

Electrical Wiring Guide

In order to wire your own home, you must comply with the requirements of the 2017 edition of the National Electrical Code (NEC). NEC code articles are indicated by brackets ([]), and Jefferson County Supplements are in brackets ({ }). The NEC is not intended as a design specification nor an instruction manual for untrained persons, its purpose is the practical safeguarding of persons and property from hazards arising from the use of electricity and addresses fundamental safety principles. This guideline is written to help the lay person comply with the NEC requirements for single family dwelling units, ***and is in no way inclusive of all requirements for every installation. CAUTION!!*** Some wiring materials sold locally may not meet the requirements of the NEC.

Along with meeting NEC requirements, the permit and inspection process defined in Colorado Revised Statutes must be followed. An electrical permit is required for the construction of a new home or any new electrical work being performed in the home/dwelling unit. The electrical permit can be inclusive of the construction meter, wiring of the dwelling unit, the temporary building service and any other electrical installations associated with the dwelling. The electrical inspector will inspect all aspects of electrical installations (ie: construction meter, underground, rough, service (temporary building service), final, etc.). If for some reason the job does not meet the requirements of the NEC and an extra visit is necessary, a re-inspection fee may be required before the inspector will return. Items required to obtain an inspection and to minimize delays:

Building address shall be posted and visible from the street or area of access.

Building shall be unlocked and accessible.

Building "PERMIT" shall be posted on the construction site.

All work shall be complete and ready for inspection, including any and all corrections from previous inspections.

County approved plans shall be on site and all work shall match county approved plans.

Access into occupied/furnished units require an adult age 18 or older.

INCLUDED IN THIS DOCUMENT:

1. Service
2. Branch Circuit Wiring
3. Required Branch Circuits
4. Required Receptacle Outlets
5. Required G.F.C.I. Protected Receptacle Outlets
6. Required Lighting Outlets
7. Conductor Fill
8. Equipment Grounding and Conductor Make-up
9. Calculating the Minimum General Lighting/Outlet requirements.
10. Electric Heat Circuitry
11. Construction meter
12. Rough-in Inspection
13. Temporary Building Service
14. Final Inspection

1. SERVICE:

The service equipment must be large enough to supply the connected load which is calculated using Article 220 of the NEC. The most common sizes of residential service equipment are 100, (minimum size for a dwelling unit) [230.79] 125, 150, and 200 amperes. The minimum size wire for service entrance conductors are listed below in TABLE 1.A:

Three Wire, Single Phase Dwelling Services:

Conductor Types and Sizes:

RHW - THWN - THHN - XHHW – USE (83% of service rating)[310.15(B)(7)]

TABLE 1.A: **NOTE: TABLE 1.A below has taken this formula into consideration.**

Copper	Aluminum & Copper-Clad AL	Service Rating in Amps
AWG	AWG	
4	2	100
2	1/0	125
1	2/0	150
2/0	4/0	200

NOTES: (1)-The serving utilities (ie: Xcel, United Power, and IREA) will not provide meter housings for residential use. Meter housings used must be on the serving utility's approval list (XCEL requires a 200-amp rated, lever by-pass meter socket).

(2)-If the service point is remote from the dwelling with a disconnect (IREA), 4 conductors are required to the dwelling. [250.32(B)(1)].

(3)-If a ground rod is used as a grounding electrode, it shall be supplemented with an additional ground rod at least 6' apart. [250.53(A)(2)&(3)].

Anti-oxidant compound required on all aluminum conductors.[mfg]

Underground conductors must be suitable for direct burial. [310.10(F)]

Underground installations shall have a minimum depth from the top of the wiring method to the finished grade of 24" for direct burial cable/conductors and 18" for conduit/raceways. [Table 300.5]

Outdoor conductors in conduit shall be suitable for wet locations. (Type THWN) [300.5(B),310.10(C)]

