Electrical Systems

UNIT 3

Objectives

After studying this unit, the student will:

1. Understand fundamentals of electricity.
2. Identify power distribution systems and equipment.
3. Be familiar with commonly used electrical material.
4. Recognize electrical symbols shown on electrical plans.
5. Be able to interpret electrical plans and specifications.
6. Acquire knowledge about the basic electrical systems common to most types of buildings.
7. Understand electrical estimating procedures.

Introduction

It is important that project managers and superintendents have a basic understanding of the fundamentals of electricity and how electrical systems work. You don't have to be an electrician or electrical engineer to understand how electrical systems work or to understand what is being installed and why.

Like many fields electrical contracting is very broad and it is nearly impossible for an individual to know everything, even after a lifetime of working in the industry, about electrical construction. Changes in the industry do occur and new systems are continually on the horizon. However, the principles on which all electrical systems work and the basics of electricity stay the same, even as more sophisticated applications are developed and installed every day.

Fundamentals of Electricity
In order to understand electrical systems and to confidently coordinate with your subcontractors, it is important that you have a working knowledge of the fundamentals of electricity.

For electricity to flow there needs to be a source, a load, and a completely closed path. Think about what happens when you "flip" on your bedroom light switch. The switch when in the off position opens the path and stops the source from being able to force the flow of electricity through the load (the lightbulb). When the switch is closed, it completes the path from the service panel located somewhere in your house that is energized by the local utility company, and current flows through the load (the lightbulb). This system is a simple electrical circuit.

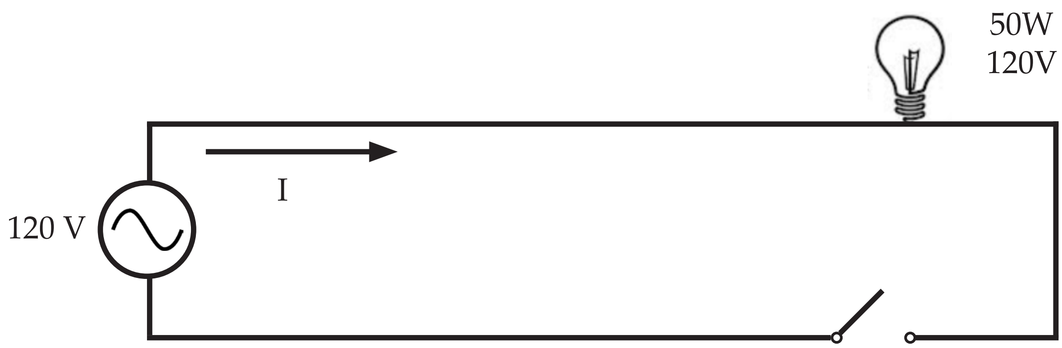


Figure 1A: Simple Circuit - Switch Open
The Current (I) is zero I = 0 Amps

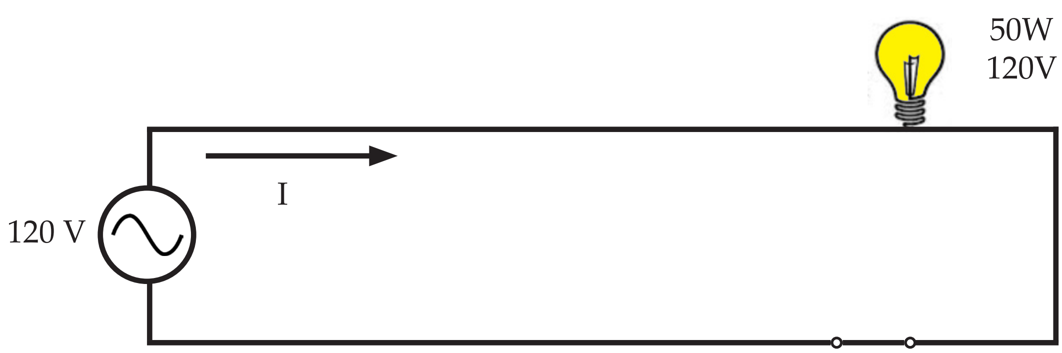


Figure 1B: Simple Circuit - Switch Closed
The current (I) is calculated using the equation: Power = Current x Voltage (Watts Law) or P = I x E
I = P / E = 50 Watts ÷ 120 V = 0.4167 Amps

Circuits

A circuit is an arrangement of closed path(s) through which electricity (i.e., electrons) can travel. Most complete circuits include an energy source, conductors, insulators, loads, a switch or other control device, and a protective device (i.e., fuse).

A simple circuit consists of only one energy source, one conductor, and one load.

A series circuit has at least two loads. The conductor, loads, and control and protective devices are connected end-to-end to make up a single path through which electricity can travel from and back to the energy source. If a series circuit is interrupted at any point, electricity will not flow.

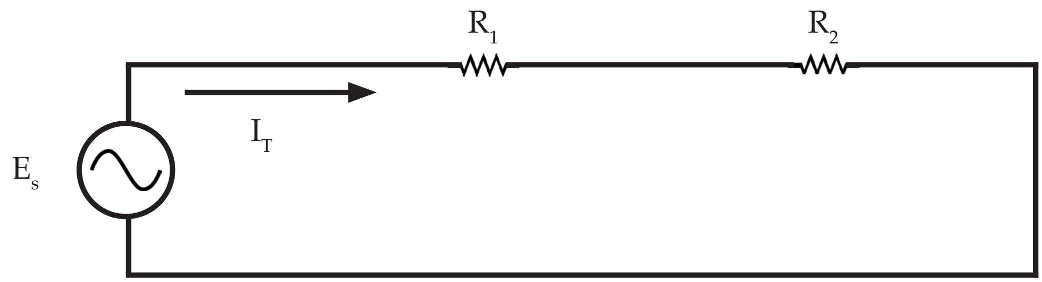


Figure 2: Series Circuit

A parallel circuit has two or more independent paths. If one path is interrupted, electricity can still flow through the remaining path(s).

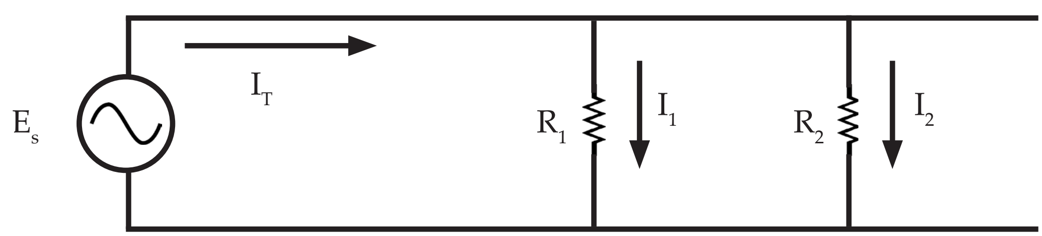


Figure 3: Parallel Circuit

A series – parallel circuit has a combination of a series path and two or more independent parallel paths. Depending on the arrangement of the loads and where a path interruption occurs the current may or may not continue to flow through the loads.

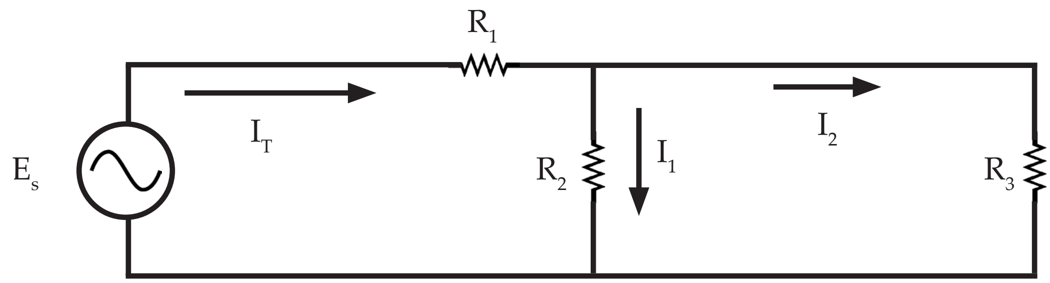


Figure 4: Series - Parallel Circuit

Electrical Quantities

The basic quantities used to measure electricity are current, voltage, resistance, and power.

Current (I) is the rate at which electricity flows through a circuit. Current is measured in amperes or amps.

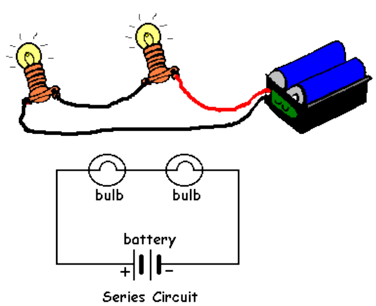
Voltage (E) also called "electromotive force" or "emf" is the force that causes electricity to flow. Voltage is measured in volts. In formulas, voltage is represented by either E or V. E will be used in this course.

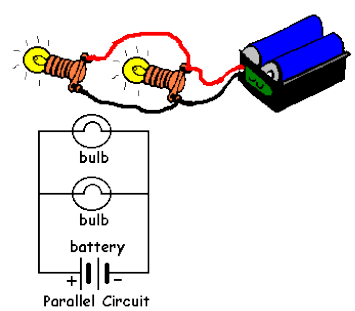
Resistance (R) Most materials making up a circuit resist the flow of electricity. The amount of this resistance depends on the type of material and its dimensions. Resistance is measured in ohms. The symbol for ohms is the Greek letter Omega (Ω).

Power is the rate at which electrical energy is transformed; it is the rate of doing work and is measured in watts.

Direct Current

Direct current (DC) is the constant flow of electricity through a conductor in one direction. A dry-cell battery connected to a light bulb is an example of a simple DC circuit.





Ohm's Law

Ohm's Law states the relationship between the current, voltage, and resistance of a simple DC circuit.

$\boxed{E = R \times I \qquad R = E / I \qquad \text{and } I = E / R}$

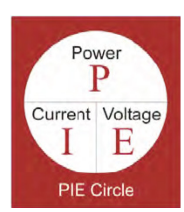
where: I = current (intensity) in amps, A
E = voltage (electromotive force) in volts, V
R = resistance in ohms, Ω

Watt's Law

The basic form of Watt's Law states that the electrical power (P) in a simple dc circuit is the product of current and voltage.

$\boxed{P = I \times E \qquad I = P / E \qquad \text{and } E = P / I}$

where: P = power in watts, W
I = current (intensity) in amps, A
E = voltage (electromotive force) in volts, V



Two other important power formulas can be derived from Ohm's and Watt's Laws:

$\boxed{P = I^2 \times R}$

<u>Derivation</u> P = I x E (Watt's Law) and E = I x R (Ohm's Law). Since E = I x R, substitute I x R for E in the Watt's Law formula: $P = I \times I \times R = I^2 \times R$.

$\boxed{P = E^2 / R}$

<u>Derivation</u> P = I x E (Watt's Law) and I = E/R (Ohm's Law). Since I = E/R, substitute E/R for I in the Watt's Law formula: $P = E/R \times E = E^2 / R$.

Ohm's Law and Watt's Law problems involving simple, series, or parallel circuits usually consist of calculating an unknown quantity (i.e., voltage) based on two or more known quantities (i.e. current, resistance, or power).

Simple Circuits

The basic Ohm's Law and Watt's Law formulas can be applied directly to problems involving simple DC circuits.

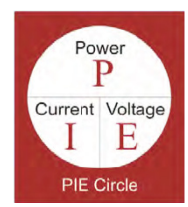
PROBLEM: A simple DC circuit has a resistance of 3 ohms and a voltage of 12 volts.

(a) What is the current?

(b) What is the power rating?

SOLUTION: (a) I = E / R = 12 volts ÷ 3 ohms = 4 amps

(b) P = I x E = 4 amps x 12 volts = 48 watts



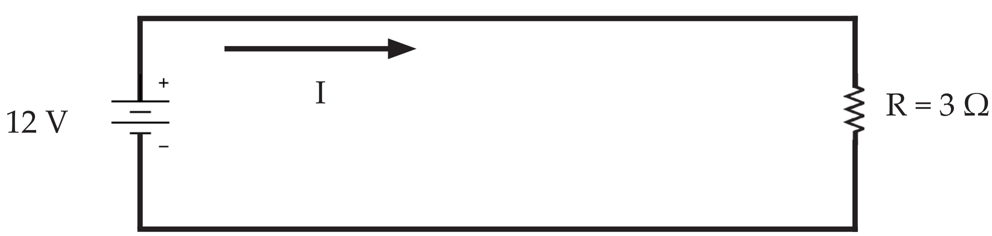


Figure 5: Simple DC Circuit

DC Series Circuits

Four rules apply to DC series circuits:

(1) The total voltage is the sum of the voltages across each load.
(2) The current is the same in all parts of the circuit.
(3) The total resistance is the sum of the individual load resistances.

$$R_{total} = R_1 + R_2 + R_3 \; . \; . \; . \; . \; .$$

(4) The total power is the sum of the powers used by the individual loads.

PROBLEM: In the DC series circuit illustrated in Figure 6, I = 6 amps, R_1 = 4 ohms, and R_2 = 2 ohms.

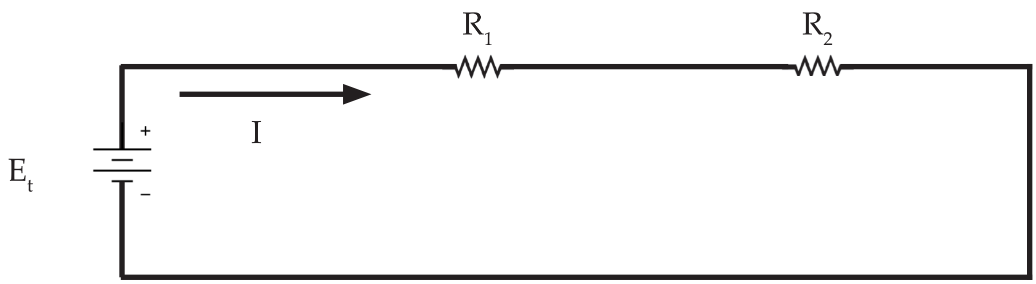


Figure 6: Series Circuit

(a) What is the total resistance (R_t)?
(b) What is the total voltage (E_t)?
(c) What is the total power (P_t)?

SOLUTION: (a) Apply Rule 3 ($R_t = R_1 + R_2$):

R_t = 4 ohms + 2 ohms = 6 ohms

(b) Apply Rule 1 ($E_t = E_1 + E_2$) and Ohm's Law:

E_1 = I x R_1 = 6 amps x 4 ohms = 24 volts
E_2 = I x R_2 = 6 amps x 2 ohms = + 12 volts
E_t = 36 volts

(c) Apply Rule 4 ($P_t = P_1 + P_2$) and Watt's Law:

P_1 = I x E_1 = 6 amps x 24 volts = 144 watts
P_2 = I x E_2 = 6 amps x 12 volts = + 72 watts
P_t = 216 watts

DC Parallel Circuits

The rules for DC parallel circuits are:

(1) The voltage across each load is the same.
(2) The total current is the sum of the currents in each load.
(3) The total resistance is always lower than the smallest load resistance. The formula for calculating total resistance (R_t) is:

$$\frac{1}{R_{total}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} \cdots\cdots$$

(4) The total power is the sum of the powers used by the individual loads.

