**Course Outline & Objectives**

**Signing Supervisor / Master Electrician Prep Course**

**Jake’s Electrical Safety & Training, LLC**

**Instructor:**

Jake Taylor

**Course Prerequisites:**

None

**Brief Description of the Course:**

This is a course to prepare attendees on how to pass the Oregon Signing Supervisor Electrician exam and/or Washington Master Electrician exam.

The main focuses of the class include:

* Understanding how the exams are implemented by the state.
* Understanding the National Electric Code (NEC) in general.
* Understanding how the Oregon Electrical Specialty Code (OESC) and Washington Administrative Code (WAC) apply and/or change the NEC.
* Understanding how the Oregon Administrative Rules (OAR), Oregon Revised Statues (ORS), and Revised Code of Washington (RCW) are applied during state exams.
* Real-world application of the electrical code as it pertains to the actual math for calculations, including larger calculation questions that can be seen during an exam.

**Course Objectives/Learning Outcomes:**

* For attendees to be able to effectively and efficiently take all portions of the Oregon Signing Supervisor Electrical exam and/or Washington Master Electrician exam.
* For attendees to be able to effectively perform any electrical calculation relevant to the licenses being awarded so that attendees will be better prepared to effectively run an electrical contracting business for the long-term. Calculations including, but not limited to:
  + Wire ampacities
  + Parallel wire ampacities / Derating
  + Conduit fill
  + Box fill
  + Voltage drop
  + Available fault current
  + Motors
  + Welders
  + Transformers
  + Standard method service / feeder single-family dwelling
  + Optional method service / feeder single-family dwelling
  + Standard method service / feeder multi-family dwelling
  + Optional method service / feeder multi-family dwelling
  + Existing dwelling service / feeder
  + Single-phase commercial service / feeder
  + Three-phase commercial service / feeder
  + RV park
  + Solar systems
  + Optional method service / feeder restaurant
  + Optional method service / feeder school
  + Upsizing equipment ground conductors due to voltage drop
* For attendees to be able to effectively decipher and properly apply electrical code as it relates to the real-world to effectively run an electrical contracting business for the long-term. Electrical code including, but not limited to:
  + General knowledge
  + Definitions
* For attendees to earn continuing education credits towards renewing their existing electrical licenses, if any.

**Detailed Course Outline:**

**Signing Supervisor / Master Electrician Prep Course**

**Jake’s Electrical Safety & Training, LLC**

**Instructor: Jake Taylor**

**Brief Introductions & Test Formats – Approx. 15 minutes**

-Who is Jake Taylor?

Started as a shop hand in 2001 for an electrical contractor

Became an electrical apprentice in 2003

Became a general journeyman in 2008

Began teaching in 2011 at the apprenticeship I completed (approximately 7 years total—various courses)

Received a Bachelor of Applied Science: Technology & Management from Oregon Institute of Technology (OIT) in 2015

Started my own electrical shop in 2022

Began teaching this course in 2023

Licenses held: OR Signing Supervisor Electrician, WA Master Electrician, OR Electrical Inspector, OR Inspector Certification (OIC), Electrical Contractor, & Construction Contractors Board

-What do we know about the OR & WA tests?

Oregon Signing Supervisor Electrician

2 sections: 1) 52 code questions, & 2) 12 calculation questions

4hrs in length total—the test taker must manage their own time

Both sections are multiple choice (A, B, C, or D) on paper Scantron

1 answer is correct and worth +1 point, 3 answers are incorrect and worth 0 points

75% or better for each section (39+ / 9+)

Both sections must be passed at the same time

Texts allowed: NEC, keyword finders (i.e. Tom Henry’s, Ferm’s Fast Finder, etc.), Ugly’s, non- programmable calculator, and OESC & OARs.

Writing & highlighting are allowed in all texts

Pencil & scratch paper will be provided, but must be turned in at the end of the test

Results are usually mailed within 2 weeks

WA Master Electrician

3 sections: 1) 80 code questions, 2) 12 calculation questions, & 3) 20 WAC / RCW administration questions

1st section is 4 hours, 2nd section is 2 hours, 3rd section is 1 hour

All sections are multiple choice (A, B, C, or D) on computer

1 answer is correct and worth +1 point, 3 answers are incorrect and worth 0 points

75% or better for each section (60+ / 9+ / 15+)

All sections can be passed at different times (once a section has been passed, the remaining sections must be passed within 1 year, or all sections must be passed again)

As soon as you click “continue” on the section, the next section begins *immediately*

Texts allowed: NEC, keyword finders (i.e. Tom Henry’s, Ferm’s Fast Finder, etc.), Ugly’s, non- programmable calculator, and WAC / RCWs.

Highlighting only is allowed in all texts

Pencil & scratch paper will be provided, but must be turned in at the end of the test

Results are given immediately after completing all three sections

**General Code Knowledge – Approx. 1 hour & 45 minutes**

-NEC 110.5

If the question / code book doesn’t state what type of wire it is, it’s copper

*NOTE: The questions can use copper, aluminum, & copper-clad aluminum, all in the same question*

-NEC 110.14(C) – temp limitations / “weakest link”

100A or smaller (or #1 or smaller wire size) = 60° C terminals

Greater than 100A (or 1/0 or larger wire size) = 75° C terminals

-NEC T240.6(A)

Standard amp ratings of fuses & fixed-trip breakers (OCPD)

*NOTE: The text setting up the table also highlights that 1, 3, 6, 10, & 601A are also standard sizes, but not on the table*

Disconnecting means have a different, *unlisted in the NEC*, set of standard ratings: 30, 60, 100, 200, 400, 600, 800, & 1200A

-Connected vs. calculated loads

Connected / Actual load = the actual load present prior to any demand factors, discounts, continuous duty, etc. (i.e. *before* math is done)

Calculated / Demand load = the allowable load after demand factors, discounts, continuous duty, etc. (i.e. *after* math is done)

-NEC 240.4(B) & (C)

If the calculated load is not a standard OCPD rating, in *most* situations, we’re allowed to go up to the next standard size (i.e. the secondary of a transformer, we’re NOT allowed to go up)

If we went up to the next standard size (i.e. does NOT apply if we go more than one for future expansion, etc.) and the OCPD is 800A or less, we’re allowed to use the calculated load for sizing

If we went up to the next standard size and the OCPD is 1000A or more, we must use the OCPD size for sizing

*NOTE: If a question asks us for the minimum allowed, we MUST use this rule*

-Exceptions

With giving the minimum size allowed in mind, the above rule is different than always using exceptions towards the minimums. We cannot assume anything in the question. We can only use what the question provides.

For example:

If a question asks us what the minimum cover for a direct bury conductor serving a residential, 120-volt, GFCI-protected circuit is, we cannot use NEC T300.5 column 4. Column 4 is reserved for residential, 120-volts or less, GFCI-protected, *AND* 20-amps or less. Because the question doesn’t mention what the amperage of the circuit is, we cannot assume it is 20-amps or less. So, column 1 must be used, rather than column 4.

-Applying voltage with 3Ø (3-phase)

When calculating voltage (i.e. Ohm’s law, voltage drop, available fault current, etc.), the calculation must have the √3, or 1.732

*NOTE: Ugly’s only shows 1.73 in its calculations. However, the tests use 1.732!*

-Ohm’s law, Page 1 of Ugly’s

P = Watts (power)

I = Amps (intensity of current)

E = Volts (electromotive force)

R = Ohms (resistance)

-Corrections in Ugly’s

Page #60 – primary & secondary XMFR

Cross out line 100kVA for both tables and write in the margins the following:

112.5kVA

208V = 312.28A

240V = 270.64A

480V = 135.32A

Page #24 – capacitance

Add the following calculation:

Ic = (Kvar \* 1,000) / (voltage \* √3)

Page #51

Add the following:

Max volts dropped @ 3%

120V = 3.6V

208V = 6.24V

240V = 7.2V

277V = 8.31V

480V = 14.4V

Page #53

Add the following XFMR secondary fault current (aka available fault current):

XFMR secondary amps / % of Z

*NOTE: 1.4% impedance = 0.014*

*NOTE: This calculation is also located on Page 63 of Ugly’s as “Short-circuit amperes”*

Back of Ugly’s, Notes page

Non-linear lighting = neutral IS a current-carrying conductor

-Recommended highlighting

OESC

Highlight each OESC in your NEC with a color that you will not use anywhere else (I prefer green). This will jump off the page if the answer might be altered by the OESC. It’s worth the extra 30 seconds to verify.

Parts of the NEC

Highlight each and every part of the NEC in a color that you will not use anywhere else (I prefer dark blue).

-Conductor definitions

Ungrounded / phase – hot conductor

GroundED – neutral conductor

GroundING – ground conductor

Equipment groundING conductor = standard ground conductor (i.e. green THHN in conduit)

GroundING electrode = component that we utilize to connect the system to earth (i.e. ground rod)

GroundING electrode conductor = ground conductor connecting the groundING electrode to the main bonding jumper (i.e. bare #4 copper to ground rods)

-NEC T250.66

Table used to size the groundING electrode conductor

Based on the largest ungrounded conductor

If connected to rod, pipes, or plates = not required to be larger than #6 copper (#4 if exposed to physical damage) – NEC 250.66(A)

If connected to concrete encased electrodes = not required to be larger than #4 copper – NEC 250.66(B)

If connected to ground ring = not required to be larger than the size of the ground ring – NEC 250.66(C)

-NEC T250.102(C)(1)

Table used to size groundED conductor, bonds, etc.

Based on the largest ungrounded conductor

If connected to metal water or structural steel = not required to be larger than 3/0 copper – NEC 250.104(D)(1) & (2)

*NOTE: If the conductor is run in parallel, the size of the conductor is based on the largest ungrounded conductor in EACH conduit*

-NEC T250.122

Table used to size the equipment groundING conductor

Based on the largest OCPD size

-NEC 310.10(G)(1)

Parallel conductors = minimum 1/0 for all conductor types EXCEPT groundING

-NEC 210.20(A)

Continuous duty = 3hrs or more

Non-residential lighting is almost *always* considered to be continuous duty – NEC T220.12 note

This can be achieved by increasing the size of the load by 25% (1.25) OR reducing the circuit by 80% (0.8)

*NOTE: When calculating for a service or feeder, this ONLY applies to the ungrounded conductor load. It does NOT apply to the neutral load.*

-Systems definitions, NEC 100

Service = The conductors and equipment connecting the serving utility to the wiring system of the premises served (i.e. initial feed from the utility)

Separately derived system = An electrical source, other than a service, having no direct connection to circuit conductors of any other electrical source (other than grounding and bonding connections) (i.e. transformer)

Feeder = All circuit conductors between the service equipment, the source of a separately derived system (or other power supply source) and the final branch-circuit overcurrent device (i.e. main panel to subpanel, secondary transformer conductors)

Branch circuit = The circuit conductors between the final overcurrent device protecting the circuit and the outlet(s) (i.e. OCPD to plugs)

-Motors

The largest motor is to be treated like a continuous duty load – NEC 430.22

This applies at every level of the system (i.e. branch circuit, service at EACH separately derived systems) for multiple largest motor

In the event of two or more motors having the same size, only one motor is selected as the largest motor

For code questions, only HP rated motors should be treated as motors (unless the question is asking to convert wattage to HP)

-Motor nameplates vs. NEC tables

Full-load current (FLC) = NEC tables

Full-load amps (FLA) = motor nameplate

Nameplate is used ONLY for sizing overloads (NEC 430.6(A)(1) & (2), elevators (NEC 620.13), cranes (NEC 610.41), and disconnecting means for refrigeration & air conditioning equipment (NEC 440.12)

-NEC 220.60

Noncoincidental loads = where it is unlikely that two or more loads can be run at the same time, only the larger of the loads need to be calculated towards the total load of the service or feeder (i.e. furnace vs. air conditioning)

-HVAC (heating & cooling) equipment

Branch circuit = connected load must be increased to 125% – NEC 424.4(B)

Service / Feeder = connected load is taken at 100% – NEC 220.51

**Wire Ampacity Calculations – Approx. 2 hours**

-Wire ampacity limerick

What was given in the question? This will determine what we do with the factors.

wi-re size = mul-ti-ply

ma-chine = di-vide

*NOTE: For continuous duty, the factor will ALWAYS be 0.8*

-NEC T310.16

Start with wire type for insulation rating – 60° vs. 75° vs. 90° rating

Ambient correction factor accordingly – NEC T310.15(B)(1)

*NOTE: Dual-rated wires (i.e. XHHW) that are found in both the 75° & 90° columns are selected based on the location. Dry location = 90°, wet location = 75°*

*NOTE: Underground conduits are considered to be a wet location*

*NOTE: Less than ⅞” above the roof to the bottom of the raceway in direct sunlight results in a 60° F temperature adder – NEC 310.15(B)(2)*

Current carrying conductors (CCCs) – NEC T310.15(C)(1)

*NOTE: Watch out for OTHER current carrying conductors in the code question*

*NOTE: Non-linear lighting = neutral is a CCC – NEC 310.15(E)*

*NOTE: Type MC & AC cables with more than 20 CCCs that are bundled together for longer than 24” results in a 60% derate – NEC 310.15(C)(1)(d)(4) exception*

Continuous duty = 0.8 is *always* the factor used

-What is the maximum allowable ampacity of a 500 kcmil type ZW copper conductor ran in ambient temperatures of 68 degrees C with 7 total current-carrying conductors in a raceway?

What’s given?

wi-re size given = mul-ti-ply factors

68 degrees C ambient @ 75° C rated wire (type ZW) = 0.33 factor

7 CCCs = 0.7 factor

380A

\* 0.33 (ambient temp.)

\* 0.7 (CCCs)

87.78 amps

-What is the maximum load a 900 kcmil type THHN-THWN copper conductor ran in ambient temperatures of 62 degrees C with 9 other current-carrying conductors in an outdoor underground raceway feeding a continuous duty load?

What’s given?

wi-re size given = mul-ti-ply factors

900 kcmil type THHN-THWN copper (75° C column, underground wiring) = 520amps

62 degrees C ambient @ 75° C rated wire = 0.47 factor

10 *other* CCC = 0.5 factor

CD = 0.8 factor

underground wiring means the conduit is considered a wet location and has a maximum rating of 75 degrees, we must start our derating in the 75° C column as a result.

520A

\* 0.47 (ambient temp)

\* 0.5 (CCCs)

\* 0.8 (CD)

97.76 amps

-What size of type THHN copper-clad conductor is necessary to supply a 225A continuous-duty load ran in 72 degrees F?

What’s given?

ma-chine given = di-vide factors

THHN copper clad = aluminum 90° C column

225A

continuous duty = 0.8

72 degrees F, 90° C column = 1.04

225A

/ 0.8 (continuous duty)

/ 1.04 (ambient temp)

270.43A = 500 kcmil (310A, 75° C column, aluminum – weakest link, gear)

*NOTE: 400 kcmil is not larger enough, only covers 270A*

-What is the maximum allowable ampacity of a three-phase feeder using 1/0 type THHN copper conductors ran in ambient temperatures of 122 degrees F, feeding non-linear lighting loads?

What’s given?

wi-re size given = mul-ti-ply factors

1/0 type THHN copper (90° C column) = 170amps

122 degrees F ambient @ 90° C rated wire (type THHN) = 0.82 factor

4 current carrying conductors (three-phases, plus neutral because of non-linear loads) = 0.8

170A

\* 0.82 (ambient temp)

\* 0.8 (CCCs)

111.52 amps

-What’s the minimum size of THHN copper conductors are needed to feed a 208Y/120V, three-phase, non-linear, commercial lighting panelboard with a calculated load of 95,000VA, ran in 110 degrees F?

What’s given?

ma-chine = di-vide

80,000VA

/ (208V \* 1.732)

222.06A total load

222.06A total load

/ 0.8 (HHHN = 4 CCCs, neutral because it’s a non-linear load)

/ 0.8 (continuous duty, non-residential lighting is considered continuous duty)

/ 0.87 (ambient temp)

398.82A total load needed to be covered after derating = 600 kcmil THHN copper (420A @ 75° C column)

**<END OF THE 1st 4-HOUR CLASS>**

**Wire Ampacities & Paralleling – Approx. 1 hour & 15 minutes**

-Last class, we found the answer to the following:

What’s the minimum size of THHN copper conductors are needed to feed a 208Y/120V, three-phase, non- linear, commercial lighting panelboard with a calculated load of 95,000VA, ran in 110 degrees F?

398.82A = 600 kcmil THHN copper (420A @ 75° C column)

What’s the minimum size THHN copper conductors needed for the same scenario, but paralleled across 2 conduits?

