

Electrical Wiring Guide

To wire your own home, you must comply with the requirements of the most recent edition of the National Electric Code (NEC). NEC articles are indicated by brackets ([]), and Jefferson County Supplements are in ({ }). 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 the 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 make inspections on all aspects of the electrical installations, (i.e. construction meter, underground, rough electric, service (temporary building service), final electric, and others). 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.

Note: Inspector will not enter a building w/valuables, without an adult being present (18 years old minimum).

INCLUDED IN THIS DOCUMENT:

1. Service
2. Branch Circuit Wiring
3. Required Branch Circuits
4. Required Receptacle Outlets
5. Required GFCI Protected Receptacles
6. Required Lighting Outlets
7. Conductor Fill
8. Equipment Grounding 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

SERVICE:

Surge protection is required for services. The service equipment must be large enough to supply the connected load. You can find how to calculate the load in Article 220 of the NEC. The most common sizes of residential service equipment is 100 amps (minimum size for a dwelling unit), [230.79], 125 amps, 150 amps, and 200 amps. The minimum size wire for service entrance conductors are listed below.

Three Wire, Single Phase, Dwelling Services:

Conductor Types and Sizes:

RHW, THWN, THHN, XHHW, USE, (83% of service rating) [310.12]

| Conductor | | |
|------------------------------------|--------|----------------------------------|
| (AWG or kcmil) | | |
| Service or Feeder Rating (Amperes) | Copper | Aluminum or Copper-Clad Aluminum |
| 100 | 4 | 2 |
| 125 | 2 | 1/0 |
| 150 | 1 | 2/0 |
| 200 | 2/0 | 4/0 |

NOTE: The serving utilities (i.e. Xcel, IREA, and United Power) will not provide meter housings for residential use. Meter housings used must comply with the local energy supplier.

(1) Xcel Energy requires a 200-ampere lever bypass type, please check with your energy supplier for their requirements.

(2) If you are having to install a meter housing remote from the structure (as on a pole most likely with IREA and United Power) a disconnect will be required, and four (4) conductors shall be ran to the structure with an additional disconnect at the nearest point of entry into the building. [250.32(B)(1)].

(3) If a ground rod is used at the pole for your Grounding Electrode Conductor connection, a supplemental rod is required to be installed a minimum of 6’ distance from the first rod. [250.53(A)(2) & (3)].

Antioxidant compound is required on all aluminum conductors. [mfg]

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

The service equipment shall be grounded in accordance with Article 250 of the NEC, which in general states that the grounded (neutral) conductor shall be bonded to the service entrance enclosure and the Grounding Electrode system defined in 250.28, 250.50, 250.52, 250.53. **For new construction: A concrete encased electrode (CEGE or UFER) is required and needs to be inspected prior to placement of the concrete.** [250.52(A)(3)] **The electrode shall be at an accessible location in the garage.** {JCBS}

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 or the width the equipment whichever is

greater and 36” deep in front of the service. The area in front of the service equipment must allow the opening of doors to a minimum of 90 degrees. [110.26(A)] This clear area must extend from floor to ceiling with no intrusions from other disciplines or obstructions. Electrical panels are not allowed in clothes closets, bathrooms, or over stairs. [240.24(A), (D), (E), and (F)] Service panels or sub panels shall not be installed in walls separating the garage from the dwelling unit (with some exceptions, consult your building inspector).

At the service equipment the grounded (neutral), grounding electrode conductors (i.e. 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 grounded (neutral) is isolated (separated) from ground and grounding conductors. [250.24(A)(5)]

BRANCH CIRCUIT WIRING:

Type NMB cable (a.k.a. Romex) is the most widely used wiring method in residential dwellings. NM cable must have 90 degree C conductor insulation rating which is designated on the cable sheath by a “B” [334.80]. #14-2 and #12-2 AWG NMB cable is used for lighting and receptacle circuits, while #10-2 AWG NMB is used for electric water heaters. #10-3 AWG with ground is used for dryers and wall mounted ovens. #8-3 AWG CU with ground and #6-3 AWG CU with ground is used for ranges and cooktop units.

