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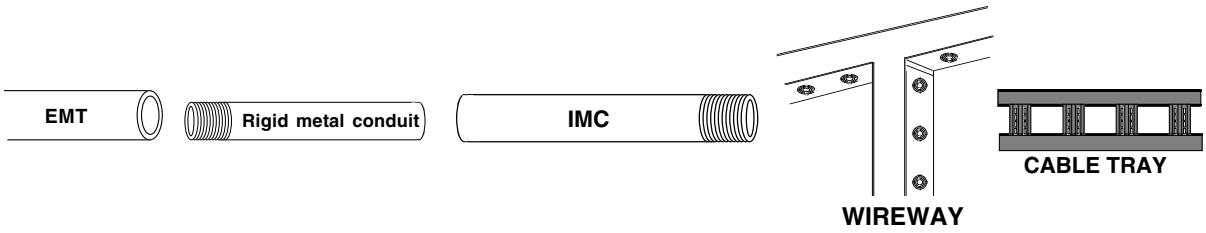
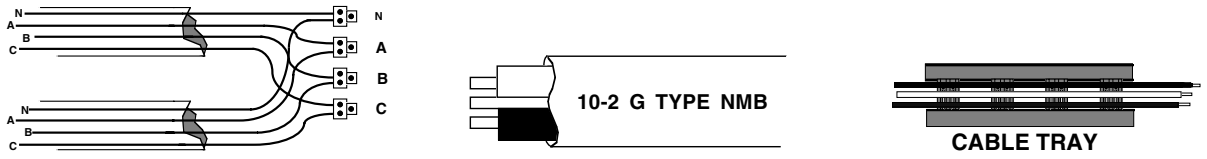
300.2(B). Temperature limitation of conductors shall be in accordance with 310.14(A)(3). Section 310.14(A)(3) states that no conductor shall be used in such a manner that its operating temperature will exceed that designated for the type of insulated conductor involved.

300.3(A). This article requires that single conductors shall be installed using a recognized wiring method in Chapter 3.

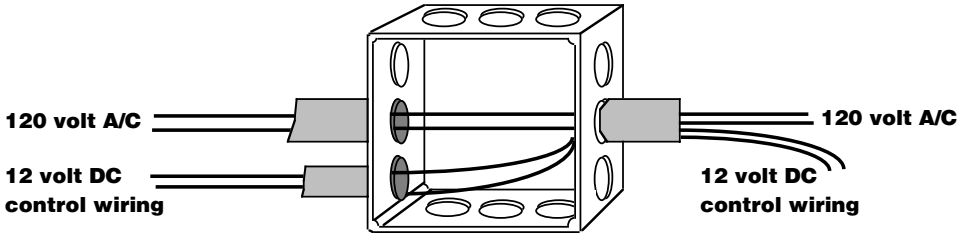


300.3 (B). All conductors including the neutral if used and the grounding conductor must be installed in the same raceway, cable, cable tray or trench.

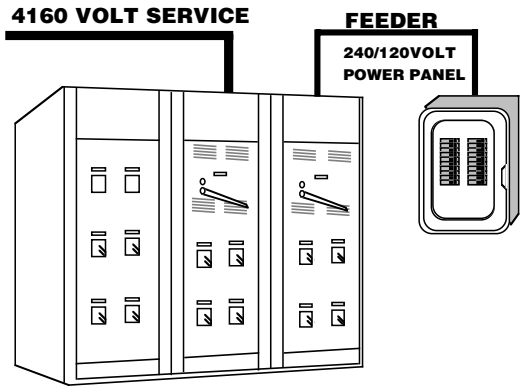


300.3(B)(3). Warns against the need for preventing induced currents where nonmetallic or nonmagnetic sheathed conductors are run through metallic walls or ceilings as in 300.20(B).

300.3(C)(1). With the exception of solar photovoltaic systems (690.31(B), the conductors of different systems such as direct current and alternating current 1000 volts or less may be installed in the same raceway, cable, or wiring enclosure if all of the conductors have an insulation rating at least equal to the highest voltage of any conductor.



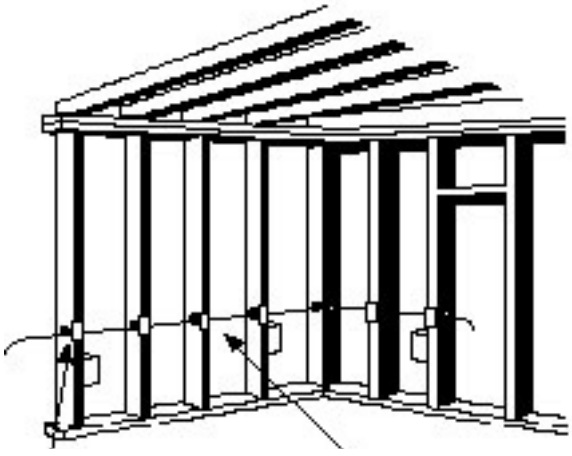
300.3(C)(2). This section prevents circuits rated over 1000 volts from being installed in the same raceway, cable, or wiring enclosure with circuits rated 1000 volts or less.