398.82A total load

/ 2 parallel conduits

199.41A = 3/0 (225A @ 90° C column)

3/0 kcmil @ 90° C column = 225A each

225A

\* 2 parallel conduits

450A total ampacity of the conductors to work with prior to derating

450A

\* 0.8 (CCCs)

\* 0.8 (CD)

\* 0.87 (ambient temp.)

250.56A max ampacity of the conductors to work with after derating

Now we need to verify that the calculated amps cover two things (otherwise we need to upsize our wire and verify again):

1) Does the calculated ampacity of the wiring after derating cover our calculated load/OCPD size? In this case, yes, 250.56A vs. 222.06A

2) Do the temperature limitations of the gear give us issues with the size we’re proposing? Think weakest link! 3/0 THHN copper @ 75° C column = 200A \* 2 parallel conduits = 400A – that covers our calculated load/OCPD size also – 400A vs. 398.82A

-What’s the minimum size of THHN copper conductors are needed to feed a 120/240V, three-phase, non-linear commercial lighting panelboard with a calculated load of 150,000VA, ran in 21 degrees C?

What’s given?

ma-chine = di-vide

150,000VA

/ (240V \* 1.732)

360.85A total load before derating

360.85A

/ 0.8 (CCCs)

/ 0.8 (CD)

/ 1.04 (ambient temp)

542.15A total load after derating = 1,000 kcmil (545A @ 75° C column)

-What’s the minimum size THHN copper conductors needed for the same scenario, but paralleled across 3 conduits?

542.15A total load after derating

/ 3 conduits

180.72A = 2/0 (195A @ 90° C column)

2/0 @ 90° C column = 195A each

195A

\* 3 parallel conduits

585A total ampacity of the conductors to work prior to derating

585A

\* 0.8 (CCCs)

\* 0.8 (CD)

\* 1.04 (ambient temp)

389.38A max ampacity of the conductors to work with after derating

Now we need to verify that the calculated amps cover two things (otherwise we need to upsize our wire and verify again):

1) Does the calculated ampacity of the wiring after derating cover our calculated load/OCPD size? In this case, yes, 389.38A vs. 360.85A

2) Do the temperature limitations of the gear give us issues with the size we’re proposing? Think weakest link! 2/0 THHN copper @ 75° C column = 175A \* 3 parallel conduits = 525A – that does NOT cover our calculated load/OCPD size – 525A vs. 542.15A

We need to increase the size of the parallel wiring to the next size up to see if those cover the 542.15A

3/0 THHN copper @ 75° C column = 200A \* 3 parallel conduits = 600A – that does cover out calculated load/OCDP size – 600A vs. 542.15

-What size of aluminum TW is necessary to feed a 210A single-phase load that will run for 8hr shifts in an ambient temperature of 50 degrees C with a total of 9 current carrying conductors fed across 2 conduits?

What’s given?

ma-chine = di-vide

210A total load

/ 0.8 (continuous duty)

/ 0.7 (CCCs)

/ 0.58 (ambient temp.)

646.55A total load after derating

646.55A

/ 2 conduits

323.26A total ampacity needed per parallel conduit

323.26A = 800 kcmil TW aluminum (covers 330A @ 60° C column)

No need to verify the gear because the gear is rated at the 75° C column.

-What’s the maximum load a 3/0 copper XHHW conductor feed in an ambient temperature of 88 degrees F with 3 other current carrying conductors across 2 conduits with 60° C rated terminals?

What’s given?

wi-re size = mul-ti-ply

3/0 copper XHHW @ 90° C column = 225A

225A

\* 0.8 (CCCs, 3 *other* conductors = 4 total CCCs)

\* 0.96 (ambient temp)

172.8A max ampacity the conductor can carry after derating

What’s the weakest link?

The max the wire can handle after derating = 172.8A

The max the gear can handle with 3/0 copper XHHW connected to it is the 60° C column = 165A

This means that the 3/0 copper @ 60 degrees in each conduit can only handle 165A

165A

\* 2 conduits

330A is the max ampacity we can put across the parallel wires with 60° C rated terminals

**Conduit Fill – Approx. 1 hour & 15 minutes**

-Conduit fill

Chapter 9 Tables

Table 1: Cross section

Information Note #1 – Upsizing conduit

Notes to tables

#2 – Sleeves for protection do not count

#3 – Non-current carrying conductors SHALL be counted

#4 – Nipples (24 inches or less) can be filled up to 60% cross section

*NOTE: Current carrying conductor derate can be ignored*

#7 – Round up at 0.8 or higher

#9 – Cables shall be counted as one conductor in terms of Table 1

Table 4: Actual conduit area

Table 5: Actual wire area

Note: Do not use Table 5A – compact wires

Note: RHW vs. RHW\* (end of table 5)

Table 8: Bare conductor area

Circular mils – at 250 kcmil, it is the actual mils

Quantity – solid bare = 1, stranded bare = 7+

Table C.1-C.12A – Maximum conductors, must be all the same type/size conductors

NOTE THE ASTERISK AT THE BEGINNING!

-What size of IMC conduit is necessary for (6) – 250 kcmil THHN, (1) – 1/0 THHN conductors?

250 kcmil THHN = 0.397 in. sq. x 6 = 2.382 in. sq.

1/0 THHN = 0.1855 in. sq.

2.382 in. sq. + 0.1855 in. sq. = 2.5675 in. sq.

**3” (3.169 in. sq. @ 40%)**

-A 2” EMT conduit that is 20” in length has (2) – #4 RHW with outer covering, how many bare stranded #8 conductors can legally fit in the conduit?

Bare #8 stranded = 0.017 in. sq.

#4 RHW with outer covering = 0.1333 in. sq. x 2 = 0.2666 in. sq.

2” EMT @ 60% = 2.013 in. sq.

2.013 in. sq. – 0.2666 in. sq. = 1.7464 in. sq.

1.7464 in. sq. / 0.017 in. sq. = 102.72 conductors = 102 conductors

*NOTE: Because all of the wires are not the same size, if the answer had been 102.8 conductors, we could NOT have rounded up to 103 conductors.*

-Can (5) - #1 THWN, (5) - #2 THWN conductors fit in a 2 ½” PVC Schedule 80 conduit?

#1 THWN = 0.1562 in. sq. x 5 = 0.781 in. sq.

#2 THWN = 0.1158 in. sq. x 5 = 0.5795 in. sq.

2 ½” PVC 80 @ 40% = 1.647 in. sq.

0.781 in. sq. + 0.5795 in. sq. = 1.3605 in. sq. vs. 1.647 in. sq.

**YES**

**Box Fill – Approx. 45 minutes**

-Box fill – NEC 314.16

Talk about allowances vs. conductors

NEC 314.16(B) – actual calculations

(5) – equipment grounding conductors: first 4 grounds in the box = 1 allowance, every ground after that is a ¼ allowance based on the largest ground in the box

(4) – each yoke: each gang of the yoke, 2 allowance per gang based on the largest conductor connected to the device

(3) – 1 or more luminaire stud/hickey: 1 allowance per type based on the largest conductor in the box

(2) – 1 or more cable clamp: internal cable clamps only, 1 allowance when present based on the largest conductor in the box

(1) – each conductor: each legal conductor = 1 allowance based on the conductor size, pigtails are free, 12” loop or more = 2 allowances, less than 12” loop = 1 allowance

-What is the total cubic inch box fill for: (2) – 12/2 romex wires, (2) – 10/3 romex wires, (1) - #12 black THHN conductor looped 12”, (1) - #10 bare conductor, (2) – fixture studs, (1) – fixture hickey, (1) – GFCI with #12s connected, (2) – internal cable clamps, and (2) – external cable clamps?

#12s

2 (GFCI)

4 (#12 romex)

2 (#12 black loop)

#10s

1.25 (grounds: first 4 grounds = 1 allowance (12/2 & 10/3 romex), each additional ground = 0.25 (#10 bare))

1 (fixture studs)

1 (fixture hickeys)

1 (internal clamps)

8 allowances @ #14

\* 2.25 cu. in.

18 cu. in.

4.25 allowances @ #10

\* 2.5 cu. in.

10.625 cu. in.

18 cu. in. + 10.625 cu. in. = 28.625 cu. in. total

-A box with 54.8 cubic inch box fill with a mud ring stamped 6.3 cubic inches has (4) – 12/2 romex cables inside. How many 14/2 romex cables can legally be added in the box?

56.3 cu. in. + 6.3 cu. in. = 61.2 cu. in. total box fill available

(4) – 12/2 romex HNG HNG HNG HNG

12s

1 (grounds: first 4 grounds = 1 allowance)

8 (12/2 hots & neutrals)

9 allowances @ #12

\* 2.25 cu. in.

20.25 cu. in.

62.6 cu. in.

- 20.25 cu. in.

40.9 cu. in. remaining space in box

(1) – 14/2 romex HNG

14s

2 (14/2 H & N)

2 allowances

\* 2.00 cu. in.

4.00 cu. in.

12s

0.25 (ground: first 4 allowances already counted from the existing 12/2 romex wires, each additional 14/2 romex = 1 additional ground = 0.25 allowance @ #12 [largest ground in the box])

0.25 allowance @ #12

\* 2.25 cu. in.

0.5625 cu. in.

Each 14/2 romex = 4.5625 cu. in.

40.95 cu. in. / 4.5625 cu. in. = 8.97 cables = 8 cables

**Voltage Drop – Approx. 30 minutes**

-Voltage Drop – NEC 210.19(A) informational note 3

Maximum voltage drop for both feeders and branch circuits = 5%

Maximum for feeders or branch circuits = 3%

Max volts dropped allowed (3%) per voltage

120V \* 0.03 = 3.6V

208V \* 0.03 = 6.24V

240V \* 0.03 = 7.2V

277V \* 0.03 = 8.31V

480V \* 0.03 = 14.4V

Actual Volts Dropped = (2\*K\*I\*L) / Cm

(1.732\*K\*L\*I) / Cm

-What’s the volts dropped for a 120V, single-phase, 30A circuit that is 225’ from the power source?

Vd = (2\*K\*I\*L) / Cm

= (2\*12.9\*30A\*225’) / 10,380

= 174,150 / 10,380

Vd = 16.78V

-What is the voltage drop percentage of said circuit?

Vd % = 16.78V / 120V = 0.1398 = 14%

-With the circuit being utilized fully, what voltage is present at the load?

120V – 16.78V = 103.22V

-What size of conductor is needed for the circuit to be at the maximum allowable voltage drop?

Cm = (2\*K\*I\*L) / 3% VD for 120V

= (2\*12.9\*30A\*225’) / 3.6V

= 174,150 / 3.6V

Cm = 48,375 = #3 (52,620 Cm – NEC Chapter 9, Table 8)

-What size of conductor is needed for a 100A, 277V, three-phase, aluminum branch circuit located 200’ away from the power source?

Cm = (1.732\*K\*I\*L) / 3% VD for 277V

= (1.732\*21.2\*100A\*200’) / 8.31V

= 734,368 / 8.31V

Cm = 88,372 = 1/0 (105,600 Cm – NEC Chapter 9, Table 8)

**Available Fault Current – Approx. 15 minutes**

-Available Fault Current

Ugly’s 2020, page 60

Short-circuit amps = Is (secondary ampacity) / %Z

-What is the available fault current for a three-phase, 277/480V service fed by a 225kVA transformer with 1.8% impedance?

225kVA secondary amps = 270.6A

270.6A / 0.018 = 15,033A

<Homework: (2) – 26 code question quizzes & Practice Calculations: Wire ampacities, conduit fill, box fill, voltage drop, available fault current>

**<END OF THE 2nd 4-HOUR CLASS>**

**Review Homework – Approx. 15 minutes**

**Motor Calculations – Approx. 2 hours & 15 minutes**

-Reminder: FLA vs FLC

-Reminder: Largest motor

Given information:

Motor sizes, 3 phase, 208V

(1) – 50HP, 140A nameplate FLA

(1) – 30HP, 80A nameplate FLA

(2) – 10HP, 30A nameplates FLA

(1) – 5HP, 15A nameplate FLA

-What’s the minimum sized feeder OCPD allowed to serve the subpanel?

NEC T430.250 🡪 FLCs

50HP = 143A \* 1.25 (largest motor) = 178.75A

30HP = 88A

10HP = 30.8A

10HP = 30.8A

5HP = 16.7A

178.75A

88A

30.8A

30.8A

30.8A

+16.7A

345.05A total calculated load

NEC 430.62 🡪 next standard size OCPD

345.05A 🡪 next standard size (NEC T240.6(A) = 350A

-What’s the minimum size THHN conductors to feed a subpanel for all motor loads?

345.05A calculated load = 500 kcmil (380A @ 75° C column)

-What is the minimum sized THHN-THWN copper conductors that can feed the 30HP branch circuit?

NEC 430.22 = 125% of FLC

88A

\*1.25

110A = #2 THHN-THWN (75 degrees for weakest link = 115A)

-What is the maximum dual-element time delay fuse that can serve the 30HP motor branch circuit for short-circuit and ground-fault protection, assuming the motor has difficulties with start up?

NEC T430.52

30HP = 88A \* 1.75A = 154A 🡪 150A with no exceptions

Exception #1 – no matter what (doesn’t matter if it can start or not), next standard size allowed 🡪 175A

Exception #2 – IF it cannot start sufficiently start using exception #1, apply the value from NEC 430.52 based on the OCPD. This is our absolute max 🡪 MUST go down to the next standard size

88A

\* 2.25

198A 🡪 175A

-What is the maximum inverse time breaker that can serve the 30HP motor branch circuit for short-circuit and ground-fault protection, assuming the motor has difficulties with start up?

88A

\* 2.5

220A 🡪 225A exception #1

88A

\* 4

352A 🡪 350A exception #2

-What’s the minimum ampacity rating of the disconnecting means for the 30HP motor branch circuit?

NEC 430.110 – not less than, must go up to the next size

88A

\* 1.15

101.2A 🡪 at minimum 110A, but it could be 200A due to the standard disconnect sizes

-What’s the minimum HP rating of the disconnecting means for the 30HP motor branch circuit?

NEC 430.110(C)(1) – 125% of the LRC for the largest motor (only 1 motor)

NEC T430.251(B) – LRC values

30HP = 481A

481A

\* 1.25

601.25A 🡪 40HP disconnect rating (641A)

-What’s the maximum size separate overload that can serve the 30HP motor (service factor & marked temperature rise are unknown)?

NEC 430.32(A)(1) – got to have both labeled, so 115% of the NAMEPLATE, must go down (MAX)

80A

\* 1.15

92A 🡪 90A separate overload

*NOTE: NEC 430.32(C) = sizing when the motor is having troubles starting due to the separate overload device*

-A branch circuit has some of the previous motors grouped together: (1) – 10HP, (1) – 10HP, and (1) – 5HP. What is the minimum sized branch circuit for the three motors fed by THHN-THWN copper conductors?

30.8A \* 1.25 = 38.5A

30.8A

+16.7A

86A = #3 THHN-THWN (100A @ 75° C for weakest link)

-A branch circuit has some of the previous motors grouped together: (1) – 10HP, (1) – 10HP, and (1) – 5HP. What’s the minimum ampacity rating of the disconnecting means for the branch circuit of the three motors?

30.8A

30.8A

+16.7A

73A

\* 1.15

90.05A 🡪 100A

-A branch circuit has some of the previous motors grouped together: (1) – 10HP, (1) – 10HP, and (1) – 5HP. What’s the minimum HP rating of the disconnecting means for the branch circuit of the three motors? They do not start at the same time.

NEC T430.251(B) – LRC

NEC T430.250 – FLC

10HP LRC = 179A

10HP FLC = 30.8A

5HP FLC = +16.7A

226.5A = 15HP disconnect rating (covers 267A)

-A branch circuit has some of the previous motors grouped together: (1) – 10HP, (1) – 10HP, and (1) – 5HP. What’s the minimum HP rating of the disconnecting means for the branch circuit of the three motors? They all start at the same time.

NEC T430.251(B) – LRC

10HP LRC = 179A

10HP LRC = 179A

5HP LRC = +102A

460A = 30HP disconnect rating (covers 481A)

**Welders – Approximately 45 minutes**

-Arc welders – NEC 630.11

NEC 630.11(A) & (B)

NEC T630.11(A)

-Resistance welders

NEC 630.31(A) & (B)

NEC T630.31(A)

-What’s the calculated ampacity of a group of non-motor generator arc welders with the following ratings: (1) – 20A, 80% duty cycle, (2) – 15A, 60% duty cycle, (2) – 30A, 30% duty cycle?

20A \* 0.89 = 17.8A

15A \* 0.78 = 11.7A

15A \* 0.78 = 11.7A

30A \* 0.55 = 16.5A

30A \* 0.55 = 16.5A

17.8A \* 1.00 = 17.8A

16.5A \* 1.00 = 16.5A

16.5A \* 0.85 = 14.03A

11.7A \* 0.70 = 8.19A

11.7A \* 0.60 = +7.02A

63.54A

-What’s the calculated ampacity of a group of resistance welders with the following ratings: (1) – 20A, 15% duty cycle, (2) – 15A, 25% duty cycle?

