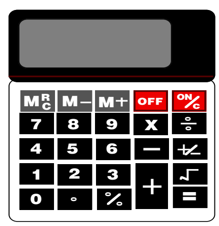
Calculations for the Electrical Exam

By Tom Henry and Tim Henry



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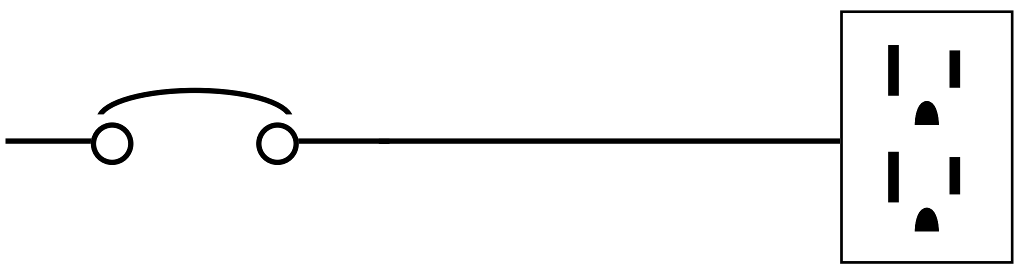
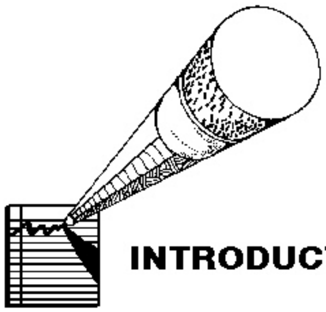
CONTENT

CHAPTER 1

BRANCH CIRCUITS



Definition: **The circuit conductors between the final overcurrent device protecting the circuit and the outlet(s).**



INTRODUCTION

The branch circuit is the final wiring after the fuse or circuit breaker.

This Chapter will start the student off on the right foot in the proper calculations and sizing of various branch circuits.

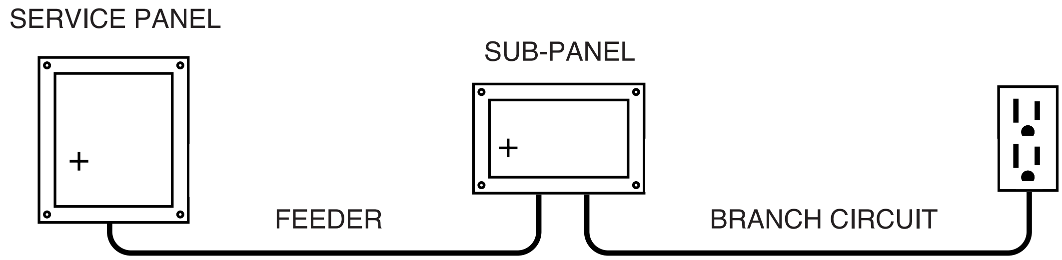
There are different Code rules for a circuit that supplies only one load compared to a circuit that supplies several loads. There are different rules for plug and cord connected than if the loads are hard wired.

You will learn how branch circuits are sized larger for continuous loads.

The basic beginning of installing wiring begins with following the Code rules for branch circuits.

•Note: Before using this book to prepare for your exam, make sure your Code book is tabbed using *Tom Henry*'s 68 tabs ***designed for exam calculations!***

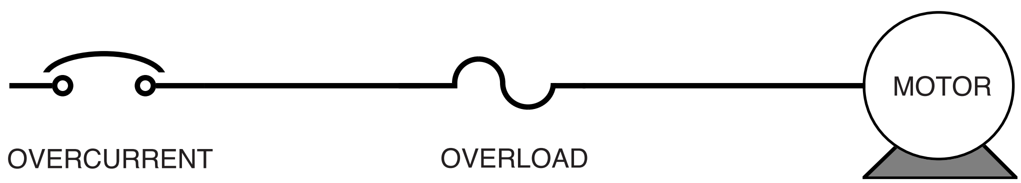
DISTRIBUTION OF ELECTRICAL POWER

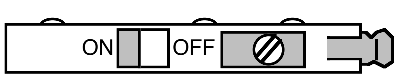


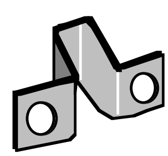
Definition of a branch circuit: The circuit conductors between the **final** over**current** device protecting the circuit and the outlet(s).

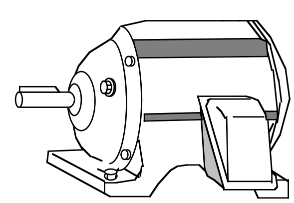
Over**current** device is a fuse or circuit breaker. Do not confuse over**current** device with over**load** device.

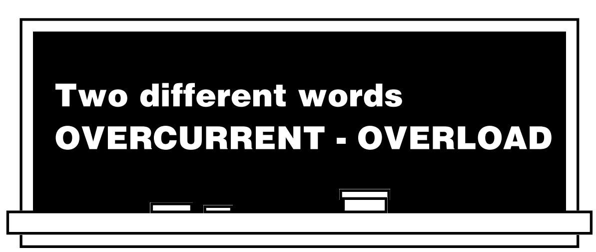
An over**load** device is a thermal protector that protects the motor against dangerous overheating. Sometimes referred to as the **heater**.



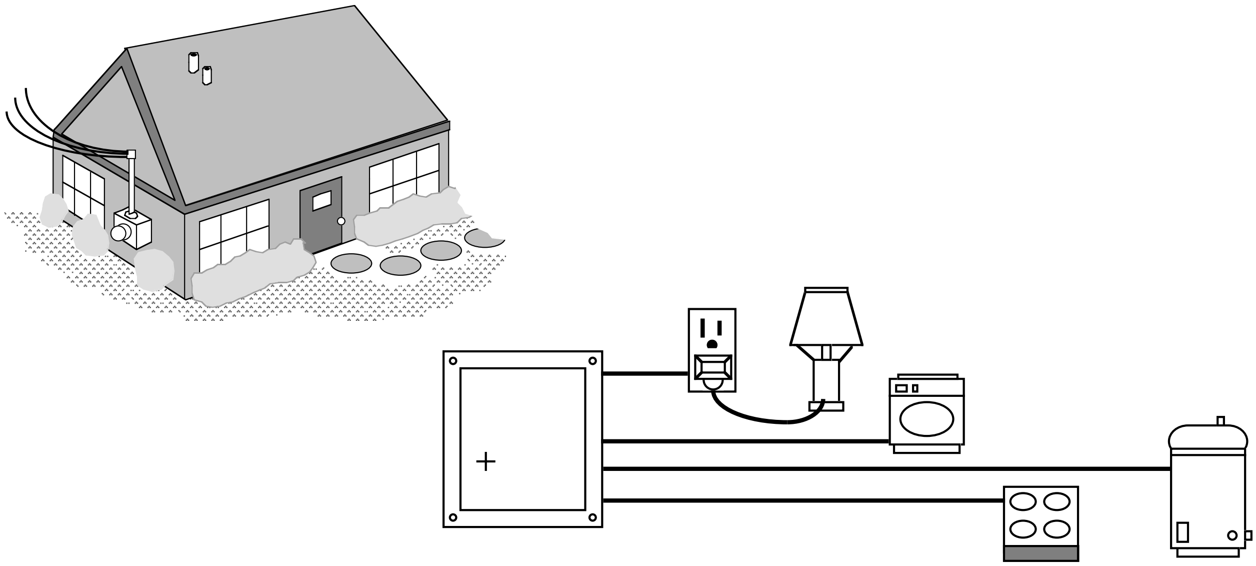






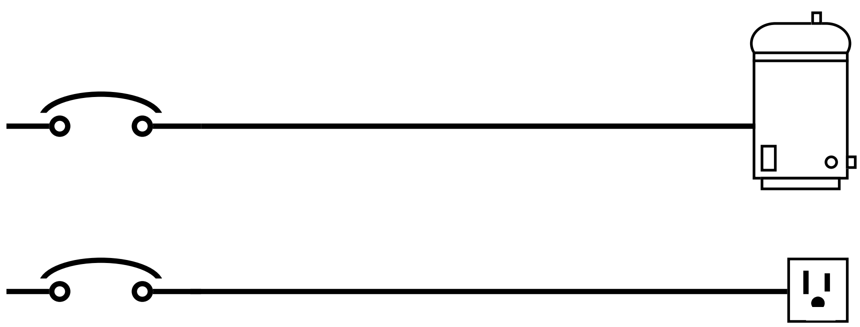


Most residential dwellings do not have feeders as the branch circuits originating at the service panel.



There are two types of branch circuits:

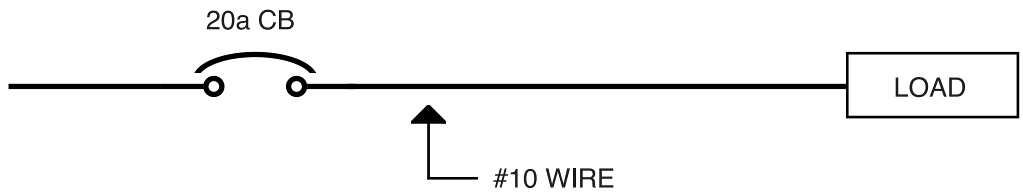
I. A single-individual load.



II. Two or more outlets.

THE RATING OF A BRANCH CIRCUIT

The **rating** of a branch circuit is determined by the overcurrent device (fuse or circuit breaker).



The branch circuit is **rated** 20 amps because the circuit breaker is 20 amps. The #10 wire may have been selected for voltage drop or for mechanical strength in an overhead circuit. The wire size does **not** determine the rating of a branch circuit.

It is very important in the designing of branch circuits and conductors to understand the rating of the branch circuit. Section 210.20(A) states the rating of the overcurrent device shall not be less than the noncontinuous load plus 125% of the continuous load. Or a 20 amp CB x 80% = 16 amp maximum continuous load.

CLASSIFICATIONS OF BRANCH CIRCUITS

Section 210.18. The classification for **other than individual** branch circuits shall be: 10,15, 20, 30, 40, and 50 amperes.

An **individual** branch circuit (to one load) can be any size. An example would be a water heater with a 25 amp overcurrent device. But branch circuits supplying **more than one load** are rated at 15, 20, 30, 40, and 50 amperes only.

15 and 20 amp branch circuits are used in residential dwellings for lighting and receptacle loads. Section 210.23(A,B,C) states that 30, 40, and 50 amp multi-outlet branch circuits are not permitted in a dwelling for lights and receptacle branch circuits. Section 210.21(A) states: lampholders used in branch circuits in **excess of 20 amps** shall be not less than 660 watts heavy-duty type which would not be used in a dwelling residence.

Branch circuits rated 10 amperes shall not supply receptacle outlets.

In a dwelling, 30, 40, and 50 amp rated branch circuits are used for a **single** load such as a clothes dryer, range, water heater, etc.

30, 40, and 50 amp **multi-outlet** branch circuits would be found in **non-dwelling** occupancies supplying heavy-duty lampholders, infrared heating units or other utilization equipment. Welders in an industrial building would be a good example of a multi-outlet branch circuit.

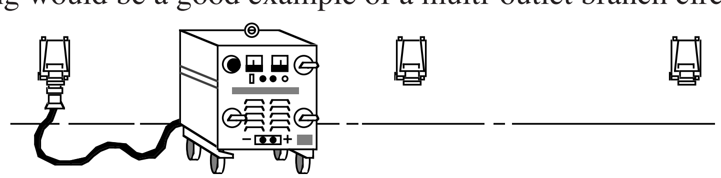
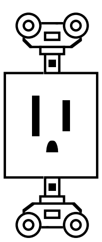


Table 210.21(B)(2) shows a **single** 20 amp rated receptacle can only be loaded to 16 amps. But, a 20 amp rated **duplex** receptacle can be loaded to 20 amps per Table 210.24(1).

KEY WORD IS "RECEPTACLE" WHICH MEANS ONE

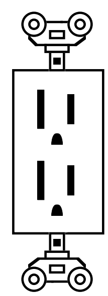
Table 210.21(B2)
Maximum Cord and Plug Connected Load to Receptacle

Circuit Rating Amperes	Receptacle Rating Amperes	Maximum Load Amperes
15 or 20	15	12
20	20	16
30	30	24



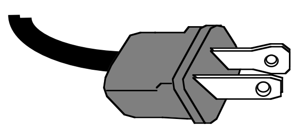
20 amp rated
Single receptacle

Maximum load 16 amps

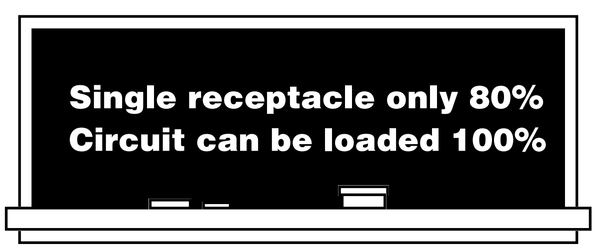


20 amp rated
Duplex receptacle

Maximum load 20 amps



CORD and PLUG CONNECTED LOADS



MAXIMUM LOADING OF BRANCH CIRCUITS

Section 210.23 and Table 210.24(1) list the maximum load permitted on each branch circuit.

