

BASIC NEC CODE RULES AND DESIGN PRACTICE

Wire Ampacity and Size

1. Maximum loading for any branch circuit is 80% of rating of circuit for ampacity of wire for any load. NEC 220-2, use NEC 310-16 for ampacity. This applies to not more than 3 phase conductors in 1 conduit.

Warning

Voltage Drop NEC³ 310-16 wire ampacity tables do not take into account voltage drop, only thermal limit. Overhead triplex, use 310-16 for wire ampacity.

Rule of Thumb

If circuit is loaded up to ampacity and distance to load is around 100 feet, then voltage drop will govern and will require larger wire size. If more than 3 phase wires are in one conduit, then wires must be derated according to Note 8, after Table 310-19 as follows:

TABLE 1

<u>Number of Conductors</u>	<u>Percent of Values in 310-16</u>
*1-3	80
*4-6	80
7-24	70
25-42	60
43 and above	50

*If circuit is loaded up to 80% ampacity, then 6 phase wires can be put in one conduit. Neutral conductors supplying balanced loads do not have to be counted.
Note: Minimum Circuit size is #12 with 20 Amp CB.

Circuit Breaker Size

2. Maximum loading of any circuit breaker is 80% of rating for non-motor loads with exceptions as noted below. Breaker cannot be larger than ampacity of wire, except for motors and a few other loads.

TABLE 2

<u>Load</u>	<u>Maximum Circuit Breaker</u> <u>Size % of Current</u>
Resistance Loads, Heat, Stoves, Toasters, Water Heater	125%
Lighting	125%
Motors except Hermetically Sealed 00-250% NEC 430-152	
Motors Hermetically Sealed, Air conditioners And heat pumps	175%
Welders	200%

Standard breaker sizes are listed Page 70-74, 240-6 NEC

Conduit Sizing

1. After circuits have been derated to get proper wire size use Table 3A if wires are all same size. Use Page 70-57"9, or Tables 4 and 5 if wires are all different size. Ground wires should be run with all branch circuits.

Example:

Load Furnace 15 KW, I phase, 230V, find current, KVA, wire size, circuit breaker size, conduit size.

$$I = \frac{KW}{KV} = \frac{15KW}{.23KV} = 65.2 \text{ Amp}$$

$$KW = KVA, P.F. = 1.0 \quad KVA = 15$$

Wire Size

$$\text{Wire Size} = \frac{\text{Load}}{.8} = \text{ampacity} = \frac{65.2 \text{ Amp}}{.8} = 81.5 \text{ Amp}$$

Use NEC 310-16, 75°C, THW, wire
 #4 wire has 85 amps Use #4 2 #4 and, 1 #4
 ground Circuit Breaker Sizing

$$CB = \frac{\text{Load}}{.8} = \frac{65.2 \text{ Amp}}{.8} = 81.5 \text{ Amp}$$

Next higher CB size is 90 Amp.

NEC 240-6 and 240-3 exception 1, conduit-size, 3 #4 in conduit Table 3A = 1" conduit which allows 3 #4 maximum in a 1" conduit

Example:

Load: Lighting circuit 9-4 tube 4', 50VA/tube 115V fluorescent circuits. find I, circuit breaker, wire.

$$(9 \text{ fixtures}) (4 \text{ tubes/fixture}) (50V A/tube) = 1800 \text{ VA} = 1.8 \text{ KVA}$$

$$I = \frac{KVA}{KV} = \frac{1.8 \text{ KVA}}{.115 \text{ KV}} = 15.6 \text{ Amp}$$

$$\text{Wire Size} = \frac{\text{Load}}{.8} = \frac{15.6A}{.8} = 19.5 \text{ amps.}$$

NEC 310-16, THW, 75°C #12 = 20 Amp

$$\text{Circuit breaker size} = \frac{\text{Load}}{.8} = \frac{15.6}{.8} = 19.5$$

USE 20 Amp breaker

2 #12 in conduit Table 3A, 1/2" conduit will take up to 4 #12 THW

Example:

Load: Motor 3 HP, 1 phase, 230V run ground wire with all motors

$$I = 17A \text{ NEC 430-148}$$

$$\text{Wire Size} = \frac{17A}{.8} = 21.5A$$

NEC 310-16 #10 is next size wire good for 30 Amp CB = (I)(2 to 2.5) NEC 430-152

$$\text{CB Size} = (17 A) (2) = 34A \quad \text{USE 35A circuit breaker.}$$

Conduit Size

3 #10, (2 power, 1 ground), Table 3A, THW, 1/2" conduit will take 4 #10

Example

Load: Unit Heater 10 KW, 230V, 3 phase, find I, wire size, circuit breaker size

Conduit Size

$$I = \frac{10 \text{ KW}}{.23 \text{ KV} \sqrt{3}} = 25.1 \text{ Amp}$$

$$\text{Wire Size- } \frac{25.1A}{.8} = 31.3 \text{ Amp}$$

NEC 310-16 Use #8 good for 45 amp, 3 #8 + 1 #8 ground in 1" RGC Table 3A

$$\text{Circuit Breaker} = \frac{25.1A}{.8} = 31.3 \text{ Amp so use 35A}$$

Conduit Size if different size wires are used

1. If different size wires are used in one conduit, the total area filled cannot exceed the percentage area given in Table 4, page 70-637 NEC. Use Table 5, Page 70-638 to get cross sectional area, then add all areas of all wires and pick the next largest conduit size

Example: 3 #12, 4 #10, 2 #8, THW, what size conduit?

From Table 5, Page 70-638

	in ²
3 # 12	$3(.0172) \text{ in}^2 = .0516$
4 # 10	$4(.0311) \text{ in}^2 = .01244$
2 # 8	$2(.0598) \text{ in}^2 = \underline{.1196}$
	$.18364 \text{ in}^2$

Page 70-582, Table 4, Over 2 Conductors, not lead covered, 40% fill.

3/4" conduit will allow 21 in².

Since .1836 in is less, use 3/4" conduit.

If, runs are over 50', increase conduit 1 size to facilitate pulling.

CIRCUIT LOADING Non-Motor Loads

<u>CIRCUIT BREAKER SIZE Amp*</u>	<u>75° C THW WIRE SIZE</u>	<u>MAXIMUM Amps</u>
<u>Non-motor load</u>	<u>any load</u>	<u>any load</u>
15	12	12
20 Normally smallest breaker	12	16
25	10	20
30	10	24
35	8	28
40	8	32
45	8	36
50	6	40
60	6	48
70	4	56
80	4	64
90	3	72
100	3	80
110	2	88
125	1	100
150	1/0	120
175	2/0	140
200	3/0	160
225	4/0	180
250	250 MCM	200
300	350 MCM or 2-1/0 Parallel	240
350	500 MCM or 2-2/0 Parallel	280
400	600 MCM or 2-3/0 Parallel	320
450	700 MCM or 2-4/0 Parallel	360
500	2-250 MCM Parallel	400
600	3-3/0 Parallel	480
700	3-4/0 Parallel	560
800	3-300 MCM Parallel	640

* For motor Loads multiply running current by 1.75-2.50 to get circuit breaker size as shown in Table 2 above.

CIRCUIT LOADING GUIDE LINES

Maximum Loading - for a 20 A Circuit

20 Amp Circuit use for all lights and outlets @ 115V Maximum load is:

$$I = (20 \text{ A})(.8) = 16 \text{ Amp maximum}$$

Maximum KVA for 20 Amp circuit is $(16 \text{ Amp})(.115 \text{ KV}) = 1.84 \text{ KVA} = 1840\text{VA}$

Out lets (Duplex = 1 outlet)

Outlets 180VA per outlet.= .18 KVA

Max. outlets per circuit= $\frac{1.84 \text{ KVA max.}}{.18 \text{ KVA per outlet}} = 10.1$ outlets per 20A circuit, use 10

Fluorescent Fixtures 4 Foot Tube

F40-T12 Tube 40 VA + 10 VA Ballast Loss = 50 VA

		<u>VA</u>	<u>KVA</u>	<u>Maximum Fixtures Per 20 A Circuit</u>
1 tube	Fixture =	50VA	= .05KVA	36
2 tube	Fixture =	100VA	= .1 KVA	18
3 tube	Fixture =	150VA	= .15KVA	12
4 tube	Fixture =	200VA	= .2KVA	9
6 tube	Fixture =	300VA	= .3KVA	6