PROBLEM: In the DC parallel circuit illustrated in Figure 7, I = 3 amps, $R_1 = 4\ \Omega$, and $R_2 = 1\ \Omega$.

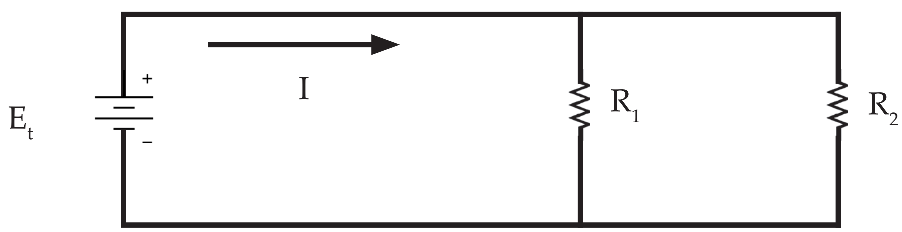


Figure 7: Parallel Circuit

(a) What is the total resistance (R_t)?
(b) What is the total voltage (E_t)?
(c) What is the total power (P_t)?

SOLUTION: (a) Apply Rule 3 formula:

$$R_t = \frac{1}{\frac{1}{4} + \frac{1}{1}} = \frac{1}{\frac{5}{4}} = \frac{4}{5} = 0.8 \text{ ohm}$$

(b) According to Rule 1, the voltage across each load is the same. Apply Ohm's Law just as you would to a problem involving a simple dc circuit where I = 3 amps and R = 0.8 ohm.

$E_t = I \times R_t = 3 \text{ amps} \times 0.8 \text{ ohm} = 2.4 \text{ volts}$

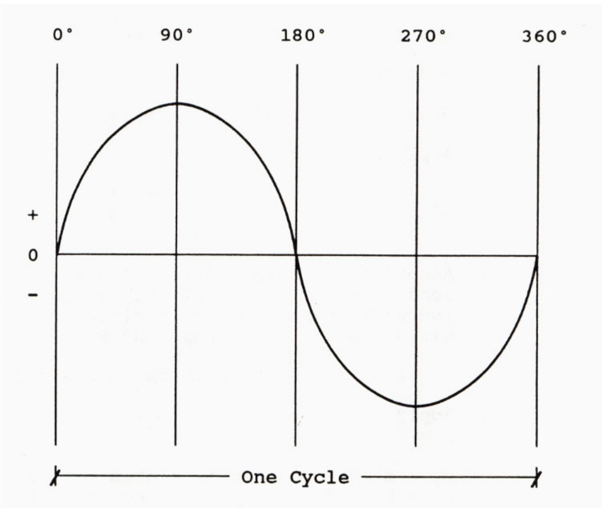
(C) Apply Rule 4 ($P_t = P_1 + P_2$) and the formula $P = E^2 / R$

$$\begin{aligned} P_1 &= E^2/R = 2.4^2 \text{ volts} / 4 \text{ ohms} = && 1.44 \text{ watts} \\ P_2 &= E^2/R = 2.4^2 \text{ volts} / 1 \text{ ohm} = && \underline{+\,5.76 \text{ watts}} \\ && P_t = && 7.20 \text{ watts} \end{aligned}$$

Alternating Current

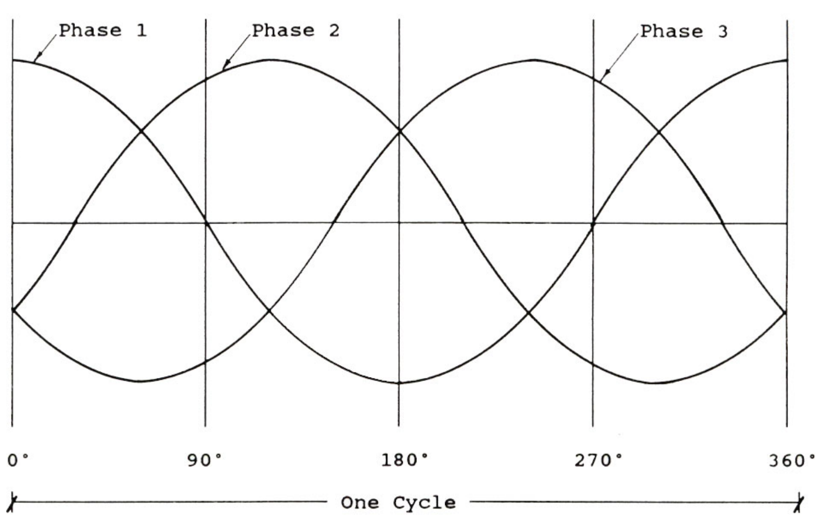
Alternating current (AC) is the flow of electricity back and forth in a conductor at regular intervals. The rate of flow reversal is called “frequency”. Nearly all AC power systems in the United States operate at a frequency of 60 cycles per second. This means that the electricity flows in one direction for 1/120 of a second and then in the other direction for 1/120 of a second. The current makes one complete cycle in 1/60 of a second or 60 complete cycles in one second.

The sine wave is commonly used to illustrate alternating current. The graph below shows the sine wave for a single-phase (1ϕ) AC current. The complete AC cycle is divided into two half cycles - - the first is given a positive value and the second a negative value. The first half cycle (+) begins at zero and rises to a peak value before returning to zero, at which point the second half cycle (-) peaks and returns to zero again.



Single-phase ac

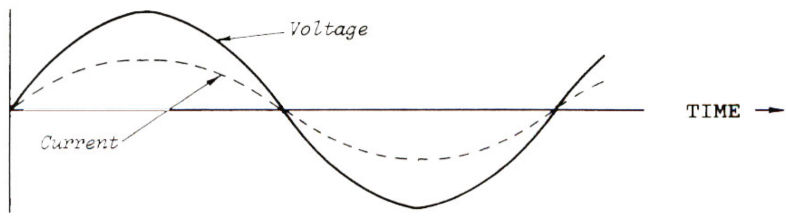
The disadvantage of single-phase AC is that the electrical power is cut off each time the current reaches “0”. This problem can be avoided with three-phase (3ϕ) ac systems that provides overlapping cycles. The power supplied to a motor or other device is never cut off because when one phase reaches “0”, the other two phases are either positive or negative.



Three-phase ac

In-Phase AC Circuits

The voltage and current of an AC circuit can be depicted on the same graph as separate sine waves. When the voltage and current begin and peak at exactly the same time, they are said to be "in phase". For all practical purposes, the "in phase" circuit consists of only resistance, the loads being devices such as light bulbs, toasters, or heaters.



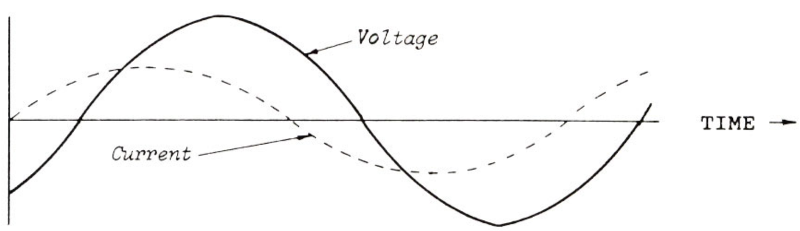
Voltage and current are in phase.

Reactance and Out-of-Phase AC Circuits

A circuit can be put "out of phase" by inductive or capacitive reactance. "Reactance" is the term used to describe opposition to voltage and current caused by capacitors and inductors.

A simple capacitor consists of two conductor plates separated by a dielectric (insulator). Each plate stores energy in the form of electric charges when electricity flows through the capacitor. One plate becomes positively charged and the other negatively charged. The opposite charges on the plates produce a voltage in the capacitor that opposes changes in the circuit voltage.

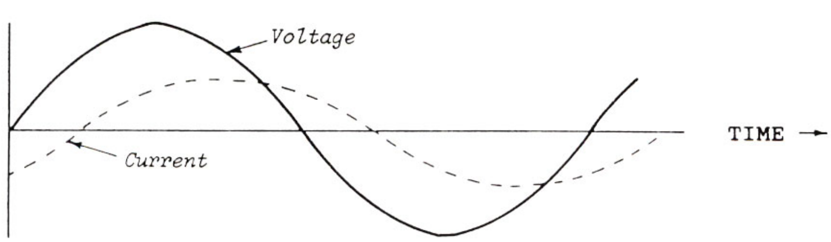
Because changes in the circuit voltage are opposed by capacitive reactance, the peak of the current wave occurs ahead of the peak of the voltage wave. In other words, "Current leads voltage".



Current leads voltage.

Inductors are usually coils. The flow of electricity in an inductor produces a circular magnetic field that is proportional to the current. When the current increases, the size of the magnetic field increases and induces a voltage in the inductor. When the current decreases, the field collapses. The collapsing field reverses the polarity of the induced voltage, which opposes the decrease in current.

Because the changes of current are opposed by inductive reactance, the peak of the current wave is delayed and arrives after the peak of the voltage wave. In other words, "Current lags behind voltage".



Current lags behind voltage.

Power Factor

The power factor (PF) is the ratio of the "true" power to the "apparent" power:

$$PF = \frac{\text{true power (watts)}}{\text{apparent power (I x E) VA}}$$

When a circuit is in phase, the true power equals the apparent power, which means that the power measured by a wattmeter would be the same as the power calculated with the formula P = I x E. In this case, the circuit is said to have a "unity" power factor or a power factor equal to 1 or 100%. If the circuit is out of phase, the power measured by the wattmeter will be less than the apparent or calculated power, and the power factor will be less than unity.

PROBLEM: An AC circuit draws 20 amps from a 240-volt source. The wattmeter measures 3,360 watts. What is the power factor?

SOLUTION: (1) Apparent power = I x E
(2) 20 amps x 240 volts = 4,800 watts
(3) True power = 3,360 watts
(4) PF = true / apparent = 3,360 ÷ 4,800 = 0.7 = 70%

Power Formulas for AC Circuits

The Watt's Law formulas for DC circuits also apply to single-phase (1ϕ) and three-phase (3ϕ) AC circuits containing only resistance.

If inductance or capacitive reactance puts the circuit out of phase, the power factor must be added to the basic power formula:

$$\boxed{P = I \times E \times PF}$$

PROBLEM: A single-phase AC circuit draws 8 amps from a 120-volt source. If the power factor is 60%, what is the power rating in watts?

SOLUTION: (1) P = I x E x PF

(2) P = 8 amps x 120 volts x 0.6 = 576 watts

The formula for a three-phase (3ϕ) system includes another term called the "three-phase factor", which is a constant equal to the square root of 3, or 1.73.

$$\boxed{P_{3\phi} = I \times E \times PF \times 1.73}$$

PROBLEM: What is the power rating in watts of a 3ϕ circuit that draws 15 amps from a 120-volt source if the power factor is 70%?

SOLUTION: (1) $P_{3\phi}$ = I x E x PF x 1.73

(2) $P_{3\phi}$ = 15 amps x 120 volts x 0.7 x 1.73 = 2,179.8 watts

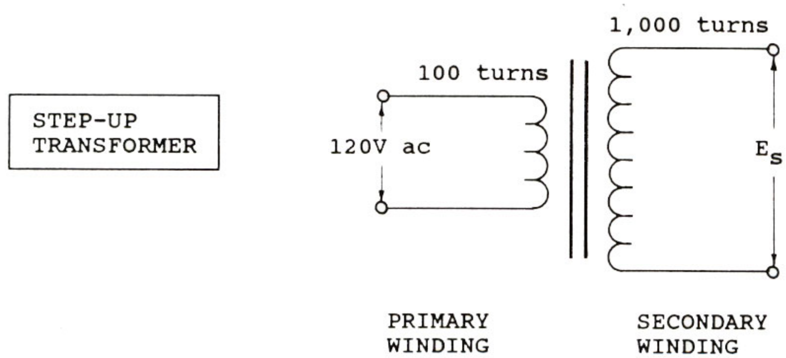
Transformers

Transformers consist of primary and secondary windings (coils) that are not connected to one another. The primary winding receives power from a primary source (i.e. a generator) and transfers (induces) it to the secondary winding, which is connected to a load.

A transformer can be either a step-up transformer that receives power at a low voltage and delivers it at a higher voltage, or a step-down transformer that receives power at a high voltage and delivers it at a lower voltage.

The voltage of the primary winding will be the same as the source voltage. The voltage of the secondary (E_S) is equal to the primary voltage (E_P) times the ratio of the number of turns (N_S) in the secondary to the number of turns (N_P) in the primary.

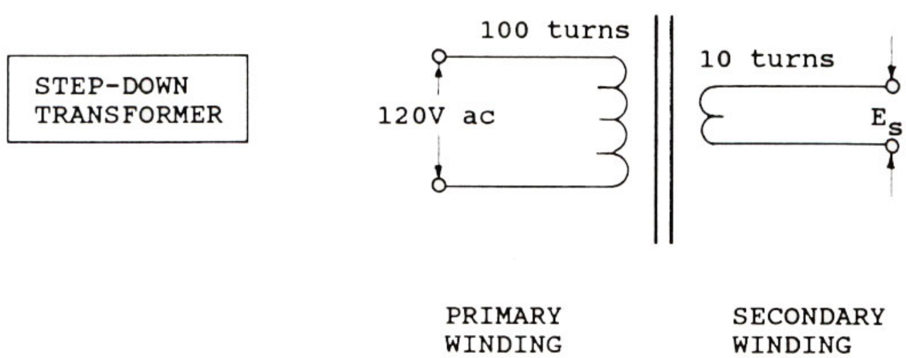
PROBLEM: The primary and secondary windings of a step-up transformer are shown below. If a voltage of 120 volts (E_P) is applied across the primary, how many volts (E_S) will be induced across the secondary?



SOLUTION: (1) $E_S = E_P \times N_S / N_P$

(2) E_S = 120 volts x 1,000 / 100 = 1,200 volts

PROBLEM: The primary and secondary windings of a step-down transformer are shown below. If a voltage of 120 volts (E_P) is applied across the primary, how many volts (E_S) will be induced across the secondary?

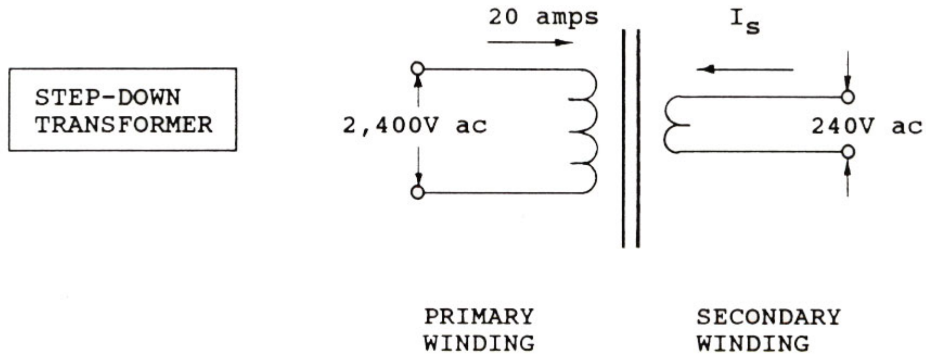


SOLUTION: (1) $E_S = E_P \times N_S / N_P$

(2) E_S = 120 volts x 10 / 100 = 12 volts

The power of the primary winding equals the power of the secondary winding. Voltage and current calculations are based on this principle.