Table 210.24(1)
Summary of Branch Circuit Requirements - Copper Conductors

CIRCUIT RATING	10 Amp	15 Amp	20 Amp	30 Amp	40 Amp	50 Amp
CONDUCTORS (Min. Size)						
Circuit Wires[1]	14	14	12	10	8	6
Taps	14	14	14	14	12	12
Fixture Wires and Cords	Refer to Section 240.5					
OVERCURRENT PROTECTION	10 Amp	15 Amp	20 Amp	30 Amp	40 Amp	50 Amp
OUTLET DEVICES:						
Lampholders Permitted	Any Type	Any Type	Any Type	Heavy Duty	Heavy Duty	Heavy Duty
Receptacle[2] Rating	Not applicable	15 Max. Amp	15 or 20 Amp	30 Amp	40 or 50 Amp	50 Amp
MAXIMUM LOAD	10 Amp	15 Amp	20 Amp	30 Amp	40 Amp	50 Amp
PERMISSIBLE LOAD	Refer to Section 210.23(A)(1)	Refer to Section 210.23(A)	Refer to Section 210.23(A)	Refer to Section 210.23(B)	Refer to Section 210.23(C)	Refer to Section 210.23(C)

As shown in Table 210.24(1), a 20 amp circuit can be loaded to a maximum of 20 amps. An example would be a 20 amp receptacle circuit in a residential dwelling. Receptacles are not considered a continuous load. Limiting the load to 80% of the rating of the branch circuit applies to a **continuous load**.

Section 210.23(B)(1). The rating of any **one** cord-and plug-connected utilization equipment shall not exceed 80% of the branch circuit rating.

Example shows a cord and plug connected refrigerator on a 20 amp rated branch circuit. The refrigerator load could not exceed 16 amps which is 80% of 20 amps. But the 20 amp circuit could be loaded another 4 amps by another load which would reach the maximum load permitted of 20 amps.

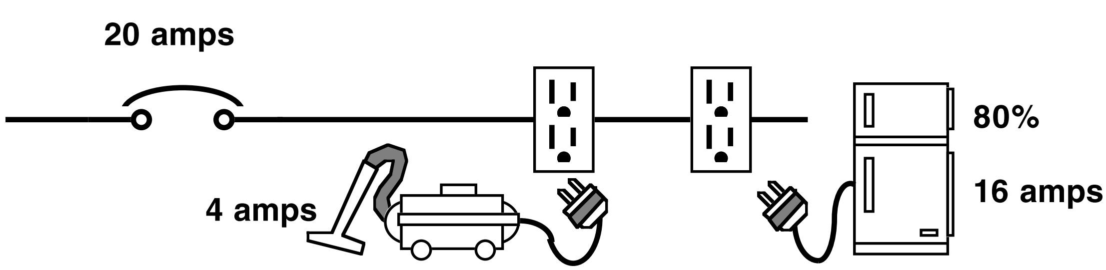
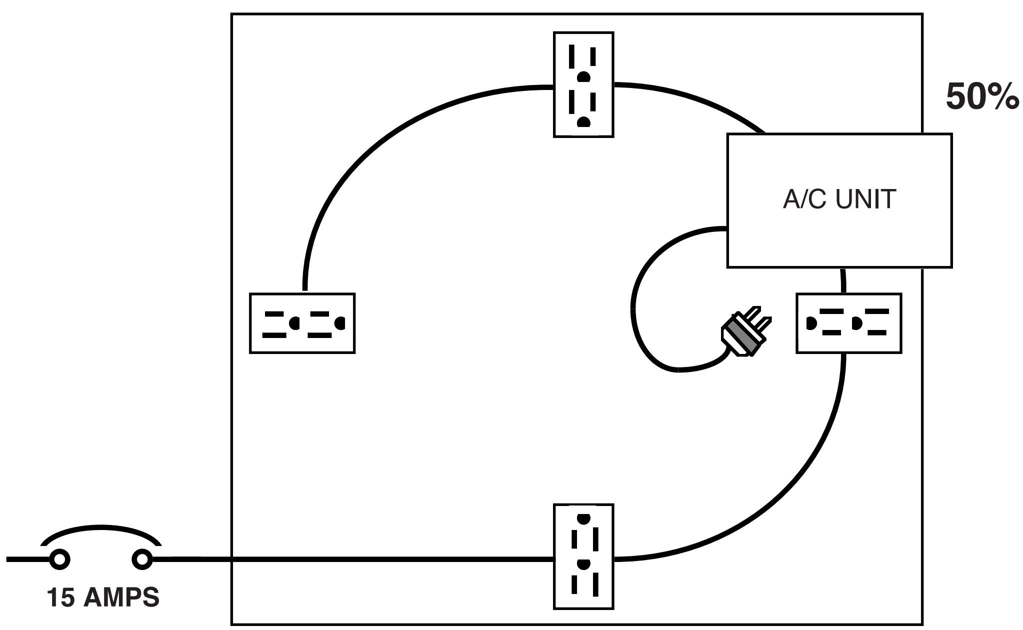


Table 210.24(2)
Summary of Branch Circuit Requirements - Aluminum & Copper Clad AL Conductors

CIRCUIT RATING	10 Amp	15 Amp	20 Amp	30 Amp	40 Amp	50 Amp
CONDUCTORS (Min. Size)						
Circuit Wires[1]	12	12	12	10	8	6
Taps	12	12	14	14	12	12
Fixture Wires and Cords						
OVERCURRENT PROTECTION	10 Amp	15 Amp	20 Amp	30 Amp	40 Amp	50 Amp
OUTLET DEVICES:						
Lampholders Permitted	Any Type	Any Type	Any Type	Heavy Duty	Heavy Duty	Heavy Duty
Receptacle[2] Rating	Not applicable	15 Max. Amp	15 or 20 Amp	30 Amp	40 or 50 Amp	50 Amp
MAXIMUM LOAD	10 Amp	15 Amp	20 Amp	30 Amp	40 Amp	50 Amp
PERMISSIBLE LOAD	Refer to Section 210.23(A)(1)	Refer to Section 210.23(A)	Refer to Section 210.23(A)	Refer to Section 210.23(B)	Refer to Section 210.23(C)	Refer to Section 210.23(C)

Section 210.23(B)(2) also states: The total rating of utilization equipment **fastened in place** shall not exceed 50% of the branch-circuit rating. Fastened in place (fixed) not portable appliances.

The following example shows a wall mounted air conditioning unit 120 volt cord and plug connected to an existing 15 amp rated branch circuit. 210.23(B)(2) states the maximum load for this fastened in place unit would be 50% of the 15 amp rated branch circuit = 7.5 amps.

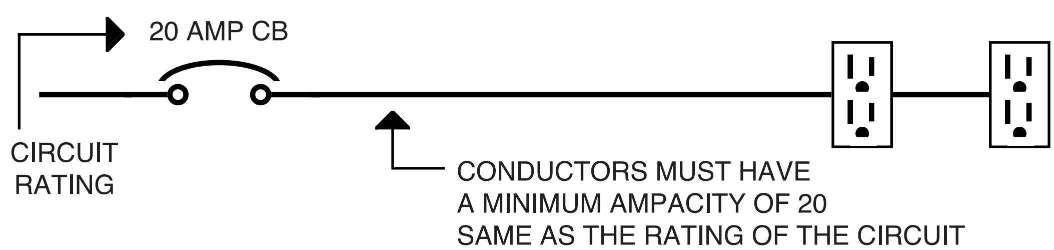


CONDUCTORS - MINIMUM SIZE AMPACITY

To properly solve branch-circuit sizing calculations, you must meet the conductor ampacity requirements.

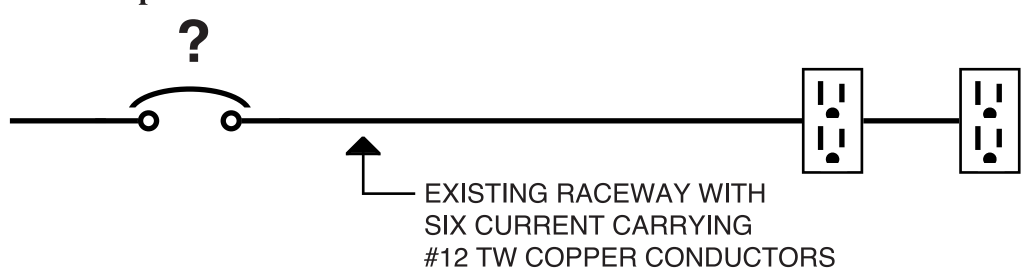
Section 210.19(A)(1). Branch-circuit conductors shall have an ampacity not less than the maximum load to be served. Where a branch circuit supplies continuous loads or any combination of continuous and noncontinuous loads, the minimum branch-circuit conductor size, before the application of any adjustment or correction factors, shall have an allowable ampacity equal to or greater than the noncontinuous load plus **125% of the continuous load**.

210.19(A)(2). Conductors of **branch circuits** supplying **more than one receptacle** for **cord-and plug-connected** portable loads shall have an ampacity of not less than the **rating** of the branch circuit.



A #14 TW conductor has an **ampacity** of 15, and the * asterisk, which refers you to the bottom of Table 310.16 states a #14 conductor can only be fused at a maximum of 15 amps (240.4D). A #12 TW with an ampacity of 20 would be protected at 20 amps and would be the correct selection of conductor for this receptacle circuit.

What is the maximum size circuit breaker permitted for the following **branch circuit** that supplies **more than one receptacle**?



Branch circuits rated 10 amperes shall not supply receptacle outlets.

Section 310.15(C)(1) requires an ampacity adjustment factor for more than three current carrying conductors, for **six** current carrying conductors, a reduction in ampacity of 80% is required.

Table 310.15(C)(1). Ampacity Adjustment Factors.
(a) More than Three Current Carrying Conductors in a Raceway or Cable. Where the number of conductors in a raceway or cable exceeds three, the ampacities shall be reduced as shown in the following table:

Number of Conductors	Percent of Values in Tables as Adjusted for Ambient Temperature if Necessary
4 through 6	80
7 through 9	70
10 through 20	50
21 through 30	45
31 through 40	40
41 through 60	35

Table 310.16: A #12 TW has an ampacity of 20. The 310.15(C)(1) factor requires the 20 ampacity to be reduced 80%. 20a x 80% = 16 ampacity and maximum load permitted on this conductor.

Section 240.4(B)(2) states the next **higher** size overcurrent protective device can be used where the ampacity of the conductor does not correspond with the standard size overcurrent device.

The reduced ampacity is 16 amps which is not a standard size fuse or breaker. The next higher standard size from Table 240.6(A) is 20 amps. If the conductor is **not** part of a **branch circuit supplying more than one receptacle for cord and plug connected portable loads**, then 20 amps is permitted per Section 240.4(B)(3).

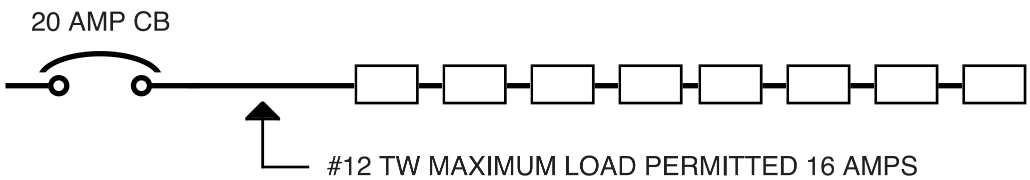
Since this example shows the branch circuit supplying receptacles, the maximum size overcurrent device would be 15 amp. A 15 amp overcurrent device would protect the conductors at 15 amp. **If** a 20 amp overcurrent device was installed, loads could be plugged into the receptacles loading the circuit to the maximum rating of 20 amp. This would be in **excess** of the 16 ampacity or maximum loading which would result in exceeding the insulation rating of the conductor. This will be explained in full detail in Chapter 2.

If the loads on this branch circuit were **hard wired** instead of plug and cord connected receptacles, then the next higher overcurrent device 20 amp is permitted.

The electrical designer or electrician designing a lighting branch circuit could encounter this very same example.

A raceway containing six #12 TW current carrying conductors to light fixtures. The reduced ampacity and maximum load permitted on these conductors is 16 amps. If each light fixture has a load of 2 amps, $16 \div 2 = 8$ or a maximum of 8 lights at 2 amps each = 16 amps which would not exceed the maximum load permitted of 16.

If eight light fixtures at 2 amps each (known loads) are **hard wired** to the branch circuit, the next higher standard size 20 amp overcurrent device is permitted per Section 240.4(B)(1).