General Design Guidelines

- 1) Lights and outlets should be on separate circuits to allow maximum loading of lighting circuits, and have maximum capacity available for outlets.
- 2) Light circuits (20A) should be loaded up as close to 1.84 KVA as practical to minimize the number of circuits.
- 3) Outlet circuits are required to have GFI protection in the following locations:
 - a. Residential construction
 - b. Any other location where portable equipment is likely to be used with grounded surface or wet areas, shops, warehouses, comfort station, etc., GFI outlets are about \$20 , GFI breakers are about \$35.

- c. Reduce outlet loading from the 10 maximum per 20 Amp circuit to less in areas of large load, shops, repair facilities, etc.
- d. Each separate piece of fixed equipment must have its own circuit. Welders, grinders, drill presses etc.

4. Minimum Service Size

Minimum size service that should be installed is 100 A, 20 circuit for very small buildings, comfort stations 200 A or 225 Amp, 40 circuit 120/240V, 1 phase for all others. This may be too small for actual load, must do load calculations.

5. Future Growth

Allow for future growth. The service entrance is the most expensive part of the electrical system to replace. Use a minimum of 25% over the connected load. Include ampacity and panel circuit space both. 50% is preferable.

6. Voltage Drop

Check service entrance to panel and branch circuits run over 75-100 feet for voltage drop, this may increase wire size.

7. Limit voltage drop to the following:

<u>Panel to Load</u>	<u>Voltage drop %</u>
Heating, Lights Outlets	3%
Motors	2%, 1% preferable
Service Entrance to Transformer	2%

8. Building Electrical Design Order

- a. Select voltage, phase
- b. Do lighting calculation and layout lighting
- c. Do heating calculations and select equipment
- d. Lay out outlets
- e. Circuit any special equipment
- f. Fill out load calculation sheets and size panel
- g. Make up panel directory
- h. Balance panel
- i. Size feeders to panel (just like branch circuits. 80% loaded wire same size or larger than ampacity of main breaker.

- j. Size grounding conductors NEC 250-94
- k. Fire alarm circuits must be tapped ahead of main breaker with a separate panel.
- l. Do short circuit calculations, see Section 10.

9. Underground Wiring

Use XLP-USE wire for underground wiring, #^AWG Copper minimum.

PROJECT: TONASKET OFFICE ADDITION

PANELA ___ VOLTAGE & PHASE: 120/240v

LOCATION OF PANEL: OPEN OFFICE AREA

CALCULATED BY: JOANN- JULY 12,79

LOAD	WIRE SIZE	LINE	KV	AMPS/PHASE	√3	KVA	P.F.	KW	PHASE	C.B.	CIR.	
OUTLETS (OPEN OFFICE)	6	12	2	.115	9.0	1	1.04	1	1.0A	1	20	1
" "	6	12	1	.115	9.0	1	1.04	1	1.0A	1	20	3
" (CONFERENCE)	9	12	2	.115	13.5	1	1.55	1	1.55	1	20	2
" (EXTRA ROOM)	3	12	1	.115	4.5	1	.52	1	.52	1	20	4
" (OUTSIDE)	2	12	1	.115	3.0	1	.35	1	.35	1	20	4
LIGHTS (OPEN OFFICE)	7	12	2	.115	12.17	1	1.4	.95	1.33	1	20	5
" "	6	12	1	.115	10.44	1	1.2	.95	1.1A	1	20	7
" "	6	12	2	.115	10.44	1	1.2	.95	1.1A	1	20	6
" "	6	12	1	.115	10.44	1	1.2	.95	1.1A	1	20	8
" "	6	12	2	.115	10.44	1	1.2	.95	1.1A	1	20	9
" (CONFERENCE)	8	12	1	.115	13.91	1	1.6	.95	1.52	1	20	11
" (EXTRA ROOM)	2	12	1	.115	3.48	1	.4	.95	.38	1	20	8
" (HALLWAY)	2	12	1	.115	1.74	1	.2	.95	.19	1	20	8
" (OUTSIDE) 100w	2	12	2	.115	1.74	1	.2	.95	.2	1	20	9
1 ∅ 115V				L1 =	56.5A	SUB	TOTAL					
1 ∅ 115V				L2 =	57.3A	SUB	TOTAL					
FURNACE #1		1,2	.23		53	1	12.2	1	12.2	1	70	18,20
FURNACE #2		1,2	.23		48	1	11.1	1	11.1	1	60	13,15
FURNACE #3		1,2	.23		48	1	11.1	1	11.1	1	60	14,16
COMPRESSOR		1,2	.23		29.3	1	6.7A	1	6.7A	1	50	22,24
				L1 =	234.8	TOTAL						
				L2 =	235.6	TOTAL						
						59.2	KVA	TOTAL				