PROBLEM: The primary of a step-down transformer has a voltage (E_P) of 2,400 volts and a current of 20 amps. If the voltage (E_S) across the secondary is 240 volts, what is the current (I_S)?



SOLUTION: (1) P_P = 20 amps x 2,400 volts = 48,000 watts

(2) Primary power equals secondary power:
$P_P = P_S$ = 48,000 watts

(3) $I_S = P_S / E_S$ = 48,000 watts ÷ 240 volts = 200 amps

Transformers convert electricity from low to high voltage for long-distance transmission, then convert it back to low voltage for use in homes and other facilities.

Power Distribution

Electrical Power Distribution will help you to understand how utility power is generated and distributed and the main system components required to distribute power throughout a building.

Power distribution and connecting the building to its permanent power source are critical items that must be considered early in the project design phase. HVAC equipment, elevators, motors, lighting, fire protection, and numerous other systems cannot be tested and inspected until permanent power has been connected. Working successfully with the electrical and mechanical superintendents requires that you have a thorough understanding of the scope of work that must be accomplished and that you are able to communicate with them efficiently.

When electrical power is distributed to its point of utilization, it is either in the form of single-phase or three-phase AC voltage. Single-phase AC voltage is distributed into residences and other small commercial buildings. Normally, three-phase AC voltage is distributed to larger commercial buildings and industrial sites.

Energy, Work, and Power

An understanding of the terms energy, work, and power is necessary in the study of electrical power systems.

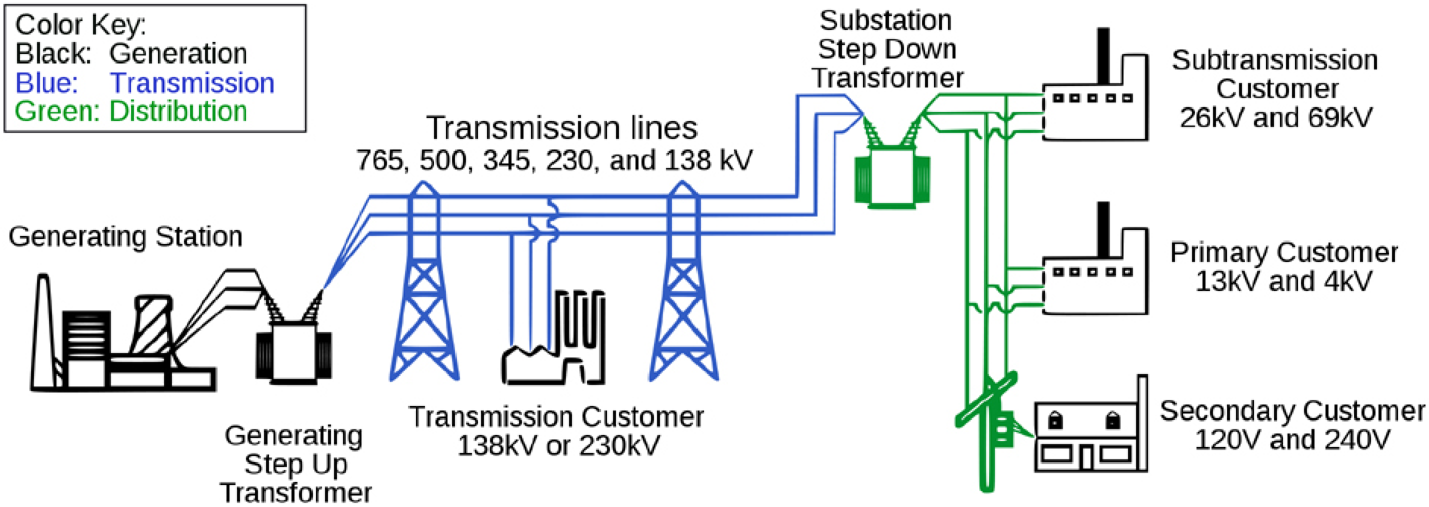
Energy means the capacity to do work. For example, the capacity to light a light bulb, to heat a home, or to move something requires energy. Energy exists in many forms, such as electrical, mechanical, chemical, and heat. Energy of an object in motion is called kinetic energy. Energy due to the position of an object that is not yet moving is called potential energy.

Work is the transferring or transforming of energy. Work is done when a force is exerted to move something over a distance against opposition, such as moving a desk from one side of a room to the other. An electric motor used to drive an elevator cab performs work. Work is performed when motion is accomplished against the action of a force that tends to oppose the motion. Work is also done each time energy changes from one form into another.

Power is the rate at which work is done. It considers not only the work that is performed but the amount of time in which the work is done. For instance, electrical power is the rate at which work is done as electrical current flows through a wire. Mechanical power is the rate at which work is done as an object is moved against opposition over a certain distance. Power is either the rate of production or the rate of use of energy. The watt is the unit of measurement of electrical power.

Generation and Distribution of Electrical Power

Power is produced at a generating plant (source). Distribution occurs between the power generating plant and the consumer by transmission lines and substations. Transformers are used to control the voltage and current levels. Conversion of electrical power to another form (light, heat, mechanical) occurs at the customer end.



Electrical Service Types and Voltages

Electrical service (service entrance) is the point of receiving power from the serving utility company.

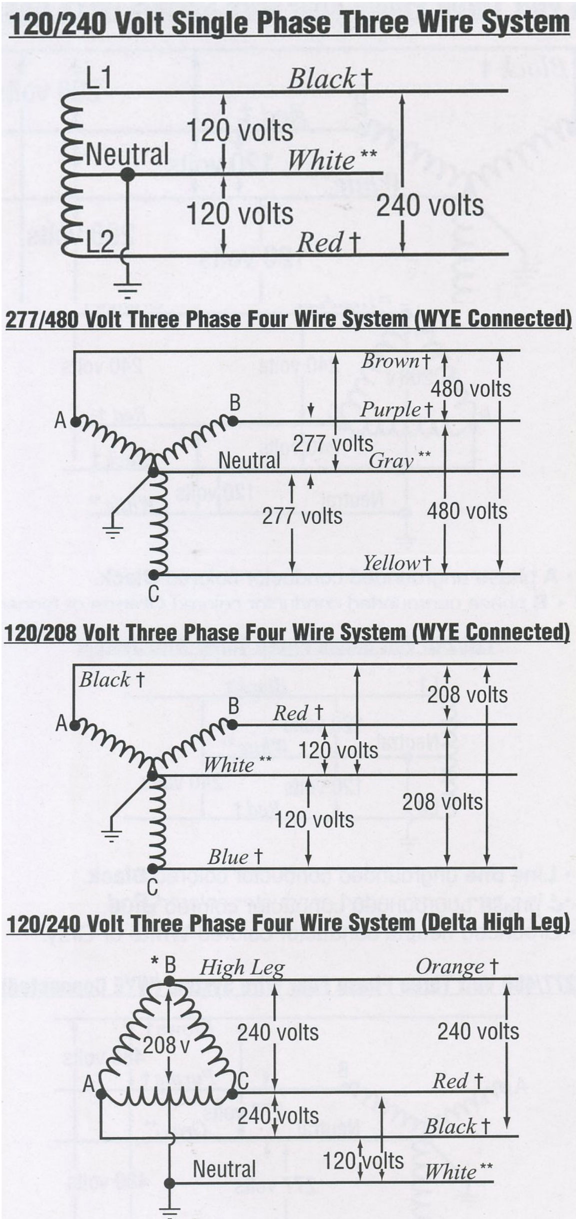
Classification of Electrical Services

Alternating current (AC) electric power distribution systems can be classified by the following properties:

- Frequency: 50 Hz or 60 Hz
- Number of phases: single or three phase
- Number of wires: 2, 3, or 4 (not counting the safety ground)
- Neutral present:
  - Wye connected systems have a neutral
  - Delta connected systems typically do not have a neutral
- Voltage levels:
  - Low Voltage: 600 volts or less
  - Medium Voltage: 601 volts to about 34,500 volts
  - High Voltage: 46,000 volts and up

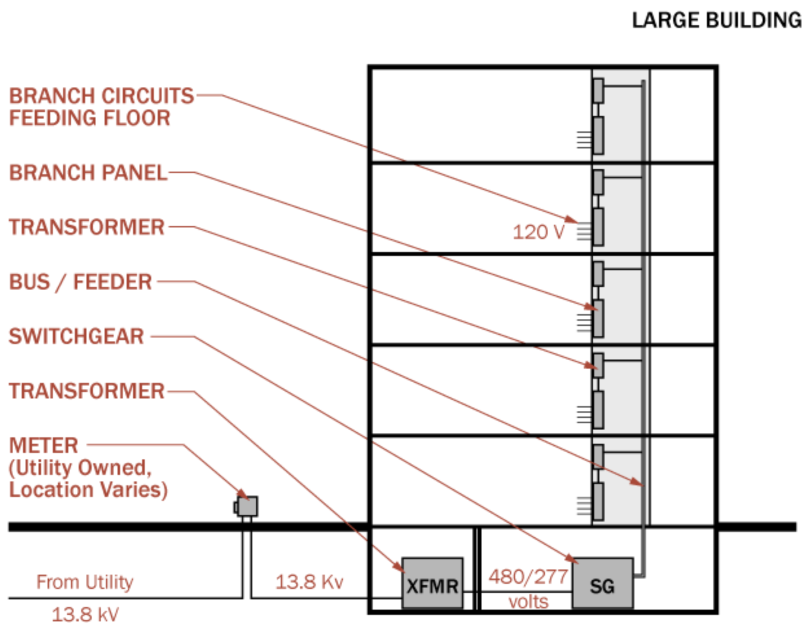
Power provided from the U.S. electrical grid (the grid) is based on a frequency of 60 Hz.

Common Electrical Distribution Systems

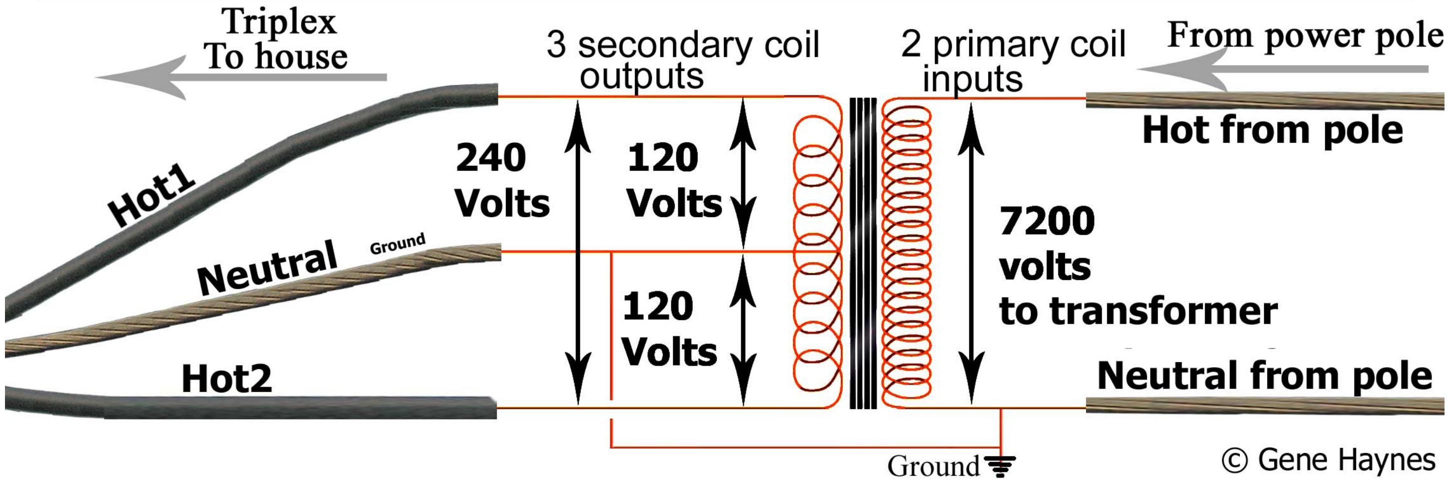


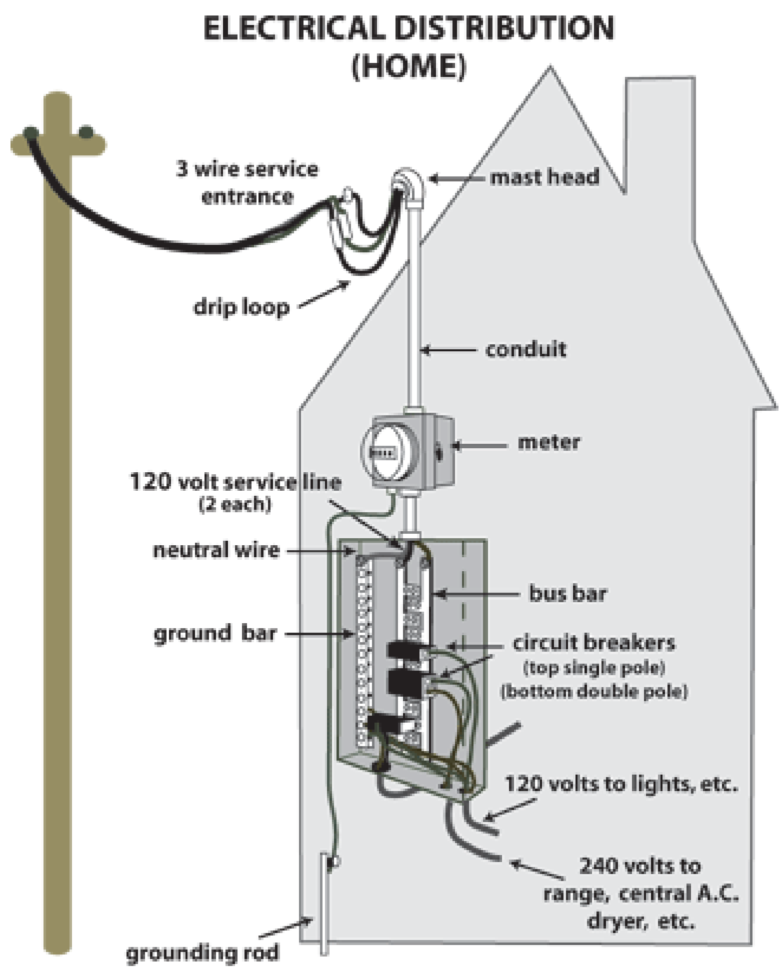
120/240-Volt, Single-Phase, Three-Wire system is the most common distribution method for residences. Most appliances and home equipment use 120 V power supplied to power receptacles. Dryers, ovens, hot water heaters, hot tubs, and other higher current requiring equipment may use the 240 V power.

