thunder/4.68
Meter = 39.37 Inches
Mile = 5280 ft, 1760 yards, 1609 meters, 1.609 km
Millimeter = 0.03937 Inch
Selling Price = Estimated Cost \$/(1 - Gross Profit %)
Speed of Sound (Sea Level) = 1128 fps or 769 mph
Temp C = (Temp F - 32)/1.8
Temp F = (Temp C x 1.8) + 32
Yard = 0.9144 Meters

Electrical Formulas Based on 60 Hz

Capacitive Reactance (X_C) in Ohms = $1/(2\pi f C)$
Effective (RMS) AC Amperes = Peak Amperes x 0.707
Effective (RMS) AC Volts = Peak Volts x 0.707
Efficiency (percent) = Output/Input x 100
Efficiency = Output/Input
Horsepower = Output Watts/746
Inductive Reactance (X_L) in Ohms = $2\pi f L$
Input = Output/Efficiency
Neutral Current (Wye) = $\sqrt{A^2 + B^2 + C^2 - (AB + BC + AC)}$
Output = Input x Efficiency
Peak AC Volts = Effective (RMS) AC Volts x $\sqrt{2}$
Peak Amperes = Effective (RMS) Amperes x $\sqrt{2}$
Power Factor (PF) = Watts/VA
VA (apparent power) = Volts x Ampere or Watts/Power Factor
VA 1-Phase = Volts x Amperes
VA 3-Phase = Volts x Amperes x $\sqrt{3}$
Watts (real power) Single-Phase = Volts x Amperes x Power Factor
Watts (real power) Three-Phase = Volts x Amperes x Power Factor x $\sqrt{3}$

Parallel Circuits

Note 1: Total resistance is always less than the smallest resistor
RT = 1/(1/R1 + 1/R2 + 1/R3 +...)
Note 2: Total current is equal to the sum of the currents of all parallel resistors
Note 3: Total power is equal to the sum of power of all parallel resistors
Note 4: Voltage is the same across each of the parallel resistors

Series Circuits

Note 1: Total resistance is equal to the sum of all the resistors
Note 2: Current in the circuit remains the same through all the resistors
Note 3: Voltage source is equal to the sum of voltage drops of all resistors
Note 4: Power of the circuit is equal to the sum of the power of all resistors

Transformer Amperes

Secondary Amperes 1-Phase = VA/Volts
Secondary Amperes 3-Phase = VA/Volts x $\sqrt{3}$
Secondary Available Fault 1-Phase = VA/(Volts x %impedance)
Secondary Available Fault 3-Phase = VA/(Volts x $\sqrt{3}$ x %Impedance)
Delta 4-Wire: Line Amperes = Phase (one winding) Amperes x $\sqrt{3}$
Delta 4-Wire: Line Volts = Phase (one Winding) Volts
Delta 4-Wire: High-Leg Voltage (L-to-G) = Phase (one winding) Volts x 0.5 x $\sqrt{3}$
Wye: Line Volts = Phase (one winding) Volts x $\sqrt{3}$
Wye: Line Amperes = Phase (one winding) Amperes

Voltage Drop

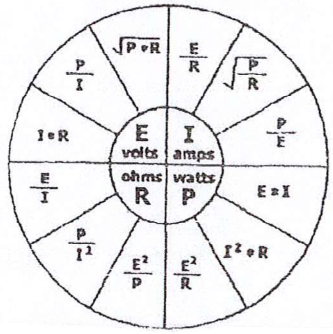
VD (1-Phase) = 2KID/CM
VD (3-Phase) = $\sqrt{3}$ KID/CM

CM (1-Phase) = 2KID/VD
CM (3-Phase) = $\sqrt{3}$ KID/VD

Code Rules

Breaker/Fuse Ratings – 240.6(A)
Conductor Ampacity – 310.15 and Table 310.16
Equipment Grounding Conductor – 250.122
Grounding Electrode Conductor – 250.66
Motor Conductor Size – 430.22 (Single) 430.24 (Multiple)
Motor Short-Circuit Protection – 430.52
Transformer Overcurrent Protection – 450.3