$\frac{59.2 \text{ KVA}}{.23 \text{ KV}} = 235.6 \text{ A} \div .8 = 294 \text{ A} + 25\% \text{ future} = 368 \text{ A}$
 MAXIMUM LOAD for 400 A Panel is $.8(400) = 320 \text{ A}$ USE 400 A PANEL

1. In Oregon, over current protection must be provided at the meter pole for each of the service drops to the buildings. This protects the conductors from a short circuit fault should it occur between the meter and the main breaker in the building. The over current device (fuse or circuit breaker) must be sized for the ampacity of the service drop, and available fault current.

2. The service drop conductors must be sized from Table 310-17. If Triplex is used, Table 310-16 must be used, as directed by NEC Article 321-5. The service drop ampacity must be the same as the ampacity of the service entrance. THW or XLP insulated conductors should be used for overhead service drops. XLP insulated conductor should be used for underground, and Table 310-16 of Chapter 9 gives the conduit size required for XLP conductors.

3. The service entrance conductors must be sized from Table 310-16. Table 310-16 of Chapter 9 gives the conduit-size for THW insulated conductors used for an overhead service entrance. Table 310-16 of Chapter 9 gives the conduit size for insulated conductors used for underground service entrances. The ampacity of the service entrance conductors should be sized for the total capacity of the building's power panels. For example, two 200 amp panels should have a 400 amp service to allow for added circuits in the future.

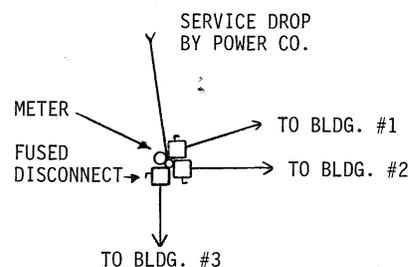
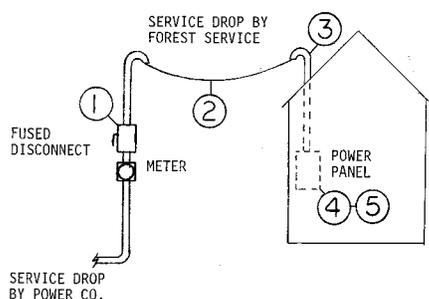
4. The main breakers in the building provide over current protection for the power panels, and must not be sized larger than the ampacity rating of the power panels.

5. NEC allows a maximum of six hand movements at one location to shut off all the power of a building with a large power distribution system. A switchboard or multiple individually mounted circuit breakers must be at the same physical location as the service entrance to shut off panels located elsewhere in the building.

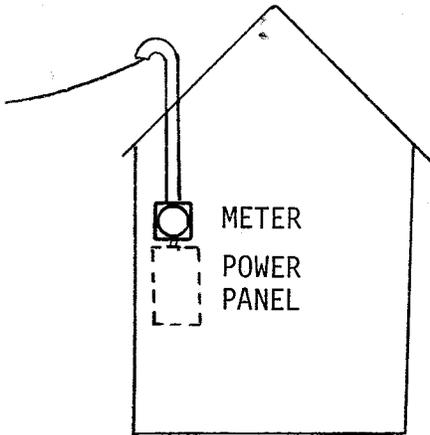
6. All the buildings served by a common transformer must be reevaluated to insure that the existing short circuit protection is adequate for the larger transformer required when additional buildings are added to the compound service system. The existing breakers must be upgraded to handle the increased short circuit potential.

7. The service entrance, service drop, and fused disconnect on the meter pole must be changed to a higher ampacity when additional service is needed for the building.