The service equipment shall be grounded in accordance with Article 250 of the NEC, which in general states that the neutral shall be bonded to the service enclosure and the grounding electrode system defined in 250-28, 250-50, 250-52, 250-53. **For new construction: A concrete-encased electrode (UFER) is required and needs to be inspected prior to placement of concrete.** [250.52(A)(3)] **The electrode shall be at an accessible location in the garage.** {JCS}

The main service equipment panel shall be mounted either outside or inside the dwelling as near as possible to the point of entrance of the service conductors to the building. [230.70(A)(1)] All service equipment and electrical panels shall have a

clear area 30" wide and 36" deep in front. [110.26(A)] This clear area must extend from floor to ceiling with no intrusions from other obstructions (cabinets, counters, appliances, etc.), Electrical panels are not allowed in clothes closets, bathrooms or over stairs. [240.24(A),(D),(E), and (F)] Service panel or sub panels shall not be installed in walls separating garages from dwelling units (with some exceptions, consult your building inspector).

At the service equipment, the neutral grounding electrode conductors (ie: water pipe, ufer, ground rods, etc.), and equipment grounding conductors are bonded (connected) together. [250.24(A)] **NOTE:** In sub-panels (electrical panels remote from the main service panel and meter) the neutral is isolated (separated) from ground/grounding conductors. [250.24(A)(5)]

All conductors shall be torqued to manufacturers specifications. [110.14(D)]

2. BRANCH CIRCUIT WIRING:

Type NMB cable (a.k.a. romex) is the most widely used wiring method used in residential dwellings. NM cable must have 90-degree conductor insulation rating which is designated on the cable sheath by a "B". [334.80] Type N.M.-B, #12, and #14 shall be used for lighting and receptacle circuits, while #10/2 with ground is commonly used for electric water heaters, #10/3 with ground for electrical dryers and ovens, and #8/3(cu) with ground and #6/3(alum) with ground for ranges and cooktops.

Type "SER" or an approved four-wire cable is required for electrical ranges, cooktops, wall ovens and clothes dryers. [250.134, 250.140]

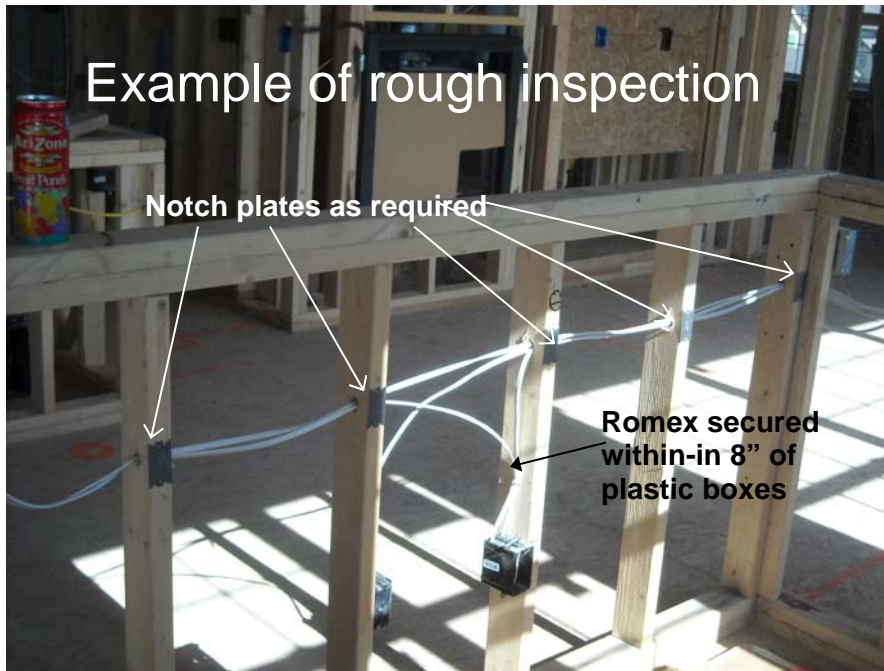
These cables must be protected by overcurrent devices (circuit breakers) which do not exceed their rated ampacity. The rated ampacities for cable types are listed below in table 2.A: [table 310.15(B)(16)]