π (Pi) = (3.142 approximately), $\sqrt{2}$ = 1.414 (approximately), $\sqrt{3}$ = 1.732 (approximately), f = Frequency, r = radius, d = diameter, C = Capacitance (farads), L = Inductance (henrys), CM = Circular Mils (Chpt. 9, Tbl. 8), VD = Volts Drop, K75°C = (12.9 ohms CU) (21.2 ohms AL), I = Amperes of load, D = Distance one way



Question No. 3

- 658,289 volt-amperes equals how many amperes at the following voltages?
  - A. 120/240 1Ø volts = _______ amperes
  - B. 120/208 3Ø volts = _______ amperes
  - C. 277/480 3Ø volts = _______ amperes

Question No. 3

- 658,289 volt-amperes equals how many amperes at the following voltage?
  - A. 120/240 1Ø volts = _______ amperes
  - 658,289 ÷ 240 = 2743

Question No. 3

- 658,289 volt-amperes equals how many amperes at the following voltage?
  - B. 120/208 3Ø volts = _______ amperes
  - $\frac{658,289}{208 \times 1.73} = 1829.39$
  - $\frac{658,289}{360} = 1828.58$

Question No. 3

- 658,289 volt-amperes equals how many amperes at the following voltage?
  - C. 277/480 3Ø volts = _______ amperes
  - $\frac{658,289}{480 \times 1.73} = 792.74$
  - $\frac{658,289}{830} = 793.12$

Using Ohms Law, you can see why a 277/480 3-phase voltage system provides an answer so that smaller conductors can be used and it also helps the grid system survive the ever-growing demand for power. However, it makes our industry aware of the problems associated in arc flash, proper gear, and personnel protection (PPE), as well as larger fault currents – all of which can be very dangerous.

Question No. 5

- What is the unbalanced current flowing in the neutral of the following 3 phase, 4-wire, 480/277 volt system?

A = 137 amps, B = 126 amps, C = 151 amps, N = ?

- A. 21.52 amperes
- B. 10.25 amperes
- C. 18.00 amperes
- D. 21.70 amperes

Question No. 5

Hint:

$$I_n = \sqrt{A^2 + B^2 + C^2 - ((AxB) + (BxC) + (CxA))}$$

Question No. 5

$$I_n = \sqrt{A^2 + B^2 + C^2 - ((AxB) + (BxC) + (CxA))}$$

A^2 = 137 x 137 = 18,769	A x B = 137 x 126 = 17,262
B^2 = 126 x 126 = 15,876	B x C = 126 x 151 = 19,026
C^2 = 151 x 151 = 22,801	C x A = 151 x 137 = 20,687
57,446	56,975

57,446 – 56,975 = 471 $\sqrt{471}$ = 21.70

- Answer: D

This shows that a neutral conductor, although not having voltage, still carries all the unbalanced current. It can kill you if, as a person, you will get in series between that conductor and ground. **It is carrying amperes** – *an old rule was that you should never carry more than a ten (10) percent unbalance; 5 (five) percent is really the norm (branch circuits should be rearranged to accomplish the 5 (five) percent unbalance – you can see it would lessen the heat generated.*

Question No. 20

- A single-phase, 240-volt, 5,000-watt duct heater is connected to a 208-volt system. What is the connected wattage and full-load current?

– Wattage ________ F. L. A. ________

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Question No. 20

- R = E x E/P (watts)
- R = 240 x 240 ÷ 5,000 = 11.52 ohms (resistance of element)
- I = E/R = 208 ÷ 11.52 = 18.06 amps
  18.06 x 208 = 3756 watts

- OR -- When 240 rated and connected at 208,
- 208 ÷ 240 = $.866^2$ = .7511 x nameplate watts
- 5,000 x .7511 = 3755.5 watts at 208
  3756 ÷ 208 = 18.06 amps

- Answer: Wattage = 3,756 F.L.A. = 18

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You can see that the use of regular voltage and wattage equipment can be used on distribution systems that is not of the same classification, so load calculations should be adjusted.

In addition to material coming from Lee Jolley and Marty Schumaker, we will be offering other diagrams and questions in the near future. I am hopeful that these practical helps will assist all of you as you weather the storm of the electrical industry.