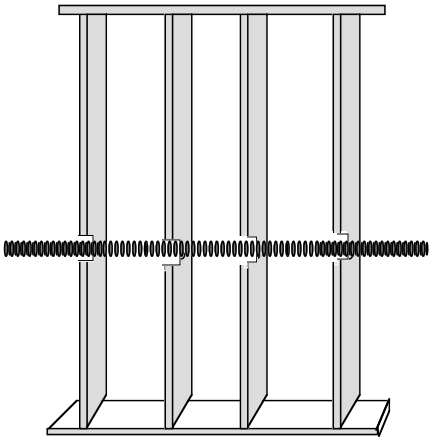
CONDUCTORS IN THE SAME ENCLOSURE WITH INTERNALLY MOUNTED TRANSFORMER

300.4. Protection from physical damage is required for conductors, raceways, and cables.

300.4(A)(1). This section requires that the outer edge of bored holes for cables or conduit be no more than 1 1/4 inches from the outer edge in wooden joists, rafters, studs or other wood members. In a standard 2" x 4" stud this in most cases is not possible, so a provision is made for protection to prevent nails or screws from damaging the conductors to be installed if the hole is less than 1 1/4 inches from the outer edge. This protection can be a steel plate at least 1/16 inch thick, a bushing must be used in steel studs, and the protection must be of the appropriate length and width to cover the area of the wiring.



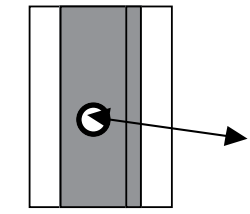
NAIL PLATES INSTALLED TO PREVENT SCREWS OR NAILS FROM DAMAGING THE CONDUCTORS



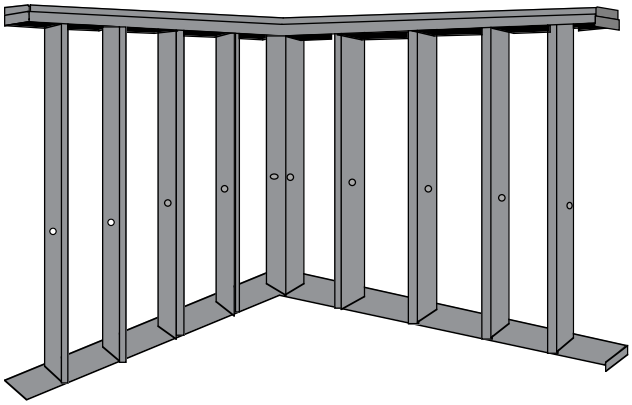
CONDUCTORS OR FLEXIBLE NON-METALLIC CONDUIT MAY BE LAID IN NOTCHES BUT STEEL PLATES MUST BE INSTALLED TO PROTECT FROM PHYSICAL DAMAGE.

300.4(A)(2) Conduit or cable is permitted to be laid in notches in wood studs, joists and rafters if protected by steel nail plates at least 1/16 inch thick and the notches do not cause any weakening.

300.4(B)(1) When steel framing members are used, nonmetallic sheathed cable is allowed to be installed through either factory or field punched holes. A bushing or grommet must be installed in the hole to protect the cable from damage that may be caused by the sharp edges.



RUBBER GROMMET OR BUSHING MUST BE INSTALLED TO PREVENT DAMAGE TO CABLE

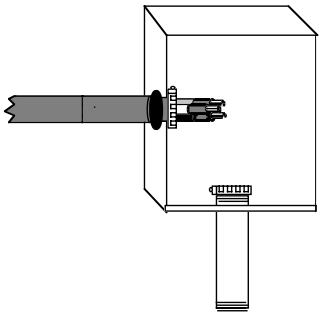


300.4(D). When cables or raceways are installed parallel to joists, rafters, or studs, the cable or raceway must be installed so that it is not less than 1 1/4 inches from the nearest edge where nails or screws may be driven. If this 1 1/4 inch distance cannot be maintained, then steel plates or metal sleeves must be used.

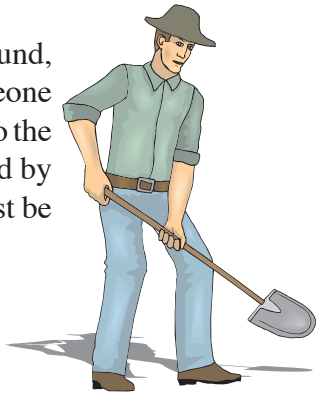
300.4(E). A cable, raceway, or box installed below a metal corrugated sheet roof decking installation require at least a 1 1/2 inch of separation from the lowest roof decking surface to the top of the cable, raceway, or box. The cable, raceway, or box **shall not** be installed in **concealed** locations. This requirement does not apply to Rigid metal or Intermediate metal conduit.