The designer of this circuit must limit the connected load to 16 amps or less.

As an electrical inspector, this is what I would explain to the electrician in the field when he said "I'm only adding **one** light to the existing circuit." As you can see in the example **one** more light would exceed the maximum load permitted on the existing conductors.

CONTINUOUS LOAD

Article 100 - Definition of Continuous Load: A load where the maximum current is expected to continue for **three** hours or more.

Article 100 - Definition of Ampacity: The maxium current in amperes a conductor can carry **continuously** under the conditions of use without exceeding its temperature rating.

Section 210.20(A). The rating of the branch-circuit overcurrent device serving continuous loads shall not be less than the noncontinuous load plus **125% of the continuous load.** The minimum branch-circuit conductor size, without the application of any adjustment or correction factors, shall have an allowable **ampacity equal to or greater than** the noncontinuous load plus 125% of the continuous load.

Continuous loads shall not exceed 80% of the rating of the branch circuit. The reason for limiting the load to 80% is **not** that the conductors can't carry the continuous load. The 80% is a current limitation on the **overcurrent device** to limit the **heat**. Remember, the overcurrent device **not** the conductors.

The **80%** limitation is based on the **inability** of the overcurrent device itself to handle continuous load without overheating.

Neutral conductor loads would **not** be calculated at continuous. The neutral conductor that is not connected to an overcurrent device has **no heating effect to the overcurrent device**. Same with service conductors. The **line** side service conductors are not calculated at continuous, they don't connect to overcurrent devices so there is no heating effect.

220.41 Dwelling Units, Minimum Unit Load.
In one and two family, and multifamily dwellings, the minimum unit load shall not be less than **3 volt-amperes** per square foot.

Table 220.45 Lighting Load Demand Factors

Type of Occupancy	Portion of Lighting Load to Which Demand Factor Applies (volt-amperes)	Demand Factor Percent
Dwelling Units	First 3000 or less at	100
	From 3001 to 120,000 at	35
	Remainder over 120,000 at	25
Hotels and Motels — Including Apartment Houses without Provisions for Cooking by Tenants*	First 20,000 or less at	60
	From 20,001 to 100,000 at	50
	Remainder over 100,000 at	35
Warehouses (Storage)	First 12,500 or less at	100
	Remainder over 12,500 at	50
All Others	Total Volt-amperes	100

* The demand factors of this table shall **not** apply to the calculated load of feeders or sevices supplying areas in hotels, and motels where the entire lighting is likely to be used at one time, as in ballrooms, or dining rooms.

Determining the Minimum Number of Lighting Branch Circuits for a 1500 square foot One-Family Dwelling

•Example D1(a) page 834

General Lighting Load	1500 x 3va (220.41) = 4500va
General Lighting Load	4500va ÷ 120 volts = 38 amps
This requires	Three 15 amp or two 20 amp branch circuits

Section 220.45 states the demand factors from Table 220.45 shall **not** apply when determining the number of branch circuits for general illumination.

Good judgement and common sense will answer most of the exam questions on continuous loading.

220.41 Dwelling occupancies are **not** considered continuous lighting loads due to the small loading.

Table 220.42(A) Non Dwelling

Table 220.42(A) General Lighting Loads by Non-Dwelling Occupancies

Type of Occupancy	Unit Load per Sq. Ft. (Volt-Amperes)
Automotive facility	1.5
Convention center	1.4
Courthouse	1.4
Dormitory	1.5
Exercise center	1.4
Fire station	1.3
Gymnasium 1	1.7
Health care clinc	1.6
Hospitals	1.6
Hotels and Motels, including apartment houses without provisions for cooking by tenants.2	1.7
Library	1.5
Manufacturing facility 3	2.2
Motion picture theater	1.6
Museum	1.6
Office 4	1.3
Parking garage 5	0.3
Penitentiary	1.2
Performing arts theater	1.5
Police station	1.3
Post office	1.6
Religious facility	2.2
Restaurant 6	1.5
Retail 7&8	1.9
School / University	3
Sports arena	3
Town hall	1.4
Transportation	1.2
Warehouse	1.2
Workshop	1.7

Note: The 125% multiplier for continuous load as specified in 210.20(A) is included when using the unit loads in this table for calculatiing the minimum lighting load for a specified occupancy.
1 Amories and auditoriums are considered gymnasium-type occupancies.
2 Lodge rooms are similar to hotels and motels.
3 Industrial commercial loft buildings are considered manufacturing type occupancies.
4 Banks are office-type occupancies.
5 Garages - commercial (storage) are considered parking garage occupancies.
6 Clubs are considered restaurant occupancies.
7 Barber shops and beauty parlors are considered retail occupancies.
8 Stores are considered retail occupancies.

Note: The 125% multiplier for a continuous load is included in the unit load va and NO additional multiplier shall be required when using the unit loads in Table 220.42(A) for calculating the minimum lighting load for a specified occupancy.

••Note 8: Table 220.42(A) is for Non-Dwelling Occupancy, Note 8 Stores are considered *retail occupancies* @ 1.9va per square foot.

Determining the Minimum Number of Lighting Branch Circuits for a 4800 square foot Store Building

General Lighting Load 4800 x 1.9 va (Table 220.42(A) = 9120va

General Lighting Load 9120va ÷ 120 volts = 76 amps

This requires Six 15 amp or two 20 amp branch circuits

Receptacle loads are **not** considered continuous. If a receptacle is a continuous load, it would be identified as such in the calculation question. Going back to the definition of a continuous load will help when it comes to a receptacle being continuous. "A load where the **maximum** current is expected to continue for three hours or more." Most receptacles are normally lightly loaded. This is also why dwelling loads are considered noncontinuous. Although Section 424.4(B) and 422.13 requires the **branch circuit** for electric heat and 120 gallon or less water heater to be calculated as continuous.

Section 220.45 states the demand factors from Table 220.45 shall **not** apply when determining the number of branch circuits for general illumination.

$$\text{Number of Branch Circuits} = \frac{\text{Lighting Load}}{\text{Circuit Capacity}}$$

220.41 Lighting load = unit va per square foot x total square footage

Circuit capacity (noncontinuous) = branch circuit rating x 120 volts

Circuit capacity (continuous) = branch circuit rating x 120 volts x **80%**

Example: (noncontinuous) 15 amp CB x 120 volts = 1800va circuit capacity

20 amp CB x 120 volts = 2400va circuit capacity

(continuous) 15 amp CB x 120v x **80%** = 1440va circuit capacity

20 amp CB x 120v x **80%** = 1920va circuit capacity

Continuous Load Example:

A 6000 square foot restaurant would require how many 20 amp lighting circuits?

80%

Table 220.42(A) $\frac{1.5\text{va} \times 6000\text{ sq.ft.}}{20\text{a CB} \times 120\text{v} \times \mathbf{80\%}} = \frac{9000\text{va}}{1920\text{va}}$ = 4.6 or 5 circuits required

Show Window Example:

How many 20 amp branch circuits are required for 80 linear feet of show window lighting?

Section 220.14(G)(2) $\frac{200\text{va} \times 80\text{ feet}}{20\text{a} \times 120\text{v} \times \mathbf{80\%}} = \frac{16{,}000\text{va}}{1920\text{va}}$ = 8.3 or 9 circuits

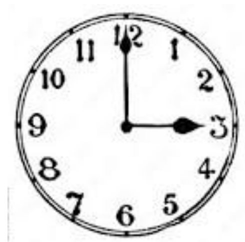
Noncontinuous Example:

An office has 100 general purpose receptacles. How many 20 amp branch circuits are required?

Section 220.14(I) 180va x 100 = 18,000va = 7.5 or 8 branch circuits
20a x 120v = 2400va

Note: The 180va per receptacle is for **other** than a dwelling unit. The demand factor Table 220.47 is for **feeders** not branch circuits. Receptacles are **not** a continuous load.

Office Continuous Example:



80%

How many 20 amp lighting branch circuits are required for a 600 square foot office?

80%

Table 220.42(A) 1.3va x 600 sq.ft. = 780va = .40 or one branch circuit
20a CB x 120v x **80%** = 1920va

Table 220.42(A) is the **minimum** lighting load permitted. If a known lighting load is calculated to be larger than the Table 220.42(A) minimum, it must be used as the Code states conductors shall have an ampacity not less than the **maximum** load to be served.

Example:

80%

If the same 600 square foot office had a **known** lighting load of 25 fixtures @ 160w each, what is the required number of 20 amp lighting branch circuits?

25 fixtures x 160 watts = 4000va = 2.08 or 3 branch circuits
20a x 120v x **80%** = 1920va.

Receptacles: A building has 55 receptacles what is the demand load?

Table 220.47 First 10 kVA = 10 kVA 55 receptacles x 180va (220.14 I) = **9900va**

In general, receptacles are not considered to be a continuous load.

Understanding the Question

How many 20 amp **branch circuits** are required?

Noncontinuous Example:

An office has 100 general purpose receptacles. How many 20 amp branch circuits are required?

Section 220.14(I) **180va** x 100 = 18,000va = 7.5 or 8 circuits
20a x 120v = 2400va

$$\frac{180va \times 100 = 18{,}000va}{20a \times 120v = 2400va} = 7.5 \text{ or } 8 \text{ circuits}$$

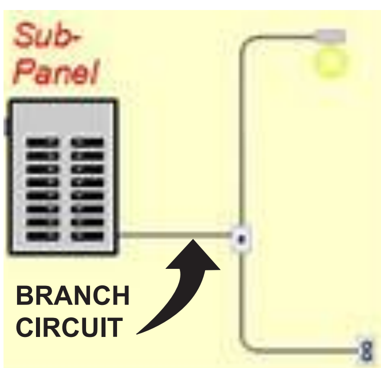
Note: The **180va** per receptacle is for **other** than a dwelling unit. The demand factor Table 220.47 is for **feeders** not branch circuits. Receptacles are **not** a continuous load.

Continuous Load Example:

A 6000 square foot restaurant would require how many 20 amp lighting branch circuits?

80%

$$\frac{\text{Table 220.42(A)} \quad 1.5va \times 6000 \text{ sq.ft.} = 9000va}{20a \text{ CB} \times 120v \times \mathbf{80\%} = 1920va} = 4.6 \text{ or } 5 \text{ circuits required}$$



Branch Circuit: Any circuit that extends beyond the final overcurrent protective device is called a branch circuit.

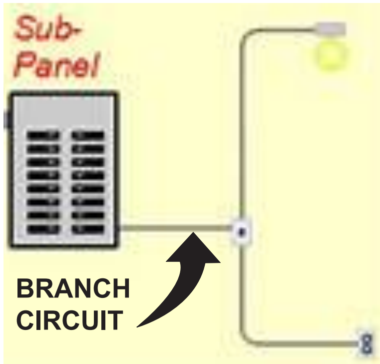
Office Receptacle Load:

$$\frac{\text{Table 220.42(A)} \quad 1.3va \times 600 \text{ sq.ft.} = 780va}{\text{Section 220.14(I)} \quad 180va = 180va} = 4.3 \text{ or } 4 \text{ receptacles}$$

The 1.3 volt-amp per square foot from Table 220.42(A) for offices and banks would provide capacity for four receptacles in the office. If a known receptacle load of more than 780va is provided, then use the **largest** receptacle load.

In general, receptacles are not considered to be a continuous load.

Understanding the Question



BRANCH CIRCUIT

- CONTINUOUS
- NONCONTINUOUS

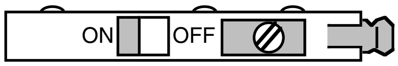
80%

RECEPTACLES

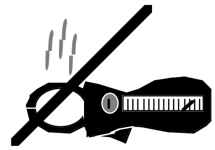
LIGHTING LOAD

SUMMARY CONTINUOUS LOAD

An overcurrent device such as a circuit breaker does not trip on **current** alone. Example: an amp clamp clamped on a conductor could read 17 amperes and a 20 amp rated circuit breaker could trip.

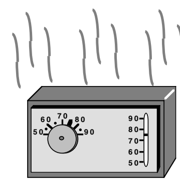


20 amp rated



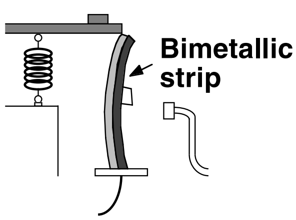
Amp clamp reads 17 amps

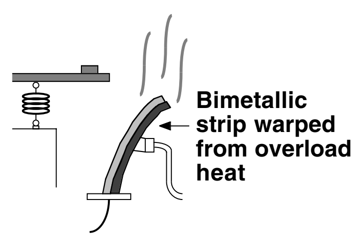
The current carrying conductor produces heat but so does the **ambient temperature**. This is the temperature surrounding the conductor or equipment (circuit breaker).