Most commercial and industrial buildings use three phase power. The most commonly used incoming service voltage system is the 277/480 V Three Phase Four Wire (WYE Connected). A step-down transformer is needed to reduce the voltage to 120/208 for receptacles and other lower voltage equipment.



Household distribution transformer



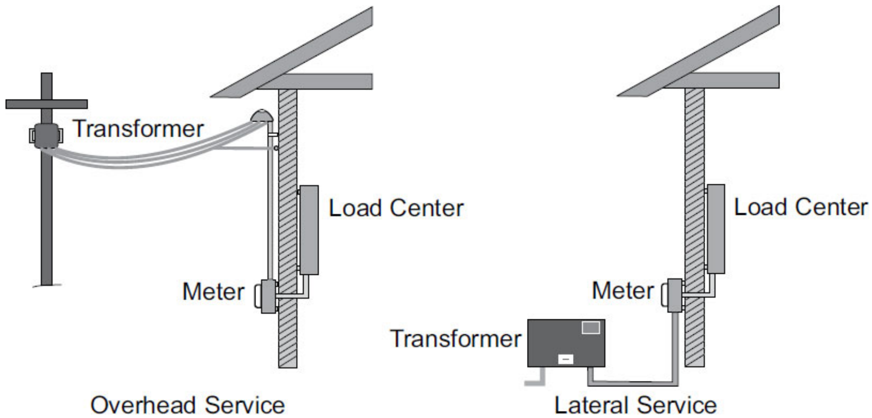


Power Distribution System Equipment

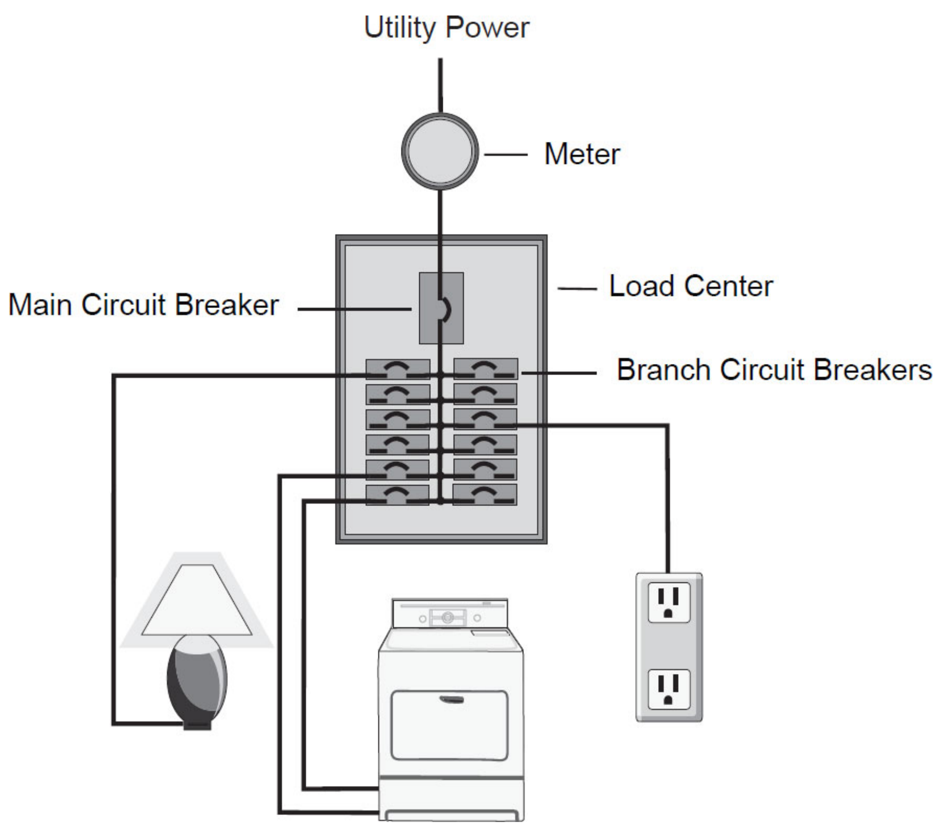
Power distribution systems are used in every residential, commercial, and industrial building to safely control the distribution of electrical power throughout the facility.

Residential Power Distribution

Power, purchased from a utility company, enters the house through a metering device and is applied to a load center. This is the service entrance. Residential service can come from an overhead utility transformer or from a lateral service run underground.



The power is then distributed by a load center to various branch circuits for lighting, appliances, and electrical outlets.



Commercial and Industrial Power Distribution

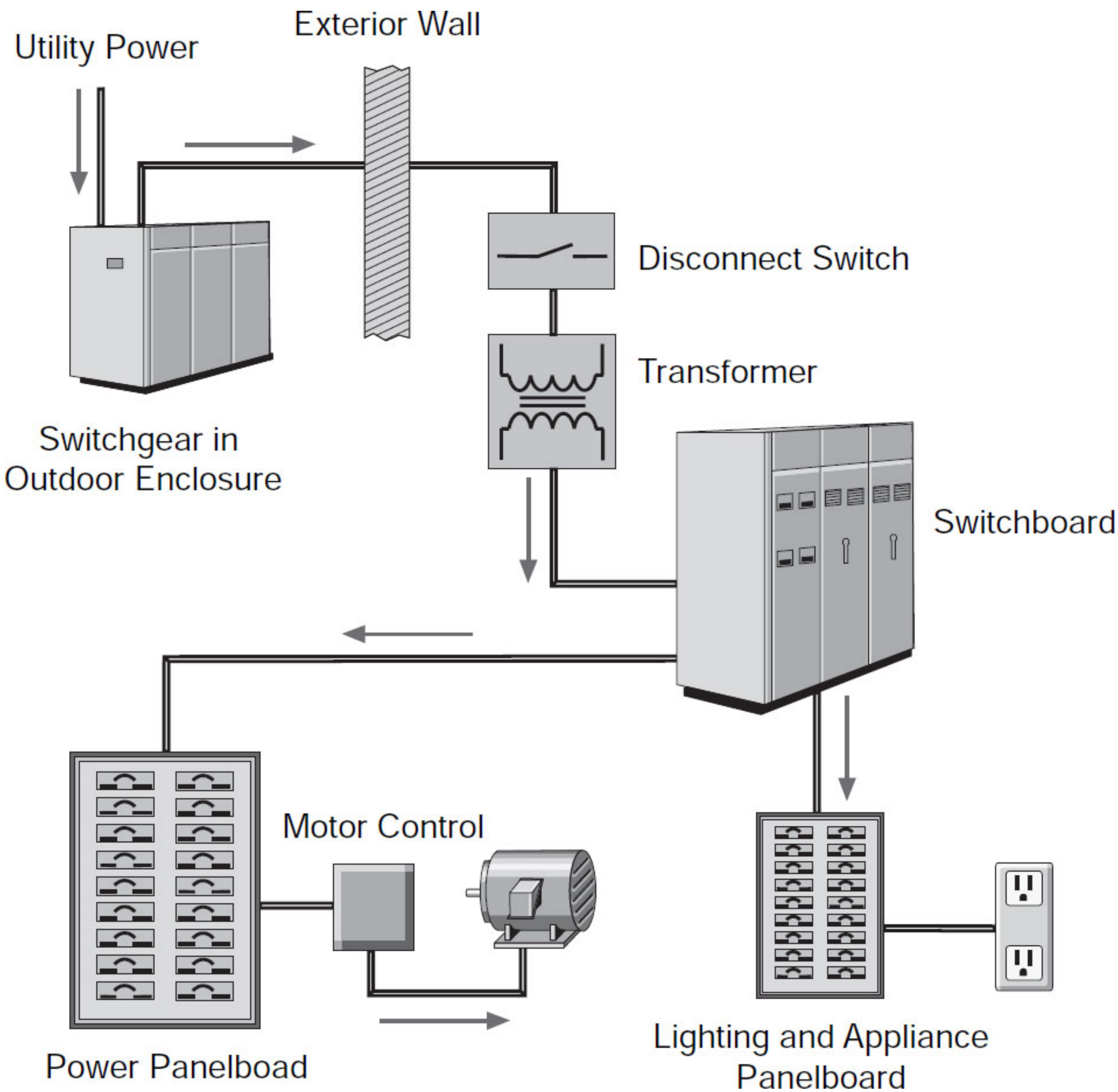
Power distribution systems used in commercial and industrial facilities are more complex than those used in single-family homes and must be capable of handling higher levels of current and voltage. Although some small facilities usually do not require switchboards, medium and large facilities commonly use switchboards to safely distribute power to transformers, panelboards, control equipment, and, ultimately, to system loads.

Switchgear

A coordinated design consisting of switching and interrupting devices and associated equipment such as control and protective devices and metering.

Switchboard

A large panel or assembly of panels containing switches, overcurrent protective devices, buses, and associated instruments. Unlike panelboards, switchboards sometimes must be mounted away from a wall to allow access to rear-mounted equipment.



Panelboard

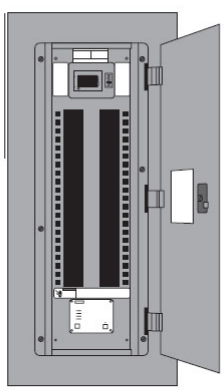
A panelboard is a type of enclosure for overcurrent protection devices and the busses and connections that provide power to these devices and their associated circuits. According to the National Electrical Code® (NEC®), a panelboard is:

- Used to control light, heat, or power circuits
- Placed in a cabinet or cutout box
- Mounted in or against a wall
- Accessible only from the front

For additional information, refer to National Electrical Code® Article 408, Switchboards and Panelboards.

Panelboards are frequently divided into two categories:

- Lighting and appliance branch-circuit panelboards
- Power panelboards (also called distribution panelboards)

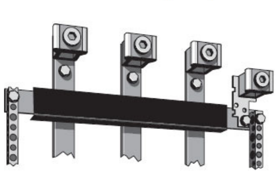


Lighting and Appliance Panelboard

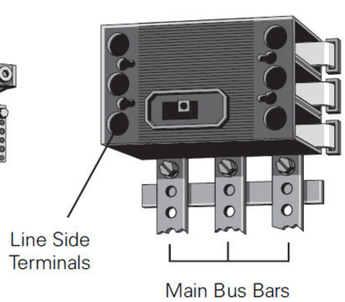
Power Panelboards

There are three types of panelboard main configurations: main lug only, main breaker, and main switch

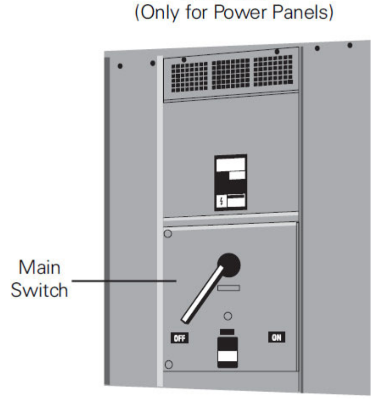
Main Lug Only

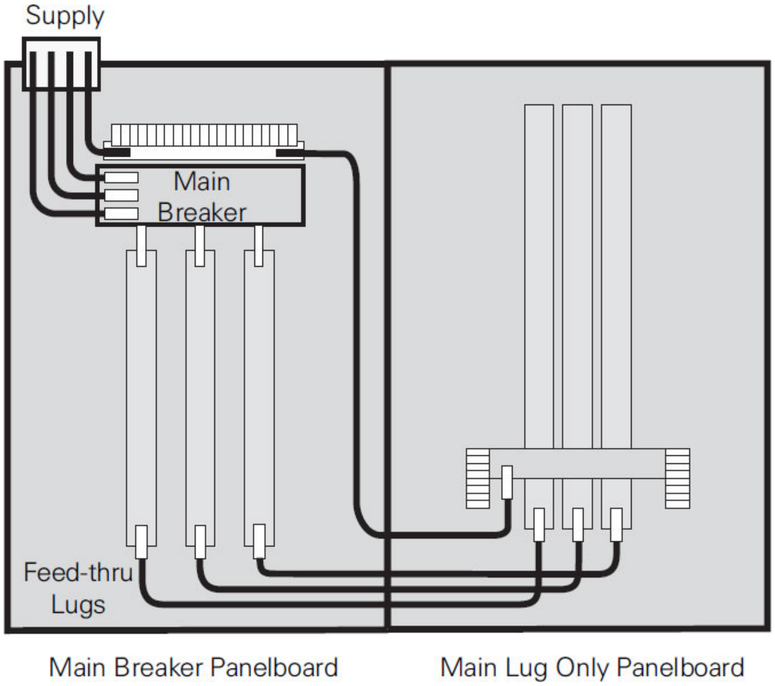


Main Breaker



Main Switch (Only for Power Panels)





In a Main Circuit Breaker (MCB) panelboard the entire panel can be de-energized by switching the main breaker off.

In a Main Lug Only (MLO) panelboard there is no main breaker and each individual circuit breaker must be switched off to turn off the power feeding each branch circuit.

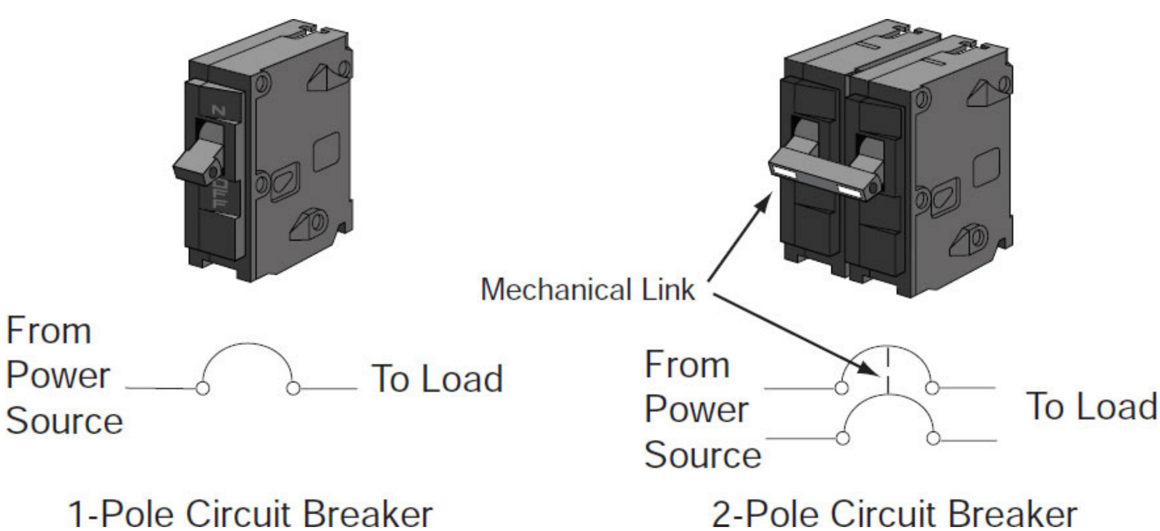
Overcurrent Protection Devices

Excess heat is damaging to electrical conductors. For that reason, conductors have a rated continuous current carrying capacity or ampacity. Current beyond the rated capability of a conductor is referred to as overcurrent. Overcurrent can result from a short circuit, an overload, or a ground fault.