300.4(G). Raceways containing ungrounded conductors #4 or larger that enter a cabinet, box, or raceway, the conductors shall be protected in accordance with any of the following:

(1) An identified fitting providing a smooth rounded insulating surface
(2) A listed metal fitting that has smoothly rounded edges
(3) Separation from the fitting or raceway using an identified insulating material that is securely fastened in place
(4) Threaded hubs or bosses that are an integral part of a cabinet, box, enclosure, or raceway providing a smoothly rounded or flared entry for conductors

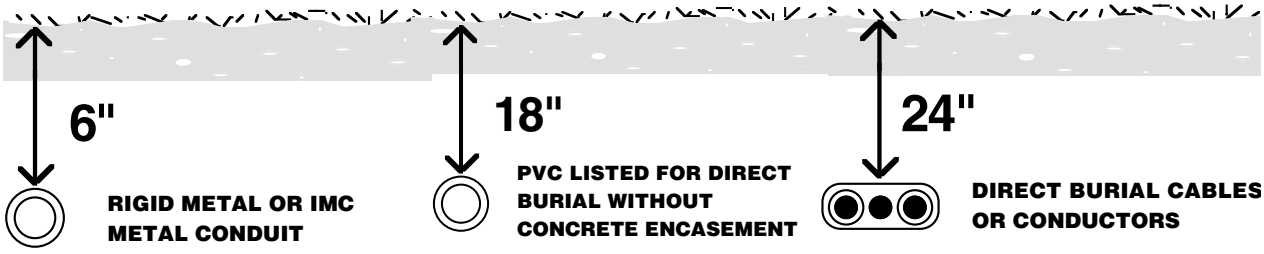


300.5. Underground Installations.



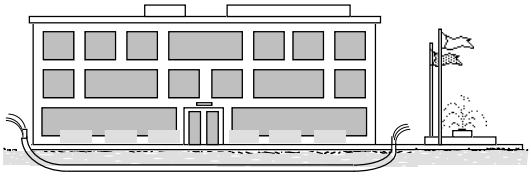
When conduit or cable listed for direct burial are installed underground, they must be buried to a depth so that it is unlikely to be damaged by someone digging in the area at a later date. The depth requirements vary according to the type of raceway or cable. Rigid non-metallic conduit will not be damaged by someone trenching with a shovel but UF cable might be, so UF cable must be buried deeper than PVC conduit.

300.5(A). The minimum cover requirements of Table 300.5(A) must be met for underground wiring installations. Table 300.5(A) lists five different wiring methods and the minimum cover requirements for each one in several different locations. The general rule for direct burial cables or conductors is 24 inches and for rigid metal or intermediate metal conduit is 6 inches. This table also lists some special problems that may be encountered such as in solid rock, if rigid metal conduit is installed with a minimum of 2 inches of concrete, the minimum cover requirement is reduced from 6 inches to 2 inches.



300.5(B). The inside of **all** raceways and enclosures installed underground are considered a wet location. All insulated conductors within those underground raceways and enclosures shall be listed for use in wet locations and comply with 310.10(C).

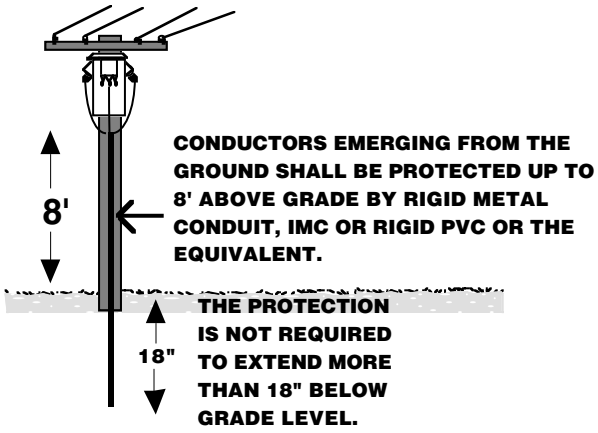
300.5(C). When underground cables are installed under a building, they shall be installed in a raceway. The required raceway must extend beyond the outside walls of the building.



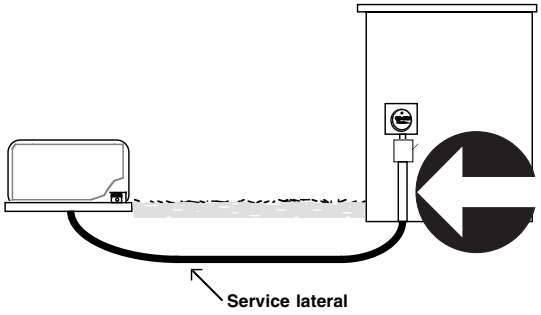
A CABLE INSTALLED UNDER A BUILDING MUST BE IN A RACEWAY

Exception 1 & 2. Type MI and MC cable shall be permitted under a building where embedded in concrete, fill, or other masonry.