Ambient temperature is the temperature surrounding the conductor or equipment

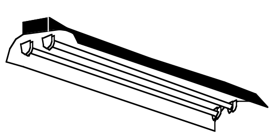
The circuit breaker has a bimetallic element that trips on the amount of **heat.** The conductor and the ambient temperature combined with heat determines when it trips.

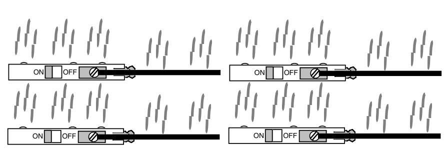


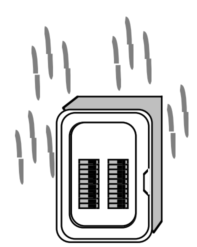


80%

The reason for the **80%** current limitation on the circuit breaker is when several circuits containing continuous loads such as lighting are contained in the same panelboard and with the cover enclosed **heat** is entrapped which has a definite affect on the tripping of the circuit breaker.

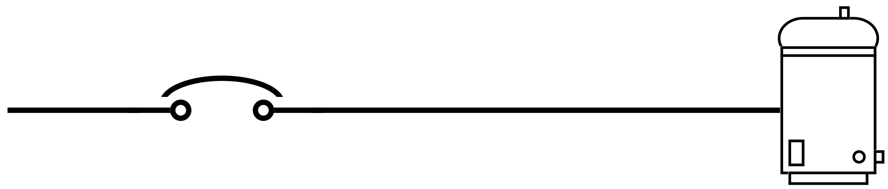






Even though only 17 amps of current is flowing through the circuit, this combined with the added ambient heat from the other circuits with continuous loads raises the heat thus tripping the circuit breaker.

SIZING OF INDIVIDUAL LOADS



4.5 kw **water heater** 40 gallon 240v single-phase

Section 422.13. A branch circuit supplying a fixed storage-type water heater having a capacity of 120 gallons **or less** shall have a **rating** not less than 125% of the nameplate rating of the water heater.

$$\frac{4500\text{w}}{240\text{v}} = 18.75 \text{ amps } \times 125\% = 23.43 \text{ amps}$$

Section 422.11(E)(3). If the branch circuit supplies a single **nonmotor**-operated appliance, the overcurrent device rating shall not exceed a protective device rating marked on the appliance or, if there is no marking, the value specified as follows:
Appliance rating greater than 13.3 amperes = **150% of appliance rating**.

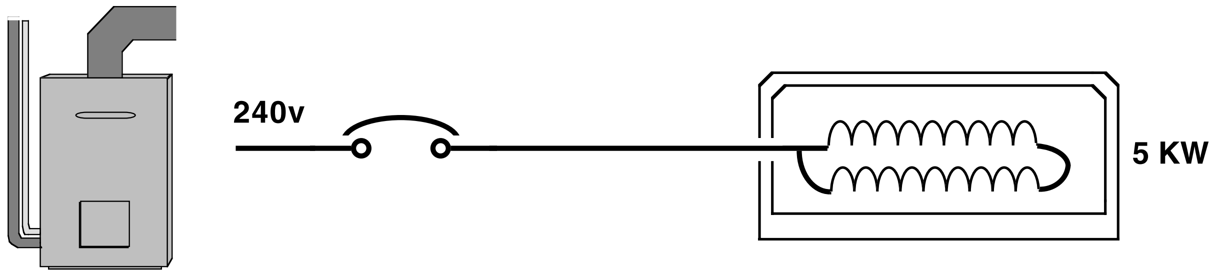
18.75 amps x 150% = 28.125 amps 422.11(E)(3) Use 30 amp circuit breaker #10 copper conductor.

SIZING OF FIXED ELECTRIC SPACE HEATING

Section 424.3(A). **Individual** branch circuits shall be permitted to supply **any size** fixed electric space heating equipment.

Branch circuits supplying **two or more** outlets for fixed electric space heating equipment shall be rated not over 30 amperes. Exception: In other than a dwelling unit, fixed **infrared** heating equipment shall be permitted to be supplied from branch circuits rated not over 50 amperes.

Section 424.4(B). The ampacity of the branch-circuit conductors and the rating or setting of overcurrent protective devices supplying fixed electric space heating equipment consisting of resistance elements with or without a motor shall not be less than 125% of the total load of the motors and the heaters.



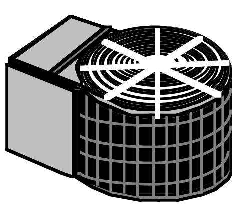
The 5 kw space heat unit shown above would calculate:

5000w ÷ 240v = 20.83 amps x 125% = 26 amps Use 30 amp CB and #10 TW copper

SIZING FOR AIR CONDITIONING EQUIPMENT

Room air conditioning units and refrigerators are usually cord and plug connected to a general purpose branch circuit following the 80% for cord and plug connected and the 50% for fastened in place appliances in **Section 210.23(B)(1,2)**.

The rules are different for an A/C unit that has a hermetic refrigerant motor-compressor than a unit that does not.



Article 100. Definition of Hermetic refrigerant motor-compressor: A combination consisting of a compressor and motor, **both** of which are enclosed in the same housing with no external shaft or shaft seals, **the motor operating in the refrigerant**.

Branch circuit sizing for motors and cooking equipment have different rules and will be covered in following chapters of this book.

Summary

Appliance, fixed: An appliance which is fastened or otherwise secured at a specific location.

Appliance, portable: An appliance which is actually moved or can easily be moved from one place to another in normal use.

Branch circuit, appliance: A branch circuit supplying energy to one or more outlets to which appliances are to be connected; such circuits to have no permanently connected lighting fixtures not part of an appliance.

Branch circuit, general purpose: A branch circuit that supplies a number of outlets for lighting and appliances.

Branch circuit, individual: A branch circuit that supplies only one utilization equipment.

Equipment: A general term including material, fittings, devices, appliances, fixtures, apparatus, and the like used as a part of, or in connection with, an electrical installation.

Lighting outlet: An outlet intended for the direct connection of a lampholder, a lighting fixture, or a pendant cord terminating in a lampholder.

Outlet: A point on the wiring system at which current is taken to supply utilization equipment.

Receptacle: A receptacle is a contact device installed at the outlet for the connection of a single attachment plug. (*Informational Note*): A **single** receptacle is a single contact device with no other contact device on the same yoke. A **multiple** receptacle is a single device containing two or more receptacles.

Receptacle outlet: An outlet where one or more receptacles are installed.

The Code uses two classifications for the wiring of appliances: Cord and plug connected or permanently connected (hard-wired).

Cord and plug connected appliances would include irons, toasters, mixers, coffee makers, vacuum cleaners, etc. Permanently connected is all appliances not cord and plug connected. Example would be a water heater as it is hard-wired.

Fastened in place appliances would include garbage disposers, dryers, cooking equipment, etc. These appliances can **not** be easily moved due to plumbing connections or are built into the counter-top, etc. These appliances might be cord and plug connected for convenience in servicing the unit.

CHAPTER 1 TEST 1 BRANCH CIRCUITS

1. Appliance outlets installed in a residence for a specific appliance, such as a washing machine, shall be installed within ____ feet of the intended location of the appliance.

(a) 2 (b) 4 (c) 6 (d) 8

2. Direct grade level access is defined as being located not more than ____ above grade level and being readily accessible.

(a) 6' 3" (b) 6' 6" (c) 7' (d) 8'

3. Show windows require that one 125v single phase, 15a or 20a rated receptacle outlet be installed within ____ inches of the top of each show window.

(a) 6 (b) 8 (c) 10 (d) 18

4. A receptacle is a contact device installed at the outlet for the connection of a ____.

(a) light (b) single contact device (c) two attachment plugs (d) device

5. In a dwelling, a 40 or 50 amp branch circuit is permitted to supply ____.

I. only fastened in place cooking appliances
II. infrared heating equipment
III. fixed lighting units with heavy-duty lampholders

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

6. Equipment grounding conductors of different branch circuits that are installed in the same raceway must be ____.

I. differentiated by having one with a green color and the others green with a colored stripe
II. differentiated by having one with a green color stripe and the others with a yellow stripe
III. color coded green, green with a yellow stripe, or bare

(a) I only (b) II only (c) III only (d) none of these

CHAPTER 1 TEST 2 BRANCH CIRCUITS

1. A branch circuit conductor shall have an ampacity equal to or greater than the noncontinuous load plus ____ percent of the continuous load.

(a) 75 (b) 80 (c) 115 (d) 125

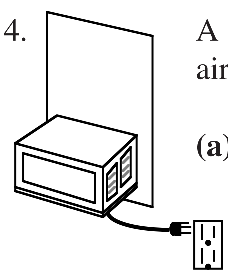
2. A 20 amp rated branch circuit with #12 wire supplying a duplex receptacle can be loaded to a maximum of ____ amps.

(a) 12 (b) 15 (c) 16 (d) 20

3. Which of the following is an overcurrent device?

I. circuit breaker II. thermal overload III. time-delay fuse

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

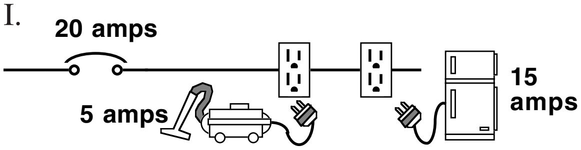
4. 

A 20 amp rated branch circuit with a #12 wire supplying a fastened in place wall air conditioner can be loaded to a maximum of ____ amps.

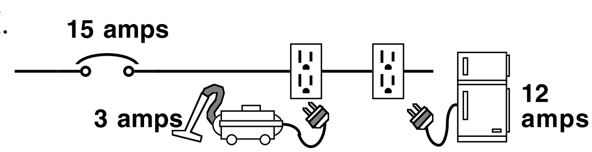
(a) 10 (b) 15 (c) 16 (d) 20

5. Which of the following would violate the branch circuit loading rules?

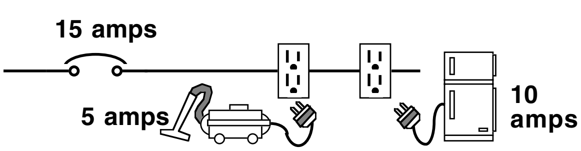
I.



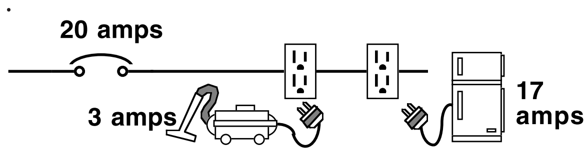
II.



III.



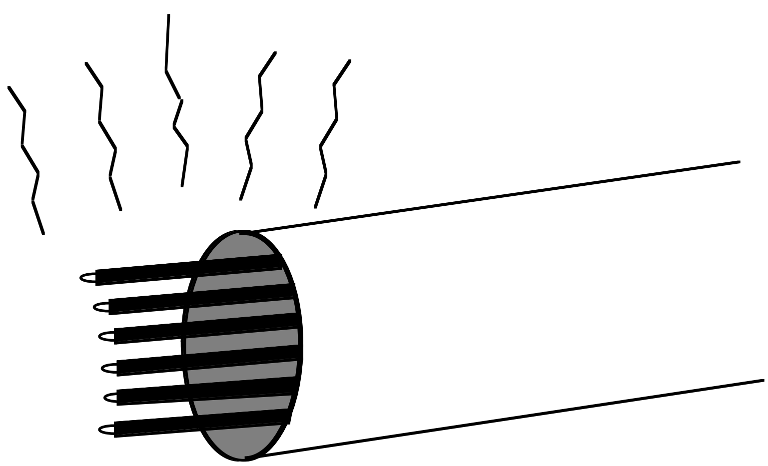
IV.

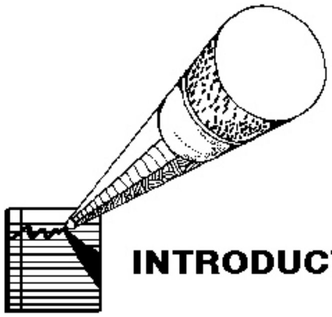


(a) I (b) II (c) III (d) IV

CHAPTER 2

AMPACITY





INTRODUCTION

This Chapter explains how the Table of Ampacity 310.16 is to be used per the Code. This is a very misused table.

The student will learn from Chapter 2:

- The definition of the insulation rating of a conductor
- As more conductors are added to the circuit, the load on the conductors must be reduced
- Nonlinear loads add heat to the neutral
- The utility company can install a smaller wire as the conductors are in free air per Table 310.17
- Equipment and conductors must be terminated as listed per section 110.14(C)

This is probably the most misused table in the Code book as the ampacities listed in Table 310.16 are generally **never** correct. This is a very important table that you must learn to use correctly.

Table 310.16. Allowable Ampacities of Insulated Conductors
Rated 0-2000 Volts, 60°to 90°C (140°to 194°F)
Not More Than Three Conductors in Raceway or Cable or Earth
(Directly Buried), Based on Ambient Temperature of 30°C (86°F)*.