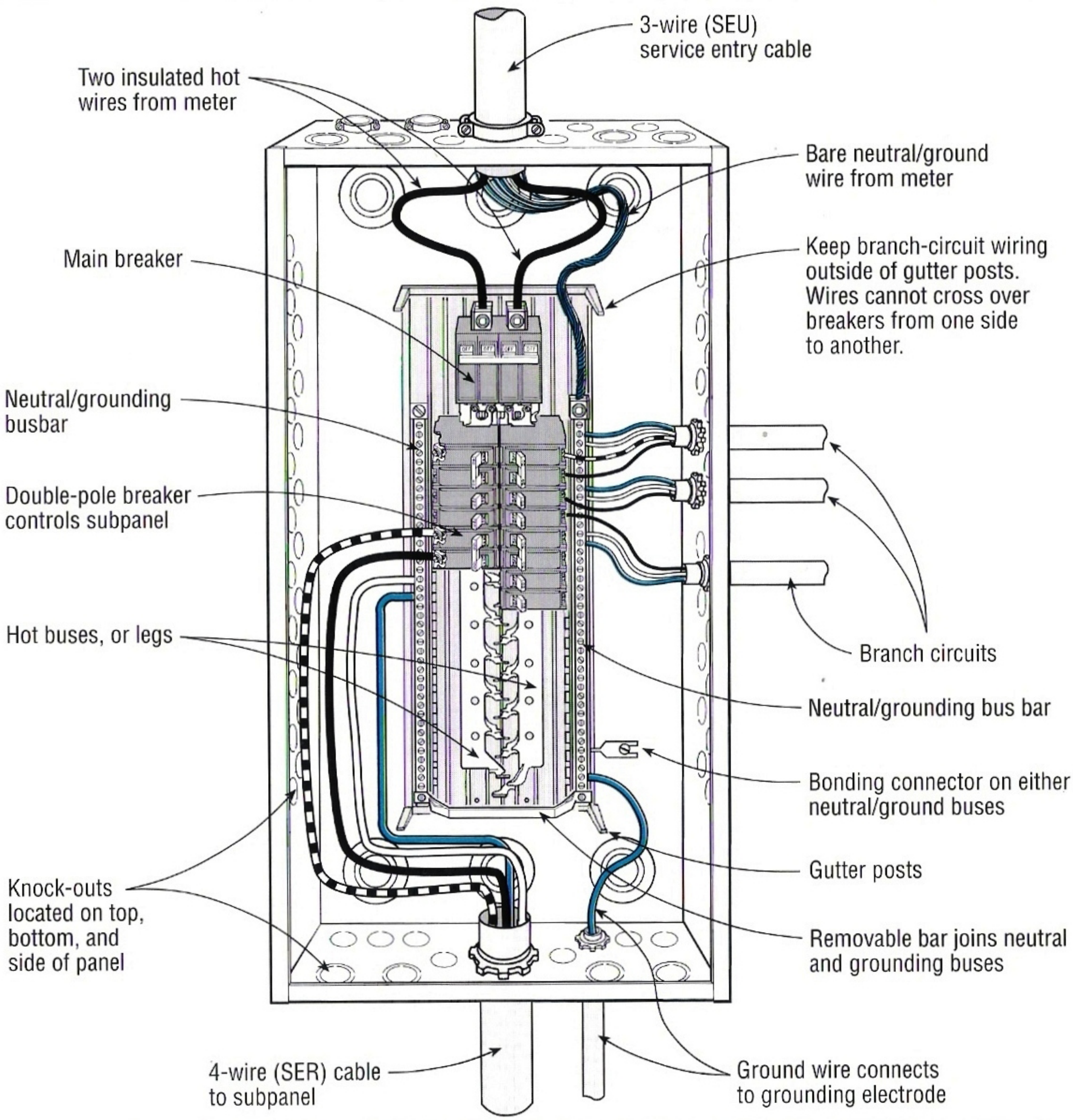
Fuse - A device designed to open a circuit when its rated current is exceeded. This is usually accomplished when a metal link in the fuse melts. Renewable fuses allow the user to replace the link and non-renewable fuses do not. Fuses are available in various sizes and types. Some have a time delay.

Fuse Class - A letter designation given to a fuse to identify its operating and construction characteristics.

Circuit Breaker - A device that can be used to open or close a circuit manually and also opens a circuit automatically when it senses an overcurrent.



Single-Phase Main Breaker Panelboard

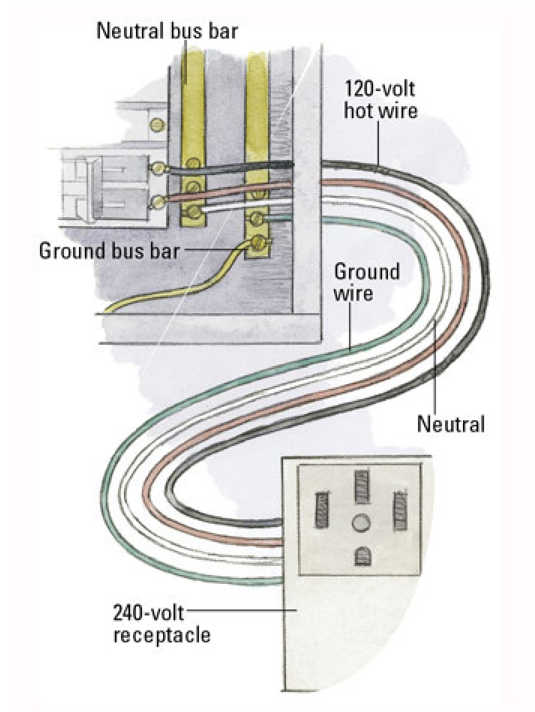


Grounding and Bonding

Grounding is the action of electrically connecting something to a grounding electrode, which is a conductive object used to create a direct connection to ground--typically a ground rod.

A grounded conductor is a circuit conductor (wire) which is intentionally grounded.

In grounded electrical systems, like virtually all electrical systems in residential and commercial structures, the grounded conductor is the white (or gray) wire, which is commonly referred to as the “neutral” or most correctly referred to as a “grounded neutral conductor”. A grounded wire is required by the National Electrical Code to be white or gray in color on the customer side of the meter.



Since the neutral is a necessary part of the electrical path for the current to return to the source, neutral conductors carry current under normal operating conditions.

A “grounding” wire on the other hand is a safety wire that has intentionally been connected to earth. The grounding wire does not carry electricity under normal circuit operations. It’s purpose is to carry electrical current only under short circuit or other conditions that would be potentially dangerous.

Grounding wires serve as an alternate path for the current to flow back to the source, rather than go through anyone touching a dangerous appliance or electrical box.

Confusion arises because it is commonly referred to as a ground wire even though it is more correctly called a “grounding” wire. Some people will refer to this wire as the “case ground” since this wire is typically connected to the cases or outer parts of electrical boxes and appliances and tools.

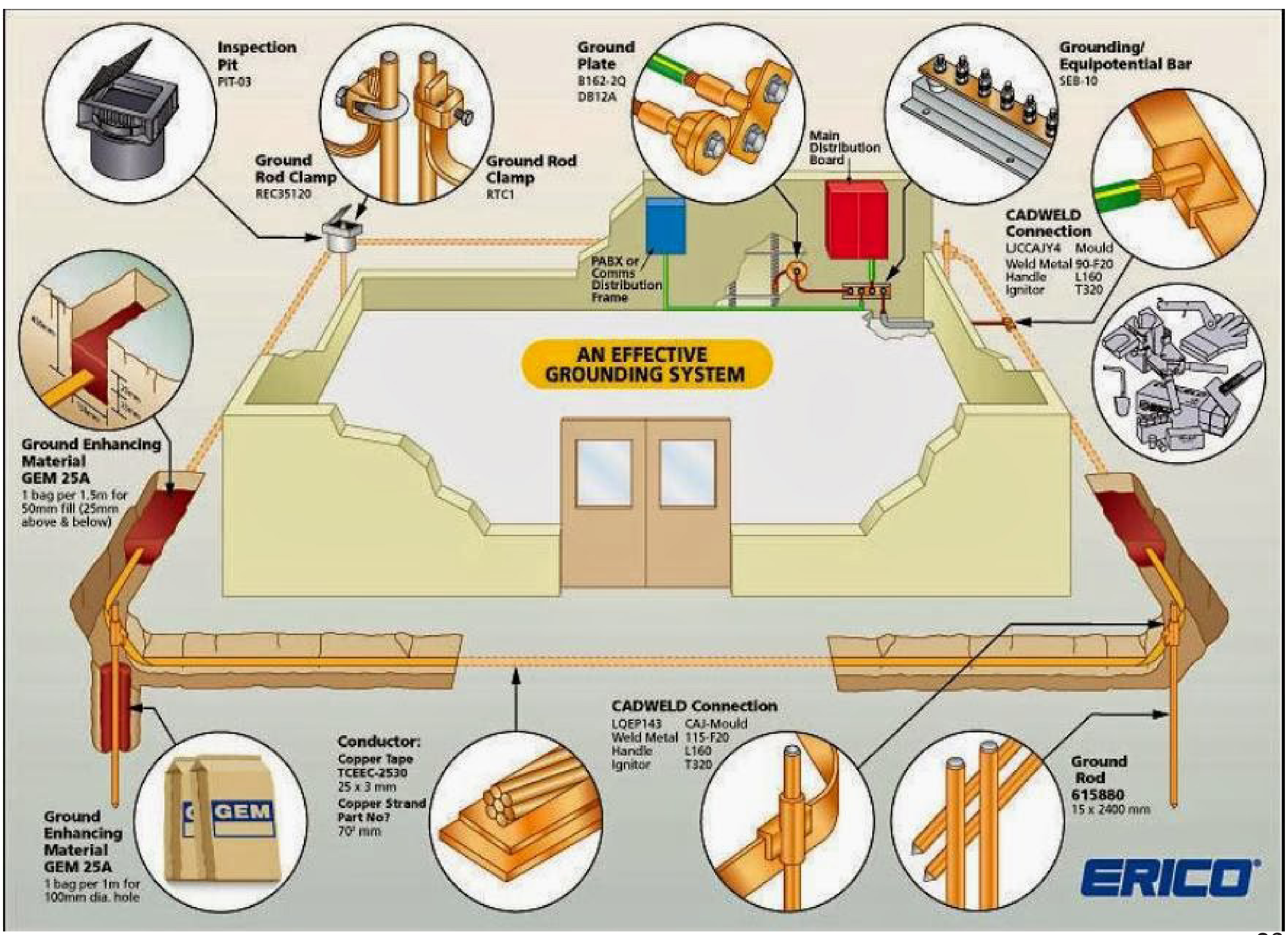
The grounding wire is required by the National Electrical Code to be a bare wire, or if insulated, a green or green with yellow colored insulation.

Grounding also serves another purpose which is not really related to safety: It provides a common reference point for voltage. If an electrical device’s only connections are to the two ends of its power source, it is electrically unstable and the voltage levels may vary. Neither one would be at zero volts. Because planet Earth stays at a common voltage, it provides a universal voltage reference point. (The planet is usually considered to be at zero volts, even though this is not perfectly true, as Earth itself is something of a conductor.)

Bonding, or equipotential bonding, is essentially an electrical connection maintaining various exposed conductive parts and extraneous conductive parts at substantially the same potential. An earthed equipotential zone is one within which exposed conductive parts and extraneous conductive parts are maintained at substantially the same potential by bonding, such as that, under fault conditions, the difference in potential between simultaneously accessible exposed and extraneous conductive parts will not cause electric shock. Bonding is the practice of connecting all accessible metalwork – whether associated with the electrical installation (known as exposed metalwork) or not (extraneous metalwork) – to the system earth.

In a building, there are typically a number of services other than electrical supply that employ metallic connections in their design. These include water piping, gas piping, HVAC ducting, and so on. A building may also contain steel structures in its construction. There is thus a possibility that a dangerous potential may develop between the conducting parts of non-electrical systems including building structures and the external conducting parts of electrical installations as well as the surrounding earth. This may give rise to undesirable current flow through paths that are not normally designed to carry current (such as joints in building structures) and also cause hazardous situations of indirect shock.

It is therefore necessary that all such parts are bonded to the electrical service earth point of the building to ensure safety of occupants. This is called equipotential bonding. There are two aspects to equipotential bonding: the main bonding where services enter the building and supplementary bonding within rooms, particularly kitchens and bathrooms.



Electrical Material

An electrical contractor is a business person or firm that performs specialized construction work related to the design, installation, and maintenance of electrical and communication systems.

An electrician is someone trained (and usually licensed) to perform electrical work. Electrical work is a highly technical profession that requires a thorough understanding of how electricity works and the materials and components used to deliver power, as well as electrical safety and standards.

An electrician can be employed by an electrical contracting firm or self-employed as an individual electrical contractor.

To organize an electrical estimate and efficiently order and supply the correct material needed for a job, electrical material is typically categorized.

NECA Categories of Work

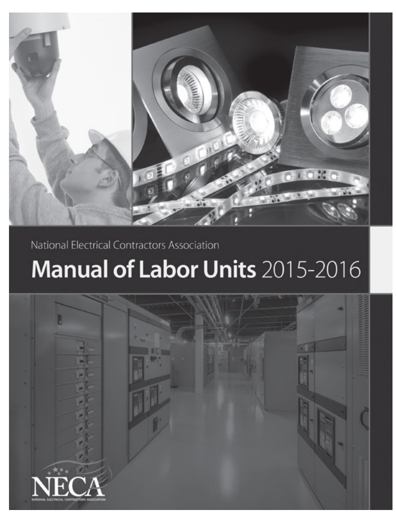
The NECA Manual of Labor Units divides electrical materials into 14 categories. Many electrical contractors use a different breakdown of electrical material for estimating purposes, but for training purposes only, students should use the following categories to breakdown their estimates.

SECTION	TITLE
01	Integrated Building Systems
02	Conduit, Raceways, Fittings, & Related Items
03	Wire, Cable, Lugs, Terminations, Busway & Bus Duct
04	Switchboards, MCC's, Panelboards, & Power Equipment
05	Lighting Fixtures, Poles, Parking Lot Lighting
06	Wiring Devices
07	Hazardous Systems
08	Grounding & Lighting Protection Systems
09	Heating Equipment Connections
10	Temporary Power & Lighting
11	Outdoor Overhead and Underground Systems
12	Equipment Installation and Connections
13	Industrial Control and Instrumentation
14	Alternative Energy Systems

Labor Units
E = One or per each item
C = Per hundred items
C = Per hundred linear feet of the item
M = Per thousand linear feet of the item
LF = Linear Foot
CY = Cubic Yard

Labor Units (Installation Conditions)

NECA 1	Normal N
NECA 2	Difficult D
NECA 3	Very Difficult VD



Section 01 - Integrated Building Systems

General Information

The labor units in this section are applicable for the installation of various IBS systems including: fire alarm, security, clock, sound, audio visual, signaling, nurse call, computer, telephone and television. In addition, this section contains components of structured cabling systems including fiber optic cable and terminations, UTP cable and terminations, various electronic cable and cable terminations and other premises cabling items. See Section 13 for temperature controls.