300.5(D)(1) Where direct buried conductors emerge from the ground and are specified in columns 1 and 4 of Table 300.5(A), they shall be protected by enclosures or raceways from the burial depth to at least 8 feet above the ground. This protection shall not be required to be more than 18 inches below grade level.



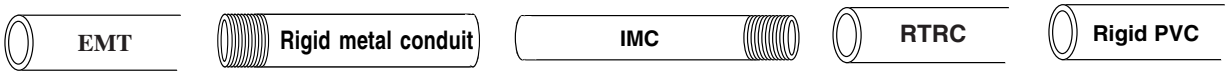
300.5(D)(2). Conductors entering a building shall be protected to the point of entrance.



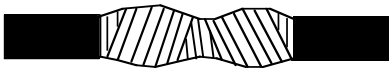
300.5(D)(3). A warning ribbon is required to be placed 12" above underground service conductors that are not buried 18" or more or encased in concrete.

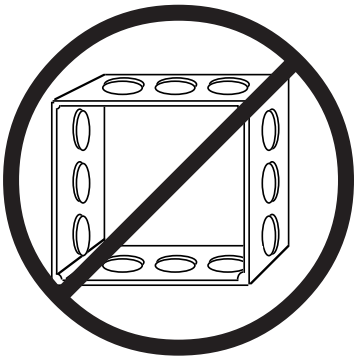
WARNING BURIED CABLE ------WARNING BURIED CABLE ------WARNING

300.5(D)(4). Where the enclosure or raceway is subject to physical damage, the conductors shall be installed in electrical metallic tubing, rigid metal conduit, intermediate metal conduit, RTRC-XW (Reinforced Thermosetting Resin Conduit), Schedule 80 PVC, or equivalent.



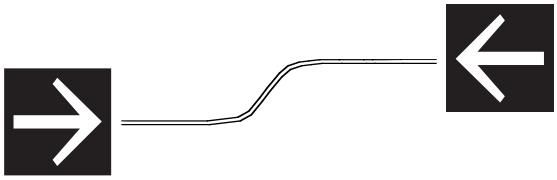
300.5(E). Underground conductors or cables shall be permitted to be spliced or tapped without the use of splice boxes. The splices or taps shall be made in accordance with 110.14(B).





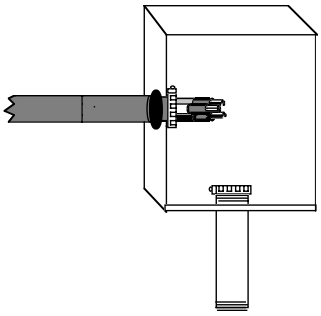
300.5(F). Backfill must contain sand or suitable running boards or other protection where backfill consists of heavy stones or sharp objects that could damage the conductors.

300.5(G). If moisture can contact live parts, the underground raceway must be sealed or plugged at either or both ends.



300.5(H)

300.5(H). Where a conduit system is changed to direct burial cable, a bushing must be installed where the conductors emerge as a direct wiring method.

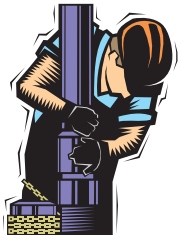


300.5(I). All conductors of the same circuit and, where used, the grounded conductor and all equipment grounding conductors shall be installed in the same raceway or cable or shall be installed in close proximity in the same trench.