Table 2.A: **NOTE: NM CABLE IS ALSO KNOWN AS ROMEX.**

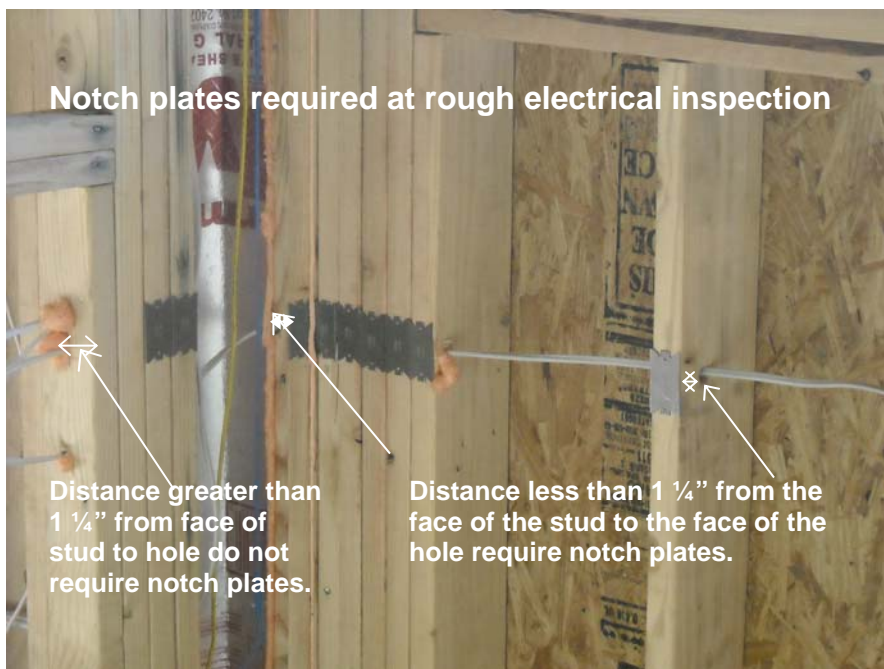
Copper NM Cable Type	S.E. and S.E.R. Aluminum Cable
15 amperes for #14	40 amperes for #8
20 amperes for #12	50 amperes for #6
30 amperes for #10	
50 amperes for #8	
65 amperes for #6	

It is important to note that if you begin a circuit with #12, you must use this same wire size throughout. You cannot mix different wire sizes on the same branch circuit.

Type NM (romex) cable shall be stapled within 12" of metal boxes, [334.30] (utilizing approved connectors), within 8" of plastic boxes [314.17(C) exception] and every 4-1/2 feet thereafter. Proper connectors shall be used where NM (romex) cable enters metal cabinets or boxes. [312.5(C)]



NM (romex)cable must be installed 1-1/4" back from the nearest edge of the hole in wood members or protected by 1/16" steel sleeve or plate. [300.4(A)(1)]



Ceiling mounted paddle fans must have a listed fan box. [314.27(C)]

Ceiling mounted boxes containing spare, switched, hot conductors shall be boxes rated for ceiling mounted paddle fans. [314.27(C)]

3. REQUIRED BRANCH CIRCUITS:

(a) Small Appliance Branch Circuits - The NEC requires a minimum of two 20-amp branch circuits to feed receptacle outlets for small appliance loads, [210.11(C)(1)] including refrigeration equipment in the kitchen, pantry, breakfast room, and dining room. These circuits, whether two or more are used, may have only four outlets each {E3901.3} and shall not supply/serve anything other than receptacles in these areas. Lighting outlets are not permitted on these circuits.

(b) Laundry Branch Circuit - One 20-amp branch circuit must be provided for the laundry. This circuit is limited to receptacles within the laundry room. No lighting outlets are permitted on this circuit. [210.11(C)(2)]

(c) A furnace requires a dedicated circuit. [422.12]

(d) Dedicated circuits may be required by manufacturer and are recommended for disposals, dishwashers, microwaves, freezers, window unit A/C, etc.