FIRE ALARM FIXTURE SCHEDULE

THIS IS A MASTER LEGEND AND NOT ALL SYMBOLS, ETC. ARE NECESSARILY USED ON THE DRAWINGS.

SYMBOL	DESCRIPTION	MANUFACTURER	PART NUMBER
FACP	FIRE ALARM CONTROL PANEL	BOSCH	FPD–7024
FAAP	FIRE ALARM ANNUNCIATOR PANEL	BOSCH	FMR–7033
	MULTI–CANDELA HORN/STROBE	SYSTEM SENSOR	P2W
WP	OUTDOOR HORN/STROBE	SYSTEM SENSOR	P2RK
	MULTI CANDELA STROBE	SYSTEM SENSOR	SW
	MANUAL PULL STATION	BOSCH	FMM–7045–D
RPS	POWER BOOSTER	BOSCH	D9142
15	MULTI–CANDELA HORN/ STROBE CEILING MOUNT	SYSTEM SENSOR	PC2W
15	MULTI–CANDELA STROBE CEILING MOUNT	SYSTEM SENSOR	SCW
	SMOKE DETECTOR	BOSCH	D7050
FS	WATERFLOW ALARM SWITCH	SYSTEM SENSOR	WFD
VT	CONTROL VALVE TAMPER SWITCH	SYSTEM SENSOR	OSY2/PIV2
RD	DUCT MOUNTED SMOKE DETECTOR	PROVIDED BY OTHERS	
RT	REMOTE TEST STATION	PROVIDED BY OTHERS	
K	KNOX BOX	PROVIDED BY OTHERS	

Section 02 Conduit, Raceways, Fittings, & Related Items

General Information

This section includes labor units for conduit, conduit fittings, conduit bending, boxes, enclosures, surface metal raceways, underfloor duct, cable trays, anchors, fasteners, supports, fireproofing material and related items.

Electrical conduits are used to protect and provide the route of electrical wiring. Electrical conduits (ECs) are made of metal, plastic, or fiber and can be rigid or flexible. The National Electric Code (NEC) sets standards for the installation for conduits and other raceways.

Common Types of Conduit

Steel Conduits

Steel conduit has been in use as a “raceway system” for electrical conductors since the early 1900s. The strength of steel makes galvanized steel rigid conduit, intermediate metal conduit and electrical metallic tubing the wiring methods recognized as providing superior mechanical protection to the enclosed wire conductors. Additionally, a properly installed metal raceway system is recognized by the National Electrical Code® (NEC) as an equipment grounding conductor. The basic types of steel raceways in use today are steel rigid metal conduit (RMC), intermediate metal conduit (IMC) and electrical metallic tubing (EMT).

Rigid Metal Conduit (RMC)

Steel RMC has the thickest-wall of the steel raceways. It is available with either a straight-tapped or integral coupling. Galvanized Steel RMC may have a primary coating of zinc on the exterior and interior of the conduit; a combination of zinc and nonmetallic coating are also permitted. Supplementary coatings can be applied for additional corrosion protection.

Electrical Code Compliance

The National Electrical Code® Article 344 covers rigid metal conduit, which includes galvanized and stainless steel, aluminum and red brass. Steel RMC is permitted in all atmospheric conditions and occupancies. The listing label for this product will be identified with one of the following: “Electrical Rigid Metal Conduit” or “ERMC-S”.

RMC Trade Sizes

RMC is available in trade sizes 1/2 through 6, and 10′ and 20′ lengths. RMC is threaded on both ends, with a coupling applied to one and a color-coded thread protector on the other. The industry-established color-coded thread protectors aid in product and trade size recognition. Thread protectors for trade sizes 1, 2, 3, 4, 5 and 6 are color coded blue; trade sizes 1/2, 1 1/2, 2 1/2 and 3 1/2 are black; and trade sizes 3/4 and 1 1/4 are red.

Steel RMC Corrosion Protection

A variety of coating options are available to protect galvanized steel RMC against corrosion. ERMC-S is provided with zinc, zinc-based, nonmetallic, or other alternate corrosion-resistant exterior coating and an organic or zinc interior coating.

Other Trade Names

Galvanized Rigid Conduit (GRC)

Galvanized Rigid Steel (GRS)

Intermediate Metal Conduit (IMC)

IMC was developed in the 1970s as a thin-wall alternative to rigid metal conduit (RMC) that weighs about one-third less. IMC ships with either a straight-tapped or integral coupling. It features a galvanized OD and corrosion-resistant ID coating.

Electrical Code Compliance
IMC is covered under Article 342 in the NEC®.

IMC Sizing
IMC is available in trade sizes 1/2 through 4, and 10′ lengths. Threads on the uncoupled end are covered by industry color-coded thread protectors to protect the threads, keep them clean and sharp, and aid in trade size recognition. Thread protectors for trade sizes 1, 2, 3 and 4 are color-coded orange; trade sizes 1/2, 1 1/2, 2 1/2 and 3 1/2 are yellow; and trade sizes 3/4 and 1 1/4 are green.

Using IMC as a Substitute for RMC
IMC is interchangeable with galvanized RMC. Both have threads with a 3/4-inch-per-foot taper, use the same couplings and fittings, have the same support requirements and are permitted to be used in the same locations.

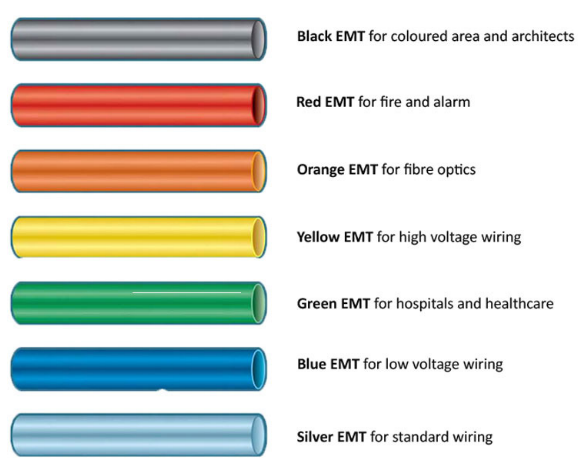
Electrical Metallic Tubing (EMT)

Electrical metallic tubing (EMT), also commonly called thin-wall, is a listed steel raceway of circular cross section, which is unthreaded, and nominally 10′ long. 20′ lengths are also available. Covered by Article 358 of the NEC, EMT is available in trade sizes 1/2 through 4. The outside is galvanized for corrosion protection and the inside has an approved corrosion-resistant organic coating.

EMT is installed by use of set-screw or compression-type couplings and connectors. It is permitted to have an integral coupling comprised of an expanded, “belled” shape tube on one end with set screws. EMT with integral couplings is available in trade sizes 1-1/4 through 4.

Electrical Code Compliance
EMT is covered by Article 358 of the NEC®.

EMT Sizing
EMT is available in trade sizes 1/2 through 4, and 10′ and 20′ lengths. Some manufacturers also produce EMT in a range of colors for easy system identification.



Rigid Aluminum Conduit (RAC)
Rigid aluminum conduit provides lightweight, nonmagnetic wiring solutions for dry, wet, exposed, concealed or hazardous locations that comply with the National Electric Code® (NEC).

Aluminum Rigid Conduit shall be supported at least every 10 feet and within 3 feet of each outlet box, junction box, cabinet, or fitting, except for straight runs of conduit connected with couplings which may be supported in accordance with NEC Table 344.30 (B)(2), provided such supports prevent transmission of stresses to termination where conduit is deflected between supports.

Flexible Steel Conduit (FSC or Greenfield)
When you decide to use "Greenfield" on the job you are really dating yourself, so I would just call it "flex". It was invented in 1902 by Harry Greenfield and Gus Johnson and when it was listed by Sprague Electric Co. it was called "Greenfield flexible steel conduit".

Today the term "Greenfield" is commonly used for all FMC (flexible metal conduit-NEC Art. 348). FMC is also manufactured in both aluminum and steel.

The NEC defines FMC as "A raceway of circular cross section made of helically wound, formed, interlocked metal strip."

Liquidtight Flexible Steel Conduit (LFSC)
Sealtite Flexible Conduit
Liquid Tight Flexible Steel Conduit is designed to hold power, control and communications cables in dry, wet or oily locations.

The conduit is constructed from a zinc coated galvanized low carbon steel strip with a uniform width and thickness.

A rugged flame retardant and moisture, oil and sunlight resistant polyvinyl chloride (PVC) jacket covers the metal conduit.

Other colors available include grey, black, red, orange, yellow and green.

PVC Coated Rigid Steel Conduit
PVC coated galvanized rigid conduit with urethane interior coating protects conductors from mechanical damage and corrosive attack. Electrical continuity is maintained across assembled joints.

Plastic Conduits

Rigid PVC pipe, electrical nonmetallic tubing (ENT), and liquid-tight flexible nonmetallic conduit (LFNC) are the most likely plastic conduits to be found in a residential, commercial, and industrial installations.

Because it's approved for direct burial and—if it's a schedule-80 pipe—can be used to meet the NEC's requirement for "protection from physical damage," rigid PVC is run in most new underground service entrances to the electricalmeter enclosure.

Sizes range from ½ in. dia. to 3 in. dia. for common residential applications. Rigid PVC is inexpensive; can be worked easily without expensive tools; and can be used in walls, outside in the sun, and underground. Connections are made with PVC glue. Rigid PVC can become brittle in cold weather, so check manufacturers' acceptable temperature ranges.

PVC Rigid Conduit

The Most Common of All Electrical Conduits

PVC is the lightest conduit material and usually the most affordable type of conduit. PVC pipes can vary in thickness depending on the uses and where the PVC will be installed.

The PVC conduit resists moisture and corrosion but the tubing is non-conductive an extra grounding conductor must be passed into each conduit.

PVC conduit has a higher thermal coefficient of expansion allowing the conduit to expand and contract. Installing PVC underground in multiple or parallel run configurations, mutual heating might cause problems on cable performance.

PVC Conduit: Schedule 40 vs. 80

Schedule 40 PVC conduit is cheaper and has a larger inside diameter, so it's easier to pull wires through it. The plastic on Schedule 80 is thicker, but the conduit has the same outside diameter as 40, so the inside diameter is smaller. Always install Schedule 80 conduit in high-traffic areas or any other areas where it could get damaged, like behind a woodpile. The fittings (such as adapters and turns) are the same for Schedule 40 and 80.

Electrical Non-Metallic Flexible Tubing (ENT)
ENT, or “Smurf tube” (nicknamed because of its light-blue color), is a corrugated, flexible PVC plastic tubing used mostly for dry interior work or in certain places, such as a basement or crawlspace, where moisture exists on the interior of a building.

ENT is easier to install than rigid PVC, although it and its fittings are about twice the price. However, not all jurisdictions allow for residential wiring with ENT, and there are some places in a house where it cannot be installed—for example, it can’t be used for exposed work, and with a few exceptions, it needs to be protected from physical damage. However, it can be encased in concrete and within slabs when the appropriate fittings are used, making it a viable choice for roughing in kitchen islands on a slab.

Fiberglass Conduit
The demand for fiberglass conduit in the United States alone has been growing significantly over the last two decades and is forecasted to increase further as project owners and engineers seek to serve long-term interests of their stakeholders.

One of the benefits of fiberglass conduit is that it will not melt or weld the wire to the inside of the conduit under fault conditions as can happen with PVC, steel and aluminum conduit.

Total installed longevity, faster installation time, less expensive installation costs, lightweight, are a few reasons why it is advantageous to use fiberglass conduit vs. PVC coated conduit.

Liquidtight Non-Metallic Flexible Tubing (LNT)
For use in situations that call for a liquid-tight conduit that is able to withstand vibration, movement, oil and corrosives. Perfect for indoor/outdoor lighting, water treatment systems and HVAC equipment.

Easy to install and cuts easily.

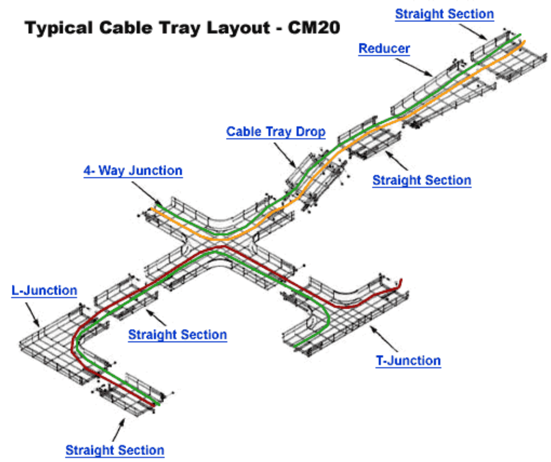
Approved for direct burial and in concrete trade sizes 3/8” through 2”

Other Raceways

Surface Metal Raceways
Nonmetallic Surface Raceways
Metal Wireway
Underfloor Duct
Trench Duct

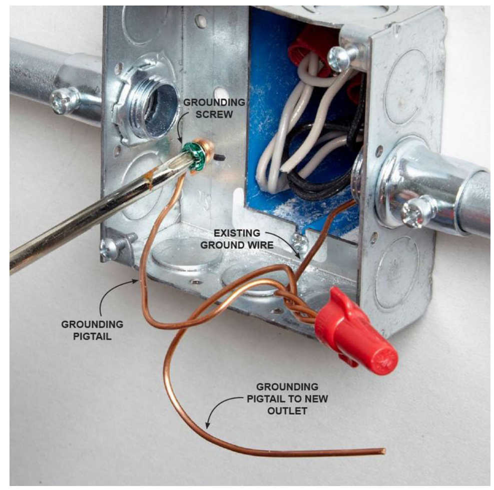
Cable Tray

Steel
Aluminum
Fiberglass



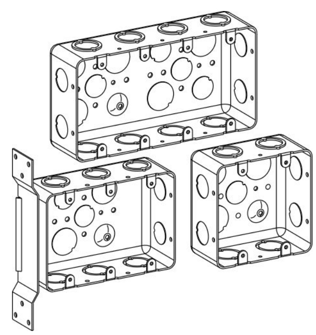
Metal Boxes

Metal boxes are typically used with metal raceway mainly as a place to pull wires, splice wires, and install devices. The types of available boxes are their applications are numerous. For example, a 4-inch square metal box with knockouts (concentric circles that can be removed for installing conduit) is used extensively for installing power devices - receptacles and lighting devices - switches, and as a back box for light fixtures and fire alarm devices. Metal boxes come in a variety of shapes: square, octagon, and round.



Depending on the installation other accessories may be required such as, mudrings (p-ring), extension rings, barhangers, covers, blank plates, connectors, and wire nuts.