Size	Temperature Rating of Conductor. See Table 310.4(1).						Size
	60°C (140°F)	75°C (167°F)	90°C (194°F)	60°C (140°F)	75°C (167°F)	90°C (194°F)	
AWG **kcmil**	TYPES TW, UF	RHW, THHW, THW, THWN, XHHW, XHHWN, USE, ZW	TYPES TBS,SA, SIS, FEP, FEPB, MI, PFA RHH, RHW-2, THHN, THHW, THW-2, THWN-2 USE-2, XHH XHHW, XHHW-2 Z ZW-2	TYPES TW, UF	RHW, THHW, THW, THWN, XHHW, USE	TYPES TBS, SA, SIS, THHN, THHW, THW-2, THWN-2, RHH, RHW-2, USE-2, XHH, XHHW, XHHW-2, XHHN	**AWG** **kcmil**
	COPPER			**ALUMINUM OR COPPER-CLAD ALUMINUM**			
18**	....	....	14	....	....	....	....
16**	....	....	18	....	....	....	....
14**	15	20	25	....	....	....	....
12**	20	25	30	15	20	25	12**
10**	30	35	40	25	30	35	10**
8	40	50	55	35	40	45	8
6	55	65	75	40	50	55	6
4	70	85	95	55	65	75	4
3	85	100	115	65	75	85	3
2	95	115	130	75	90	100	2
1	110	130	145	85	100	115	1
1/0	125	150	170	100	120	135	1/0
2/0	145	175	195	115	135	150	2/0
3/0	165	200	225	130	155	175	3/0
4/0	195	230	260	150	180	205	4/0
250	215	255	290	170	205	230	250
300	240	285	320	195	230	260	300
350	260	310	350	210	250	280	350
400	280	335	380	225	270	305	400
500	320	380	430	260	310	350	500
600	350	420	475	285	340	385	600
700	385	460	520	315	375	425	700
750	400	475	535	320	385	435	750
800	410	490	555	330	395	445	800
900	435	520	585	355	425	480	900
1000	455	545	615	375	445	500	1000
1250	495	590	665	405	485	545	1250
1500	525	625	705	435	520	585	1500
1750	545	650	735	455	545	615	1750
2000	555	665	750	470	560	630	2000

***Table 310.15(B)(1)(1) CORRECTION FACTORS based on 30°C (86°F)**

Ambient Temp. °C	**For ambient temperatures other than 30°C (86°F), multiply the ampacities shown above by the appropritate factor shown below.**						**Ambient Temp. °F**
10 or less	1.29	1.20	1.15	1.29	1.20	1.15	50 or less
11-15	1.22	1.15	1.12	1.22	1.15	1.12	51-59
16-20	1.15	1.11	1.08	1.15	1.11	1.08	60-68
21-25	1.08	1.05	1.04	1.08	1.05	1.04	69-77
26-30	1.00	1.00	1.00	1.00	1.00	1.00	78-86
31-35	.91	.94	.96	.91	.94	.96	87-95
36-40	.82	.88	.91	.82	.88	.91	96-104
41-45	.71	.82	.87	.71	.82	.87	105-113
46-50	.58	.75	.82	.58	.75	.82	114-122
51-55	.41	.67	.76	.41	.67	.76	123-131
56-60	—	.58	.71	—	.58	.71	132-140
61-65	—	.47	.65	—	.47	.65	141-149
66-70	—	.33	.58	—	.33	.58	150-158
71-75	—	—	.50	—	—	.50	159-167
76-80	—	—	.41.	—	—	.41.	168-176
81-85	—	—	29	—	—	29	177-185

* Refer to 310.15(B)(1) for the amapacity correction factors where the ambient temperature is other than 30°C (86°F). Refer to 310.15(C)(1)(a) for more than three current carrying conductors.

** See Section 240.4(D)

The reason for the misuse of the table comes from not reading the heading which states the ampacities shown for the various conductors are correct if you don't: (1) install over three current carrying conductors in a raceway or cable (2) exceed 30°C or 86°F in ambient temperature.

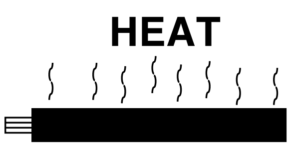
(1)

Table 310.16. Ampacities of Insulated Conductors Rated 0-2000 Volts,
60° to 90°C (140° to 194°F) **Not more Than Three Conductors in Raceway or Cable or Earth** (Directly Buried),
Based on Ambient Air Temperature of 30°C (86°F).

(2)

Common sense would remind you that normally you are installing more than three conductors in a conduit and also the surrounding temperature of these conductors would be above 86°F. The **normal** ampacities listed in the table must be corrected if either condition (1) or (2) is present.

The conductor ampacity is the current carried **continuously** without increasing the temperature of its insulation beyond the danger point. The conductor ampacity varies with the type of insulation and the method of installation.



Except for mechanical abuse, the greatest hazard that conductors must endure is **heat**. Conductor insulation can be damaged by excessive heat in various ways, depending on the type of insulation and the degree of overheating. Continued exposure to excessive heat causes insulation to become soft, perhaps to melt, and in extreme cases to burn.

This heat comes from two sources: From the ambient air surrounding the conductors or from the current the conductors must carry. There is a point where an increase in current causes excessive heat even though conducting materials such as copper or aluminum have a low resistivity.

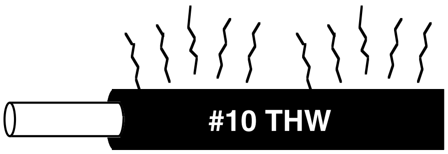
For many years natural rubber was used to insulate conductors, but age along with heat caused such rubber insulation to dry out, to crack, and to become brittle. Today we have better quality rubber and thermoplastic materials that not only permit thinner insulation on conductors but also withstand temperature better resulting in higher ampacities of conductors.

The maximum temperature permitted for conductor insulation is called the **temperature rating** of the conductor. **Table 310.4(1)** shows the **maximum** temperature that the insulation type is permitted to reach. That maximum temperature will be reached when a conductor is loaded to its full ampacity in an ambient temperature of 30 degrees C or 86 degrees F.

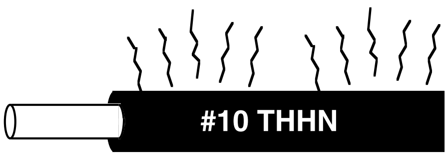
The type letter on the insulation indicates its insulation, maximum operating temperature, and application provisions.

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

THHN insulation, 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. An "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.

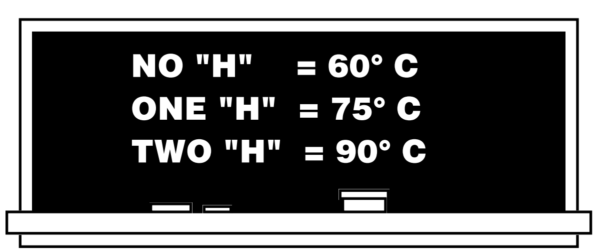
You must first understand what words mean; such as ampacity, ambient temperature, insulation rating, etc.

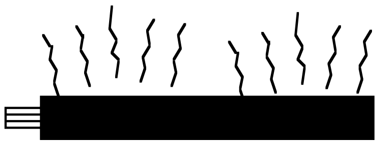
#10 TW 30 ampacity
60°C - 140°F temperature rating

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.

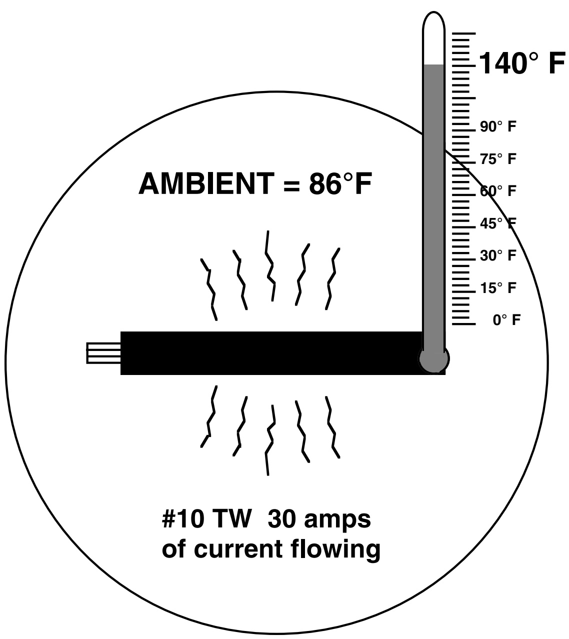




#10 TW 30 amps of current flowing

The 30 amps of current flowing produces heat in the conductor which must dissipate through the insulation to the ambient.

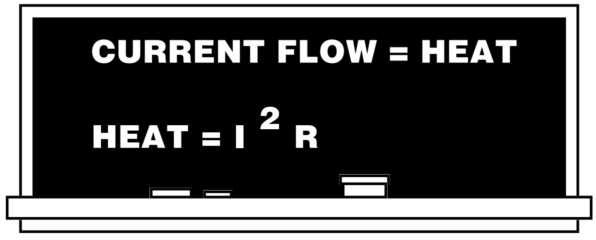
With the ambient temperature at 86°F and with 30 amperes of current flowing through the conductor, a thermometer placed on the *insulation* would read 140°F which is maximum operating temperature for this type insulation (TW).



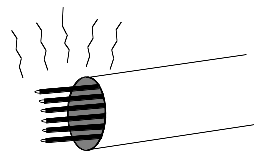
For a #10 TW conductor, any current above 30 amps or any ambient temperature above 86°F will cause insulation damage, as you will exceed the maximum operating temperature of the conductor; 140°F.

Maximum operating temperature = Full ampacity at 86°F.

140°F - 86°F = 54°F for the 30 amperes of current flow in the #10 TW conductor.



ADJUSTMENT FACTORS



When there are more than three current-carrying conductors in a raceway or cable, the ampacity of each conductor must be reduced as indicated in Table 310.15(C)(1) to compensate for heating effects and reduced heat dissipation due to reduced ventilation of individual conductors.

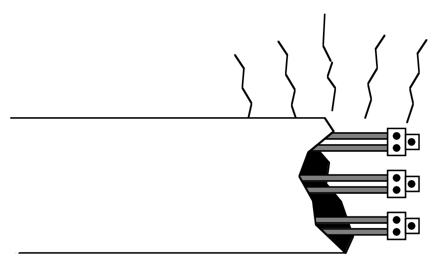
Table 310.15(C)(1) Adjustment Factors.

(a) More than Three Current Carrying Conductors in a Raceway or Cable. Where the number of conductors in a raceway or cable exceeds three, the ampacities shall be reduced as shown in the following table:

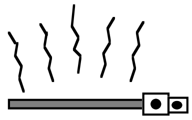
Number of Conductors	Percent of Values in Tables 310.16 through Table 310.19 as Adjusted for Ambient Temperature if Necessary
4 through 6	80
7 through 9	70
10 through 20	50
21 through 30	45
31 through 40	40
41 and above	35

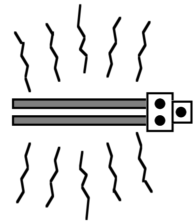
Example: A conduit contains six #8 TW current carrying conductors. The normal ampacity is 40 amps x 80% from Table 310.15(C)(1) = 32. The maximum current that can be passed through the #8 TW conductor without subjecting it to insulation damage is 32 amps.

Adjustment factors also apply when paralleling conductors per Section 310.10(G)(4).

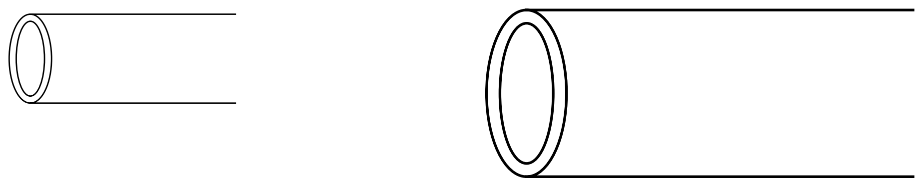


It is wrong to think since you connected two conductors in parallel on one lug that you now only have one conductor. Heat is measured by $W = I^2R$. In parallel you have **two** conductors carrying current producing heat.

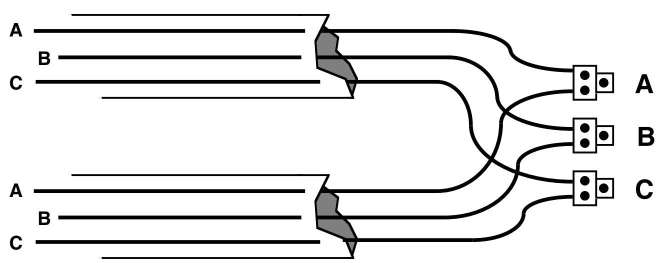




It is wrong to think that by using a larger size conduit than required would satisfy the adjustment factor required for the reduction of ampacity. The larger conduit would have more volume area, but it's like heating a rock, it may take a little longer but it will still reach the same temperature.