COMPOUND MATERING (USER-OWNED SERVICE DROPS)



SERVICE DROP
BY POWER CO.



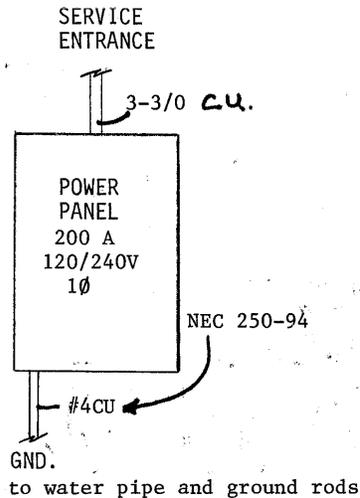
METER ON INDIVIDUAL BUILDINGS (UTILITY-OWNED SERVICE DROPS)

1.

1. The utility company is responsible for everything up to the weather head-for an over head service, and up to the meter for most underground service entrances. All future maintenance and upgrading is done by the utility.

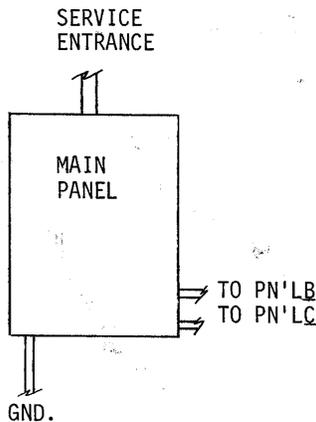
2. Items 3,4,5, and 6 in the Compound Metering section is still the responsibility of. the user.

SERVICE ENTRANCES AND GROUNDING



Single Panel Service

1. The neutral is grounded to the power panel which is grounded to the water pipe, and to the concrete foundation or to ground rods.
2. All the branch circuits must have their ground wires attached to the -g grounded neutral.
3. The main breaker in the panel serves as a single point to shut power off for the entire building.



Remotely Located Panels from a Main Panel

1. 1.2., & 3 of single panel service apply to the main panel.
2. The subfed conductors and the circuit breakers in the main panel are sized to the ampacity rating of the subfed panels.
3. The neutral in the subfed panels must not be grounded. The neutrals and grounds of the branch circuits in the subfed panels must be kept separate. The subpanels must have a separate grounding bar for the branch circuit ground wires. A separate ground wire must be run with the conductors from the main panel grounding point to the subfed panels grounding bar.