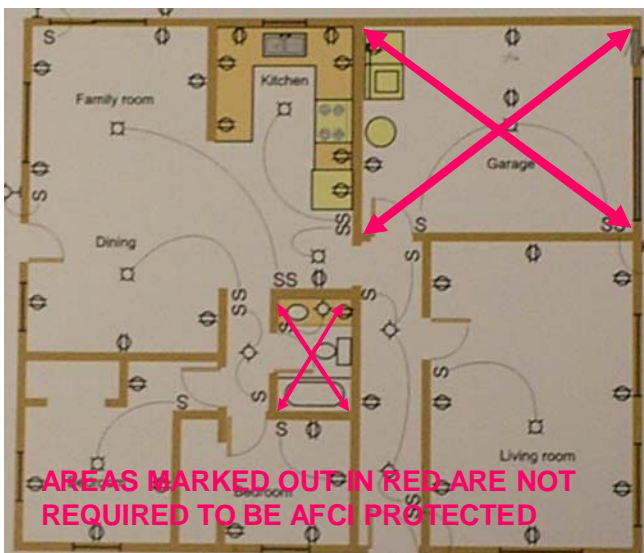
(e) Bathrooms require a dedicated 20-amp branch circuit. Two (2) options are available; #1. All receptacles in all bathrooms in the dwelling can be on the same dedicated circuit but serve no other outlets or equipment. #2. All outlets and equipment (ie: receptacles, light, fan etc.) in a single bathroom can be on the same dedicated circuit and not serve any other outlets. [210.11(C)(3)].

(f) a dedicated branch circuit is required for hydro massage bathtubs. (680.71)

(g) a dedicated 20-amp branch circuit is required for garage receptacles (this circuit shall not leave the garage and supply other outlets except it shall be permitted to supply readily accessible outdoor receptacle outlets), there shall be at least 1 (one) receptacle for each vehicle bay and not more than 5-1/2' above the floor. [210.11(C)(4)]

Note: All branch circuits that supply 125 volt, 15- and 20- ampere outlets (inclusive of light fixtures, receptacles, and smoke detectors) installed in all areas of dwelling units (EXEMPT AREAS: bathrooms, garages, unfinished basement areas, and outside outlets) shall be protected by a combination

arc-fault circuit interrupter listed to provide protection of the entire branch circuit [210.12(A)]. Any existing (old) receptacle outlets (not in the exempt areas) that are extended or modified shall be afci protected [210.12(B)]. All replaced receptacles (not exempt) shall be AFCI protected. [406.4]



AREAS MARKED OUT IN RED ARE NOT REQUIRED TO BE AFCI PROTECTED

4. REQUIRED RECEPTACLE OUTLETS:

NOTE: ALL RECEPTACLES IN DWELLING UNITS (including detached garages and accessory buildings) SHALL BE TAMPER-RESISTANT RECEPTACLES (this includes existing receptacles that are replaced)

(Exception #1: receptacles located over 5’6” above the floor; **Exception #2:** receptacles for cord and plug connected appliances [that are not easily moved from one place to another] located in dedicated space(s)) (ie: ref, freezers, etc)[406.12]

(a) Receptacles, in bathrooms, must be on a 20-amp dedicated circuit and have no other outlets.[210.11(C)(3)] At least one (1) receptacle outlet shall be installed adjacent to and within 3’ of each basin (sink).[210.52(D)]

(b) At least one receptacle in every attached garage, detached garage and accessory building with electric power. (a receptacle outlet is required in garages for each vehicle bay) and not over 5-1/2’ above the floor.[210.52(G)(1)]

(c) At least one receptacle installed outdoors (required in the front and back of the house) not more than 6’-6” above grade. Any porch, deck, or balcony attached to the dwelling and accessible from the inside of the dwelling requires a receptacle outlet. [210.52(E)(1)&(3)].