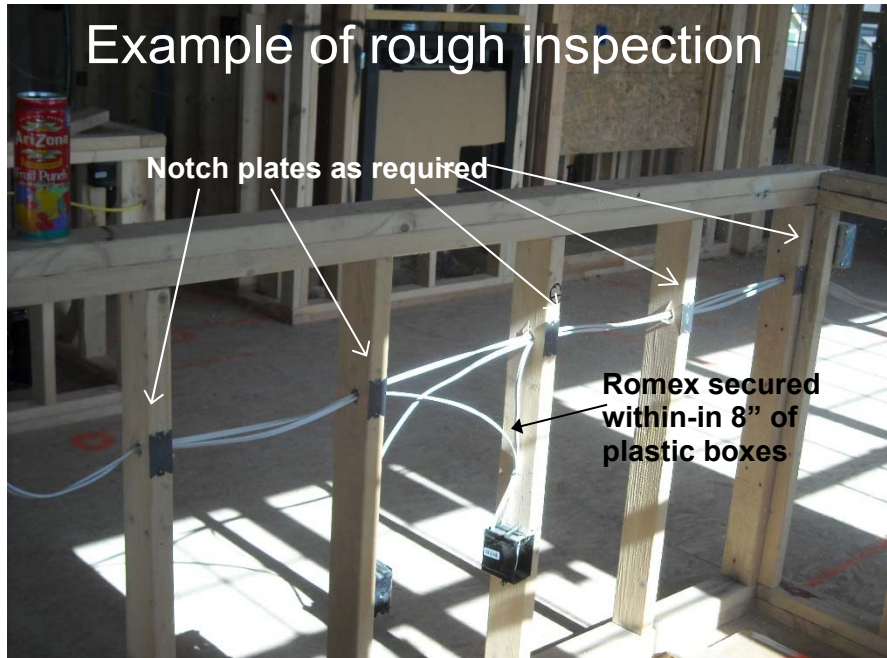
Type SER cable or an approved four-wire cable is required for electrical ranges, cooktops, wall ovens and clothes dryers. [250.134, 250.140].

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, based on [240.4(D)]:

| Copper NM Cable Type | SE and SER Aluminum Cable |
|----------------------|---------------------------|
| #14 AWG 15amperes | #8 AWG 40amperes |
| #12 AWG 20amperes | #6 AWG 50amperes |
| #10 AWG 30amperes | |
| #8 AWG 50amperes | |
| #6 AWG 65amperes | |

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

Type NM (romex) cable shall be stapled within 12” of metal boxes utilizing approved connectors [334.30], and every 4-1/2 feet thereafter. Proper connectors shall be used.



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)]

REQUIRED BRANCH CIRCUITS:

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 recommended to have only four receptacle openings per circuit, {E3901.3}, and shall not supply/serve any other receptacle outlets outside the areas listed above. Lighting outlets are not permitted on these circuits.

NOTE: 125volt receptacles serving countertop surfaces require AFCI/GFCI protection, other receptacles within 6' of sinks require AFCI/GFCI protection. 250volt receptacles serving countertop surfaces require GFCI protection. [210.8(A), 210.8(A)(6), 210.8(A)(7)]

Laundry Branch Circuit – At least one 20amp branch circuit must be provided for the laundry area. This circuit is limited to receptacles within the laundry area only. Lighting outlets are not permitted on this circuit, [210.11(C)(2)].

NOTE: 125volt receptacles require AFCI/GFCI protection. 250volt receptacles require GFCI protection. [210.8(A)]

Furnace - A furnace requires a dedicated circuit. [422.12].

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

NOTE: Dishwasher receptacles require AFCI/GFCI protection.