20A \* 0.39 = 7.8A

15A \* 0.5 = 7.5A

15A \* 0.5 = 7.5A

7.8A \* 1.00 = 7.8A

7.5A \* 0.6 = 4.5A

7.5A \* 0.6 = +4.5A

16.8A

**Transformers – Approximately 45 minutes**

-Page 60 / 63 in Ugly’s – primary / secondary ampacity tables (page 60) & manual calculations (page 63)

-What is the primary and secondary ampacities of a 400kVA 3-phase transformer, 480V to 208Y/120V?

Ip = (kVA \* 1,000) / (Ep \* 1.732)

(400kVA \* 1,000) / (480V \* 1.732)

481.14A

Is = (kVA \* 1,000) / (Es \* 1.732)

(400kVA \* 1,000) / (208V \* 1.732)

1,110.32A

-What is the primary and secondary ampacities of a 150kVA 3-phase transformer, 480V to 208Y/120V?

Ip = (kVA \* 1,000) / (Ip \* 1.732)

(150kVA \* 1,000) / (480V \* 1.732)

180.43A

Ip = 180.4A (Ugly’s page 60)

Is = (kVA \* 1,000) / (Es \* 1.732)

150kVA \* 1,000) / (208V \* 1.732)

416.37A

Is = 416.4A (Ugly’s page 60)

-NEC T450.3(B) – OCPD for transformers of 1,000V or less

Split between Primary and Secondary

Split between Primary Only vs. Primary & Secondary protection

Split based on the actual calculated ampacity of the transformers

*Note #1: We go UP to the next standard size. If we’re not using note #1, we go DOWN to the next standard size*

-What is the maximum OCPD for the primary & secondary protection of the 150kVA, 3 phase, 480V to 208Y/120V transformer?

Primary protection

Primary protection 🡪 Primary & Secondary protection 🡪 Currents of 9A or more = 250% 🡪 down to the next standard size

Primary calculated amps = 180.4A (Ugly’s page 60)

180.4A

\* 2.5

451A 🡪 450A max primary OCPD

Secondary protection

Secondary protection 🡪 Primary & Secondary protection 🡪 Current of 9A or more = 125% with note #1 🡪 go UP to the next standard size

Secondary calculated amps = 416.4A (Ugly’s page 60)

416.4A

\* 1.25

520.5 🡪 600A OCPD

-What are the required THHN copper conductors needed to feed the primary side of the transformer from the previous question?

We could use at minimum a 200A breaker to cover the 180.4A on the primary. But we used the max of 450A, so we cannot size the wiring off of the load of 180.4A; we have to use the OCPD 450A.

450A = 700kcmil THHN (460A @ 75° C column for weakest link)

-What is the minimum sized grounded THHN copper conductor to feed the primary side of the transformer from the previous question?

NEC T250.102(C)(1)

700kmcil ungrounded conductor = 2/0 THHN

-What are the required THHN copper conductors needed to feed the secondary side of the transformer from the previous question?

We CANNOT use NEC 240.4(B) (i.e. going up one standard size rule) for sizing the secondary conductors of a transformer. We MUST match the secondary OCDP.

600A = 1,500kcmil THHN (625A @ 75° C column for weakest link)

-What is the minimum sized grounded THHN copper conductor to feed the secondary side of the transformer from the previous question?

NEC T250.102(C)(1)

1,500kcmil ungrounded conductor

1,500,000 Cm

\* 0.125 (note 1)

187,500 Cm = 4/0 (NEC Chapter 9, Table 8)

-What size is our equipment grounding conductor for the primary side feed of the transformer from the previous question?

NEC T250.122

Primary OCPD = 450A = #2 THHN copper (400A is smaller than our OCPD, must size it off of 500A)

-What size is our supply-side bonding jumper for the secondary of the transformer from the previous question?

NEC T250.102(C)(1)

1,500kcmil ungrounded conductor

1,500,000 Cm

\* 0.125 (note 1)

187,500 Cm = 4/0 (NEC Chapter 9, Table 8)

**<END OF THE 3rd 4-HOUR CLASS>**

**Single-Family Dwelling Service / Feeder, Standard Method Calcs – Approx. 4 hours**

-Step 1: Lighting loads

NEC 220.14(J) – General lighting & receptacle loads – 3VA per square ft.

NEC 220.52(A) – small appliance

minimum 1,500VA per small appliance circuit

minimum of 2 small appliance circuits per kitchen

*NOTE: A dwelling MUST have a kitchen, unless shared facilities are noted. Shared facilities are generally not allowed per building codes for a single-family dwelling.*

*NOTE: Code questions often will NOT list the kitchen. We’re supposed to remember that it’s required.*

NEC 220.52(B) – laundry circuit (washing machine)

minimum 1,500VA per laundry

*NOTE: A dwelling MUST have a laundry circuit, unless shared facilities are noted. Shared facilities are generally not allowed per building codes for a single-family dwelling.*

*NOTE: Code questions often will NOT list the laundry circuit. We’re supposed to remember that it’s required.*

NEC T220.42 derates the sum of above to provide the calculated hots (neutrals match because all loads are 120-volt w/neutral present)

1st 3,000VA @ 100%

Next 117,000VA @ 35%

Remaining VA (anything over 120,000VA) @ 25%

-Step 2: NEC 220.53 – Appliances

Nameplate rating of fastened in place appliances (with exception of cooking equipment, clothes dryers, & HVAC (heat or AC)

4 or more appliances = derate to 75%

Hot & neutrals vary based on the actual appliance (120V with neutral vs. 240V with neutral vs. 240V without neutral)

-Step 3: NEC 220.54 – Electric Clothes Dryers

5000VA (watts) per clothes dryer *OR* nameplate, whichever is larger

NEC T220.54 derate applies for 5 or more dryers

NEC 220.61(B)(1) – Neutral to be derated to 70%

For 3-phase feeders / services with single-phase dryers only, the same rules above apply, but the calculated load is twice the maximum number connected between any 2 phases (AB vs. BC vs. CA). The calculated load is then evenly split across the three phases.

-Step 4: NEC 220.55 – Electric Cooking Equipment

NEC T220.55 should be applied for all electric cooking equipment larger than 1.75kW – 27kW

Note 1 (column C) – All the same range sizes 12kW – 27kW

Range sizes are over 12kW, for every 1kW (or major fraction thereof) over, increase kW answer from column C by 5%

Note 2 (column C) – Different range sizes, greater than 8.75kW – 27kW

Any range less than 12kW, is treated like 12kW

Find average sized connected range

Average sized connected ranges over 12kW, for every 1kW (or major fraction thereof) over, increase kW answer from column C by 5%

Note 3 (column A & B) – Column A = ranges greater than 1.75kW – less than 3.5kW

Column B = ranges 3.5kW – 8.75kW

Total connected loads for each column separately

Apply percentage derate to each column separately

Total calculated loads of column A & B together

Note 4 – Branch circuits can derate based on notes 1, 2, or 3

(1) counter-mounted cooking unit & up to (2) wall-mounted ovens all in the same room, fed by the same branch circuit can be treated as an individual range

Note 5 – Instructional / School classrooms also use this table for derates

NEC 220.61(B)(1) – Neutral to be derated to 70%

For 3-phase feeders / services with single-phase dryers only, the same rules above apply, but the calculated load is twice the maximum number connected between any 2 phases (AB vs. BC vs. CA). The calculated load is then evenly split across the three phases.

-Steps 5 & 6: NEC 220.50 / 220.51 – HVAC

100% of the larger of heat vs. A/C (unless the question states that both heat & A/C will run at the same time – NEC 220.60)

No neutral is typically present

-Step 7: Largest Motor

Increase largest motor by 25% – NEC 430 Part XIV

Single-phase AC motors – NEC T430.248

Three-phase AC motors – NEC T430.250

Largest motor has already been counted during a previous step (so only 25% during step 7)

*NOTE: Only use motors listed in HP in the question towards largest motor. For example, we do NOT have to determine how much of the dishwasher is considered a motor vs. heating elements.*

-Overall service / feeder total notes

We may be able to use NEC T310.12 for conductor sizing at the overall service / feeder level if *all* the following items are true:

The *single-family dwelling* service / feeder is single-phase

The voltage is either 120/240V or 120/208V

The ampacity of the service is 100A – 400A

*NOTE: Ambient temperatures would still apply (i.e. attics!).*

If the calculated ampacity of the neutral at the total service / feeder level is over 200A, we get a derate. The first 200A is always at 100%. Everything greater than 200A is derated to 70%. – NEC 220.61(B)(2)

*NOTE: This is true for all service / feeder calculations—not just residential.*

-Given:

Single-Family dwelling, standard method calculation, 120/240v, THHN copper conductors, single-phase, paralleled twice (i.e. two risers)

44,315 sq. ft., (5) – kitchens w/2 circuits each, (2) – kitchens w/3 circuits each, (4) – laundry w/1 circuit each, (4) – laundry w/2 circuits each, (5) – 1/2HP @ 115v disposals, (5) – 1,200VA micro hoods 120v, (2) – 10kVA water heaters 240v, (1) – 60A car charger 120/240v, (6) – 4kW clothes dryers 120/240v, (2) – 6,000w clothes dryers 120/240v, (5) – 10kW ranges 120/240v, (2) – 19kW ranges 120/240v, (2) – 10kVA furnaces 240v, (2) – 7.5HP @ 230v A/Cs

What is the minimum size service allowed for this dwelling?

What are the minimum size ungrounded conductors allowed?

What are the minimum size grounded conductors allowed?

Step 1 – lighting loads

44,315 sq. ft. \* 3VA = 132,945VA

(5) – kitchens \* 2 circuits each \* 1,500VA per circuit = 15,000VA

(2) – kitchens \* 3 circuits each \* 1,500VA per circuit = 9,000VA

(4) – laundry \* 1 circuit each \* 1,500VA per circuit = 6,000VA

(4) – laundry \* 2 circuits each \* 1,500VA per circuit = 12,000VA

132,945VA (sq. ft.)

15,000VA (kitchens w/2 circuits)

9,000VA (kitchens w/3 circuits)

6,000VA (laundry w/1 circuit)

+12,000VA (laundry w/2 circuits)

174,945VA total connected load

174,945VA (total connected load)

- 3,000VA (@ 100%) 3,000VA

171,945VA

- 117,000VA (@ 35%) 117,000VA

54,945VA \* 0.35% (@ 35%)

\* 0.25 (@ 25%) 40,950VA

13,736.25 🡪 13,736VA

3,000VA (@ 100%)

40,950VA (@ 35%)

+13,736VA (@ 25%)

57,686VA total calculated load for the hots & neutral for step 1

Step 2 – appliances

step 2A – 120s / with neutral step 2B – 240s / without neutral

1/2HP @ 115v disposal 10,000VA water heater

9.8 = 9.8A \* 120v = 1,176VA 10,000VA water heater

1,176VA disposal

1,176VA disposal

1,176VA disposal

1,176VA disposal

1,200VA micro hood

1,200VA micro hood

1,200VA micro hood

1,200VA micro hood

1,200VA micro hood

60A car charger 120/240v

60A \* 240v = 14,400VA \* 1.25 (continuous duty) = 18,000VA

5 \* 1,176VA (disposals) 2 \* 10,000VA (water heaters)

5 \* 1,200VA (micro hoods)

+18,000VA car charger

29,880VA total connected load for step 2A 20,000VA total connected load for step 2B

how many appliances do we have total? 13 = 75% derate allowed

29,880VA (total connected) 20,000VA (total connected)

\* 0.75 \* 0.75

22,410VA total calculated load for the hots 15,000VA total calculated load for the hots for step 2B

and neutral for step 2A

0VA total calculated load for the neutral for step 2B

Step 3 – dryers

4,000VA clothes dryer 🡪 5,000VA

4,000VA clothes dryer 🡪 5,000VA

4,000VA clothes dryer 🡪 5,000VA

4,000VA clothes dryer 🡪 5,000VA

4,000VA clothes dryer 🡪 5,000VA

4,000VA clothes dryer 🡪 5,000VA

6,000VA clothes dryer

+6,000VA clothes dryer

42,000VA total connected load for step 3

42,000VA (total connected)

\* 0.6 (60% derate from NEC T220.54)

25,200VA total calculated load for the hots for step 3

25,200VA (total calculated)

\* 0.7 (70% neutral derate)

17,640VA total calculated neutral for step 3

Step 4 - ranges

note 2, NEC T220.55 (all ranges are greater than 8.75kW – 27kW of unequal ratings)

10kW range 🡪 12kW

10kW range 🡪 12kW

10kW range 🡪 12kW

10kW range 🡪 12kW

10kW range 🡪 12kW

19kW range

+19kW range

98kW total connected load for step 4

98kW (total connected)

/ 7 (total ranges = 7)

14kW average connected range size

12kW = average connected range that column C expects

14kW (actual average connected range size)

- 12kW (column C expectation of average connected range)

2kW over the average connected range size for column C

1kW over the average connected range size for column C = 5% increase to the number given in column C

1kW + 1kW = 2kW

5% + 5% = 10% increase to column C

column C, 7 ranges = 22 = 22kW

22kW

\* 1.1 (10% increase for 2kW over the average connected range size of 12kW)

24.2kW (24,200VA) total calculated load for the hots for step 4

24,200VA (total calculated)

\* 0.7 (70% derate to the neutral)

16,940VA total calculated load for the neutral for step 4

Steps 5 & 6 - HVAC

Step 5 - heat

10,000VA furnace

+10,000VA furnace

20,000VA total connected and calculated load for step 5

Step 6 – cooling

7.5HP @ 230v A/C

40 = 40A \* 240V = 9,600VA

9,600VA a/c

+9,600VA a/c

19,200VA total connected & calculated load for step 6

20,000VA (step 5)

vs.

19,200VA (step 6)

Step 5 is larger than step 6

20,000VA calculated load for the hots for step 5

0VA calculated load for the neutral for step 5

0VA calculated load for the hots for step 6

0VA calculated load for the neutral for step 6

Step 7 – largest motor

1/2HP @ 115v disposal 🡪 1,176VA

~~7.5HP @ 230v a/c~~ (eliminated during steps 5 & 6 due to noncoincidental loads)

1,176VA

\* 0.25 (25% step 7)

294VA total calculated load for the hots for step 7

294VA total calculated load for the neutral for step 7 (120v disposal has a neutral)

hots neutral

step 1 – lighting loads 57,686VA 57,686VA

step 2A – 120s / neutral 22,410VA 22,410VA

step 2B – 240s / no neutral 15,000VA 0VA

step 3 – dryers 25,200VA 17,640VA

step 4 – ranges 24,200VA 16,940VA

step 5 – heat 20,000VA 0VA

step 6 – a/c 0VA 0VA

step 7 – largest motor +294VA +294VA

164,790VA 114,970VA

164,790VA total calculated hots load for the service

114,970VA total calculated neutral load for the service

164,790VA (total calculated hots)

/ 240V

686.63A total amps for the service 🡪 700A service

NEC 240.4(B) = 800 amps or less for the next size up OCPD = calculated service amps for the wire sizing

NEC 240.4(C) = 1,000amps or less for the next size up OCPD = OCPD size for the wire sizing

686.63A (NEC 240.4(B))

/ 2 (service paralleled twice = 2 risers)

343.31A per riser

343.31A, copper conductors, NEC T310.16, 75° C column (service size greater than 100A) = 500 kcmil THHN for the hots in each riser

114,970VA (total calculated load for the service neutral)

/ 240V

479.04A total connected service neutral amps

479.04A (total connected service neutral amps)

- 200A (first 200A @ 100%, NEC 220.61(B)(2))

279.04A

\* 0.7 (70% derate to the neutral after the first 200A for the service / feeder, NEC 220.61(B)(2))

195.33A

+ 200A (@ 100%)

395.33A total calculated neutral amps for the service

395.33A (total calculated neutral amps for the service)

/ 2 (2 risers)

197.67A

197.67A, copper conductors, NEC 310.16, 75° C column (service size greater than 100A) = 3/0 kcmil THHN for the neutral in each riser

*OR*

NEC T250.102(C)(1), 500 kcmil copper hot conductors in each riser = 1/0 THHN for the neutral in each riser

3/0 kcmil (NEC T310.16)

vs.