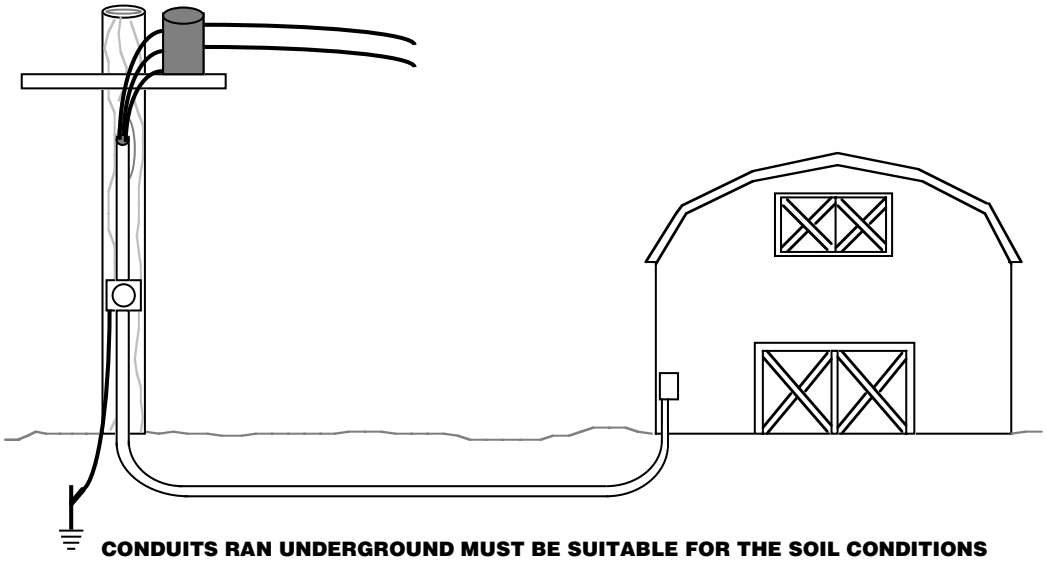
300.5(J). Direct buried conductors, raceways or cables that are subject to movement by settlement or frost shall be arranged so as to prevent damage to the enclosed conductors or to the equipment connected to the raceways.

Informational Note: This section recognizes "S" loops in underground direct burial to raceway transitions, expansion fittings in raceway risers to fixed equipment, and, generally, the provision of flexible connections to equipment subject to settlement or frost heaves.

300.5(K). Cables or raceways installed using directional boring equipment shall be approved for the purpose.



300.6. Metal raceways, cable armor, cable sheath and fittings must be suitable for the conditions in which they are installed. The material must be resistant to moisture and corrosion. It must be strong enough to withstand the continued loading. Metal raceways buried in the soil can corrode, and should be coated before the installation to prevent the corrosion. Cable sheath may develop a fungus or rot easily in the dampness of the soil, so the sheath must be resistant to fungus and rot.



CONDUITS RAN UNDERGROUND MUST BE SUITABLE FOR THE SOIL CONDITIONS

300.6(A). Ferrous metal equipment shall be suitably protected against corrosion inside and outside (except threads at joints) by a coating of listed corrosion-resistant material.

Definition of ferrous: Containing iron.

Note: Field-cut threads are those threads that are cut in conduit, elbows, or nipples anywhere other than at the factory where the product is listed.

Exception. Stainless steel shall not be required to have protective coatings.

300.6(A)(1). Ferrous metal equipment protected from corrosion solely by enamel shall not be used outdoors or in wet locations.

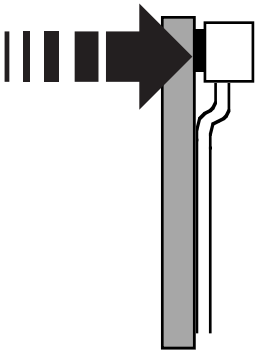
300.6(A)(2). Boxes or cabinets having an approved system of organic coatings and marked "Raintight," "Rainproof," or "Outdoor Type," shall be permitted outdoors.

300.6(A)(3). Ferrous metal equipment shall be permitted to be installed in concrete or in direct contact with earth where made of material approved for the condition or where provided with corrosion protection approved for the condition.

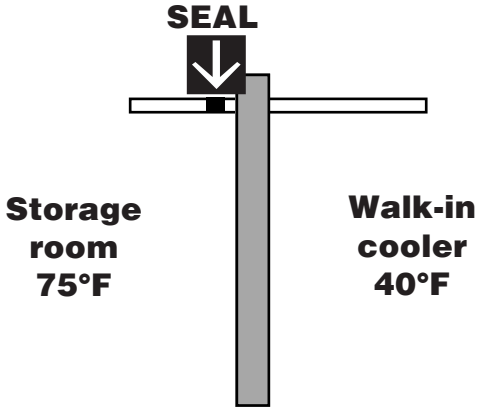
300.6(C)(1). Nonmetallic equipment where exposed to sunlight, the materials, shall be listed as sunlight resistant or shall be identified as sunlight resistant.

300.6(D). Indoor wet locations where walls are washed frequently, all electrical equipment shall be mounted so that there is at least 1/4" airspace between the equipment and the wall.

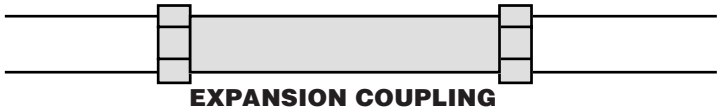
Exception: Nonmetallic equipment shall be permitted without the airspace on a concrete, masonry, tile, or similar surface.



300.7(A). This section requires protection against moisture accumulation. If air is allowed to circulate from warmer to the colder section of a raceway or sleeve, moisture in the warm air will condense in the cold section of the raceway or sleeve. Most often this can be prevented by sealing just outside the cold rooms.