Gang is used to describe the number of devices housed inside the box. 1-Gang Box will house one device, a 2-Gang Box will house two devices, etc.



Masonry, weatherproof, utilty (handy box), and ceiling fan are just a few of the varieties available.

Pull/Junction Boxes are large enclosures that are used to splice large conductors, as a place to pull wires, and to house electrical controls.

Cast boxes are often used in hazardous locations where ignitable gases, dusts, or fibers are present. Explosion-proof boxes can prevent an arc inside the box from escaping and igniting combustible material. Cast boxes are sometimes referred to as hub boxes because they have threaded hubs for connecting metal conduit.

Plastic Boxes

Nonmetallic boxes are typically used with nonmetallic sheathed cable or nonmetallic raceways. They come in many different shapes and types depending on the application.

Section 03 Wire, Cable, Lugs, Terminations, Busway and Bus Duct

General Information

This section includes labor units for building wire, power cable plenum cable, control cable, tray cable, undercarpet cable, lugs, stress relief cones, pot heads, cable terminators, busway and bus duct.

Building Wire

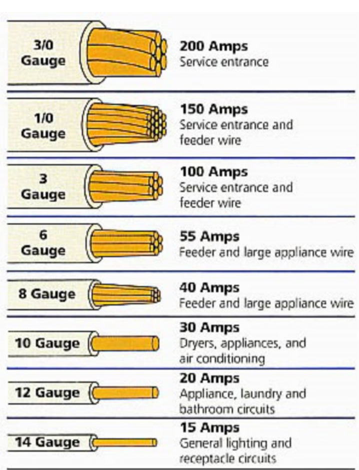
A wire is an electrical conductor made from a conductive material like copper or aluminium that is covered with a protective insulation to prevent contact with other conductors or objects. If the wire is bare it is being used as a grounding wire.

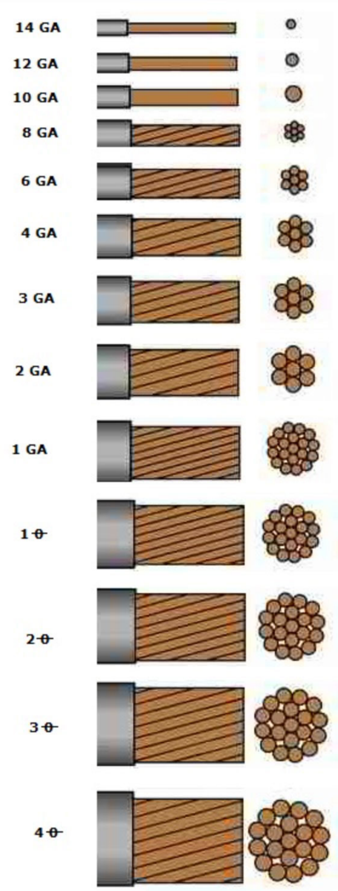
Single-conductor wire can be either solid or stranded. Solid wire consists of a single strand or core of wire that is insulated with non-conductive material. Typically you will find solid core wire in situations where the wire is not designed to be continuously flexed (i.e. your house electrical wiring, wires for breadboards, etc.)

Stranded wire consists of a bundle of small gauge wires compressed and insulated with non-conductive material. Typically you will find stranded wires in situations where the wire needs to be routed through tight spaces or experiences frequent flexing/vibration (i.e. headphone cables, speaker wire, automotive wire, appliance cables, etc.)

The AWG - American Wire Gauge - is used as a standard method denoting wire diameter, measuring the diameter of the conductor (the bare wire) with the insulation removed. AWG is sometimes also known as Brown and Sharpe (B&S) Wire Gauge.

The higher the number - the thinner the wire. Typical household wiring is AWG number 12 or 14. Telephone wire is typical AWG 22, 24, or 26.





WIRE TYPE	THHN/THWN-2 – Polyvinylchloride (PVC)	XHHW-2 – Cross-Linked Polyethylene (XLPE)	
Wire Insulation	Thermoplastic	Thermoset	
Minimum Installation Temp°C	-10°C (14°F)	-40°C	BEST
Emergency Overload Temp°C	105°C	130°C	BEST
Maximum Short Circuit Temp°C	150°C	250°C	BEST
Insulation Resistance after 12 wks (Meg Ω – 1000 ft.)	0.85	105,250	BEST

<u>THHN Wire</u>

T Thermoplastic
HH Hot Hot (90 degrees Celcius)
N Nylon Outer Covering

<u>XHHW-2</u>

X Cross Linked Polyethelyne
HH Hot Hot (90 degrees Celcius)
W Wet Locations
-2 90 degrees wet or dry locations

<u>RHW</u>

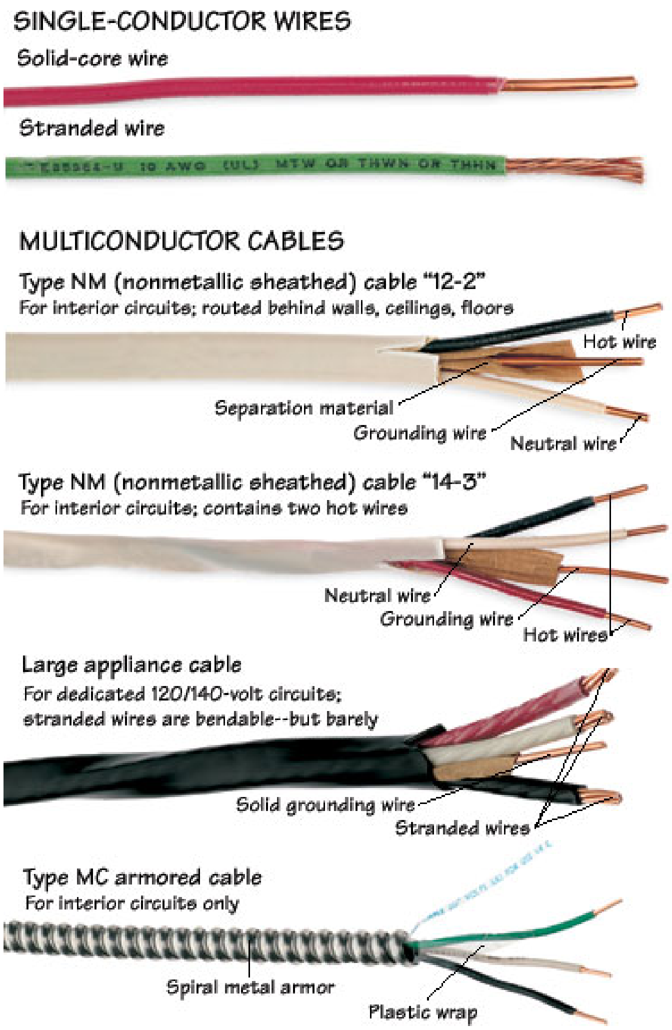
R Rubber
H Hot (75 degrees Celcius)
W Wet

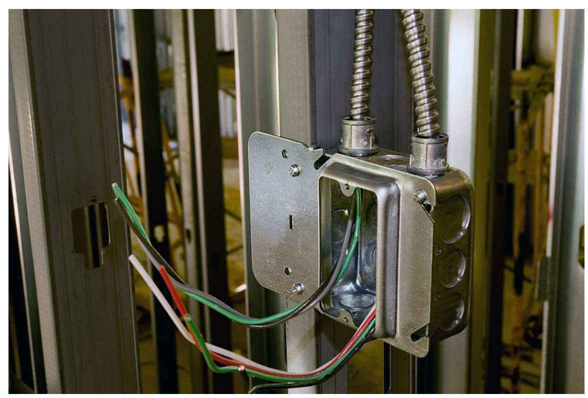
Cable

Cable is a group of two or more wires wrapped in a nonmetallic sheath (NM) or an armored or metal clad (AC, MC) protective flexible housing. Cable is both the conductor “wire” and the sheath “conduit” fabricated together. Installation is typically faster than installing conduit “pipe” and conductors “wire” since once installed, no additional labor is required to pull the wires through the housing.

There are many different types of cable available to meet various installation requirements. Indoor, outdoor, and direct burial are just a few options.

The most common cable used in residential installations is Romex®. The Romex® brand of Non-Metallic Building Wire (“NM”) originated in 1922 with its development by the former Rome Wire Company, a predecessor to General Cable Corporation.





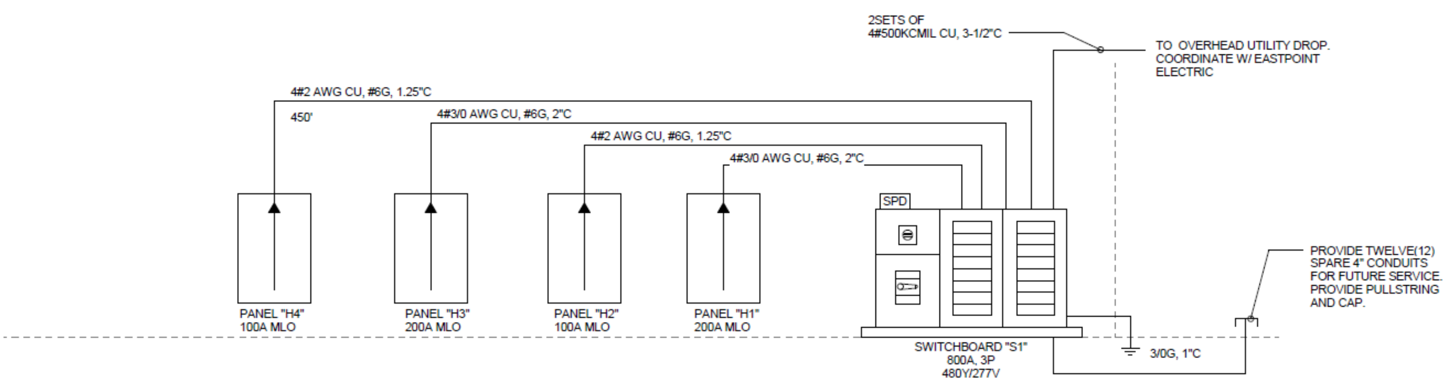
General Information

Several pages in this section contain labor units for handling electrical equipment and exclude the labor for conductor terminations. The labor for conductor terminations must be added separately for these items. When labor units in this section do include the conductor terminations, the labor units are based on the minimum sizes of copper conductors allowed by the National Electrical Code.

Electric Power Distribution System

The function of the electric power distribution system in a building or an installation site is to receive power at one or more supply points and to deliver it to the lighting loads, motors and all other electrically operated devices. The importance of the distribution system to the function of a building makes it imperative that the best system be designed and installed.

Switchboards, Motor Control Centers (MCC’s), and panelboards are electrical assemblies that make up the buildings electric power distribution system. Power system designers communicate their design requirements through a combination of drawings, schedules and specifications. One of the key tools in developing and documenting an electrical power system is the System One-Line (also called a Single Line Diagram). This drawing starts with the incoming power source from the utility service and/or on-site generation and their associated distribution equipment. It then follows the power flow down through the various conductors as well as any voltage transformations to feed distribution equipment buses for the key loads served.



1 ELECTRICAL RISER DIAGRAM
12" = 1'-0"

ANSI and IEEE voltage classes

ANSI and IEEE standards define voltage classifications as follows:

- Low voltage: up to 600V
- Medium voltage: between 600V and 69 kV
- High voltage: between 69 kV and 230 kV
- Extra-high voltage and ultra-high voltage classes are also defined in the ANSI/IEEE standards; however, NEC 2014 expanded the definition of low voltage to include up to 1,000V.

Medium voltage switchgear is classified by the maximum voltage it can service. For example, 15 kV switchgear (maximum voltage rating) is commonly applied at various actual voltages including: 12.47 kV, 13.2 kV, 13.8 kV and 14.4 kV.

National Electric Code (NEC)
Artical 100 - Definitions

Switchboard. A large single panel, frame, or assembly of panels on which are mounted on the face, back, or both switches, overcurrent and other protective devices, buses, and usually instruments. These assemblies are generally accessible from the rear as well as from the front and are not intended to be installed in cabinets.

Switchgear. An assembly completely enclosed on all sides and top with sheet metal (except for ventilating openings and inspection windows) and containing primary power circuit switching, interrupting devices, or both, with buses and connections. The assembly may include control and auxiliary devices. Access to the interior of the enclosure is provided by doors, removable covers, or both.

> Informational Note: All switchgear subject to NEC requirements is metal enclosed. Switchgear rated below 1000 V or less may be identified as "low-voltage power circuit breaker switchgear." Switchgear rated over 1000 V may be identified as "metal-enclosed switchgear" or "metal-clad switchgear." Switchgear is availble in non-arc-resistant or arc-resistant constructions.

Motor Control Center. An assembly of one or more enclosed sections having a common power bus and principally containing motor control units.

Panelboard. A single panel or group of panel units designed for assembly in the form of a single panel, including buses and automatic overcurrent devices, and equipped with or without switches for the control of light, heat, or power circuits; designed to be placed in a cabinet or cutout box places in or against a wall, partition, or other support; and accessible only from the front.

Section 05 – Lighting Fixtures, Poles, Parking Lot Lighting

General Information

This section includes labor units for the installation of incandescent fixtures, metal halide, multi-vapor HID indoor and outdoor fixtures, fluorescent fixtures, LED fixtures, exit fixtures, chandeliers, showroom, stage and auditorium fixtures, airport lighting fixtures and parking lot lighting.

Light Fixtures

The appropriate type of light fixture required depends on several factors; where it is installed, purpose for lighting the area, cost, and other considerations. Most lighting designers categorize lighting fixtures into three types: ambient, task, and accent.

Ambient light is fundamental light that brightens up a whole area. A ceiling light fixture is an excellent example of normal lighting. An ambient light fixture may usually be able to handle light bulbs with larger wattages than process or accent accessories.

Task lighting is the lighting you utilize to do tasks, hence the name! A desk lamp is just a excellent example of the task light installation as it can be used especially to do work. Activity lighting tends to be focused on small areas such as for example end tables or desks but does provide a small number of ambient lighting.

Accent lighting is just as the name implies used to provide feature illumination. A light fixture employed for accent lighting won't be bright enough to provide sufficient background or task lighting. This sort of light is used to display artwork or to enhance the atmosphere of any room.

Fixture Lamp Types

A light fixture or luminaire is a technical and professional term for the electrical fixtures used to hold a lamp—a light bulb—the light source.
Incandescent (INC)
Halogen
Fluorescent (FL)
High Intensity Discharge (HID)
Light Emitting Diode (LED)

Vintage LED filament light bulb

Fixture Mounting Methods

Troffer

A troffer is a rectangular or square light fixture that fits into a modular dropped ceiling grid (i.e. 2' by 2' or 2' by 4').

Troffer fixtures have typically been designed to accommodate standard fluorescent lamps (T12, T8, or T5), but are now more commonly designed with integral LED sources. Also referred to as Lay-in fixtures or recessed fluorescent.

Surface

Surface mounted fixtures are usually mounted indoors on ceilings and walls and outdoors on the exterior of buildings.