1/0 (NEC T250.102(C)(1))

3/0 is larger

3/0 THHN neutral in each riser

<Homework: (2) – 26 code question quizzes & Practice Calculations: motors, welders, transformers, single-family dwelling service / feeder standard method>

**<END OF THE 4th 4-HOUR CLASS>**

**Review Homework – Approx. 15 minutes**

**Multi-Family Dwelling Service / Feeder, Standard Method Calcs – Approx. 1 hour & 15 minutes**

-For the most part, a multi-family dwelling service / feeder standard method calculation has the same rules as a single-family dwelling service / feeder standard method calculation except that each unit is combined to be treated like one, big, giant “single-family” dwelling—then apply the same rules.

*NOTE: Individual units in a multi-family dwelling are considered to be a single-family dwelling feeder for calculation purposes.*

-Given:

Multi-family dwelling service, standard method calculation, 120/240v, single-phase, copper conductors, paralleled three times

2 units, each with the following: 3,900 sq. ft., (3) – kitchens with (4) small appliance branch circuits, (3) – laundry with (3) receptacle branch circuits, (1) – 1/3HP @ 115v disposal, (1) – 4kW water heater 240v, (1) – 6kW clothes dryer 120/240v, (1) – 8kw range 120/240v, (1) – 8kW furnace 240v, (1) - 10HP @ 230V A/C

6 units, each with the following: 2,200 sq. ft., (1) - 1/2HP @ 230v disposal, (1) - 3kW water heater 240v, (1) - 5kW clothes dryer 120/240v, (1) - 3kW range 120/240v, (1) - 4kW furnace 240v

What’s the minimum size service to the multi-family building?

What’s the calculated loads for the hots & neutral for the multi-family building?

What’s the minimum size hot & neutral conductors in each riser for the multi-family building?

Step 1 – Lighting Loads

3,900 sq. ft. \* 2 units \* 3VA = 23,400VA

2,200 sq. ft. \* 6 units \* 3VA = 39,600VA

(3) – kitchens \* 2 units \* 4 circuits per kitchen \* 1,500VA per circuit = 36,000VA

(3) – laundry \* 2 units \* 3 circuits per laundry \* 1,500VA per circuit = 27,000VA

(1) – kitchen \* 6 units \* 2 circuits per kitchen \* 1,500VA per circuit = 18,000VA

(1) – laundry \* 6 units \* 1 circuit per laundry \* 1,500VA per circuit = 9,000VA

23,400VA (3,900 sq. ft.)

39,600VA (2,200 sq. ft.)

36,000VA (3,900 sq. ft. kitchens)

27,000VA (3,900 sq. ft. laundry)

18,000VA (2,200 sq. ft. kitchens)

+9,000VA (2,200 sq. ft. laundry)

153,000VA total connected

153,000VA (total connected)

- 3,000VA (@ 100%) 3,000VA

150,000VA

- 117,000VA (@ 35%) 117,000VA

33,000VA \* 0.35 (@ 35%)

\* 0.25 (@ 25%) 40,950VA

8,250VA

3,000VA (@ 100%)

40,950VA (@ 35%)

+8,250VA (@ 25%)

52,200VA total calculated load for the hots & neutral for step 1

Step 2 – Appliances

2 units: (1) – 1/3HP @ 115v disposal, (1) – 4kW water heater 240v

6 units: (1) - 1/2HP @ 230v disposal, (1) - 3kW water heater 240v

Step 2A – 120s / with neutral Step 2B – 240s / without neutral

(2) – 1/3HP @ 115v disposals (2) – 4kW water heaters 240v

NEC T430.248 = 7.2 = 7.2A (6) - 3kW water heaters 240v

7.2A \* 120V = 864VA (6) - 1/2HP @ 230v disposals

NEC T430.248 = 4.9 = 4.9A

4.9A \* 240V = 1,176VA

4,000VA WH

4,000VA WH

3,000VA WH

3,000VA WH

3,000VA WH

3,000VA WH

3,000VA WH

3,000VA WH

1,176VA disposal

1,176VA disposal

1,176VA disposal

1,176VA disposal

864VA disposal 1,176VA disposal

+864VA disposal +1,176VA disposal

1,728VA total connected load for step 2A 33,056VA total connected load for step 2B

\* 0.75 (75% derate for 4+ appliances for step 2) \* 0.75 (75% derate for 4+ appliances for step 2)

1,296VA total calculated load for the hots for 2A 24,792VA total calculated load for the hots & neutral 2B

1,296VA total calculated load for the neutral 2A 0VA total calculated load for the neutral for step 2B

Step 3 – Clothes Dryers

(2) – 6kW clothes dryers 120/240v

(6) – 5kW clothes dryers 120/240v

6,000VA

6,000VA

5,000VA

5,000VA

5,000VA

5,000VA

5,000VA

+5,000VA

42,000VA total connected load for the hots

42,000VA (total connected)

\* 0.6 (8 dryers, NEC T220.54)

25,200VA total calculated load for the hots for step 3

25,200VA (total calculated hots)

\* 0.7 (70% derate for the neutral, NEC 220.61(B)(1))

17,640VA total calculated neutral load for step 3

Step 4 – Ranges

(2) – 8kw ranges 120/240v

(6) – 3kw ranges 120/240v

Are all the ranges greater than 12kW - 27kW? No, so we can't use note #1

Are all the ranges greater than 8.75kW - 27kW? No, so we can't use note #2

Are all the ranges greater than 1.75kW - 8.75kW? Yes, so we use note #3

Column A (greater than 1.75kW - less than 3.5kW) Column B (3.5kW - 8.75kW)

3kW

3kW

3kW

3kW

3kW 8kW

+3kW +8kW

18kW total connected for column A 16kW total connected for column B

18kW (total connected column A) 16kW (total connected column B)

\* 0.59 (6 ranges, column A) \* 0.65 (2 ranges, column B)

10,620VA total calculated hots for col. A 10,400VA total calculated hots for col. B

10,620VA (total calculated column A)

+10,400VA (total calculated column B)

21,020VA total calculated hots for step 4

21,020VA (total calculated hots)

\* 0.7 (70% derate for the neutral, NEC 220.61(B)(1))

14,714VA total calculated neutral for step 4

Steps 5 & 6 – HVAC

Step 5 - heat

(2) – 8kW furnaces 240v

(6) - 4kW furnaces 240v

8,000VA

8,000VA

4,000VA

4,000VA

4,000VA

4,000VA

4,000VA

+4,000VA

40,000VA total connected heating for step 5

Step 6 - A/C

(2) - 10HP @ 230V A/Cs

NEC T430.248 = 50 = 50A

50A \* 240V = 12,000VA

12,000VA

+12,000VA

24,000VA total connected cooling for step 6

40,000VA (step 5)

vs.

24,000VA (step 6)

step 5 is larger than step 6

40,000VA total calculated load for the hots for step 5

0VA total calculated load for the neutral for step 5

0VA total calculated load for the hots for step 6

0VA total calculated load for the neutral for step 6

Step 7 – Largest Motor

(2) – 1/3HP @ 115v disposals

NEC T430.248 = 7.2 = 7.2A

7.2A \* 120V = 864VA

(6) - 1/2HP @ 230v disposals

NEC T430.248 = 4.9 = 4.9A

4.9A \* 240V = 1,176VA

864VA disposal

864VA disposal

1,176VA disposal

1,176VA disposal

1,176VA disposal

1,176VA disposal

1,176VA disposal

1,176VA disposal

Tie for the largest motor = 1 of the larger disposals

1,176VA total calculated for the disposal

\* 0.25 (25% for the largest motor)

294VA total calculated load for the hots for step 7

0VA total calculated load for the neutral for step 7 (230V = motor has no neutral)

hots neutral

step 1 – lighting loads 52,200VA 52,200VA

step 2A – 120s / with neutral appliances 1,296VA 1,296VA

step 2B – 240s / without neut. appliances 24,792VA 0VA

step 3 – dryers 25,200VA 17,640VA

step 4 – ranges 21,020VA 14,714VA

step 5 – heat 40,000VA 0VA

step 6 – A/C 0VA 0VA

step 7 – largest motor +294VA +0VA

164,802VA 85,850VA

164,802VA (total calculated for the hots for the service)

/ 240V

686.68A --> 700A service size

*NOTE: We CANNOT use multifamily service wire sizing for NEC T310.12. We can ONLY use the table for single-family dwellings service & feeders in a two- or multi-family buildings.*

686.68A calculated ampacity for the service

/ 3 (3 parallel risers)

228.89A for the hots in each riser

228.89A = NEC T310.16, 75° C column = 4/0 for the hots in each riser

85,850VA (total calculated for the neutral)

/ 240V

357.71A total connected neutral ampacity

357.71A (total connected neutral ampacity)

- 200A (@ 100%)

157.71A

\* 0.7 (70% derate to the neutral AFTER the 1st 200A)

110.4A

200A (@ 100%)

+110.4A (@ 70%)

310.4A total calculated neutral ampacity

310.4A (total calculated neutral ampacity)

/ 3 (3 risers)

103.47A neutral ampacity in each riser

103.47A = NEC T310.16, 75 degree (service is greater than 100A) = #2 neutral

OR

NEC T250.102(C)(1)

4/0 hot conductor = #2 neutral

#2 (NEC T310.16)

vs.

#2 (NEC 250.102(C)(1)

Larger of the two = #2 neutral = 1/0 neutral in each riser (smallest size conductor that can be paralleled, NEC 310.10(G)(1))

**Single-Family Dwelling Service / Feeder, Optional Method Calcs – Approx. 1 hour**

-NEC 220.80 – Optional method single-family service / feeder dwelling calculation

The key to the optional method is NAMEPLATE, NAMEPLATE, NAMEPLATE!

NEC 220.82(A) – Minimum size service 100A.

*NOTE: A neutral calculation CANNOT be determined through the optional method alone. A full- sized neutral MUST be used (or a standard method calculation can be used to install a reduced sized neutral.*

NEC 220.82(B) – General Loads

NEC 220.82 – 3VA x Square Foot

NEC 220.82(B)(2) – 1500VA x Per Laundry & Small Appliance

Minimum 2 small appliance branch circuits per kitchen

NEC 220.82(B)(3) & (4) – Nameplate of the following:

Fixed appliances (i.e. the same appliances we would use in step 2 of the standard method)

Cooking equipment

Clothes dryers

Water heaters

Any other items with a “nameplate” (*except HVAC*)

NEC 220.82(B) – Add the above together

First 10kVA @ 100%

Remaining @ 40%

NEC 220.82(C) – HVAC, one of the following (largest calculated load present):

100% of nameplate of AC

100% of heat pump (furnace)

100% of heat pump & 65% of supplemental heat (if can be run at the same time)

65% of 3 or less wall heaters

40% of 4+ wall heaters

100% of nameplate of thermal equipment

We then total both sections (i.e. general loads & HVAC) for our total calculated service / feeder

-Given:

Single-family dwelling, optional method, 120/240v, single-phase, XHHW aluminum wires

1,450sq. ft., (1) - 1,200VA micro 120v, (1) – 2.75kW water heater 240v, (1) – 3kW clothes dryer 120/240v, (1) – 3.5kW range 120/240v, (1) - air conditioner 3HP @ 230v, (1) - 3kW furnace 240v, (1) - 2HP @ 230v supplemental heat pump, (9) - 1,000VA wall heaters 240v, (1) - 4kW geothermal system 240v

What's the minimum size service?

What's the total calculated hot loads?

What's the total calculated neutral load (using only the optional method)?

What's the minimum size hot & neutral conductors?

General Loads (“Upper Half” – NEC 220.82(B))

1,450sq. ft. \* 3VA = 4,350VA

(1) - kitchen \* 2 circuits per kitchen \* 1,500VA per circuit = 3,000VA

(1) - laundry \* 1 circuit per laundry \* 1,500VA per circuit = 1,500VA

(1) - 1,200VA micro 120v = 1,200VA

(1) – 2.75kW water heater 240v = 2,750VA

(1) - 3kW clothes dryer 120/240v = 3,000VA

(1) – 3.5kW range 120/240v = 3,500VA

19,300VA total connected load for the upper half

- 10,000VA (@ 100%) 10,000VA

9,300VA

\* 0.4 (@ 40% remaining)

3,720VA

10,000VA (@ 100%)

+ 3,720VA (@ 40%)

13,720VA total calculated load for the upper half general loads

HVAC (“Lower Half” – NEC 220.82(C))

1. A/C @ 100% = 4,080VA

(1) - air conditioner 3HP @ 230v

17A \* 240V = 4,080VA

2. Furnace w/o supplemental - N/A

3. Furnace (100%) w/ supplemental (65%) = 4,872VA

(1) - 3kW furnace 240v = 3,000VA \* 1.00 = 3,000VA

(1) - 2HP @ 230v supplemental heat pump

12A \* 240V = 2,880VA \* 0.65 (@ 65%) = 1,872VA

4. Space heating w/ 3 or less controlled units - N/A

5. Space heating w/ 4 or more controlled units (@ 40%) = 3,600VA

(9) - 1,000VA wall heaters 240v

1,000VA \* 9 units = 9,000VA \* 0.4 (@ 40%) = 3,600VA

6. Geothermal (@ 100%) = 4,000VA

(1) - 4kW geothermal system 240v = 4,000VA

Largest of the six = #3 – furnace with supplemental heat

4,872VA total calculated load for the lower half HVAC

13,720VA (total calculated upper half general loads)

+4,872VA (total calculated lower half HVAC loads)

18,592VA total calculated hots for the service

18,592VA (total calculated)

/ 240V

77.47A 🡪 80A service (NEC T240.6(A)) 🡪 100A service minimum (NEC 220.82(A))

100A service, dwelling, 120/240v, single-phase = NEC T310.12, aluminum conductors = #2 XHHW for the hots & neutral conductors

*NOTE: We cannot determine the neutral calculated load for a service / feeder using the optional method— full-size neutral conductors (same size as the hot conductors) only*

**Multi-Family Dwelling Service / Feeder, Optional Method Calcs – Approx. 45 minutes**

-NEC 220.84(A) – Multi-family dwelling optional calculation method

In order to be able to use:

1. The multi-family building (as well as none of the single-family dwelling units inside) can be one service / feeder.

2. Each dwelling is equipped with electric cooking equipment (unless a “phantom” cooking equipment at 8kW per single-family dwelling unit is applied to the calculation).

3. Each dwelling must be supplied with electric space heating, AC, or both.

*NOTE: A neutral calculation CANNOT be determined through the optional method alone. A full-sized neutral MUST be used (or a standard method calculation can be used to install a reduced sized neutral.*

-NEC 220.84(B) – house loads (i.e. common area lighting, swimming pools, lobby, elevators, etc.) are added via the standard dwelling calculation at the end *after* the multi-family discount is applied from the table.

-NEC 220.84(C) – calculated loads

3VA per sq. ft. of all units

1,500VA minimum for each laundry and small appliance circuit

Appliances at nameplate (i.e. appliances from step 2 of the standard method)

Each cooking equipment at nameplate

Clothes dryers at nameplate

AC or heat, whichever is larger at nameplate

Water heaters at nameplate

Add up all calculated loads, apply derate based on NEC T220.84

-Given:

Multi-family dwelling service, optional method, 120/240v, single-phase, THHN copper conductors

(2) units with the following: 1,665 sq. ft., (1) – 1/3 HP @ 230V disposal, (1) – 120v micro 950VA, (1) – 4,500VA water heater 240v, (1) – 3.75kW clothes dryer 120/240v, (1) – 4,300VA range 120/240v, (1) – 2.75kW range 120/240v, (1) – 7.5HP @ 115V A/C, (1) – 4kW main heat pump 240v with (1) - 5kw supplemental furnace 240v

(3) units with the following: 1,900 sq. ft., (1) – 3/4 HP @ 230V disposal, (1) – 120v micro 1,350VA, (1) – 5,500VA water heater 240v, (1) – 4.75kW clothes dryer 120/240v, (1) – 5,600VA range 120/240v, (1) – 3.75kW range 120/240v, (1) – 7.5HP @ 115V A/C, (1) – 6kW main heat pump 240v with (1) - 6kw supplemental furnace 240v

What’s the minimum size service allowed?

What’s the minimum size hot conductors allowed based on the OCPD size?