300.7(B). Raceway shall be provided with expansion-deflection fittings where necessary to compensate for thermal expansion, deflection and contraction.



Informational Note: Data regarding the use of expansion fittings for PVC, IMC, EMT, and rigid steel conduit.

SUMMARY OF 310.16 and Table 310.15(B)(1)(1)

It is very important to get started off on the right foot by completely understanding the function of a conductor, the insulation and how temperature effects the conductor.

A conductor is a component of the electrical circuit and is used to carry the current to and from the load in the circuit. The current flowing through the conductor produces heat.

The capacity of current the conductor can carry is referred to as the *ampacity* (amp-capacity).

Ampacity is defined as the current in amperes that a conductor can carry *continuously* under the conditions of use without exceeding its temperature rating.

Conductor ampacities are listed starting at Table 310.16 through 310.20. **Table 310.16** is the ampacity table used for wiring buildings.

The current a conductor can safely carry is determined by several factors. The size of the conductor, the alloy (copper or aluminum), the type of insulation, the environment, etc.

Table 310.16 lists different types of insulations, different ampacities and different temperature ratings for the same size conductor.

#10 TW 30 ampacity
60°C - 140°F temperature rating

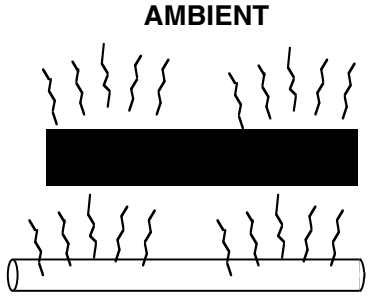
#10 THW 35 ampacity
75°C - 167°F temperature rating

#10 THHN 40 ampacity
90°C - 194°F temperature rating

A #10 wire is the same size with a circular mil area of 10,380, but as you can see, it has three different ampacities and different temperature ratings.

Insulation around a conductor is like a pipe carrying water. With the water pressure (voltage) and the flow (amperes) of water, the pipe (insulation) is used to contain the water. If the pipe were to "spring a leak" you would lose some of the water pressure.

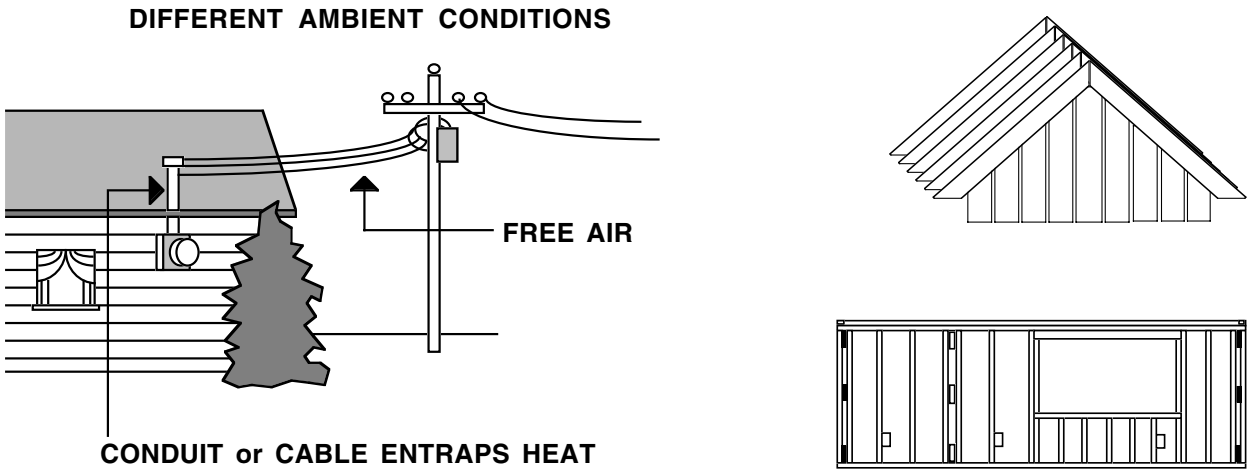
"Good" insulation means a high resistance to current to keep it from "leaking".



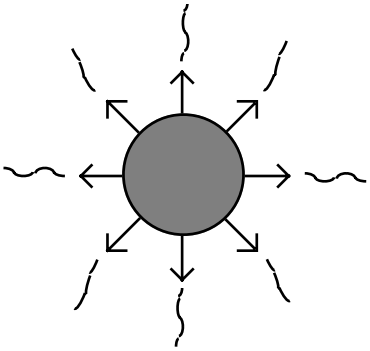
As current is passed through the conductor, the heat that is produced (I^2R) must be dissipated through the insulation to the ambient. Ambient is that which encompasses on all sides.

Ambient temperature is the temperature surrounding the conductor into which the heat of the conductor is dissipated. If the ambient temperature is higher it slows down the dissipation of the heat.