These receptacles shall be tamper resistant and of the weather-resistant type and include weather proof in-use covers and be of extra duty in exposed locations. [406.9(B)]

(d) At least one receptacle must be installed in each unfinished basement area, and be gfci protected[210.52(G)(3)]

(e) In every kitchen, family room, dining room, living room, parlor, library, den, sunroom, bedroom, recreation room, or similar rooms of dwelling units, receptacle outlets shall be installed so that no point along the floor line in any wall space is more than six feet, measured horizontally (unbroken at the floor line), from a receptacle outlet in that space including any wall space two feet or more in width and the space occupied by fixed panels in exterior walls excluding sliding panels. The space afforded by fixed room dividers (with counter tops), such as free-standing bar-type counters or railings shall be included in the six-foot measurement.[210.52(A)] Receptacle outlets may not be installed over electric baseboard heaters.[424.9 FPN]



KITCHENS: A minimum of two (2) small appliance branch circuits are required. Wall counter space; a receptacle outlet shall be installed at each wall counter space 12 inches or wider. Receptacle outlets shall be installed so that no point along the wall line is more than 24 inches measured horizontally from a receptacle outlet in that space. (See item 3-(a) and 5-(f)). A maximum of four (4) receptacle outlets are permitted on a small-appliance branch circuit {E3109.3}.



At least one receptacle outlet is required at kitchen islands and peninsulas. [210.52(C)(2),(3),&(4)] Receptacles installed in appliance garages (cabinets with doors installed on counter tops to enclose countertop appliances [ie. Toasters, coffee makers, etc.]) **do not count as the "required receptacles"**. [210.52(C)(5)]



Hallways 10' or longer shall have at least one (1) receptacle outlet [210.52(H)]. (hallways more than 4' in width shall comply with article 210.52(A)).

Foyers containing 60 square feet or more in area shall have a receptacle outlet in each wall 3' in width or more unbroken at the floor line. [210.52(I)]

5. REQUIRED G.F.C.I. PROTECTED RECEPTACLE AND LIGHTING OUTLETS:

A Ground Fault Circuit Interrupter: [210.8(A)] must protect all receptacles listed below

Ground fault receptacles shall be readily accessible. (not behind furniture, appliances, ETC.)

- a) Bathroom receptacles;
- (b) All outdoor receptacles (also weather resistant);
- (c) Garage and accessory buildings with work areas, storage areas and similar use areas;

- (d) All outlets (receptacles and lights) in unfinished basement areas;
- (e) All receptacles within 6' of sinks (ie. Kitchen, laundry, utility, mop, and wet bar sinks) **(including dishwasher, refrigerator, compactor, etc.); (the 6' measurement is the shortest path a flexible cord would take) (FPN)**
- (f) All kitchen outlets that serve counter tops, including islands and peninsulas; [210.8(A)(6)]
- (g) laundry areas (including washer circuit);
- (h) bathtub and shower (receptacles within 6' of outside edge)
- (i) crawlspace lighting outlets. [210.8(E)]

6. REQUIRED LIGHTING OUTLETS:[210.70]

Every switch location must contain a neutral conductor installed with the phase/hot conductor(s), switch leg(s) (conductors from the switch location to the fixture or device) and an equipment grounding conductor.

- (a) **Wall switch-controlled:** habitable rooms, bathrooms, hallways, garages, detached garages with electric power, and stairways (switched at every floor level, with 6 or more risers).
- (b) **Switch-controlled:** attics, underfloor spaces, utility rooms and basements. Switch to be located at the usual point of entry to these spaces.

7. CONDUCTOR FILL:[314.16]

Outlet and junction boxes shall be of sufficient size to provide free space for all conductors and devices enclosed in the box. All outlet boxes have a specific volume measured in cubic inches. This volume must be equal to or greater than the cubic inches required for the number of conductors and devices in the box. (See Table 314.16(B) NEC).