-Non-HVAC loads

1,665 sq. ft. \* 3VA \* 2 units = 9,990VA

(1) – kitchen \* 2 circuits per kitchen \* 1,500VA per circuit \* 5 units = 15,000VA

(1) – laundry \* 1 circuit per laundry \* 1,500VA per circuit \* 5 units = 7,500VA

(1) – 1/3 HP @ 230V disposal

1/3HP @ 230V 🡪 3.6A (NEC T430.248) \* 240V = 864VA \* 2 units = 1,728VA

(1) – 120v micro 950VA \* 2 units = 1,900VA

(1) – 4,500VA water heater 240v \* 2 units = 9,000VA

(1) – 3.75kW clothes dryer 120/240v \* 2 units = 7,500VA

(1) – 4,300VA range 120/240v \* 2 units = 8,600VA

(1) – 2.75kW range 120/240v \* 2 units = 5,500VA

1,900 sq. ft. \* 3VA \* 3 units = 17,100VA

(1) – 3/4 HP @ 230V disposal

3/4HP @ 230V 🡪 6.9A (NEC T430.248) \* 240V = 1,656VA \* 3 units = 4,968VA

(1) – 120v micro hood 1,350VA \* 3 units = 4,050VA

(1) – 5,500VA water heater 240v \* 3 units = 16,500VA

(1) – 4.75kW clothes dryer 120/240v \* 3 units = 14,250VA

(1) – 5,600VA range 120/240v \* 3 units = 16,800VA

(1) – 3.75kW range 120/240v \* 3 units = 11,250VA

9,990VA

15,000VA

7,500VA

1,728VA

1,900VA

9,000VA

7,500VA

8,600VA

5,500VA

17,100VA

4,968VA

4,050VA

16,500VA

14,250VA

16,800VA

+11,250VA

151,636VA total non-HVAC connected loads

-HVAC loads

Heating

(1) – 7.5HP @ 115V A/C

7.5HP @ 115V 🡪 80A (NEC T430.248) \* 120V = 9,600VA \* 2 units = 19,200VA

(1) – 7.5HP @ 115V A/C

7.5HP @ 115V 🡪 80A (NEC T430.248) \* 120V = 9,600VA \* 3 units = 28,800VA

19,200VA

+28,800VA

48,000VA total heating connected loads

Cooling

(1) – 4kW main heat pump 240v with (1) - 5kw supplemental furnace 240v \* 2 units = 18,000VA

(1) – 6kW main heat pump 240v with (1) 6kw supplemental furnace 240v \* 3 units = 36,000VA

18,000VA

+36,000VA

54,000VA total cooling connected loads

48,000VA (heating)

vs.

54,000VA (cooling)

Cooling is larger than heating (NEC 220.60) 🡪 54,000VA total HVAC connected loads

151,636VA (total non-HVAC connected loads)

+54,000VA (total HVAC connected loads)

205,636VA total connected loads

205,636VA (total connected loads)

\* 0.45 (5 total units, NEC T220.84)

92,536.2 🡪 92,536VA total calculated loads

92,536VA (total calculated loads)

/ 240V

385.57A 🡪 400A minimum size service

400A 🡪 NEC 310.16 = 600kcmil THHN

*NOTE: We cannot use NEC T310.12 because the service being sized is multi-family.*

*NOTE: We cannot size the neutral when using the optional method only. So, a full-size neutral must be used.*

-NEC 220.85 – two-family dwellings (i.e. duplex buildings)

Where fed by a single service / feeder, when the calculated load of the two units via the single-family standard dwelling calculation method exceed three identical units calculated via the multi-family dwelling optional calculation method, the lesser of the two calculations can be used (multi-family optional is only for 3 or more units—so, if you only have a duplex, make the unit with the largest calculated load the unit by 3 for the multi-family dwelling optional method portion to compare).

**Existing Dwelling Unit Service / Feeder Calculation – Approx. 45 minutes**

-Existing dwelling unit service / feeder calculation – NEC 220.83(A) & (B)

Calculate the total load by either part A (adding non-HVAC loads) or part B (adding HVAC loads)

Part A: Non-HVAC loads being added

Total all existing *AND NEW* loads being added (*INCLUDING* any existing HVAC) at nameplate values

Take the first 8kVA @ 100%

Apply a 40% derate to the remaining loads

This becomes your total calculated load

Divide the total by the voltage for the overall minimum service ampacity needed

Go up to the next standard OCPD size

Is the existing service / feeder large enough to accept the additional loads?

Part B: HVAC loads being added

Total all existing loads (*EXLUDING* any existing HVAC) at nameplate values

Take the first 8kVA @ 100%

Apply a 40% derate to the remaining loads

Add the HVAC additional loads at 100%

These become your total calculated load

Divide the total by the voltage for the overall minimum service ampacity needed

Go up to the next standard OCPD size

Is the existing service large enough to accept the additional loads?

*NOTE: Non-coincidental loads apply to both.*

**<END OF THE 5th 4-HOUR CLASS>**

**Commercial Building Calculation Rules Standard Method – Approx. 1 hour & 30 minutes**

-Commercial calculations vary based on how the building is being utilized (i.e. occupancy), as well as what’s located on the premises. Most calculation rules are located in NEC 220.

*NOTE: All non-dwelling buildings are commercial with varying occupancies.*

-Almost all commercial lighting is considered to be continuous duty.

-Unlike dwelling calculations, commercial services / feeders evenly distribute loads across all phases, as evenly as possible.

For example, a 120/240V, 3Ø panel with (3) – connected lighting branch circuits of 1,200VA would be a total calculated load of 4,500VA.

1,200VA \* 1.25 (continuous duty) = 1,500VA

Phase A Phase B Phase C

1,500VA - -

- 1,500VA -

- - 1,500VA

-Commercial general-use receptacles – NEC 220.14(H) & (I)

Standard receptacles – NEC 220.14(I)

Each single or duplex receptacle = 180VA

Each device on the same yoke larger than a quad = 90VA per receptacle (i.e. a three-gang yoke with (2) duplex receptacles & (1) single receptacle = 450VA)

NEC 220.14(I) receptacle loads are part of the derate allowed per NEC T220.44

Fixed multi-outlet assemblies (FMOAs, aka plug-mold) – NEC 220.14(H)

Where multiple receptacles on FMOAs are unlikely to be used simultaneously (very uncommon), every 5’ or fraction thereof = 180VA (i.e. 5’1” = 360VA)

Where multiple receptacles on FMOAs are likely to be used simultaneously (common), every 1’ of fraction thereof = 180VA (i.e. 1’1” = 360VA)

NEC 220.14(H) receptacle loads are part of the derate allowed per NEC T220.44

Banks & Office buildings – NEC 220.14(K)

Banks & Office building receptacle loads shall be larger of the two:

1) Follow standard rules (and derating from NEC T220.44) of NEC 220.14(H) & (I)

2) 1 VA per square foot (*NO DERATE FROM NEC T220.44*)

-Commercial lighting loads – NEC T220.12

The minimum general-use lighting loads for a commercial location is the larger of the two:

1) The actual known lighting loads being installed in the building.

2) The unit load multiplier based on occupancy & square footage from NEC T220.12

Warehouse occupancies are allowed to include general-use receptacle loads (NEC 220.14(H) & (I)) with the lighting loads prior to applying the derates found in NEC T220.42

*NOTE: NEC T220.12 has already included continuous duty in the occupancy load multiplier.*

Hotel / Motels – NEC 220.14(M)

Hotel / Motel rooms (not common areas) general-use receptacles & general-use lighting loads are accounted for in the 1.7 VA per square foot multiplier in NEC T220.12

Hotel / Motel rooms (not common areas) general-use receptacles & general-use lighting loads are allowed to apply the derates found on NEC T220.42

-What’s the minimum lighting demand for a 5,000 sq. ft. industrial commercial loft with (25) – 400w metal halide fixtures?

5,000 sq. ft. \* 2.2 (NEC T220.12, manufacturing facility note C) = 11,000VA

25 fixtures \* 400w = 10,000VA \* 1.25 = 12,500VA

Minimum lighting demand is 12,500VA

-Sign / Outline lighting – NEC 220.14(F)

At least one outlet, served by a 20A or more dedicated branch circuit is required for all commercial occupancies with customer pedestrian access (not required for employee only access), as well as each tenant space with customer pedestrian access. – NEC 600.5(A)

For service / feeder calculations, these circuits shall be counted at minimum as 1,200VA connected (1,500VA calculated after continuous duty) – NEC 220.14(F)

-Show windows shall be served by either receptacles or lighting – NEC 220.14(G) or NEC 220.43(A)

Show window receptacles shall be calculated at either 1 or 2: – NEC 220.14(G)

1) 180VA per receptacle (if known)

2) 200VA per 1’ of show window

Show window lighting – NEC 220.43(A)

200VA per 1’ of show window PLUS 25% for continuous duty commercial lighting

-Track lighting – NEC 220.43(B)

Track lighting = 150VA per 1’ of linear track lighting or FRACTION thereof PLUS 25% for continuous duty commercial lighting

-Commercial kitchen equipment – NEC 220.56

Commercial kitchens have an allowable derate at the service / feeder level based on NEC T220.56 for kitchen equipment with thermostatic control and/or intermittent use for the following: cooking equipment, dishwasher booster heaters, water heaters, and other kitchen equipment.

The derating shall NOT apply to space heating, ventilating, or air-conditioning equipment.

In no case shall the service / feeder calculated load be less than the sum of the largest two kitchen equipment loads.

-Reminders:

Continuous duty ONLY applies to the ungrounded portion of the calculation for other than 1Ø loads. It does NOT apply to the neutral portion of the calculation.

The largest motor of every portion of a service or feeder is to be increased by 25%.

For example:

Building service = 277/480V, 3Ø

(1) – 50HP motor, 480V, 3Ø

(1) – 10HP motor, 480V, 3Ø

(1) – 120/208V, 3Ø transformer & subpanel

(1) – 20HP motor, 208V, 3Ø

(1) – 120/240V, 3Ø transformer & subpanel

(1) – 5HP motor, 120V, 1Ø

(1) – 1HP motor, 120V, 1Ø

This building would have (3) largest motors:

(1) – 50HP motor, 480V, 3Ø

(1) – 20HP motor, 208V, 3Ø

(1) – 5HP motor, 120V, 1Ø

At the main service of the building, all (3) motors would be treated as largest motors.

At each transformer, the neutral has a “clean break” and does not “count against” the overall neutral calculated load at the building service. However, at each transformer, the ungrounded load is “counted against” the overall ungrounded calculated building service.

**Single-Phase Commercial Building Calculation Practice – Approx. 2 hours & 30 minutes**

-Given:

A warehouse with a 120/240V, 1Ø service has the following: 50,000 square feet, (36) – general-use receptacles 120V, (135) – 400W metal halide fixtures, (2) – sign circuits 120V, (1) – 5HP motor @ 240V with a nameplate of 24A, and (1) – 1HP motor @ 120V with a nameplate of 13A.

What is the total ungrounded calculated load?

What is the minimum service allowed to feed this building?

What is the grounded calculated load?

What are the smallest THHN cu conductors allowed to serve the building?

What is the smallest THHN cu neutral conductor allowed to serve the building?

What is the smallest THHN cu metal water bond conductor allowed to serve the building?

**General Lights & Plugs, 120V**

~~50,000 square feet \* 1.2VA = 60,000VA total connected phase & neutral lighting loads~~

*OR*

135 fixtures \* 400W = 54,000VA total connected phase & neutral load for lighting

54,000VA (total connected phase & neutral load for lighting)

\* 1.25 (continuous duty)

67,500VA total connected phase load for lighting

36 plugs \* 180VA = 6,480VA total connected phase & neutral general-use plug loads

67,500VA (lighting)

+6,480VA (plugs)

73,980VA total connected phase general lighting & receptacle loads

73,980VA (total connected phase general lighting & receptacles)

-12,500VA (@100%, NEC T220.42)

61,480VA

\* 0.5 (@ 50%, NEC T220.42)

30,740VA

12,500VA (phase @100%)

+30,740VA (phase @ 50%)

43,240VA total calculated phase & neutral loads

43,240VA (total calculated phase & neutral loads)

/ 2 phases

21,620VA total loads per phase

**(2) – sign circuits, 120V**

1,200VA (NEC 220.14(F))

\* 2 sign circuits

2,400VA total connected phase & neutral loads

2,400VA (total connected phase & neutral loads)

\* 1.25 (continuous duty)

3,000VA total calculated phase & neutral loads

3,000VA (total calculated phase & neutral loads)

/ 2 phases

1,500VA total loads per phase

**(1) – 5HP motor, 240V, 1Ø**

5HP @ 240V = 28A (NEC T430.248)

28A

\* 240V

6,720VA total connected phase load

0VA total calculated neutral load (240V load, no neutral)

**(1) – 1HP motor 120V, 1Ø**

1HP @ 120V = 16A (NEC T430.248)

16A

\* 120V

1,920VA total calculated phase & neutral loads

1,920VA (total calculated phase & neutral loads)

/ 2 phases

960VA per phase

**Largest motor**

5HP @ 240V = 6,720VA per phase

\* 2 phases of power

13,440VA total power consumption

1HP @ 120V = 1,920VA per phase

\* 1 phase of power

1,920VA total power consumption

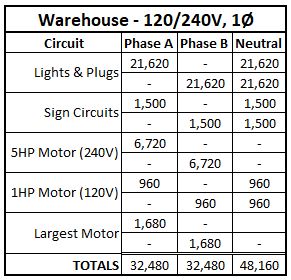
5HP motor = largest motor

6,720A (5HP @ 240V)

\* 0.25 (largest motor, NEC 430.24)

1,680VA total calculated phase loads for largest motor

0VA total calculated neutral load (240V load, no neutral)



What is the total ungrounded calculated load?

32,480VA (phase A total)

+32,480VA (phase B total)

64,960VA

What is the minimum service allowed to feed this building?

64,960VA (total calculated phase loads)

/ 240V

270.67A 🡪 300A service (NEC T240.6(A))

What is the grounded calculated load?

48,160VA

What are the smallest THHN cu conductors allowed to serve the building?

270.67A calculated *commercial* service load = 300kcmil THHN cu conductors per phase (NEC T310.16 @ 75° C column)

*NOTE: This is a commercial service, so NEC T310.12 cannot be used.*

*NOTE: Our calculated service load was used rather than the OCPD of the service due to NEC 240.4(B) & (C). We went up one standard OCPD size, and the OCPD size was 800A or less. Had the OCPD size been 1,000A or more, we would’ve sized the conductors based on the OCPD size.*

What is the smallest THHN cu neutral conductor allowed to serve the building?

48,160VA (total calculated neutral loads)

/ 240V

200.66A = 4/0 THHN cu (NEC T310.16 @ 75° C column)

*OR*

300kcmil THHN cu (phase conductors) = #2 THHN cu (NEC T250.104(C)(1))

4/0 THHN cu (NEC T310.16)

vs.

~~#2 THHN cu (NEC T250.104(C)(1))~~

What is the smallest THHN cu metal water bond conductor allowed to serve the building?

300kcmil THHN cu (phase conductor) = #2 THHN cu [NEC T250.104(A)(1) 🡪 NEC T250.102(C)(1)]

*NOTE: NEC 250.104(A)(1) states that regardless of the table, the largest size metal water bond required is a 3/0 copper or 250kcmil aluminum conductor.*

-Given:

A 200’ x 150’ strip mall building with a 120/240V, 1Ø service has the following:

(6) – parking lot 400W LED wall pack fixtures

(10) – parking lot 1,000W LED pole light fixtures

Bank: 100’ x 100’, (3) – 7.5HP @ 240V HVAC rooftop units, (68) – general-use receptacles 120V, (5) – 1,150VA copier machines 120V, (2) – customer pedestrian entrances, and (1) – employee pedestrian entrance

Library: 125’ x 100’, (2) – 10HP @ 240V HVAC rooftop units, (35) – general-use receptacles 120V, (3) – 1,100VA copier machines 120V, 24’1” of likely to be used simultaneously plug-mold, 50’ – show windows, (1) – customer pedestrian entrance, (1) – vehicle delivery entrance, and (1) – employee pedestrian entrance

Armory: (3) – 3HP @ 240V HVAC rooftop units, (5) – general-use receptacles, 160’ – LED track lighting 120V, and (5) – 5HP @ 120V moving target machines with 50A nameplate ratings, and (1) – pedestrian entrance

What is the minimum sized sub-panels allowed to serve each tenet space?

What are the smallest XHHW aluminum phase conductors allowed to serve each tenet space?

What is the smallest XHHW aluminum neutral conductor allowed to serve each tenet space?

What is the smallest XHHW aluminum equipment grounding conductor allowed to serve each tenet space?

**Bank**

100’ \* 100’ = 10,000 square feet total for the bank

General lighting, 120V

10,000 sq. ft. \* 1.3VA (NEC T220.12, note D) = 13,000VA total calculated phase loads

13,000VA (total calculated phase & neutral loads)

/ 2 phases

6,500VA total load per phase

General plugs, 120V

NEC 220.12(K)(2)

10,000 sq. ft. \* 1VA = 10,000VA total calculated phase load

vs.

NEC 220.12(K)(1)

68 plugs \* 180VA = 12,240VA total connected phase load

12,240VA (total connected phase load using NEC 220.12(K)(1))

-10,000VA (@100%, NEC T220.44)

2,240VA

\* 0.5 (@ 50%, NEC T220.44)

1,120VA

10,000VA (@100%)

+1,120VA (@50%)

11,120VA total calculated phase load using NEC 220.12(K)(1)

~~10,000VA (NEC 220.12(K)(2)~~

vs.