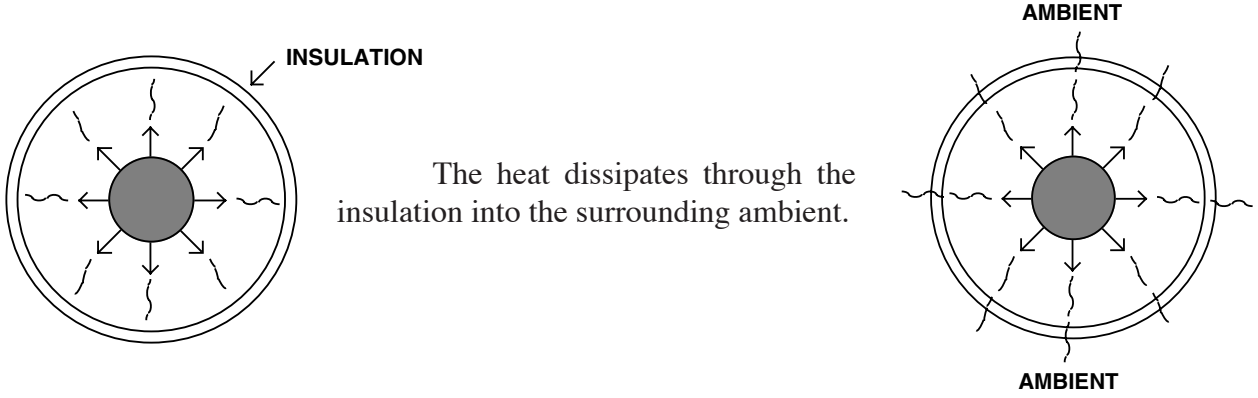
A conductor in free air, as shown below, can carry more amperage than one that is installed in a conduit, as the conduit will entrap the heat. The conductors installed in attics, around a furnace, or a boiler encounters higher ambient temperatures that requires lowering the current flow on the conductor to prevent insulation damage. Table 310.17 is for conductors in free air.



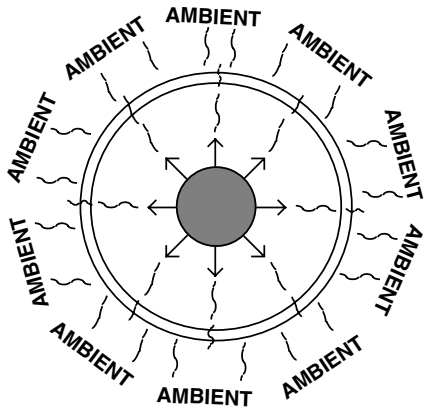
It is important to understand how a conductor dissipates heat.



The heat produced from the current flowing through the conductor is dissipated through the skin in all directions.



The heat dissipates through the insulation into the surrounding ambient.



If the surrounding ambient temperature is higher, it opposes the dissipation of the heat through the insulation. The ampacity of the conductor must be reduced for the higher ambient temperature. If the ampacity is not reduced, the heat is contained longer in the conductor and the insulation, thus causing insulation damage. Even though the ambient is cooler when a conductor is buried, it is slower in dissipating heat the deeper it is buried.

Example: A conduit contains six #8 TW current-carrying conductors. The normal ampacity is 40 amps. But, an adjustment factor of 80% from Table 310.15(C)(1) must be applied for the six current-carrying conductors. 40 amps x 80% = 32 amps is the maximum current that can be passed through a #8 TW conductor without subjecting it to insulation damage.

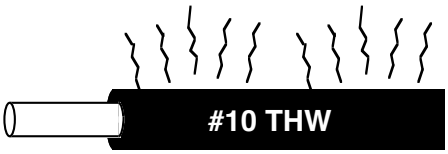
The type letter on the insulation indicates its insulation, maximum operating temperature, and application provisions.

#10 RHW

The #10 RHW, the "R" indicates rubber insulation. The "H" indicates 75°C - 167°F maximum operating temperature (insulation rating). The "W" indicates moisture resistant.

#10 THHN

The #10 THHN, the "T" indicates thermoplastic insulation. The "HH" indicates 90°C - 194°F maximum operating temperature (insulation rating). The "N" indicates nylon covering.



The #10 THW has a maximum operating temperature of 75°C which is 167°F.

The #10 THHN has a maximum operating temperature of 90°C which is 194°F. A "HH" rated insulation will allow more heat to be dissipated faster than an "H" rated insulation thus, raising the ampacity (the current the conductor can carry safely without damage).

The maximum operating temperature is the insulation rating of the conductor and must not be exceeded. Proper designing is a very important factor.