Suspended

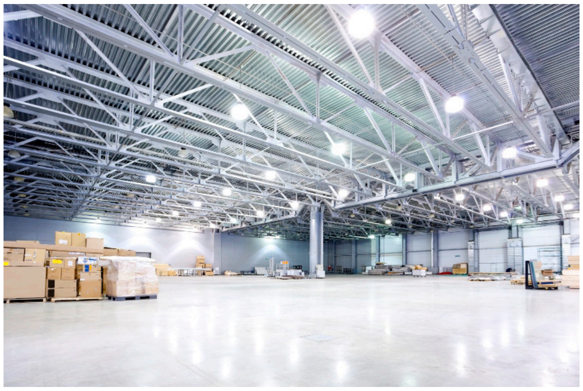
Fixtures can be suspended by pendant, stem, aircraft cable, swival and canopy, wire, chain, cable, cords, or other similar methods.

Recessed

Flush mounted fixtures are recessed into surfaces such as gypsum board or hard lid ceilings. When installed they are flush with the surface and blend in with the surroundng area. Round recessed lights are called downlights or can lights.

High-Bay

High bay lighting fixtures are designed for applications of 20 feet or more. A wide range of indoor lighting fixtures provide specific light patterns for high bay lighting applications, including maintenance lighting, warehouse lighting, recreation center lighting, hangar lighting and storage lighting.



Low-Bay

Used to light areas with lower ceilings 20 feet or less. Low bay lighting options have diffusers at the bottom of the fixtures. These diffuse the light, cutting down on the harsh reflections that lower ceilings can cause. The result is a more natural, pleasing light in rooms with low ceilings. The applications for this technology are endless, and they are the perfect option for any tight space.

Section 06 – Wiring Devices
General Information

The labor units in this section include the installation of the wiring device in a box already in place and the termination of copper conductors on the wiring device. The labor units for wiring devices which are factory mounted in enclosures include the installation of the enclosure and the termination of copper conductors. When aluminum conductors are terminated on wiring devices the labor units in this section must be increased.

Devices

Device. A unit of an electrical system that carries or controls electric energy as its principal function. NEC 100. The most common example of devices used everyday are switches and receptacles.

Devices are typically selected based on the rated amperage and voltage. Exceeding either of these values can lead to early failure or a potential hazard.

Receptacle outlets are available in a number of options: general-purpose grade, specification (spec) grade, and hospital grade as well as a few others. The National Electrical Manufacturers Association (NEMA) has created standards that receptacles and plugs are built to.

Tamper-resistant and weather-resistant receptacles are designed for specific locations.

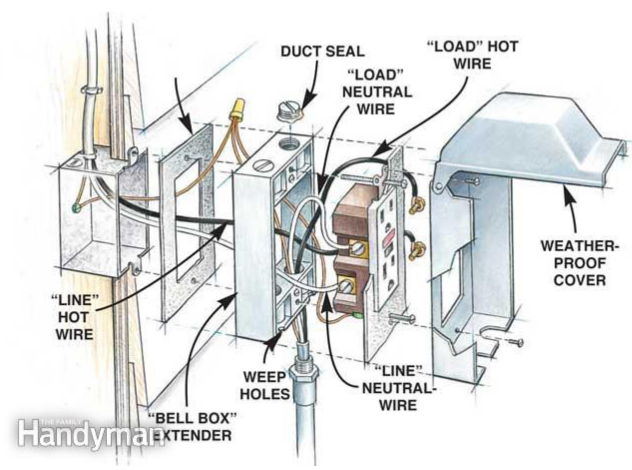
GFCI receptacles provide ground-fault circit interruption. Class A GFCA devices will open the circuit if a groud fault of 4-6 milliamperes or more occurs. GFCI receptacles are less expensive than GFCI circuit breakers. NEC 210.8 lists the locations that are required to have GFCI protection, such as bathroom and kitchen outlets near water.

15A, 120V
General-Purpose

20A, 120V
Spec Grade

20A, 120V
Hospital Grade

20A, 120V
GFCI



Switches

Switches open and close electrical circuits, allowing power to flow through lights and appliances. The switch used should match the amperage and voltage for the circuit they serve. Switches designated "CU-AL" are compatible for both copper and aluminum wiring. Be sure to select compatible switches, otherwise, they can present a fire hazard.

The simplest and most common switch is a Single Pole Single Throw Switch (SPST) used frequently for controlling lights. Flipping the switch up completes the circuit, turning lights or appliances on, and flipping it down breaks (opens) the circuit, turning the lights or receptacle off. A single-pole switch has two brass terminal screws on the side that receive the black and white wires of the circuit. (The number of terminal screws identifies the type of switch.) Modern single-pole switches also have a green grounding screw (not shown) that connects to the circuit's ground wire.

A switch that can operate hallway lights from either end of the hallway is called a three-way switch ; it has an extra terminal.

Occupancy Sensors

- A occupancy sensor automatically turns the lights ON upon detection of motion and turns the lights OFF automatically after the area is vacated
- Occupancy sensors may offer the option to switch the sensor from automatically turning the lighs ON to requiring manual button press from the occupant (Manual/Vacancy Mode)

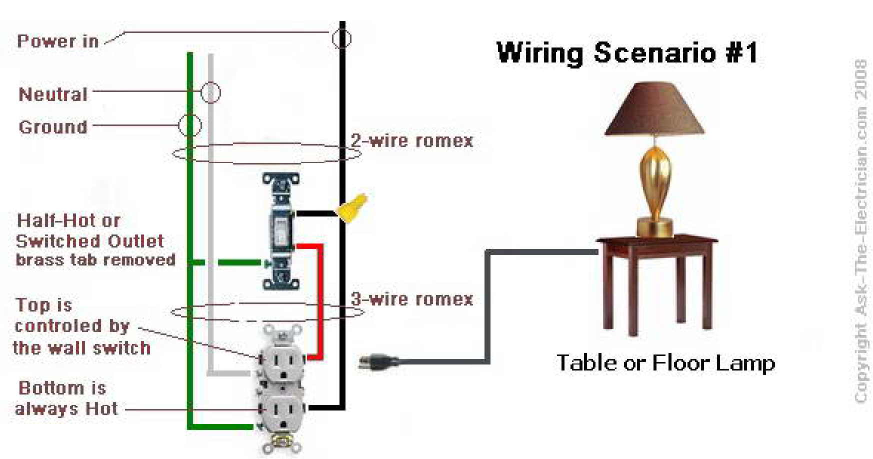
Vacancy Sensors

- A vacancy sensor requires manual activation of the lights by the occupant, then turns the lights OFF automatically soon after the area is vacated
- A vacancy sensor does not offer an option of automatically turning the lights ON

Why would I use a Vacancy over an Occupancy Sensor?

- ASHRAE 90.1-2010 and many other codes no longer permit the entire space to be switched on automatically upon occupancy. Automatic ON is only allowed for up to 50% of the controlled load. This requires a sensor that allows for Manual On capability for some or all of the load. For most applications, an occupancy sensor will meet this requirement as long as it allows for dual zone control and manual switch interface.
- New York City Energy Code LL48/2010 states that where occupancy sensors are required, occupancy sensors cannot have an onboard override switch that converts from Manual On to Automatic On functionality. In New York City, vacancy sensors must be used to meet this requirement when used as a stand-alone solution.

Other types of switches:
4-way Switch
Dimmer Switch
Occupancy Sensor
Time Clock



Section 07 – Hazardous Systems

General Information

The labor units in this section are applicable for hazardous location electrical systems more commonly referred to as explosion proof equipment. See Section 2 of this manual for metal conduit and fastener labor units.

OSHA Publication 3073 defines a hazardous location as follows:
Hazardous locations are areas where flammable liquids, gases or vapors or combustible dusts exist in sufficient quantities to produce an explosion or fire. In hazardous locations, specially designed equipment and special installation techniques must be used to protect against the explosive and flammable potential of these substances.

The National Electrical Code (NEC) and the Canadian Electrical Code (CEC) defines hazardous areas as the following:
An area where a potential hazard (e.g., a fire, an explosion, etc.) may exist under normal or abnormal conditions because of the presence of flammable gases or vapors, combustible dusts or ignitable fibers or flyings.

Hazardous locations can also be described as those locations where electrical equipment might be installed and which, by their nature, might present a condition which could become explosive if the elements for ignition are present. Unfortunately, flammable substances are not always avoidable, e.g., methane and coal dust in mines. Therefore, it is of great importance that a user of electrical equipment, such as push buttons and pilot lights, be aware of the environment in which these products will be installed. The user’s understanding of the hazard will help ensure that the electrical equipment is properly selected, installed and operated to provide a safe operating system.

Area Classification

Area classification methods provide a succinct description of the hazardous material that may be present, and the probability that it is present, so that the appropriate equipment may be selected and safe installation practices may be followed. It is intended that each room, section, or area of a facility shall be considered individually in determining its classification. The hazardous location areas take into account the different dangers presented by potentially explosive atmospheres. This enables protective measures to be taken which account for both cost and safety factors.

Class Definition

The NFPA Publication 70, NEC, and CEC define three categories of hazardous materials that have been designated as Class I, Class II, or Class III. The Classes define the type of explosive or ignitable substances which are present in the atmosphere such as:

- Class I locations are those in which flammable vapors and gases may be present.
- Class II locations are those in which combustible dust may be found.
- Class III locations are those which are hazardous because of the presence of easily ignitable fibers or flyings.



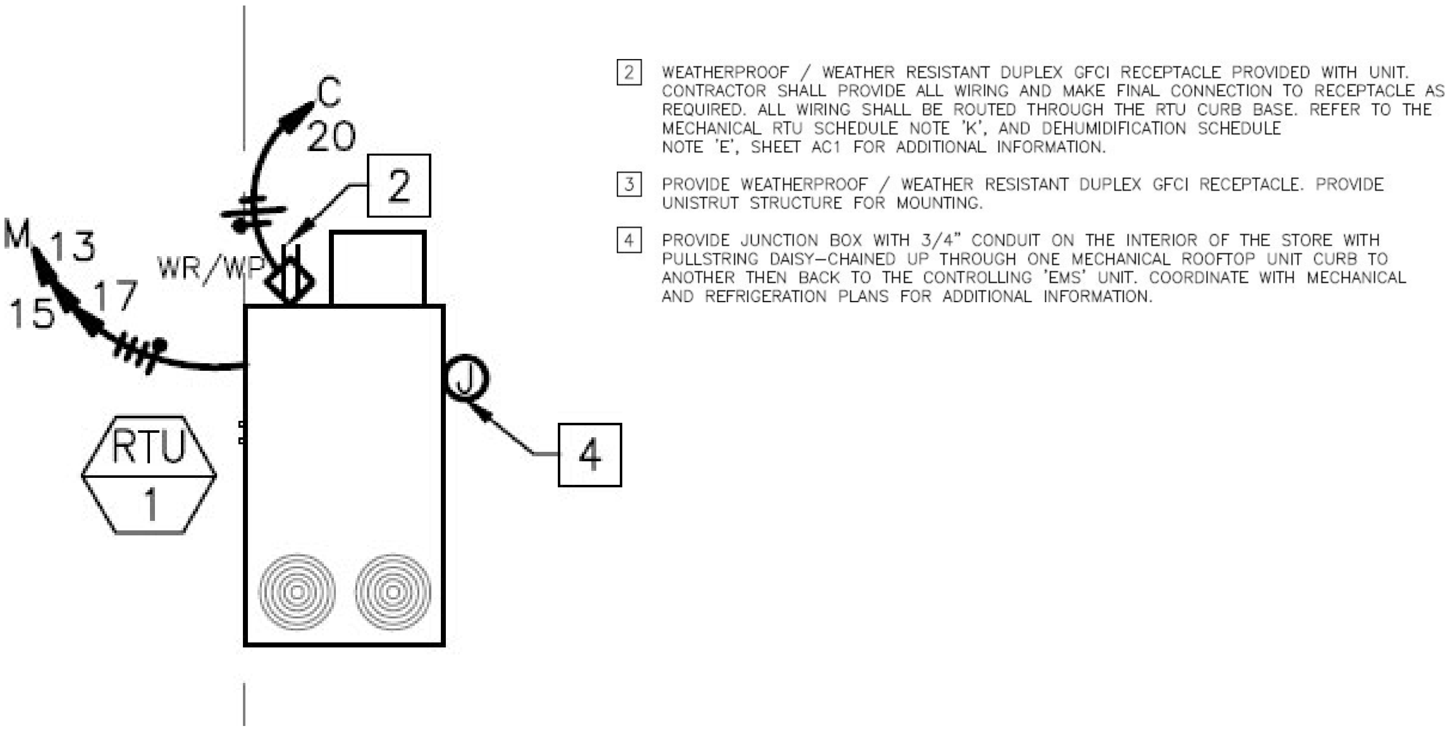
Section 08 – Grounding and Lightning Protection Systems
General Information
The labor units in this section are applicable for the installation of exposed indoor grounding systems and outdoor buried grounding systems. These labor units do not include the excavation or backfilling for outdoor grounding systems.

What is a Cadweld?
The CADWELD® process is a method of making electrical connections of copper-to-copper or copper-to-steel in which no outside source of heat or power is required. In this process, conductors are prepared, placed in a purpose-designed graphite mold, and exothermically welded to produce a permanent electrical connection.

https://www.youtube.com/watch?v=GRc8X5nfPNM

Section 09 – Heating Equipment Connections
General Information

The labor units in this section are applicable for the installation of electrical heating equipment and their controls. A separate labor unit table is included for the power conductor termination labor on other heating, ventilating, air conditioning and related items not listed in this manual. For electric motor conductor termination labor units, see Section 12.



Section 10 – Temporary Power and Lighting

General Information

The labor units in this section are applicable for the installation of temporary 600-volt power services and temporary lighting. For electric motor conductor termination labor units see Section 12 in this manual. The labor units for temporary portable electrical equipment in this section do not include the labor to fabricate or assemble the portable equipment. The labor units for temporary lighting, temporary receptacle outlets and temporary extension cords do not include labor to service, inspect, or maintain these items.

Section 11 – Outdoor Overhead and Underground Systems

Section 11 (A) – Outdoor Overhead and Underground Systems

General Information

The labor units within Section 11 are intended for inside electrical contractors installing overhead and underground electrical systems permitted by their craft jurisdiction. The labor units within Section 11 (A) are applicable for electrical inside and line contractors installing up to and including 35 KV overhead or underground electrical power systems, if trained and certified with these medium voltage systems.

Section 12 – Equipment Installation and Connections
General Information
The labor units in this section include installing and terminating power equipment, variable frequency drives, DC drives, motors, fixed and adjustable motor bases and similar equipment.

Section 13 – Industrial Control and Instrumentation

General Information

The labor units in this section include installing and terminating control and instrumentation equipment including temperature control cabinets and devices.

Section 14 – Alternative Energy Systems

General Information

This section includes labor units for installing and terminating generating equipment and the related controls and instrumentation, including photovoltaic modules, wind turbines, gas fired cogeneration and fuel cell technologies.