11,120VA (NEC 220.12(K)(1)

11,120VA total calculated phase & neutral loads

11,120VA (total calculated phase & neutral loads)

/ 2 phases

5,560VA total load per phase

Copiers, 120V

1,150VA copier machine

\* 5 copiers

5,750VA total calculated phase & neutral loads

5,750VA (total calculated phase loads)

/ 2 phases

2,875VA total load per phase

Entrances

Each customer pedestrian entrance = 1 sign circuit required (NEC 220.12(F) 🡪 NEC 600.5(A))

Each employee pedestrian entrance = 0 sign circuit required (NEC 220.12(F) 🡪 NEC 6005.(A))

2 customer pedestrian entrances

1,200VA sign circuit (NEC 220.12(F))

\* 2 customer pedestrian entrances

2,400VA total connected phase & calculated neutral loads

2,400VA (total connected phase & neutral loads)

\* 1.25 (continuous duty)

3,000VA total calculated phase & neutral loads

3,000VA (total calculated phase & neutral loads)

/ 2 phases

1,500VA total load per phase

Rooftop units, 240V

7.5HP @ 240V = 40A (NEC T430.248)

3 rooftop units

40A

\* 240V

9,600VA per HVAC unit

9,600VA per HVAC unit

\* 3 units

28,800VA total calculated phase loads

28,800VA total calculated load per phase

0VA neutral load

Largest Motor

7.5HP motor = largest motor

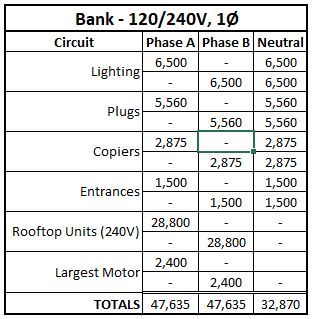
9,600VA @ 240V

9,600VA

\* 0.25 (largest motor, NEC 430.24)

2,400VA total load per phase

0VA neutral load



**Library**

125’ \* 100’ = 12,500 square feet total for the library

General Lighting, 120V

12,500 sq. ft. \* 1.5VA (NEC T220.12) = 18,750VA total calculated phase loads

18,750VA (total calculated phase & neutral loads)

/ 2 phases

9,375VA total load per phase

General plugs, 120V

35 plugs

\* 180VA (NEC 220.12(I))

6,300VA total connected general-use plug phase loads

Likely to be used simultaneously plug-mold = 1’ sections (NEC 220.12(H)(2))

24’1” / 1’ = 24.08 = 25 sections of plug-mold

25 sections of plug-mold

\* 180VA per section (NEC 220.12(H)(2))

4,500VA total connected plug-mold phase loads

6,300VA (general-use plugs)

+4,500VA (plug-mold)

10,800VA total connected plug loads

10,800VA (total connected plug loads)

-10,000VA (@ 100%, NEC T220.44)

800VA

\* 0.5 (@ 50%, NEC T220.44)

400VA

10,000VA (@ 100%)

+400VA (@ 50%)

10,400VA total calculated plug phase & neutral loads

10,400VA (total calculated phase & neutral loads)

/ 2 phases

5,200VA total load per phase

Show Window Lighting, 120V

50’ of show window lighting

\* 200VA (NEC 220.43(A))

10,000VA total connected phase & calculated neutral loads

10,000VA (total connected phase & neutral loads)

\* 1.25 (continuous duty)

12,500VA total calculated phase & neutral loads

12,500VA (total calculated phase & neutral loads)

/ 2 phases

6,250VA total load per phase

Copiers, 120V

1,100VA per copier machine

\* 3 copiers

3,300VA total calculated phase & neutral loads

3,300VA (total calculated phase loads)

/ 2 phases

1,650VA total load per phase

Entrances, 120V

Each customer pedestrian entrance = 1 sign circuit required (NEC 220.12(F) 🡪 NEC 600.5(A))

Each vehicle delivery entrance = 0 sign circuit required (NEC 220.12(F) 🡪 NEC 600.5(A))

Each employee pedestrian entrance = 0 sign circuit required (NEC 220.12(F) 🡪 NEC 600.5(A))

1 customer pedestrian entrance

1,200VA sign circuit (NEC 220.12(F))

\* 1 customer pedestrian entrance

1,200VA total connected phase & neutral loads

1,200VA (total connected phase & neutral loads)

\* 1.25 (continuous duty)

1,500VA total calculated phase & neutral loads

1,500VA (total calculated phase & neutral loads)

/ 2 phases

750VA total load per phase

Rooftop Units, 240V

10HP @ 240V = 50A (NEC T430.248)

2 rooftop units

50A

\* 240V

12,000VA per HVAC unit

12,000VA per HVAC unit

\* 2 units

24,000VA total calculated loads per phase

0VA neutral load

Largest Motor

10HP motor = largest motor

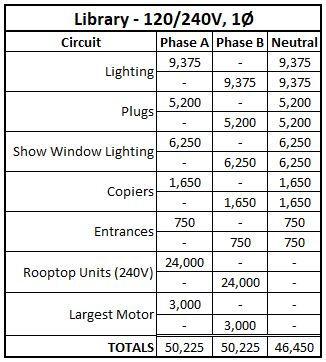
12,000VA @ 240V

12,000VA

\* 0.25 (largest motor, NEC 430.24)

3,000VA total load per phase

0VA neutral load



**Armory**

200’ x 150’ = 30,000 sq. ft. total for the strip mall

30,000 sq. ft. (strip mall) – 10,000 sq. ft. (bank) – 12,500 sq. ft. (library) = 7,500 sq. ft. total for the Armory

General Lighting, 120V

7,500 sq. ft. \* 1.7VA (NEC T220.12, note A) = 12,750VA total calculated phase & neutral loads

*OR*

160’ track lighting / 2’ = 80 sections of track lighting (NEC 220.43(B))

80 sections of track lighting

\* 150VA (NEC 220.43(B))

12,000VA total connected phase & neutral loads

12,000VA (total connected phase & neutral loads)

\* 1.25 (continuous duty)

15,000VA total calculated phase & neutral loads

~~12,750VA (NEC T220.12, note A)~~

vs.

15,000VA (NEC 220.43(B))

15,000VA (total calculated phase & neutral loads)

/ 2 phases

7,500VA total per phase

General Plugs, 120V

5 plugs

\* 180VA (NEC 220.12(I))

900VA total calculated phase & neutral loads

900VA (total calculated phase & neutral loads)

/ 2 phases

450VA total per phase

Target Machines, 120V

5HP @ 120V = 56A (NEC T430.248)

5 target machines

56A

\* 120V

6,720VA total calculated phase & neutral load per machine

6,720VA (total calculated phase & neutral per machine)

\* 5 machines

33,600VA total calculated phase & neutral loads

33,600VA (total calculated phase loads)

/ 2 phases

16,800VA total per phase

Entrances, 120V

Each customer pedestrian entrance = 1 sign circuit required (NEC 220.12(F) 🡪 NEC 600.5(A))

1 customer pedestrian entrance

1,200VA sign circuit (NEC 220.12(F))

\* 1 customer pedestrian entrance

1,200VA total connected phase & neutral loads

1,200VA (total connected phase & neutral loads)

\* 1.25 (continuous duty)

1,500VA total calculated phase & neutral loads

1,500VA (total calculated phase & neutral loads)

/ 2 phases

750VA total load per phase

Rooftop Units, 240V

3HP @ 240V = 17A (NEC 430.248)

3 rooftop units

17A

\* 240V

4,080VA total calculated phase load per HVAC unit

4,080VA (total calculated phase load per HVAC unit

\* 3 units

12,240VA total calculated phase loads

0VA neutral load

Largest Motor

(1) – 5HP @ 120V target machine = 6,720VA

6,720VA per phase of machine

\* 1 phase of power

6,720VA total power consumption

*OR*

(1) – 3HP @ 240V rooftop unit = 4,080VA

4,080VA per phase of rooftop unit

\* 2 phases of power

8,160VA total power consumption

~~6,720VA target machine~~

vs.

8,160VA rooftop unit

8,160VA (rooftop unit, 240V)

\* 0.25 (largest motor, NEC 430.24)

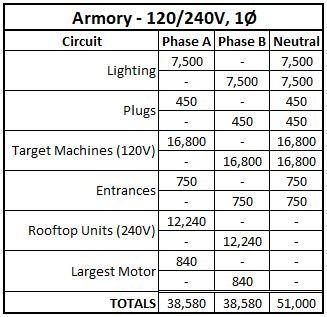
1,680VA total calculated phase & neutral loads

1,680VA (total calculated phase loads)

/ 2 phases

840VA total per phase

0VA neutral load



What is the minimum sized sub-panels allowed to serve each tenet space?

**Bank**

47,635VA (total calculated loads per phase)

\* 2 phases

95,270VA total phase calculated load

95,270VA (total phase calculated load)

/ 240V

396.96A 🡪 400A service (NEC T240.6(A))

**Library**

50,225VA (total calculated loads per phase)

\* 2 phases

100,450VA total phase calculated load

100,450VA (total phase calculated load)

/ 240V

418.54A 🡪 450A service (NEC T240.6(A))

**Armory**

38,580VA (total calculated loads per phase)

\* 2 phases

77,160VA total phase calculated load

77,160VA (total phase calculated load)

/ 240V

321.5A 🡪 350A service (NEC T240.6(A))

What are the smallest XHHW aluminum phase conductors allowed to serve each tenet space?

**Bank**

396.96A (calculated service load) = 900kcmil XHHW aluminum (NEC T310.16 @ 75° C column)

**Library**

418.54A (calculated service load) = 900kcmil XHHW aluminum (NEC T310.16 @ 75° C column)

**Armory**

321.5A (calculated service load) = 600kcmil XHHW aluminum (NEC T310.16 @ 75° C column)

What is the smallest XHHW aluminum neutral conductor allowed to serve each tenet space?

**Bank**

32,870VA (calculated service neutral load)

/ 240V

136.96A = 3/0 XHHW aluminum (NEC T310.16 @ 75° C column)

*OR*

900kcmil XHHW aluminum phase conductor = 3/0 XHHW aluminum (NEC T250.102(C)(1))

3/0 XHHW aluminum (NEC T310.16)

vs.

3/0 XHHW aluminum (NEC 250.102(C)(1))

**Library**

46,450VA (calculated service neutral load)

/ 240V

193.45A = 250kcmil XHHW aluminum (NEC T310.16 @ 75° C column)

*OR*

900kcmil XHHW aluminum phase conductor = 3/0 XHHW aluminum (NEC T250.102(C)(1))

250kcmil XHHW aluminum (NEC T310.16)

vs.

~~3/0 XHHW aluminum (NEC 250.102(C)(1))~~

**Armory**

51,000VA (calculated service neutral load)

/ 240V

212.5A = 300kcmil XHHW aluminum (NEC T310.16 @ 75° C column)

*OR*

600kcmil XHHW aluminum phase conductor = 3/0 XHHW aluminum (NEC T250.102(C)(1))

300kcmil XHHW aluminum (NEC T310.16)

vs.

~~3/0 XHHW aluminum (NEC 250.102(C)(1))~~

What is the smallest XHHW aluminum equipment grounding conductor allowed to serve each tenet space?

**Bank**

400A service = #1 XHHW aluminum (NEC T250.122)

**Library**

450A service = 1/0 XHHW aluminum (NEC T250.122)

**Armory**

350A service = #1 XHHW aluminum (NEC T250.122)

<Homework: (2) – 26 code question quizzes & Practice Calculations: multi-family dwelling service / feeder standard method, single-family dwelling service / feeder optional method, multi-family dwelling service / feeder optional method, existing dwelling, & commercial calculations>

**<END OF THE 6th 4-HOUR CLASS>**

**Review Homework – Approx. 15 minutes**

**Three-Phase Commercial Building Calculation Practice – Approx. 3 hours & 45 minutes**

-NEC 220.56

Electric commercial kitchen equipment is derated by NEC T220.56

Electric commercial kitchen equipment includes the following: cooking equipment, dishwasher booster heaters, water heaters (that serve at least part of the kitchen), and other kitchen equipment not including space-heating, ventilating, or air-conditioning equipment.

-Same calculations for 3Ø as 1Ø systems. Except we distribute across 3 phases, rather than 2. Don’t forget to apply √3 when applying 3Ø voltage.

-Given:

A two-tenet 5,000 sq. ft. commercial building has a 3Ø, 120/208V service from the same transformer by the utility. Each tenet has its own panelboard fed from the main building distribution.

Tenet #1 – Barber Shop

2,000 sq. ft. overall space, 1,810 sq. ft. customer-facing barber shop area, 190 sq. ft. back-office space, (4) – 15A barber chairs 120/208V 1Ø, (10) – general-use receptacles 120V, (4) – 6’9” portions of unlikely to be used simultaneously plug-mold , (1) – pedestrian customer entrance, 40’ – show windows, and (1) – 5HP @ 208V 3Ø rooftop unit.

Tenet #2 – Restaurant

2,270 sq. ft. retail seating area, 500 sq. ft. commercial kitchen, the remainder sq. ft. is office space, 5,000W water heater 208V 1Ø, (65) – general-use duplex receptacles 120V, (34) – 4-lamp 17W per lamp dimmable LED troffer fixtures 120V, (1) – 2HP disposal 120V, (1) – 14kW range 120/208V, (1) – 1,110VA dishwasher 120V, (2) – 1,500W sandwich grillers 208V 3Ø, (2) – pedestrian customer entrances, (1) – 7 ½ HP rooftop heating unit 208V 3Ø with a 22A nameplate, and (1) – 24A air conditioner 208V 3Ø.

The water heater serves the kitchen area.

What are the ungrounded calculated loads in VA for the barber shop & restaurant?

What are the minimum feeder OCPD sizes allowed to feed the barber shop & restaurant?

What are the grounded calculated loads in amps for the barber shop & restaurant?

**Barber Shop**

General Lighting, 120V

1,810 sq. ft. retail space \* 1.9VA (NEC T220.12, note G) = 3,439VA

190 sq. ft. office space \* 1.3VA (NEC T220.12) = 247VA

3,439VA (retail)

+247VA (office)

3,686VA total calculated phase & neutral loads

3,686VA (total calculated phase & neutral loads)

/ 3 phases

1,228.67 🡪 1,229VA per phase

General Receptacles, 120V

10 general-use receptacles \* 180VA (NEC 220.12(I)) = 1,800VA

Unlikely to be used simultaneously plug-mold = each 5’ length @180VA (NEC 220.12(H)(1))

5’ \* 12” = 60”

6’ \* 12” = 72” + 9” = 81” each section of plug mold being installed

81” / 60” = 1.35 = 2 lengths @ 180VA of plug mold per 6’9” section of plug mold being installed

4 sections of 6’9” plug-mold being installed

\* 2 lengths @ 180VA per section

8 total lengths @ 180V

8 total lengths

\* 180VA per length (NEC 220.12(H)(2))

1,440VA total connected plug-mold phase loads

1,800VA (plugs)

+1,440VA (plug-mold)

3,240VA total calculated phase & neutral loads

*NOTE: If the total calculated phase & neutral loads for general-use plugs were above 10,000VA, we would need to derate according to NEC T220.44*

3,240VA (total calculated phase & neutral loads)

/ 3 phases

1,080VA total load per phase

Barber Chairs, 120/208V 1Ø

(4) – 15A barber chairs 120/208V 1Ø

15A

\* 208V

3,120VA per 2 phases & neutral per chair

3,120VA each chair

\* 4 chairs

12,480VA total calculated phase & neutral loads

12,480VA (total calculated phase & neutral loads)

\* 2 phases of power

24,960VA total power consumed by the chairs

24,960VA (total power consumed by the chairs)

/ 3 phases

8,320VA total load on each phase

3,120VA total neutral per chair

\* 4 chairs

12,480VA total calculated neutral load

12,480VA (total calculated neutral load)

/ 3 phases

4,160VA total load on each neutral

Entrances, 120V

Each customer pedestrian entrance = 1 sign circuit required (NEC 220.12(F) 🡪 NEC 600.5(A))

1,200VA sign circuit (NEC 220.12(F))

\* 1.25 (continuous duty)

1,500VA total calculated phase loads

1,500VA (total calculated phase loads)

/ 3 phases

500VA total load per phase & neutral

Show Windows, 120V

40’ of show window lighting

\* 200VA (NEC 220.43(A))

8,000VA total connected phase & neutral loads

8,000VA (total connected phase & neutral loads)

\* 1.25 (continuous duty)

10,000VA total calculated phase & neutral loads

10,000VA (total calculated phase & neutral loads)

/ 3 phases

3,333.33 🡪 3,333VA total per phase

Rooftop Unit

(1) – 5HP @ 208V 3Ø rooftop unit = 16.7A (NEC T430.250)

16.7A

\* (208V\* 1.732)

6,016.28 🡪 6,016VA total load per phase

6,016VA total calculated phase load

0VA total calculated neutral load

Largest motor

5HP @ 208V 3Ø rooftop unit

6,016VA (largest motor, 5HP @ 208V 3Ø)

\* 0.25 (largest motor, NEC 430.24)

1,504VA total calculated phase load

0VA total calculated neutral load



**Restaurant**

5,000 sq. ft. total (building) – 2,000 sq. ft. (barber shop) – 2,270 sq. ft. (restaurant seating) – 500 sq. ft. (commercial kitchen) = 230 sq. ft. restaurant office space

General Lighting, 120V

2,270 sq. ft. \* 1.5VA (NEC T220.12, restaurant) = 3,405VA

500 sq. ft. \* 1.5VA (NEC T220.12, restaurant) = 750VA

230 sq. ft. \* 1.3VA (NEC T220.12, office) = 299VA

3,405VA (restaurant seating)

750VA (kitchen)

+299VA (office)

4,454VA total calculated phase & neutral loads using NEC T220.12

*OR*

(60) – 4-lamp 17W fixtures

17W per lamp

\* 4 lamps per fixture

68VA per fixture

68VA per fixture

\* 50 fixtures

3,400VA total connected phase neutral loads

3,400VA (total connected phase loads)

\* 1.25 (continuous duty)

4,250VA total calculated phase & neutral loads using known fixtures

4,454VA (total calculated phase & neutral loads using NEC T220.12)

vs.