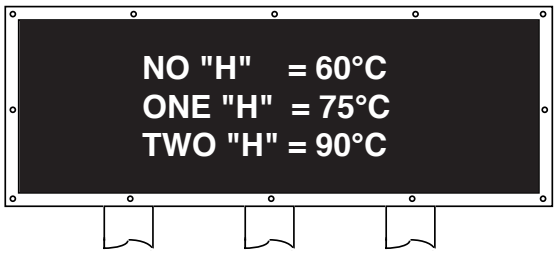
You must first understand what words mean; such as ampacity, ambient temperature, insulation rating, etc.

#10 TW 30 ampacity
60°C - 140°F temperature rating

A #10 TW conductor has an ampacity of 30 amperes. The insulation rating is 60°C or 140°F.
This does *not* mean that a TW insulation can be installed where the ambient temperature reaches 140°F.

What this means is: If a #10 TW conductor is loaded to the allowable ampacity, 30 amperes in an ambient that has a temperature of 30°C or 86°F, the temperature of the *insulation* will reach 60°C or 140°F.

Table 310.16 the table of ampacity is aimed at designating a level of current that will permit the conductor to reach its thermal limit, but not exceed it.



15. Where space is too limited to provide minimum clearances, such as at meters, panelboards, outlets, and switch points, concealed knob and tube wiring shall be enclosed in ____ which shall be continuous in length between the last support and the enclosure or terminal point.

(a) rigid metal conduit (b) EMT (c) IMC (d) flexible nonmetallic tubing

16. What is the ampacity of four #6 THW copper current-carrying conductors enclosed in schedule 80 PVC conduit, 8 feet in length entering a trench?

(a) 65 amps (b) 52 amps (c) 44 amps (d) 40 amps

17. Flat cable assemblies may be installed ___.

I. for small power loads outdoors, not subject to physical damage
II. as tap devices for lighting and small appliances
III. for small power loads in hoistways

(a) I only (b) II only (c) I and III only (d) I, II, and III

18. Surge arresters over 1kV shall be permitted to be located ____ and shall be made inaccessible to unqualified persons unless listed for installation in accessible location.

I. outdoors II. indoors

(a) I only (b) II only (c) either I or II (d) neither I nor II

19. The internal depth of outlet boxes intended to enclose flush devices supplied by a #14 wire or smaller shall be at least ____.

(a) 1/2" (b) 7/8" (c) 15/16" (d) 1 1/2"

20. Where a single AC conductor carrying current passes through metal with magnetic properties, the inductive effect shall be minimized by ____.

I. cutting slots in the metal between the individual holes through which individual conductors pass
II. passing all the conductors in the circuit through an insulating wall sufficiently large for all the conductors of the circuit

(a) I only (b) II only (c) both I and II (d) neither I nor II

21. Which of the following is **true** concerning type NM cable?

(a) It may be installed where exposed to corrosive fumes
(b) It may be fished in air voids in masonry block or tile walls
(c) It may be embedded in masonry, concrete, or plaster
(d) It may be covered with plaster, adobe, or similar finish

22. The temperature rating of a conductor is the maximum temperature, at any location along its length, that the conductor can withstand over a prolonged time period without ____.

(a) tripping the breaker **(b) serious degradation**
(c) short circuiting **(d) a ground fault**

23. Auxiliary gutters shall be permitted to supplement wiring spaces at meter centers, distribution centers, switchboards, and similar points of wiring systems and may enclose ___.

I. switches II. overcurrent devices III. conductors IV. busbars

(a) I & II only (b) I & III only (c) I & III only (d) III & IV only

24. Type ____ cable is a factory assembly of one or more conductors, each individually insulated and enclosed in an armor of interlocking metal tape, or a smooth or corrugated metallic sheath.

(a) MI (b) AC (c) MC (d) MV

25. 100 feet of rigid PVC conduit is run between two cabinets. If its thermal expansion is less than ____ inches, an expansion joint is not required.

(a) .25 (b) .28 (c) .30 (d) .35

26. A means shall be provided in each metal box over 100 cubic inches for the connection of an equipment grounding conductor. The means shall be permitted to be ___.

I. a tapped hole II. the cover screw III. a screw used to mount the box

(a) I only (b) II only (c) I and II only (d) I, II, or III

27. There shall be an air space of at least ____ between walls, back, gutter partition, if of metal, or door of any cabinet, or cut out box and nearest exposed current-carrying parts of devices mounted within the cabinet where the voltage exceeds **251** volts.

(a) 1/4" (b) 1/2" (c) 1" (d) 1 1/2"

28. Which of the following methods is **not** approved for conductor supports?

(a) deflecting of cables in junction boxes **(b) insertion of boxes**
(c) clamping devices **(d) loop connectors**

29. Nonmetallic sheath cable: If the attic is **not** accessible by stairs or permanent ladder, the cable needs to be protected only within ____ feet of a scuttle hole.

(a) 2 (b) 3 (c) 6 (d) 10