Table 250-94

Grounding Electrode Conductor for AC Systems

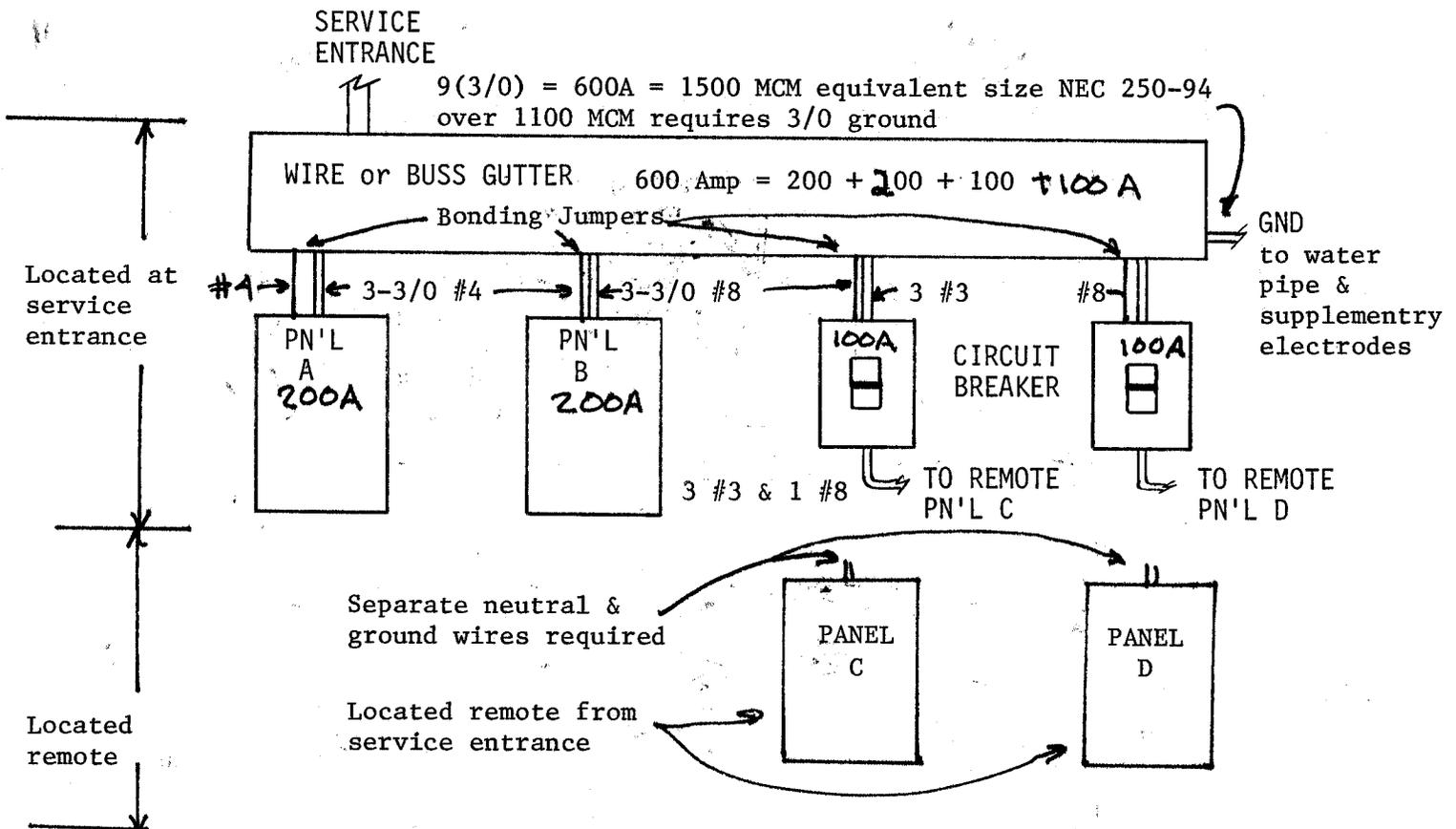
Size of Largest Service-Entrance Conductor or Equivalent Area for Parallel Conductors		Size of Grounding Electrode Conductor	
Copper	Aluminum or Copper-Clad Aluminum	Copper	*Aluminum or Copper-Clad Aluminum
2 or smaller	0 or smaller	8	6
1 or 0	2/0 or 3/0	6	4
2/0 or 3/0	4/0 or 250 MCM	4	2
Over 3/0 thru 350 MCM	Over 250 MCM thru 500 MCM	2	0
Over 350 MCM thru 600 MCM	Over 500 MCM thru 900 MCM	0	3/0
Over 600 MCM thru 1100 MCM	Over 900 MCM thru 1750 MCM	2/0	4/0
Over 1100 MCM	Over 1750 MCM	3/0	250 MCM

Where there are no service-entrance conductors, the grounding electrode conductor size shall be determined by the equivalent size of the largest service-entrance conductor required for the load to be served.

* See installation restrictions in Section 250-92(a).

See Section 250-23(b).

REMOTELY LOCATED PANELS FROM A WIRE GUTTER



1. The neutral in Panel A and Panel B are grounded to the panel which is grounded by a ground wire to the service entrance grounding point in the wire gutter.
2. Subpanels C and D are remotely located and require over current protection at the service entrance for the conductors from the wire gutter to the panels. The individually mounted circuit breakers also enable someone to shut off all the power at the service entrance. All the above must be located in the same room with a maximum 15 feet between the wire gutter and the panels or circuit breakers.
3. All power must be shut off with a maximum of 6 hand movements. The main breakers in Panels A and B, plus the individually mounted breaker for panels C and D, can be shut off with 4 hand movements.
4. Panels C and D require ungrounded neutrals, and separate grounding bars. A separate grounding wire must be run from the wire gutter to each subpanel, and connected to the ground bar. The ground wires of the branch circuits of Panels C and D must be attached to a separate ground bar in each panel.