~~4,250VA (total calculated phase & neutral loads using known fixtures)~~

4,454VA (total calculated phase & neutral loads)

/ 3 phases

1,484.67 🡪 1,485VA total per phase & neutral

General Receptacles, 120V

65 general-use duplex receptacles

\* 180VA (NEC 220.12(I))

11,700VA total connected phase & neutral loads

11,700VA (total connected phase & neutral loads)

-10,000VA (@ 100%, NEC T220.44)

1,700VA

\* 0.5 (@ 50%, NEC T220.44)

850VA total load after 50% derate

10,000VA (@ 100%)

+850VA (@ 50%)

10,850VA total calculated phase & neutral loads

10,850VA (total calculated phase & neutral loads)

/ 3 phases

3,616.67 🡪 3,617VA total per phase & neutral

Entrances

Each customer pedestrian entrance = 1 sign circuit required (NEC 220.12(F) 🡪 NEC 600.5(A))

1,200VA sign circuit (NEC 220.12(F))

\* 2 sign circuits

2,400VA total connected phase & neutral loads

2,400VA (total connected phase & neutral loads)

\* 1.25 (continuous duty)

3,000VA total calculated phase & neutral loads

3,000VA (total calculated phase & neutral loads)

/ 3 phases

1,000VA total load per phase & neutral

HVAC

(1) – 7 ½ HP rooftop heating unit 208V 3Ø = 24.2A (NEC T430.250)

24.2A

\* (208V \* 1.732)

8,718.2 🡪 8,718VA total phase load

vs. (larger of the two, non-coincidental loads – NEC 220.60)

(1) – 24A air conditioner 208V 3Ø = 24A

\* (208V \* 1.732)

8,646.14 🡪 8,646VA total phase load

8,718VA (rooftop heating unit)

vs.

~~8,646VA (air conditioner)~~

8,718VA total calculated load per phase

0VA total calculated neutral load

Kitchen Equipment

Total number of kitchen appliances = 6 = 65% demand factor (NEC T220.56)

**120V with neutral, 1Ø**

(1) – 2HP disposal 120V

2HP @ 120V = 24A (NEC T430.248) \* 0.65 (NEC T220.56) = 15.6A

15.6A \* 120V = 1,872VA

(1) – 1,110VA dishwasher 120V

1,110VA \* 0.65 (NEC T220.56) = 721.5 🡪 722VA

1,872VA (disposal)

+722VA (dishwasher)

2,594VA total calculated phase & neutral loads

2,594VA (total calculated phase & neutral loads)

/ 3 phases

864.67 🡪 865VA total load per phase & neutral

**208V with neutral, 3Ø**

(1) – 14kW range 120/208V 3Ø

14,000VA \* 0.65 (NEC T220.56) = 9,100VA

9,100VA total calculated phase & neutral load

/ 3 phases

3,033.33 🡪 3,033VA total load per phase & neutral

*NOTE: The neutral derate of 70% per NEC 220.61(B)(1) only applies to residential ranges (or residential ranges in a classroom setting).*

**208V without neutral, 1Ø**

(1) – 5,000W water heater 208V 1Ø

5,000VA \* 0.65 (NEC T220.56) = 3,250VA total calculated phase for 2 phases

3,250VA (total calculated phase for 2 phases)

\* 2 phases

6,500VA total calculated power consumption

6,500VA (total calculated power consumption)

/ 3 phases

2,166.67 🡪 2,167VA total load per phase

0VA per neutral phase

**208V without neutral, 3Ø**

(1) – 1,500W sandwich griller 208V

(1) – 1,500W sandwich griller 208V

1,500VA + 1,500VA = 3,000VA \* 0.65 (NEC T220.56) = 1,950VA total calculated phase loads

1,950VA total calculated phase loads

0VA total neutral load

Largest Motor

7 ½ HP rooftop heating unit = 8,718VA

vs.

2 HP disposal = 24A \* 120V = 2,880VA

8,718VA (rooftop heating unit)

vs.

~~2,880VA (disposal)~~

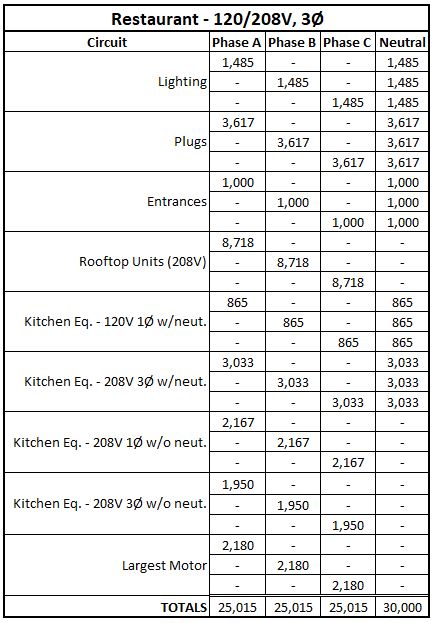
7 ½ HP rooftop heating unit = largest motor

8,718VA (total calculated phase load)

\* 0.25 (largest motor, NEC 430.24)

2,179.5 🡪 2,180VA total load per phase

0VA total neutral load



What are the ungrounded calculated loads in VA for the barber shop & restaurant?

**Barber Shop**

21,982VA total calculated load per phase

\* 3 phases

65,946VA total calculated load

**Restaurant**

25,015VA total calculated load per phase

\* 3 phases

75,045VA total calculated load

What are the minimum feeder OCPD sizes allowed to feed the barber shop & restaurant?

**Barber Shop**

65,946VA (total phase calculated load)

/ (208V \* 1.732)

183.05A 🡪 200A feeder OCPD (NEC 240.6(A))

**Restaurant**

75,045VA (total phase calculated load)

/ (208V \* 1.732)

208.31A 🡪 225A feeder OCPD (NEC 240.6(A))

What are the grounded calculated loads in amps for the barber shop & restaurant?

**Barber Shop**

43,386VA (total grounded calculated load)

/ (208V \* 1.732)

120.43A

**Restaurant**

30,000VA (total grounded calculated load)

/ (208V \*1.732)

83.27A

*NOTE: If either of the neutral ampacities were greater than 200A, we would get a derate of 70% for everything greater than 200A per NEC 220.61(B)(2).*

-When dealing with transformers in the system:

Neutrals do NOT get added upstream (transformers are separately derived systems)

Phase loads DO get added upstream (a watt is a watt is a watt)

At each transformer “level,” there is the potential for a “new” largest motor (i.e. a building’s overall system may have multiple largest motors due to multiple transformers / motors downline in the system).

-Given:

A hazelnut farm would like to build a new multi-use building. The overall building is 300,000 sq. ft. It will be fed by a 277/480V, 3Ø transformer from the utility by (3) underground parallel runs fed by THHW cu conductors. There will be (3) different areas of the building: a 150,000 sq. ft. warehouse, a 130,000 sq. ft. manufacturing area, and a 20,000 sq. ft. retail space with (4) customer pedestrian entrances. All warehouse & manufacturing area lighting is 277V non-linear.

The 277/480V 3Ø main distribution of the building will have the following loads: (1) – 120/240V 3Ø lighting subpanel A fed by on-site transformer A, (1) – 120/208V 3Ø subpanel B fed by on-site transformer B, (1) – 20HP 480V 3Ø shelling machine, (3) – 25HP 480V 3Ø rooftop units, and (20) – 400W exterior wall pack fixtures 277V 1Ø.

Transformer A will have primary & secondary protection and have the following loads: track lighting 120V 1Ø, (200) – general-use receptacles, (1) – 1HP disposal 120/240V 1Ø, and 56’ of simultaneously used plug-mold to serve the manufacturing area.

Transformer B will have primary & secondary protection and have the following loads: (2) – 30HP 208V 3Ø roasters, (2) – 5kW water heaters 208V 1Ø, and (1) – 20HP 120/208V 3Ø peeling machine.

What are the minimum sizes required for lighting subpanel A (OCPD) & transformer A (kVA rating)?

What are the minimum sizes required for subpanel B (OCPD) & transformer B (kVA rating)?

What is the minimum size of the overall service to the building?

What is the minimum size ungrounded conductor allowed to serve the building?

What is the minimum size grounded conductor allowed to serve the building?

**Lighting Subpanel / Transformer A**

Retail Space = 20,000 sq. ft.

General Lighting, 120V

20,000 sq. ft. (retail)

\* 1.9VA (NEC T220.12)

38,000VA total calculated phase & neutral loads

38,000VA (total calculated phase & neutral loads)

/ 3 phases

12,666.67 🡪 12,667VA total per phase & neutral

General Receptacles, 120V

200 plugs for manufacturing & retail \* 180VA = 36,000VA

Likely to be used simultaneously plug-mold = 1’ sections (NEC 220.12(H)(2))

56’ / 1’ = 24.08 = 56 sections of plug-mold

56 sections of plug-mold

\* 180VA per section (NEC 220.12(H)(2))

10,080VA total connected plug-mold phase loads

36,000VA (plugs)

+10,080VA (plug-mold)

46,080VA total connected phase & neutral loads for general receptacles

46,080VA (total connected phase receptacle loads)

-10,000VA (@100%, NEC T220.44)

36,080VA

\* 0.5 (@ 50%, NEC T220.44)

18,040VA

10,000VA (@ 100%)

+18,040VA (@ 50%)

28,040VA total calculated phase & neutral receptacle loads

28,040VA (total calculated phase receptacle loads)

/ 3 phases

9,346.67 🡪 9,347VA total per phase & neutral

Entrances, 120V

Each customer pedestrian entrance = 1 sign circuit required (NEC 220.12(F) 🡪 NEC 600.5(A))

1,200VA sign circuit (NEC 220.12(F))

\* 4 sign circuits

4,800VA total connected phase & neutral loads

4,800VA (total connected phase & neutral loads)

\* 1.25 (continuous duty)

6,000VA total calculated phase & neutral loads

6,000VA (total calculated phase & neutral loads)

/ 3 phases

2,000VA total load per phase & neutral

Disposal, 120/240V

(1) – 1HP disposal 120/240V 1Ø

8A (NEC T430.248)

\* 240V

1,920VA total calculated phase (across 2 phases) & neutral loads

1,920VA (total calculated phase & neutral loads)

\* 2 phases of power

3,840VA total power consumption

3,840VA (total power consumption)

/ 3 phases

1,280VA total per phase

1,920VA (total calculated phase & neutral loads)

\* 1 appliance

1,920VA (total neutral return)

1,920VA (total neutral return)

/ 3 phases

640VA total per neutral

Largest Motor

(1) – 1HP disposal 120/240V 1Ø

1,280VA total per phase

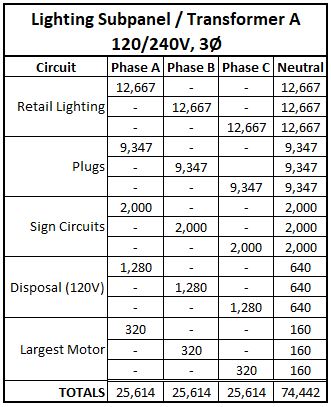
\* 0.25 (continuous duty)

320VA total per phase

640VA total per neutral

\* 0.25 (continuous duty)

160VA total per neutral



**Subpanel / Transformer B**

Roasters, 208V 3Ø

(1) – 30HP 208V 3Ø roaster

(1) – 30HP 208V 3Ø roaster

30HP @ 208V 3Ø = 88A (NEC T430.250)

88A

\* (208V \* √3)

31,702.53VA🡪 31,703VA total calculated phase load per roaster

31,703VA

\* 2 roasters

63,406VA total load per phase

0VA total neutral calculated loads

Water Heater, 208V

(2) – 5kW water heater 208V 1Ø

5,000VA per water heater

\* 2 water heaters

10,000VA total calculated phase loads across 2 phases

10,000VA (total calculated phase loads across 2 phases)

\* 2 phases

20,000VA total power consumption

20,000VA (total power consumption)

/ 3 phases

6,666.66 🡪 6,667VA total per phase

0VA total neutral load

Peeling Machine, 120/208V 3Ø

20HP 208V 3Ø peeling machine

20HP @ 208V 3Ø = 59.4A

59.4A

\* (208V \* √3)

21,399.21 🡪 21,399VA total calculated phase & neutral load

21,399VA (total calculated phase & neutral load)

/ 3 phases

7,133VA per neutral phase

Largest Motor

31,703VA (roaster calculated phase load)

\* 3 phases

95,109VA total power consumption

vs.

21,399VA (peeling machine calculated phase load)

\* 3 phases

64,197VA total power consumption

95,109VA (roaster)

vs.

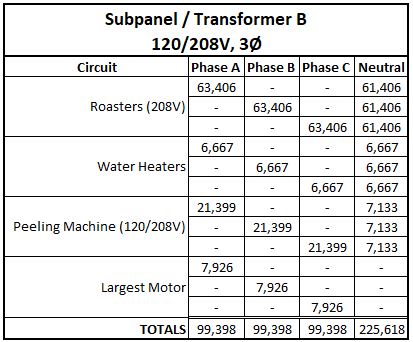
~~64,197VA (peeling machine)~~

31,703VA (roaster calculated phase load)

\* 0.25 (largest motor)

7,925.75🡪 7,926VA total load per phase

0VA total per neutral load



**Main Distribution**

Lighting Subpanel / Transformer A

Calculated phase loads from subpanel / transformer A = 25,614VA across all 3 phases

Subpanel / Transformer B

Calculated phase loads from subpanel / transformer B = 99,398VA across all 3 phases

*NOTE: We never bring the neutral loads up from downstream transformers. Only the phase loads*

General Lighting, 277V

Warehouse = 150,000 sq. ft.

Manufacturing Area = 130,000 sq. ft.

150,000 sq. ft. (warehouse) \* 1.2VA (NEC T220.12) = 180,000VA

180,000VA (warehouse lighting)

-12,500VA (@ 100%, NEC T220.42)

167,500VA

\* 0.5 (@ 50%, NEC T220.42)

83,750VA

12,500VA (@100%)

+83,750VA (@50%)

96,250VA total calculated phase & neutral load for the warehouse lighting

130,000 sq. ft. (manufacturing) \* 2.2VA (NEC T220.12) = 286,000VA

96,250VA (warehouse)

+286,000VA (manufacturing)

382,250VA total calculated phase & neutral loads

382,250VA (total calculated phase & neutral loads)

/ 3 phases

127,416.67 🡪 127,417VA total per phase & neutral

Exterior Lighting, 277V

(20) – 400W exterior wall pack fixtures 277V 1Ø

400W \* 20 fixtures = 8,000VA total connected phase & neutral loads

8,000VA (total connected phase & neutral loads)

\* 1.25 (continuous duty)

10,000VA total calculated phase & neutral loads

10,000VA (total calculated phase & neutral loads)

/ 3 phases

3,333.33 🡪 3,333VA total per phase & neutral

Shelling Machine, 480V 3Ø

(1) – 20HP 480V 3Ø shelling machine

20HP @ 480V 3Ø = 27A (NEC T430.250)

27A

\* (480V \* √3)

22,446.72 🡪 22,447VA total calculated per phase load

Rooftop Units, 480V 3Ø

(3) – 25HP 480V 3Ø rooftop units

25HP @ 480V 3Ø = 34A

34A

\* (480V \* √3)

28,266.24 🡪 28,266VA total calculated phase load per rooftop unit

28,266VA (total calculated phase load per rooftop unit)

\* 3 rooftop units

84,798VA total calculated per phase load

0VA total calculated neutral load for the shelling machine

Largest Motor

22,447VA (shelling machine total calculated per phase load)

\* 3 phases

67,341VA total power consumption

*vs.*

28,266VA (rooftop unit total calculated per phase load)

\* 3 phases

84,798VA total power consumption

~~67,341VA (shelling machine)~~

vs.