Bathroom - Receptacles require a dedicated 20amp branch circuit. Two (2) options are available. #1 – All receptacles in all bathrooms in the dwelling can be on the same dedicated branch circuit but serve no other receptacle outlets or equipment.

#2 – All outlets and equipment (i.e. receptacles, lights, fans, etc.) in a single bathroom can be on the same dedicated branch circuit but cannot serve any other outlets. [210.11(C)(3)].

Hydro-Massage Tub - A dedicated branch circuit is required for Hydro-massage bathtubs. [680.71].

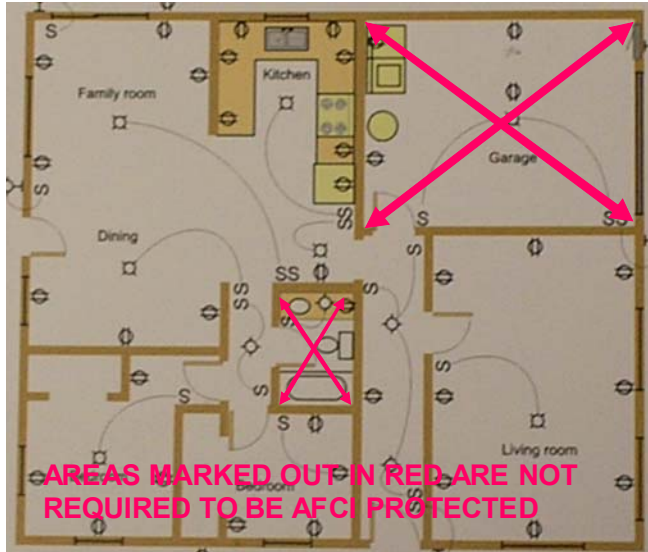
NOTE: AFCI/GFCI protection is required.

Garage – A dedicated 20amp branch circuit is required for garage receptacle outlets. There must be one receptacle outlet for each vehicle bay space, and not more than 5-1/2' above the floor level. The circuit may be extended to serve outdoor receptacle outlets that are readily accessible. [210.11(C)(4)].

NOTE: GFCI protection is required.

NOTE: ALL unfinished or finished basement receptacles shall be GFCI protected.

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(D)]. All replaced receptacles (not exempt) shall be AFCI protected and Tamper resistant. [406.4]



REQUIRED RECEPTACLE OUTLETS:

Note: ALL RECEPTACLES IN DWELLING UNITS (including detached garages and accessory buildings) SHALL BE TAMPER RESISTANT RECEPTACLES.

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) (i.e. refrigerators, freezers, etc.).

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

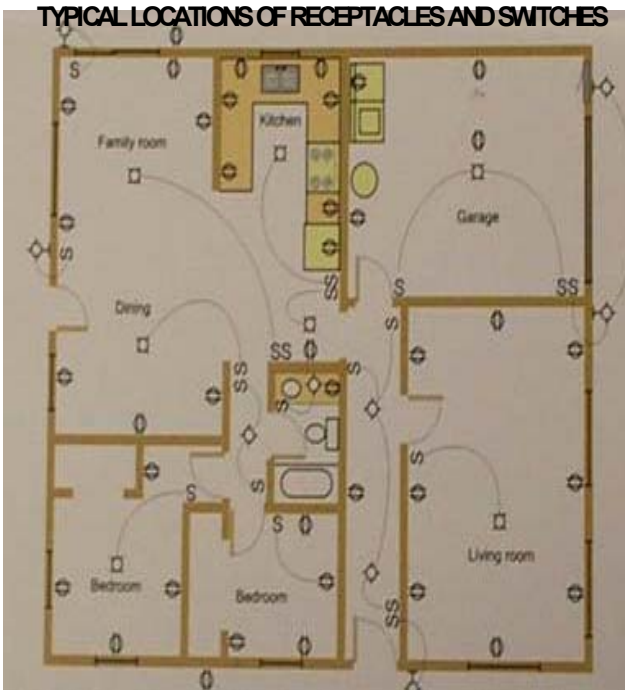
Garage – At least one (1) receptacle in every attached garage, detached garage, and accessory building with electric power. A receptacle is required in each vehicle bay space. [210.52(G)(1)]

Outdoors – At least one receptacle outlet is required in the front, 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 weather resistant type (WR). [406.9(B)].