(Excerpt from table 314.16(B) NEC)

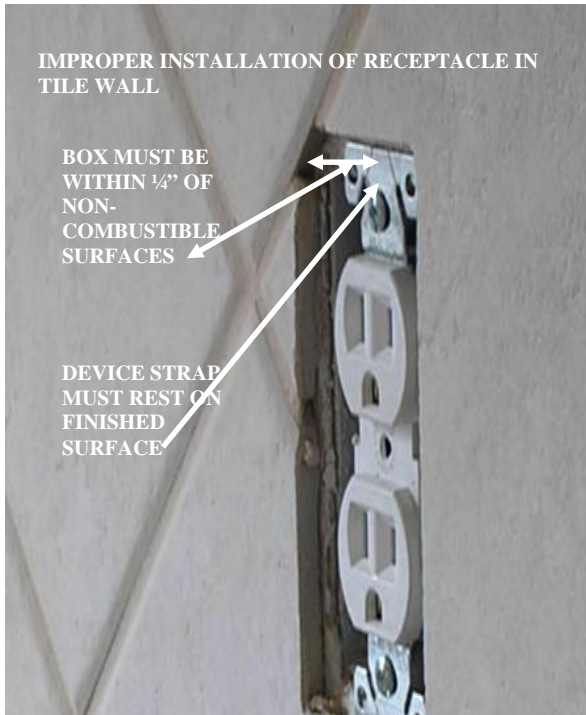
Conductor/Device Box Fill	Cubic inches required in the box (per conductor)
Each #14	2.0
Each #12	2.25
Each #10	2.50
Each device counts as	2 wire sizes
Note: Count only as one conductor (the largest) ground/bond wire (for all ground wires in that box)	

Example:

2 - #12-NM-B cables (each cable containing 2-insulated conductors and 1-bare [ground] conductor), and one duplex receptacle.

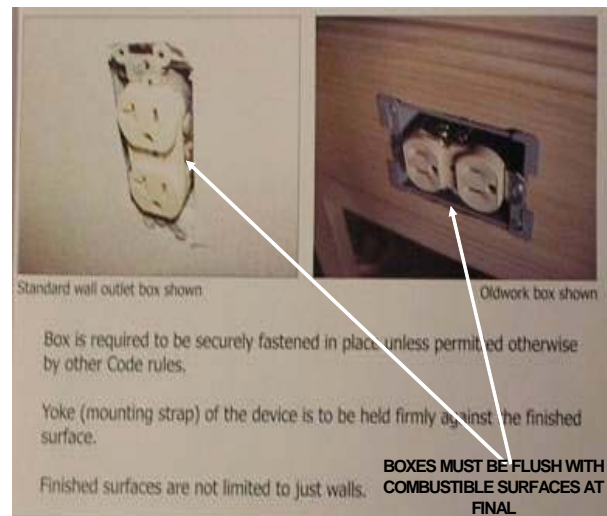
4 X 2.25 = 9.0 cu. in. (insulated conductors)
 1 X 2.25 = 2.25 cu. in. (ground conductor)
 1 X 4.50 = 4.5 cu. in. (2 wire sizes for the device)
 NOTE: 15.75 cu. in. minimum box size is required.

Receptacles and switches mounted in boxes shall be installed such that the mounting yoke or strap is held rigidly against the finished surface. [406.5]. Screws for mounting devices shall be listed for the device (sheetrock/deck style screws are not permitted. [404.10(B), 406.5])



Boxes must be within 1/4" of **NON-COMBUSTIBLE SURFACES** (drywall, tile, etc.) and flush with **COMBUSTIBLE SURFACES** (wood, wallpaper, etc.). [314.20]

Gaps or open spaces around boxes shall not exceed 1/8" at the edge of the box. [314.21]



8. EQUIPMENT GROUNDING AND CONDUCTOR MAKE-UP:

All equipment grounding/bonding conductors shall be connected together with solder-less pressure connectors, such as wire nuts or crimp sleeves, leaving sufficient extra conductor for attachment to the metal box and/or device. When crimp type connectors are used, they shall be installed per manufacturer's installation instructions and crimped using the tool required by the manufacturer. [110.3(B)]



Please note: that all metal junction and outlet boxes shall be grounded/bonded by attaching the equipment grounding/bonding conductor out of the NM cable to the metal box using an approved

screw or grounding/bonding clip (sheet metal screws are not permitted for grounding/bonding). [250.8] When circuit conductors are made-up, **six inches of wire (from the face of the box)** shall be left for use in make-up and for the attachment of devices.