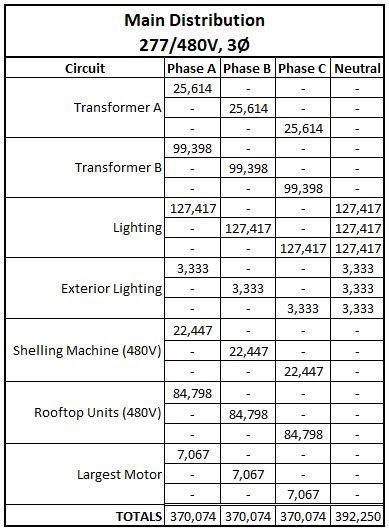
84,798VA (rooftop unit)

28,266VA (rooftop unit total calculated per phase load)

\* 0.25 (largest motor)

7,066.5 🡪 7,067VA total load per phase

0VA total calculated neutral load



What are the minimum sizes required for lighting subpanel A (OCPD) & transformer A (kVA rating)?

Lighting Subpanel A

25,614VA per phase

\* 3 phases

76,842VA total calculated load

76,842VA (total calculated load)

/ (240V \* 1.732)

184.86A 🡪 200A OCPD

Transformer A

480V to 240V 3Ø transformer to produce at least 184.86A of power = 112.5kVA transformer (Ugly’s Page 60)

112.5kVA transformer = 270.6A

75kVA transformer = 180.4A

76,842VA (total calculated load)

/ 1,000

78.842kVA 🡪 112.5kVA transformer

What are the minimum sizes required for subpanel B (OCPD) & transformer B (kVA rating)?

Subpanel B

99,398VA per phase

\* 3 phases

298,194VA total calculated load

298,194VA (total calculated load)

/ (208V \* 1.732)

827.73A 🡪 1,000A OCPD

Transformer B

480V to 208V 3Ø transformer to produce at least 811.07A of power = 300kVA transformer (Ugly’s Page 60)

300kVA transformer = 832.7A

225kVA transformer = 624.6A

292,194VA total calculated load

/ 1,000

292.194kVA 🡪 300kVA transformer

What is the minimum size of the overall service to the building?

370,074VA per phase

\* 3 phases

1,110,222VA total calculated load

1,110,222VA (total calculated load)

/ (480V \* √3)

1,335.43A 🡪 1,600A OCPD

What is the minimum size ungrounded conductor allowed to serve the building?

1,600A (OCPD of the overall service to the building per NEC 240.4(C))

/ 3 parallel runs

533.33A 🡪 1,000kcmil THHW cu conductors

*NOTE: Underground conduit is considered a wet location. Dual-rated conductors (i.e. THHW being in the 75 & 90° C columns in NEC T310.16) start the derate calculations in the 90° C column when in dry locations, and they start in the 75° C column when in wet locations.*

What is the minimum size grounded conductor allowed to serve the building?

392,250VA (main distribution calculated neutral load)

/ (480V \* √3)

471.82A main distribution calculated neutral amps

- 200A (neutral derate over 200A for services & feeders, NEC 220.61(B)(2))

271.82A

\* 0.7 (NEC 220.62(B)(2))

190.27A

200A (@100%)

+190.27A (@ 50%)

390.27A main distribution total calculated neutral ampacity

NEC 250.30(A)(3) – grounded conductors in parallel conduits for AC systems

The size of the neutral conductor in each raceway shall be based on the circular mils of the ungrounded conductor in the raceway, then apply NEC T250.102(C)(1).

The size of the neutral conductor shall not be required to be larger than the ungrounded conductors.

The size of the neutral conductor shall not be smaller than 1/0 while paralleling.

1,000kcmil (size of the ungrounded conductors)

\* 3 ungrounded conductors

3,000kcmil total circular mils of the ungrounded conductors

3,000kcmil (total circular mils of the ungrounded conductors)

\* 0.125 (12.5% per NEC T250.102(C)(1) note 1

375kcmil 🡪 400kcmil THHW cu conductor

**<END OF THE 7th 4-HOUR CLASS>**

**RV Park Calculations – Approx. 30 minutes**

-NEC 551.2 gives the definition of what an RV park is, does OESC alter that definition? No.

-NEC 551.73(A) gives the calculation values for each type of site:

12,000VA per site w/50A power

3,600VA per site w/30A & 20A power

2,400VA per site w/20A power

600VA per site for just tent sites

-NEC 551.73(A), each site is based on the largest power available at the site (i.e. a site with 50A, 30A, and 20A power would have a value of 12,000VA).

-NEC T551.73(A) derate only applies to the sites locations themselves (i.e. “house” power is added separately to the calculation)

What’s the minimum sized 120/240V, 1Ø service allowed to serve an RV park with the following RV sites: (5) – 50A RV power sites, (2) – 50A RV power sites w/20A tent plug power, (10) – 20A & 30A RV power sites, and (5) – 20A tent only plug power sites?

12,000VA \* 7 sites = 84,000VA

3,600VA \* 10 sites = 36,000VA

600VA x 5 sites = 3,000VA

123,000VA total connected load

123,000VA (total connected load)

/ 240V

512.5A

\* 0.43 (22 sites, NEC T551.73(A))

220.36A 🡪 225A service

**Solar Calculations – Approx. 45 minutes**

-Solar calculations fall back on our understanding of parallel vs. series circuits.

Parallel circuit = same voltage across the system

Series circuit = same amperage across the system

-Each module (solar panel) added to a string (series branch circuit) increases the voltage of the string.

-Each string has a set ampacity; regardless how many modules are on the string (think a typical parallel A/C branch circuit—voltage is the same across the circuit regardless of the loads added).

-Each string adds to the total ampacity of the solar system.

-Solar systems are considered to be continuous duty because they will run for 3 hours or more (each string is a continuous duty load).

A solar inverter has a maximum rating of 600VDC & 20A. Each module is 37VDC & 5A. What is the maximum production this solar system can produce?

a) 1 string with 16 modules

b) 2 strings with 8 modules each string

c) 3 strings with 5 modules each string

d) 4 strings with 4 modules each string

Each string is 5A \* 1.25 (continuous duty) = 6.25A per string

20A / 6.25A = 3.2 strings max (cannot be answer D)

5 modules \* 44VDC = 220VDC (less than max 600VDC)

Answer B

7) A solar inverter has a maximum rating of 450VDC & 20A and has 3 strings of 11 modules per string. What’s the maximum sized modules allowed to serve this solar system?

a) 40VDC & 5.25A

b) 45VDC & 5.25A

c) 40VDC & 5.5A

d) 45VDC & 5.5A

20A \* 0.8 (continuous duty) = 16A / 3 strings = 5.33A max per module

450VDC / 11 modules = 40.91VDC max per module

Answer A

**Optional Restaurant Calculations – Approx. 45 minutes**

-NEC T220.88

Nameplate of *everything* (noncoincidental loads still apply) 🡪 find total kVA (if not given)

Apply NEC T220.88

all electric vs. partial electric

the total kVA determines the row to use

-What’s the calculated load for a new all electric restaurant with a total connected load of 325kVA using the optional method?

NEC T220.88 – 2nd row, middle column

total calculated load (TCL) = (10% \* [total connected load – 200kVA]) + 160.0kVA

total calculated load (TCL) = (10% \* [total connected load – 200kVA]) + 160.0kVA

(10% \* [325kVA – 200kVA]) + 160.0kVA

(10% \* 125kVA) + 160.0kVA

12.5kVA + 160.0kVA

TCL = 172.5kVA

-What’s the calculated load for a new partial electric, partial gas restaurant with a total connected load of 380kVA using the optional method?

NEC T220.88 – 3rd row, right column

total calculated load (TCL) = (45% \* [total connected load – 325kVA]) + 262.5kVA

total calculated load (TCL) = (45% \* [total connected load – 325kVA]) + 262.5kVA (10% \* [380kVA – 325kVA]) + 262.5kVA

(10% \* 55kVA) + 262.5kVA

5.5kVA + 262.5kVA

TCL = 267.5kVA

**Optional School Calculations – Approx. 1 hour**

-NEC T220.86

Nameplate of *everything* (noncoincidental loads still apply) 🡪 find total connected VA load (if not given)

Total connected VA load / total square footage of the school = total connected VA per sq. ft.

Total connected VA per sq. ft.

First 3VA per sq. ft. @ 100% = 3VA

Next 17VA per sq. ft. @ 75% = Up to 12.75VA

Remaining VA per sq. ft. @ 25% = X

3VA + 12.75VA + X = Total demand VA load per sq. ft.

Total demand VA load per sq. ft. \* sq. ft. = total demand load (then divide by voltage & phase)

-What’s the calculated load for a new 30,000 sq. ft. school with a total connected load of 200kVA using the optional method?

200kVA \* 1,000 = 200,000VA

Total connected VA load / total square footage of the school = total connected VA per sq. ft.

200,000VA / 30,000 sq. ft. = 6.67 total connected VA per sq. ft.

Total connected VA per sq. ft.

First 3VA per sq. ft. @ 100% = 3VA

Next 17VA per sq. ft. @ 75% = Up to 12.75VA

Remaining VA per sq. ft. @ 25%

6.67 total connected VA per sq. ft.

- 3VA per sq. ft. (@ 100%) 3VA per sq. ft.

3.67VA per sq. ft. remaining

3.67VA per sq. ft. remaining

\* 0.75 (@ 75%, up to 17VA per sq. ft.)

2.75VA per sq. ft.

3VA per sq. ft. (@ 100%)

2.75VA per sq. ft. (@ 75%)

+0 (@ 25%)

5.75VA per sq. ft.

5.75VA \* 30,000 sq. ft. = 172,500VA total calculated load for the school

-What’s the calculated load for a new 18,000 sq. ft. school with a total connected load of 430kVA using the optional method?

430kVA \* 1,000 = 430,000VA

Total connected VA load / total square footage of the school = total connected VA per sq. ft.

430,000VA / 18,000 sq. ft. = 22.22 total connected VA per sq. ft.

Total connected VA per sq. ft.

First 3VA per sq. ft. @ 100% = 3VA

Next 17VA per sq. ft. @ 75% = Up to 12.75VA

Remaining VA per sq. ft. @ 25%

22.22 total connected VA per sq. ft.

- 3VA per sq. ft. (@ 100%) 3VA per sq. ft.

19.22VA per sq. ft. remaining

19.22VA per sq. ft. remaining

- 17VA per sq. ft. 17VA per sq. ft.

2.22VA per sq. ft. remaining \* 0.75 (@ 75%)

12.75VA per sq. ft.

2.22VA per sq. ft. remaining

\* 0.25 (@ 25%)

0.56VA per sq. ft.

3VA per sq. ft. (@ 100%)

12.75VA per sq. ft. (@ 75%)

+0.56VA per sq. ft. (@ 25%)

16.31VA per sq. ft.

16.31VA \* 18,000 sq. ft. = 293,580VA total calculated load for the school

**Upsizing Equipment Grounding Conductors for Voltage Drop Calculations – Approx. 1 hour**

-If we upsize the ungrounded/grounded conductors for voltage drop, we have to upsize the equipment grounding conductors for voltage drop also.

-Reminder:

The overall volts drop across services/feeders & branch circuits is 5%

The maximum volts dropped either can be (service/feeders OR branch circuits) is 3%

Voltage drop calculations begin on Page 50 of Ugly’s

-Actual volts dropped @ 3% max drop for all voltages:

120V \* 0.03 = 3.6V

208V \* 0.03 = 6.24V

240V \* 0.03 = 7.2V

277V \* 0.03 = 8.31V

480V \* 0.03 = 14.4V

600V \* 0.03 = 18V

1,000V \* 0.03 = 30V

-CM needed = (√3 \* K \* I \* L) / (actual volts dropped at 3% max for applied voltage)

-Ratio = upsized phase conductor in CM / minimum required phase conductor in CM

-Apply ratio to EGC CM 🡪 next size up

-What’s the minimum sized equipment grounding conductor necessary for 150A, 120/240V, 1Ø load located 925’ from the main distribution?

150A OCPD = 1/0 phase conductor normally

1/0 = 105,600CM

CM needed = (K \* I \* L) / (actual volts dropped at 3% max for applied voltage)

= (12.9 \* 150A \* 925’) / 7.2V

= 1,741,500CM / 7.2V

CM needed = 241,875CM = 250kcmil (NEC Chap. 9, Table 8)

Ratio = 250kcmil / 1/0

= 250,000 / 105,600

Ratio = 2.367

150A OCPD = #6 EGC normally (NEC T250.122)

#6 = 26,240CM

26,240CM (#6)

\* 2.367

62121.21CM = #2 EGC (NEC Chap. 9, Table 8)

-What’s the minimum sized equipment grounding conductor necessary for 200A, 277/480V, 3Ø load located 700’ from the main distribution?

200A OCPD = 3/0 phase conductor normally

3/0 = 167,800CM

CM needed = (√3 \* K \* I \* L) / (actual volts dropped at 3% max for applied voltage)

= (√3 \* 12.9 \* 200A \* 700’) / 14.4V

= 3128083.76CM / 14.4V

CM needed = 217,228.04CM = 250kcmil (NEC Chap. 9, Table 8)

Ratio = 250kcmil / 3/0

= 250,000 / 167,800

Ratio = 1.4899

200A OCPD = #6 EGC normally (NEC T250.122)

#6 = 26,240CM

26,240CM (#6)

\* 1.4899

39,094.16CM = #4 EGC (NEC Chap. 9, Table 8)

<Homework: (2) – 26 code question quizzes; (1) – 20 question Washington RCW / WAC quiz>

**<END OF THE 8th 4-HOUR CLASS>**

**Review Homework – Approx. 15 minutes**

**Additional Calculation Practice (Attendees Decide Specific Calcs) – Approx. 3 hours & 45 minutes**

**<END OF THE 9th 4-HOUR CLASS>**

**Additional Calculation Practice (Attendees Decide Specific Calcs) – Approx. 3 hours & 15 minutes**

**General Test Taking, Prep Recommendations, and Q&A / Student Review Questions – Approx. 45 minutes**

-Timeline on the OR test itself:

Start with the 12-question calculation portion of the test. Try to be completed with an answer on every question in approximately 1 ½ hours. *THIS ONLY GIVES YOU 7 ½ minutes per calculation!*

Take the 52-question code portion of the test. Try to be completed with an answer on every question in approximately 2 hours. *THIS ONLY GIVES YOU about 2.3 minutes per question!*

These timelines will allow you another 30 minutes to go back over calculation questions that you’re not 100% confident on.

-Timeline on the WA test itself:

The order of the test is predetermined by the state: code questions, calculation questions, WA / RCW questions.

Before clicking “submit” on the code questions, go take a break (i.e. stretch, go to the bathroom, have a drink of water, etc.). You will probably not have time after the calculation portion and before the WA / RCW portion.

-Highlight the OESC in your NEC codebook with a color that you have not used for any other highlighting.

This will let you know when a question *may* have been altered by OESC.

This will also let you know when a question definitely hasn’t been altered by the OESC.

-Highlight the various “parts” of each code article with a color that you have not used for any other highlighting.

This will help you stay in the areas of the code where you have it narrowed down while looking for the answer and not accidentally move into a different part that isn’t relevant to your answer (i.e. think Swimming Pools).

-Make flash cards of the NEC.

One side = NEC Code name, One side = NEC Code article

One side = Relevant NEC table, One side = Relevant NEC table code article and/or what is found using the table

-Continue to study and practice!

Reach out for specific types of practice questions from me that you feel you’re struggling the most with.

-Before the test:

Go to bed early the night before.

Drink lots of water to be hydrated (preferably the day before).

Set all your exam materials out the night before (codebook, calculator, etc.)

Determine how long the drive to the testing center is, and plan to be there a half hour before your test time (don’t forget about traffic!).

Eat a small breakfast before leaving for the testing center.

Stop ALL studying at least 1 or 2 days before your test.

Wear something comfortable to test in.

Bring a sweatshirt in case the testing center is chilly.

-Last chance for questions from students…

**<END OF THE 10th 4-HOUR CLASS>**