To avoid applying the adjustment factors of 310.15(C)(1) you can install two separate conduits as shown below. Now you only have 3 current carrying conductors in each conduit.



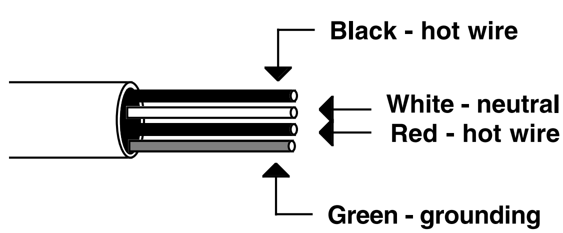
*Some conductors are **not** counted when applying 310.15(C)(1):*

310.15(C)(1)	Conductors of different systems
310.15(C)(1)(A)	Cable trays
310.15(C)(1)(b)	Nipples
310.15(C)(1)(c)	Outdoor trench
310.15(E)(1)	The neutral conductor in a normally balanced circuit is **not** counted

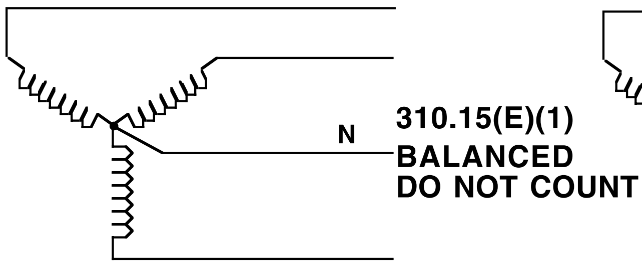
But, 310.15(E)(2) states: The neutral conductor is **counted** in a 3-wire circuit consisting of 2-phase wires of a 3-phase wye system.

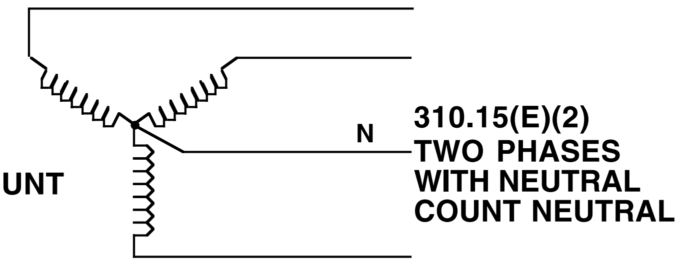
310.15(E)(3) states: The neutral is considered a **current carrying** conductor in nonlinear loads. Circuits such as discharge lighting (fluorescent, mercury, sodium) data processing, or similar equipment. The Harmonic currents in the nonlinear loads can cause the neutral currents to rise a little higher than the line current.

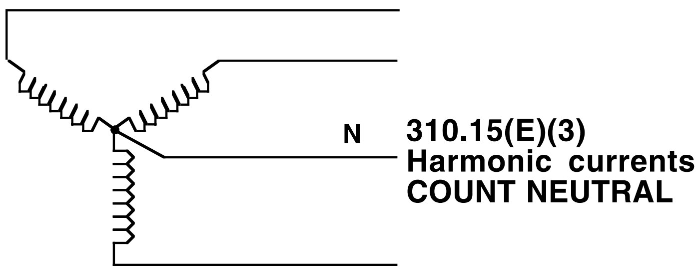
310.15(F) states: A grounding or bonding conductor shall **not** be counted when applying the provisions of Table 310.15(C)(1) The grounding conductor (green or bare wire) only carries fault current to trip the overcurrent device. This is **not** a heat factor.



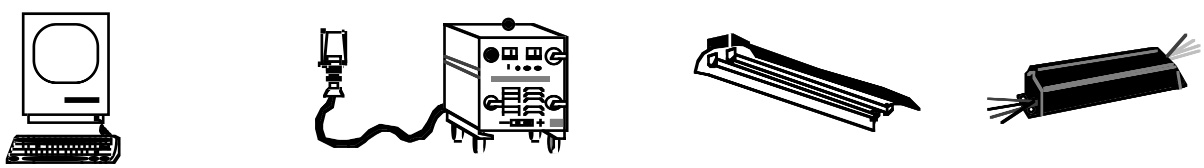
Summary of 310.15(E)(1)(2)(3) on when to count the neutral as current carrying:







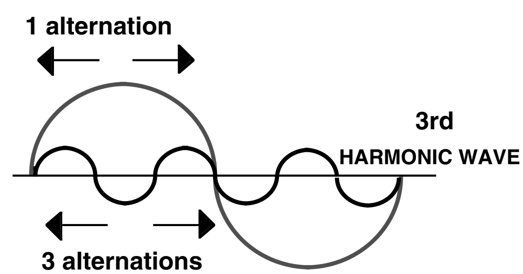
Non-linear loads which contain harmonic currents



When a linear load is turned on, the voltage and current start and turn off together. When a non-linear load is turned on, the voltage starts but the current is purposely delayed.

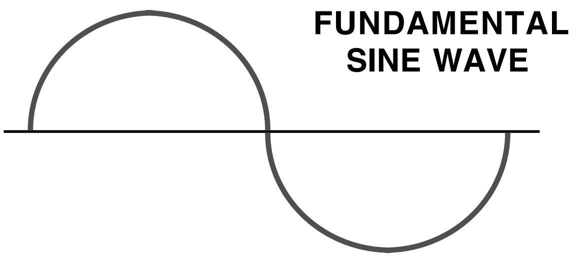
Harmonic simply indicates that the current waveform is distorted. The closer the waveform is to a fundamental sine wave, the lower the harmonic content. With a fundamental sine wave, there are no high order harmonics.

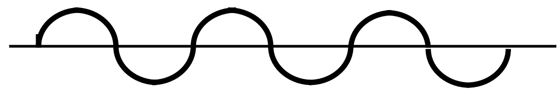
A 3rd harmonic makes 3 alternations in one alternation of the fundamental wave form. A 5th harmonic makes 5 alternations in one alternation of the fundamental wave. The 7th harmonic makes 7 alternations, and so on.

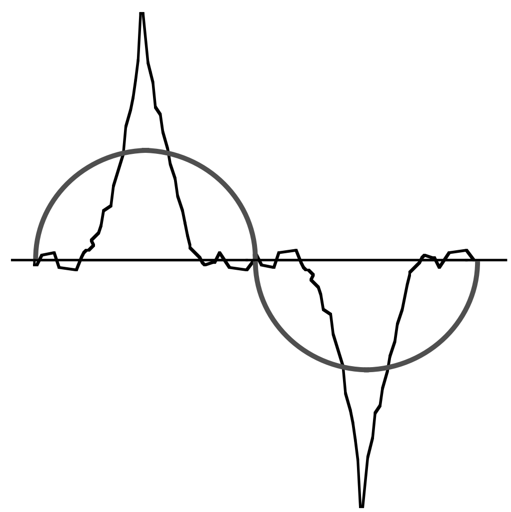


The highest peak of the wave is determined by **adding** all of the odd harmonics together. The frequency is determined by the number of complete cycles per second, measured in Hertz. 60 cycles per second equals 60 Hertz, or 60 Hz.

On a 60 Hz AC system, the 3rd harmonic is 180 Hz, the 5th harmonic is 300 Hz, the 7th harmonic is 420 Hz, etc.







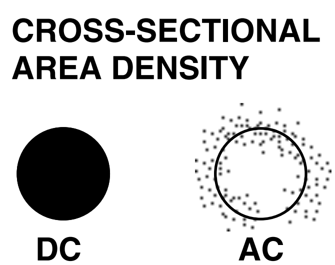
A **harmonic wave** is a **distorted wave** pattern consisting of the fundamental wave and other **higher frequency waves** that are superimposed on the fundamental wave.

The harmonic currents are delayed then **added** together and then burst into action causing a high peak wave form and a higher frequency.

Heat is increased by an increase in current frequency. The heating effect on transformers, circuit breakers and conductors supplying **non-linear** loads is a function of I^2R.

The higher I^2R heating where harmonic currents are supplied is caused by what is known as **skin effect**. Skin effect is an increase in resistance due to the fact that **higher-frequency** currents flow on the **skin** of the conductor, rather than throughout the entire conductor.

AC tends to flow along the surface of a conductor. DC acts through the entire cross-sectional area of the conductor in a uniform manner. The name skin effect is given to the action whereby AC is forced toward the surface of the conductor. Because of skin effect, there is less useful copper conductive area with AC. As a result, there is an increase in resistance.



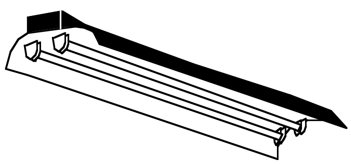
For the 3rd harmonic, instead of 60 Hz, it's now 180 Hz, there is a 42% change in the skin effect concentration point. For the 5th harmonic, there is a 55% difference and a 62% difference for the 7th harmonic. The result is a proportionate increase of resistance.

As you can see, the harmonic currents raised the frequency, thus raising the resistance and the I^2R heating effect.

In multiwire branch circuits, the odd numbered harmonics do not cancel out on the neutral, but are additive, resulting in a high neutral load. Because the heating effect on the conductor is proportional to I^2R and because the conductor resistance will be greater at 180 Hz than at 60 Hz, the heating effect in the neutral conductor will be greater than that of the phase conductors.

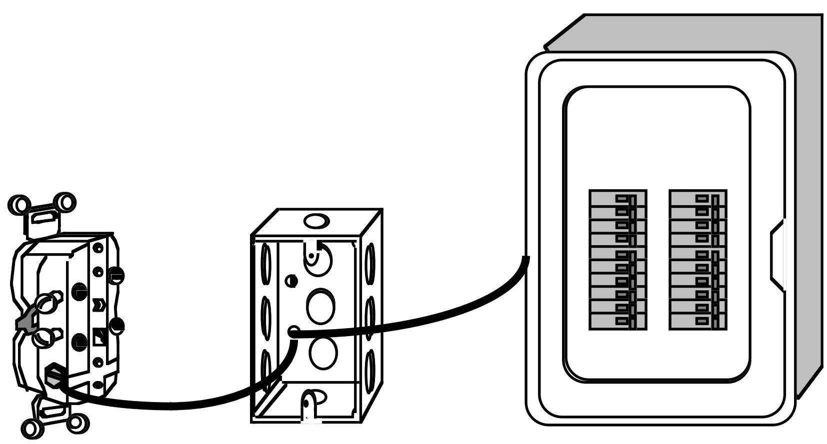
This is the reason in section 310.15(E)(3) of the Code it requires counting the neutral conductor in a 3ø, 4-wire circuit supplying **nonlinear loads.** The neutral conductor is actually **hotter** in temperature than the phase conductors.

An electrician is familar with the fluorescent light fixture containing a ballast. This fixture is referred to as discharge lighting since it contains a ballast (winding).



Harmonics cause problems to transformers and neutral conductors in multiwire feeders and branch circuits. The largest contributor to harmonic distortion is the static power converter used in adjustable speed drives.

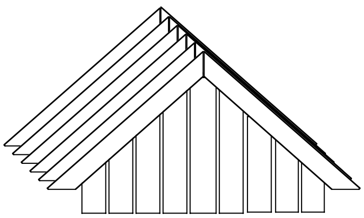
310.15(F) is a very interesting section which states you do **not** have to count the green or bare conductor (grounding or bonding). This conductor only carries current during a fault condition and if the circuit is designed properly will trip the circuit breaker in .008 of a second which is not a heat factor. But one must remember that this conductor carries **extremely high current** during this short time. The Code requires an effective grounding path. It's just important to make sure the conduits and grounding conductors are properly tightened as it is to check the hot wires.

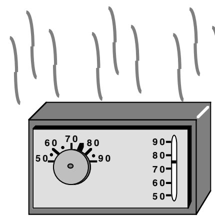


310.15(F) Grounding or bonding conductor DO NOT COUNT

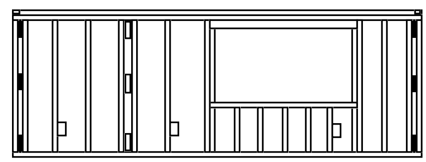
AMBIENT TEMPERATURE

Ambient temperature is the temperature of the medium, such as air, water or earth into which the heat of the conductor is dissipated. It's the temperature surrounding the conductor.