Unfinished Basement Area – At least one receptacle must be installed in each unfinished basement area and be GFCI protected. [210.52(G)(3)].

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 (6) feet measured horizontally (unbroken at the floor line), from a receptacle in that space. Any wall space greater than two (2) feet requires a receptacle outlet. The space occupied by fixed panels shall be included in the measurements. Sliding panels are excluded. The space afforded by fixed room dividers, such as free-standing bar-type counters or railings shall be included in the six (6) 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" or wider. Receptacle outlets shall be so installed so that no point along the wall line is more than 24" measured horizontally along the wall line to a receptacle outlet. It is recommended that no more than 4 receptacles be installed on a small appliance branch circuit.



Kitchen Islands and Peninsulas – At least one receptacle outlet is required at kitchen islands and peninsulas. [210.52(C)(2)(a) and (C)(2)(b)].

Islands – At least one receptacle outlet shall be provided for the first 9 sq. ft., or fraction thereof, of the countertop or work surface. A receptacle outlet shall be provided for every additional 18 sq. ft., or fraction thereof of the countertop or work surface.

Peninsulas – At least one receptacle outlet shall be located within 2 ft. of the outer end of a peninsular countertop or work surface.

Receptacle outlets must meet the following requirements:



On or above the countertop or work surface:

On or above but not more than 20” above the countertop or work surface. [210.52(C)(3)(1)]

In countertop or work surface: Receptacle assemblies, must be listed for the purpose. [210.52(C)(3)(2)]

Below countertop or work surface: Cannot be more than 12” below the countertop or work surface. Receptacles shall not be installed where the countertop or work surface extends more than 6” beyond its support base. [210.52(C)(3)(3)]

Hallways 10’ or longer shall have at least one (1) receptacle outlet. [210.52(H)]

Foyers (not part of a hallway) containing 60 sq. ft. or more in area shall have a receptacle outlet in each wall 3’ in width or more unbroken along the floor line. [210.52(I)]

REQUIRED GFCI PROTECTED RECEPTACLE OUTLETS:

A ground circuit interrupter [210.8] must protect all receptacles listed below.

Ground fault receptacles shall be readily accessible, (not behind furniture, appliances, under/behind cabinet doors, etc.).

- a. All bathroom receptacles
- b. All outdoor receptacles and outlets (i.e. A/C disconnect)
- c. Attached garage and detached garage & accessory buildings with electric power
- d. All receptacles in basements
- e. All receptacles within 6’ of sinks (kitchen, laundry, utility, mop, wet bar, etc.)
- f. All kitchen receptacles serving the countertop (125volt and 250volt)
- g. All receptacles in laundry areas (125volt and 250volt)
- h. All receptacles within 6’ of shower pans and bathtubs
- i. Dishwasher receptacles

REQUIRED LIGHTING OUTLETS [210.70]

Lighting controlled by dimmers in multiple locations shall have the full range of dimming at all locations [210.70(A)(2)(4)]

Wall switch-controlled – At least one lighting outlet controlled by a wall switch must be in habitable rooms, bathrooms, hallways, garages, detached garages with electric power, stairways (switched at every floor level with 6 or more risers), outdoors where it is accessible from inside the dwelling (decks, patios, porches, service doors from garages, etc.).

Switch-controlled – Attics, underfloor spaces, utility rooms, basements (switch to be located at the usual point of entry to these spaces).

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 AWG | 2.0 |
| Each #12 AWG | 2.25 |
| Each #10 AWG | 2.50 |
| Each device counts as | 2 times the largest conductor in the box |

Note: Count only as one conductor (the largest) ground/bond wire for all ground wires in the box.