9. CALCULATING THE MINIMUM GENERAL LIGHTING/OUTLET REQUIREMENTS:

Requirements: Reference Table 220-12. 2017 N.E.C

One 120 volt 15-amp circuit per 500 sq.ft.
 Each 15-amp circuit @ 80% = 12 amps.

RULE OF THUMB:

At 1.5 amps per light/outlet. Using a 15-amp circuit, a maximum of 8 outlets are allowed

If using a 20-amp circuit, a maximum of 10 outlets are allowed

10. ELECTRIC HEAT CIRCUITRY:

Electric heat may be installed on 15, 20, or 30-amp branch circuits. Listed below is the maximum wattage that may be installed on each size branch circuit, all circuits are figured at 240V.[424.3(A)]

AMPS	Maximum Wattage
15	2,880
20	3,840
30	5,760

For example, if you are installing baseboard heaters which are rated 250 watts per linear foot, you could install 15 feet on a 20 amp 240-volt circuit. (250W X 15 = 3,750 watts).

11. CONSTRUCTION METER:

The construction meter shall be constructed as a complete service including all necessary grounding/bonding, proper wire sizes, etc.. There shall be at least one 120 volt, 15 or 20 amp GFCI protected receptacle (any other receptacles, including 240 volt, [any ampere] receptacles shall also be GFCI protected). The receptacles shall be of the weather-resistant type and in-use **(extra duty type)** covers shall also be installed.[406.9(B)(1)] The construction meter must be "stand-alone" and not attached to the dwelling unit. **NOTE:** The construction meter cannot be mounted on Xcel's power poles. A ground rod is required at all construction meters supplied by Xcel (Xcel also requires a by-pass style meter socket), but is not required by United Power and IREA. **CHECK WITH YOUR LOCAL SERVICING UTILITY FOR SPECIFIC REQUIREMENTS.**

12. ROUGH-IN INSPECTION:

At the time you call for your rough-in inspection you should have all wire pulled, stapled properly, and all splices (equipment grounding conductors, etc.) made up and ready to accept devices and fixtures. **Do not** install any devices or fixtures or cover any wiring with insulation or wall covering, (i.e., drywall or paneling) until inspected and approved.



13. TEMPORARY BUILDING SERVICE:

Temporary building service meters shall be permitted and inspected, are only valid for sixty (60) days from date of issue and are for construction purposes only. To obtain a temporary building service meter, the rough electrical inspections shall have been made and approved, the service shall be 100% complete and a G.F.C.I. receptacle shall be installed on the laundry branch circuit only. Additional "**allowable options**" (allowed but not required) for temporary building service are:

1. Heat Source (i.e.: furnace, boiler, electric heat, etc.) **NOTE:** all appropriate heating equipment shall be installed per manufacturer's installation requirements. Appropriate venting for heating appliances shall be installed and any unused openings capped off properly. Thermostats shall be installed and operable.
2. A 30 amp, 240 volt G.F.C.I. protected receptacle installed at the dryer outlet location.
3. Well pump (to provide water).

If "**allowable options**" are used, they must have been installed and completed prior to the temporary building service inspection.

The only breakers to be terminated in the panel are the breakers for the mandatory G.F.C.I. (120 volt) receptacle and "**allowable options**". **If this meter is used for any purpose other than construction or if the building is occupied the Inspector will have the meter removed without prior notice.**

14. FINAL INSPECTION:



The electrical installation shall be complete at the time of request. The “temporary building service”/permanent power meter is set, service equipment complete and labeled properly. All wiring shall be free from short circuits, ground faults, and open circuits. All light fixtures are required to be complete (ie. Lenses, trims, etc. installed) and grounded along with light switches that are within five feet of a grounded object. All 120-volt circuits shall have power.

Questions?

If you have questions, please contact your electrical inspector at 303-271-8260 between 7:30-8:30 a.m. or 3:30-4:00 p.m. Monday through Friday.