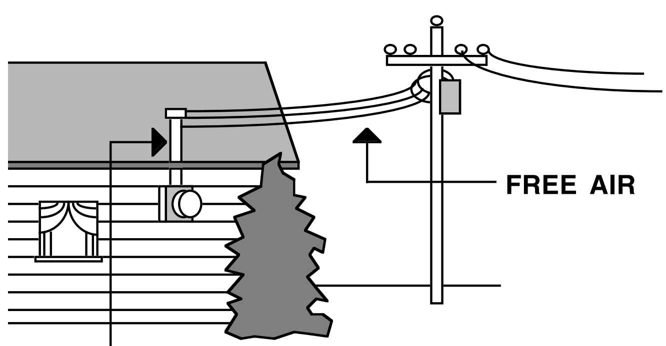


Ambient temperature is the temperature surrounding the conductor or equipment



A conductor in free air as shown below can carry more amperage than one that is installed in a conduit, cable, wall, attic, etc. where the higher ambient requires lowering the current flow on the conductor. This explains one reason why the power company can use smaller conductors.

DIFFERENT AMBIENT CONDITIONS

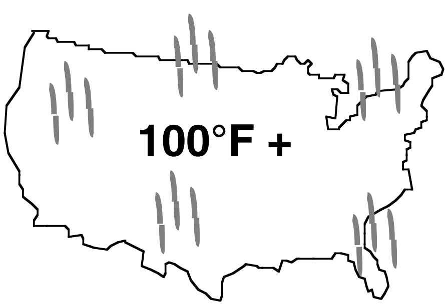


CONDUIT or CABLE ENTRAPS HEAT

The Table 310-20c is from the **1971 Code**. This Table reflects the temperatures and insulations that were required for the heat. On the electrical exam, the ambient temperature will be stated in the calculation.

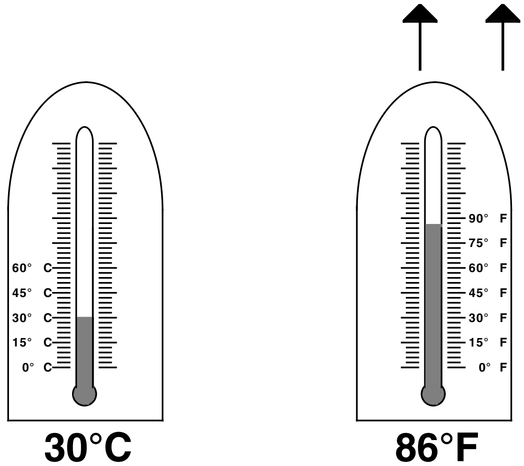
Table 310-20(c) / Typical Ambient Temperatures

LOCATION	TEMPERATURE	Minimum Rating of Required Conductor Insulation
WELL VENTILATED, NORMALLY HEATED BUILDINGS	30° C (86° F)	* (See note below)
BUILDINGS WITH SUCH MAJOR HEAT SOURCES AS POWER STATIONS OR INDUSTRIAL PROCESSES	40° C (104° F)	75° C (167° F)
POORLY VENTILATED SPACES SUCH AS ATTICS	45° C (113° F)	75° C (167° F)
FURNACES AND BOILER ROOMS		
(min.)	40° C (104° F)	75° C (167° F)
(max.)	60° C (140° F)	90° C (194° F)
OUTDOORS IN SHADE IN AIR	40° C (104° F)	75° C (167° F)
IN THERMAL INSULATION	45° C (113° F)	75° C (167° F)
DIRECT SOLAR EXPOSURE	45° C (113° F)	75° C (167° F)
PLACES ABOVE 60° C (140° F)		110° C (230° F)



Remember in the proper sizing of conductors you must consider the **worst** heat condition the conductor would ever encounter. I recently read an article in the newspaper where all 50 states in the U.S.A. have reached a temperature over 100 degrees F at some time. The ampacity Table 310.16 is based on an ambient temperature of 86 degrees F. If the conductor is subject to a temperature higher than 86 degrees F, the **correction factor** must be applied.

Table 310.16. Ampacities of Insulated Conductors Rated 0 -2000 Volts,
60° to 90°C (140° to 194°F) Not more Than Three Conductors in Raceway or Cable or Earth (Directly Buried),
Based on Ambient Air Temperature of 30°C (86°F).



When a conductor is installed in an ambient above or below 30°C or 86°F a correction factor must be applied

***Table 310.15(B)(1)(1) CORRECTION FACTORS**

Ambient Temp. °C	For ambient temperatures other than 30°C (86°F), multiply the ampacities shown above by the appropriate factor shown below. 60°	75°	90°	60°	75°	90°	**Ambient Temp. °F**
10 or less	1.29	1.20	1.15	1.29	1.20	1.15	50 or less
11-15	1.22	1.15	1.12	1.22	1.15	1.12	51-59
16-20	1.15	1.11	1.08	1.15	1.11	1.08	60-68
21-25	1.08	1.05	1.04	1.08	1.05	1.04	69-77
26-30	1.00	1.00	1.00	1.00	1.00	1.00	78-86
31-35	.91	.94	.96	.91	.94	.96	87-95
36-40	.82	.88	.91	.82	.88	.91	96-104
41-45	.71	.82	.87	.71	.82	.87	105-113
46-50	.58	.75	.82	.58	.75	.82	114-122
51-55	.41	.67	.76	.41	.67	.76	123-131
56-60	—	.58	.71	—	.58	.71	132-140
61-65	—	.47	.65	—	.47	.65	141-149
66-70	—	.33	.58	—	.33	.58	150-158
71-75	—	—	.50	—	—	.50	159-167
76-80	—	—	.41.	—	—	.41.	168-176
81-85	—	—	29	—	—	29	177-185

For ambient temperatures above 30 degrees C or 86 degrees F **multiply** the **ampacities** shown above by the appropriate correction factor shown below. Remember, correction factors change with different temperatures and different **types of insulations**.

A #10 TW copper conductor in an ambient temperature of 106 degrees F has a correction factor of .71, whereas a #10 **THW** copper conductor in the same ambient temperature has a correction factor of .82. A #10 **THHN** copper conductor in the same ambient temperature has a correction factor of .87.

A #10 TW copper conductor has an ampacity of 30. In an ambient temperature of 106 degrees F the ampacity shall be reduced: 30 ampacity x .71 correction factor = 21.3 amps. This is the reduced ampacity and the maximum load that can be applied to this conductor at 106 degrees F, without exceeding the temperature rating of 140 degrees F for TW insulation.

An error I have seen made by students trying to select the correct multiplier from the correction factor table is called a **line of sight** error. As you can see when selecting the 106 degrees F from the far right column, that you now have to go back to the second column from the left (TW insulation copper) to select the correction factor of .71. I suggest when using tables from the Code to use a **straight edge** such as a **ruler** so that you can follow the same line across the table and avoid selecting wrong numbers. Columns, numbers and lines have a tendency to "jump around". Your eyes can become weary after several exam hours of working calculations. **Use a straight edge**.

The left half of Table 310.16 is for **copper** and the right half of this table is for **aluminum or copper-clad aluminum** conductors. A #10 TW **aluminum** conductor has an ampacity of 25. In an ambient temperature of 106 degrees F, the correction factor is .71. The ampacity shall be reduced 25 ampacity x .71 correction factor = 17.75 amps. This is the reduced ampacity and maximum load on this conductor at 106 degrees F.

A #10 **THHN** copper conductor has an ampacity of 40. In an ambient temperature of 106 degrees F the correction factor **changes** to .87. 40 ampacity x .87 = 34.8 reduced ampacity, **but** the **maximum load** is limited to 30 amps by **overcurrent protection** device per the **asterisk (*)** at the bottom of Table 310.16:

" * 240.4(D) Unless otherwise specifically permitted in (e) or (g), the **overcurrent protection** shall not exceed 15 amperes for #14 AWG, 20 amperes for #12 AWG, and 30 amperes for #10 AWG **copper**; or 15 amperes for #12 AWG and 25 amperes for #10 AWG **aluminum and copper-clad aluminum** after any **correction factors for ambient temperature and number of conductors have been applied**."

Example: A #12 THW copper conductor has an ampacity of 25. The **overcurrent protection** (fuse or circuit breaker) shall not exceed 20 amps.

When answering exam calculations, watch the **wording**. Ask yourself: "Is the question asking for **conductor ampacity** or asking for **overcurrent protection**?"

I've had students ask, "What good is it to have a conductor with an ampacity of 25, if you can only fuse it at 20 amps?"

Even though a #12 conductor can only be **fused** at a maximum of 20 amps, the conductor is **derated** from the **25 ampacity** rather than 20.

In an ambient temperature of 104°F #12 THW copper has an ampacity of 25 x .88 correction factor = 22 reduced ampacity. A #12 THW copper conductor will carry an 18 amp load in an ambient temperature of 104°F.

A #12 THW copper conductor can carry 25 amperes continuously @ 86°F, but the devices you connect the conductor to are not rated for these higher currents. The asterisk (*) limit of 20 amps on the overcurrent protection is because the protective device will not protect the conductor from short-circuit currents, it will protect the conductor from overcurrent but not short circuits.

Conductors and devices must be used as listed in Section 110.3(B). An example of a daily **misuse** of Table 310.16 would be using the ampacities of a 90°C conductor such as the popular **THHN** insulation. Table 310.16 shows a #6 THHN copper conductor with an ampacity of 75, **but** this ampacity applies when the 90°C conductor is connected to devices with a rating of 90°C.

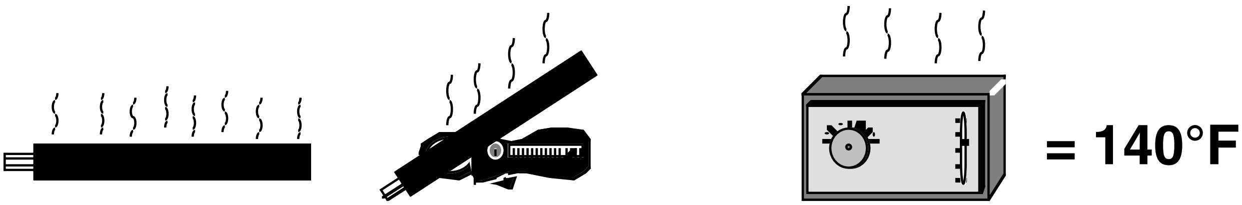
From the UL Electrical Construction Materials Directory and Code section 110.14(C)(1): "The termination provisions on equipment are based on the use of 60°C conductors in circuits rated 100 amperes or less and the use of 75°C conductors in higher rated circuits.

If the termination provisions on the equipment are based on the use of other conductors, the equipment is either marked with both the size and temperature rating of the conductors to be used. If the equipment is marked only with the temperature rating of the conductors to be used, that temperature rating is required for the ambient temperature in the equipment and the 60°C ampacity (100 ampere or less circuits) or 75°C ampacity (over 100 ampere circuits) should be used to determine the size of conductors.

Higher temperature rated conductors may be used, though not required, if the size of the conductors is determined on the basis of the 60°C ampacity (100 ampere or less circuits) or 75°C ampacity (over 100 ampere circuits)."

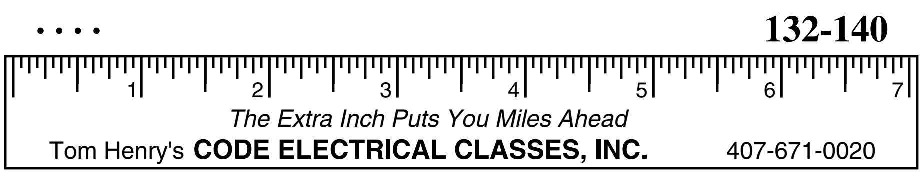
Example: A #6 TW has a normal ampacity of 55 amps. Which means when the conductor is loaded to 55 amps in an ambient of 86°F or 30°C it will reach an **operating temperature** of 140°F or 60°C.

When the conductor insulation is exposed to a temperature **above** 86°F or 30°C, it is subject to insulation damage when loaded to its ampacity value. This is why a **correction factor** is applied when the ambient temperature exceeds 86°F or 30°C.



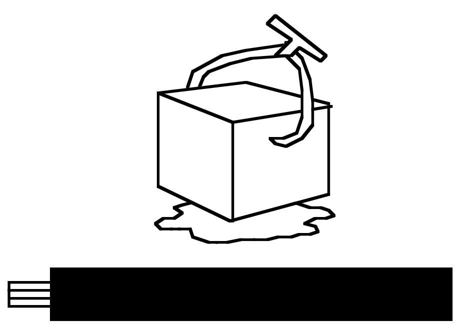
#6 TW **Loaded to 55 amps** **Ambient temperature is 86°F**

If you lay your ruler on 140°F(Table 310.15(B)(1)(1) and read the column for TW insulation (60°C-140°F), you'll see there is **no** correction factor. This simply means you are not permitted to use this insulation in this high of an ambient temperature.



When the ambient temperature is **below** 86°F or 30°C the ampacity can be adjusted to a **higher** value than shown.

Example: The #6 TW has a normal ampacity of 55 amps. If the ambient temperature is 70°F the correction factor is now **1.08**. 55 ampacity x 1.08 = **59.4 ampacity**.