Example:

2 - #12 NMB cables (each cable contains 2 – insulated conductors and 1 bare grounding conductor and 1 duplex receptacle)

4 x 2.25 = 9.0 cu. in. (insulated conductors)

1 x 2.25 = 2.25 cu. in. (grounding conductor)

1 x 4.50 = 4.50 cu. in. (device equals two conductors)

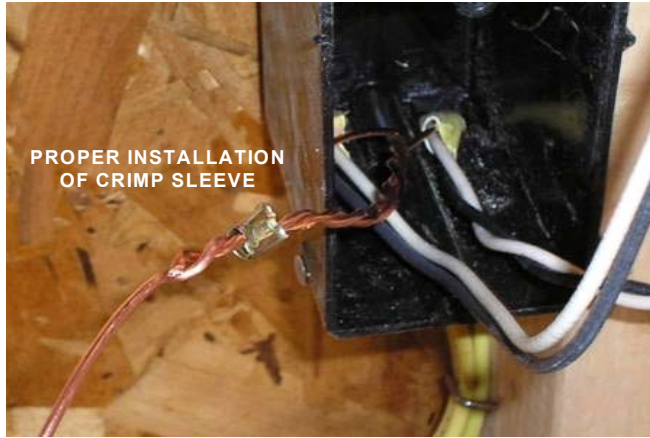
Total 15.75 cu. in. (minimum size box required)

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(A)]. Screws for mounting devices shall be listed for the device (sheetrock/deck style screws are not permitted. [404.10(B), 406.5]

Boxes shall be mounted so that the front of the box is planned to be not greater than 1/4" the finished face of the wall. If a combustible surface is installed on the wall the box must be within 1/8" [314.20]

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





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)].

Note: ALL conductors will be a minimum of 6” in length when they exit the sheathing and the sheathing shall be a minimum of ¼” inside the box. When a metal box is used, the grounding conductor inside the cable will need to be longer to afford to ground/bond the box. The box shall be bonded by an approved screw or clip.

The crimp of the ground wire is correct in the picture on the left, however one of the grounding conductors is too short to meet the NEC requirements.

CALCULATING THE MINIMUM GENERAL LIGHTING/OUTLET REQUIREMENTS

Reference Tables in Article 220 of the latest edition of the NEC.

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

At 1.5 amps per light/outlet = maximum of 8 outlets are allowed
 If using a 20amp circuit, a maximum of 10 outlets are allowed
 Note: These are a rule of thumb.

ELECTRIC HEAT CIRCUITRY

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

| AMPS | Maximum Volt/amps |
|------|-------------------|
| 15 | 2,880 |
| 20 | 3,840 |
| 30 | 5,760 |

For example, if you are installing baseboard heaters which are rated 250V/A per linear foot, you could install 15 feet on a 20amp 240volt circuit. (250V/A x 15 = 3750V/A).

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 120volt, 15 or 20amp GFCI protected receptacle (any other receptacles, including 240volt, [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 and be of the extra duty type. [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 served by Xcel Energy, (Xcel also requires a lever bypass style meter housing) but is not required by United Power or IREA. **CHECK WITH YOUR LOCAL SERVICING UTILITY FOR SPECIFIC REQUIREMENTS.**

ROUGH-IN INSPECTION:

At the time you call for your rough-in inspection, you should have all wire pulled, stapled properly, and all splices 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, paneling) until inspected and approved.



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 GFCI receptacle on site, NOT IN the refrigerator space.

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 30amp, 240volt GFCI protected receptacle installed at the dryer receptacle outlet location.
3. Well pump (to provide water).

These options must be installed prior to building service inspection or recall an inspection for these options when installed.

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

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 (i.e. Lensed, glass, trims, and lamps installed) and grounded along with light switches that are within five feet of a grounded object. All 120volt circuits shall have power.

Questions?

Please contact 303-271-8260 between the hours of 7:30 am and 5:00 pm, Monday through Thursday.