Cooler ambient allows a higher ampacity

TWO TYPES OF AMPACITY QUESTIONS

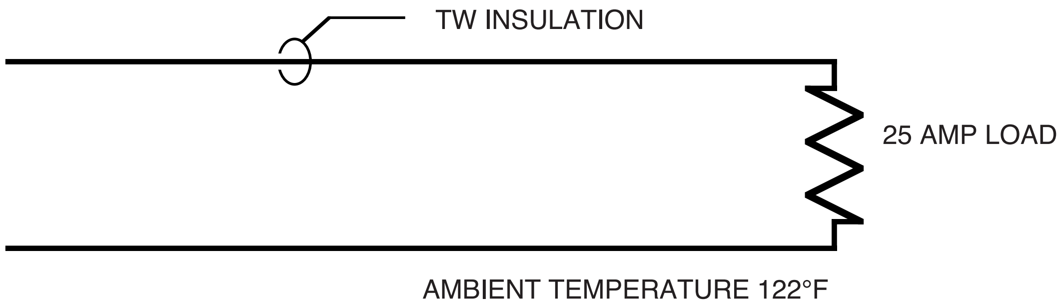
The first type of question will state the conductor, insulation type, and an ambient temperature either in Celsius (Centigrade) or Fahrenheit, and the question will ask the **ampacity** of the conductor.

Example: What is the ampacity of a #6 TW conductor in an ambient temperature of 122°F?

#6 TW = 55 ampacity x .58 correction factor = 31.9 reduced ampacity.

The second type of question will state a load, type of insulation, and an ambient temperature, and the question will ask the **size** of conductor required.

Example: What is the minimum size copper conductor required for the circuit shown below?



Use the formula: $\text{Required Table Ampacity} = \dfrac{\text{Load}}{\text{Correction Factor}}$

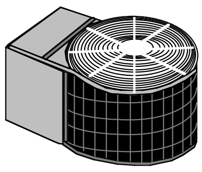
You can select the minimum size conductor very easily by using this formula.

$$\frac{\text{25 amp load}}{\text{.58 correction factor}} = \text{43.1 required ampacity}$$

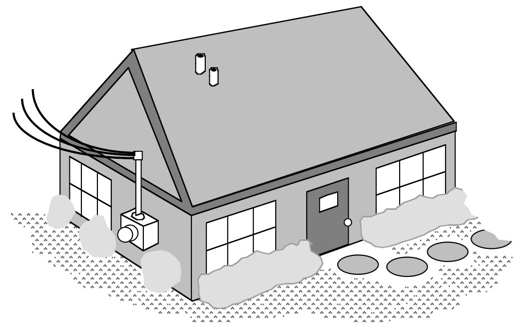
Turn to Table 310.16 for copper TW insulation and select a conductor from this column that would carry at least 43.1 amps. This would require a #6 TW with an ampacity of 55.

Note: Section 110.5: Conductors normally used to carry current shall be of **copper or aluminum** unless otherwise provided in this Code. Where the conductor material is **not** specified, the sizes given in this Code shall apply to copper conductors.

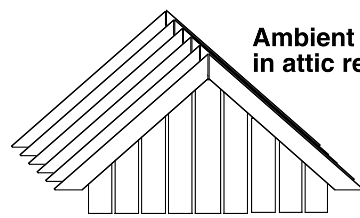
To correctly apply Table 310.16 to reality and check the misuse of the table by using a #10 for a **25 amp load**, let's calculate the **minimum** size conductor required for a 3 ton A/C unit in a dwelling using TW conductors in EMT through the attic to the load center. The ambient temperature in the attic has reached **114°F**.



3 ton A/C unit
load 25 amps



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



Ambient temperature in attic reaches 114°F

#10 TW ampacity 30a x .58 (correction factor for 114°F) = 17.4 derated ampacity.

#8 TW ampacity 40a x .58 (correction factor for 114°F) = 23.2 derated ampacity.

#6 TW ampacity 55a x .58 (correction factor for 114°F) = 31.9 derated ampacity.

You must select a conductor that has at least an ampacity of 25 amps after derating as the load is 25 amps. A #6 TW is the **minimum** size permitted.

OR USE THIS FORMULA

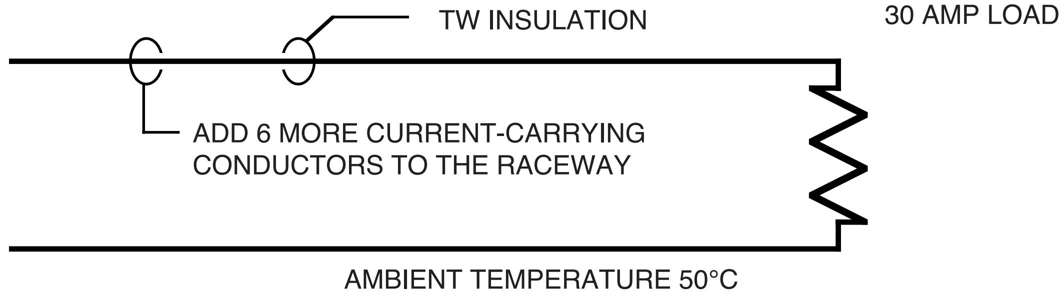
$$\text{Minimum wire size} = \frac{\text{LOAD}}{\text{CORRECTION FACTOR}}$$

$$\text{Minimum wire size} = \frac{\text{25 amps}}{\text{.58 correction factor}} = \text{43.1 required ampacity}$$

Turn to Table 310.16 for copper TW insulation and select a conductor from this column that would carry at least 43.1 amps. This would require a **#6 TW with an ampacity of 55**. Now you can see how **heat** affects ampacity and the sizing of conductors.

Table 310.16 is a very **misused** table in reality.

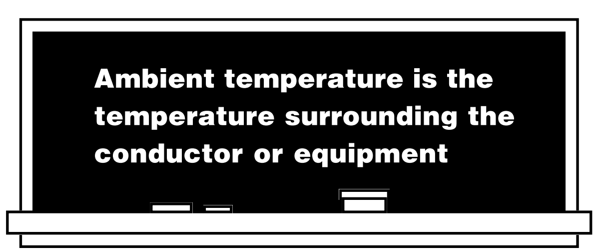
Shown below is an example applying **both** factors, an ambient correction and adjustment factor from Table 310.15(C)(1).



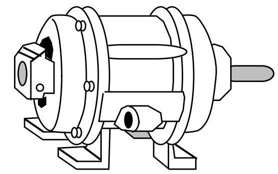
Use the formula: Required Table Ampacity $= \dfrac{\text{Load}}{\text{Correction Factor} \times \text{Adjustment Factor}}$

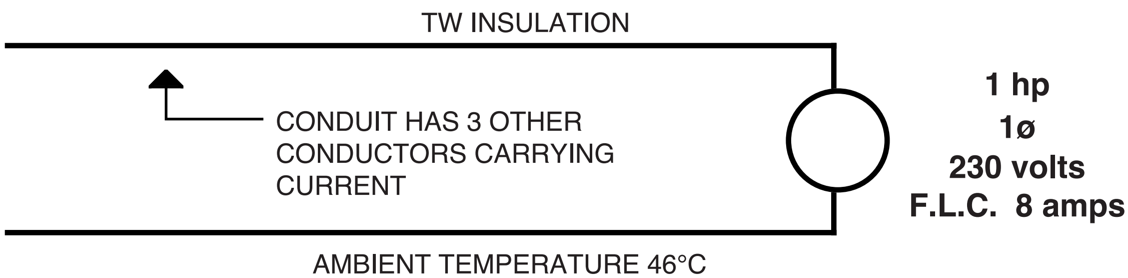
$$\frac{30 \text{ amp load}}{.58 \times .70} = 73.89 \text{ required ampacity}$$

Turn to Table 310.16 for copper TW insulation and select a conductor from this column that would carry at least 73.89 amps. This would require a #3 TW with an ampacity of 85.



A motor circuit would be a different calculation.





The load for a single-phase motor is found in Table 430.248 F.L.C. (full load current)

$$\frac{8 \text{ amp load}}{.58 \times .80} = 17.24$$

Section 430.22(A) requires an **increase** in ampacity of 125% for motor branch circuits.

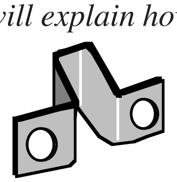
17.24 x 125% = 21.5 required ampacity

Turn to Table 310.16 for copper TW insulation and select a conductor from this column that would carry at least 21.5 amps. This would require a #10 TW with an ampacity of 30.

In the notes the asterisk (*) that states a #10 copper conductor has a maximum overcurrent protection of 30 amps. The asterisk (*) rules for overcurrent protection do **not** apply to **motor circuits** per section 240.4(G) which states motor overcurrent protection is calculated from Part IV of 430.

The reason that motors have different overcurrent protection rules from lighting and appliance circuits, motors have an extra element called an **overload device**. You may refer to this overload device as **heaters** or **thermal running overload protective devices**.

The next chapter, which is "Motors", will explain how a motor circuit is better protected than a



Overload (heater)

CONDUCTOR TERMINATIONS

The frequent misapplication of conductor temperature ratings occurs when the rating of the equipment is ignored when connecting the conductor. One must follow the rules of section 110.14(C)(1).

Shown below are the ampacities and temperature ratings for a #10 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

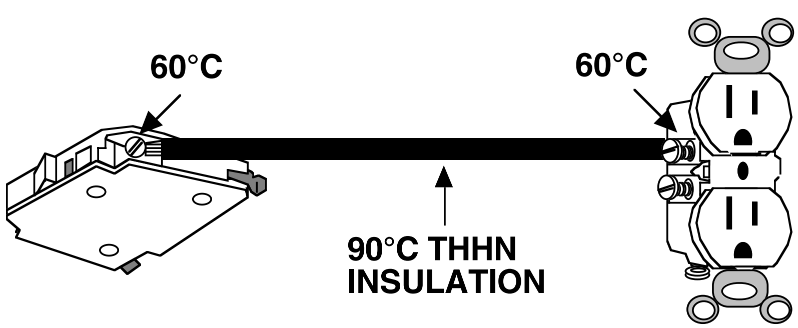
Conductors carry a specific temperature rating based on the *type* of insulation on the conductor.

Conductor sizing must be determined to where the conductors will terminate and the rating of the termination.

If a termination is rated for 60°C, this means that the temperature at that termination may rise up to 60°C when the equipment is loaded to its *ampacity*. Any additional heat at the connection above the 60°C conductor insulation rating could cause damage to the conductor insulation.

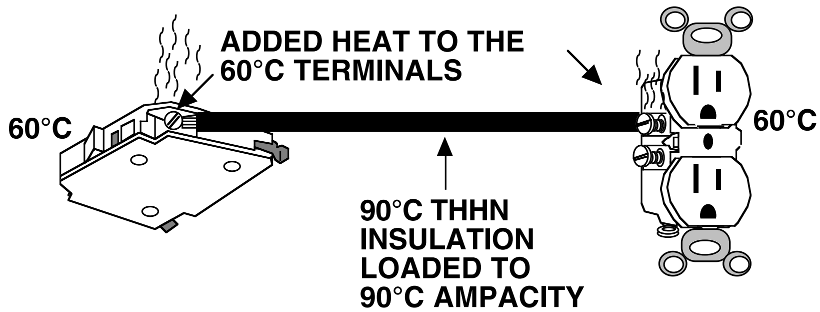
When a conductor is chosen to carry a specific load, the electrician must know the termination ratings of the equipment in the entire circuit.

When connecting the 90°C THHN insulation to 60°C rated equipment, the THHN cannot be loaded over the 60°C ampacity.



If the temperature rating of the equipment is not considered and the THHN is loaded to the 90°C ampacity, it will lead to overheating at the termination and *premature opening* of the breaker.

The breaker has a heat sink which determines when it will open, the added extra heat is a determining factor in the premature opening.



Electrical equipment such as circuit breakers, panelboards, receptacles, switches, terminal blocks, wire nuts, lugs, etc. have *temperature ratings* that must be observed.

The termination provisions are based on the use of 60°C ampacities for wire sizes #14 - #1 and 75°C ampacities for wire sizes #1/0 and larger. If using wire sizes #14-#1 in equipment marked "75°C only" or "60/75°C", it is intended that 75°C wire may be used at its full ampacity.

If the equipment is not marked, it is 60°C rated for 100 amps and less. Over 100 amps is 75°C rated. If the equipment is rated higher, it would have to be marked to indicate the higher temperature.

100 amps or less	Over 100 amps
Wire size #14 - #1	Wire size #1/0 and larger
60°C ampacity	75°C ampacity

The Code states in section 110.14(C) the temperature rating associated with the ampacity of the conductor shall be so selected not to exceed the lowest temperature rating of any conductor, device or connected termination.

This Code section is often violated, even ignored. A THHN 90°C conductor *cannot* be connected to a 60°C terminal and the conductor loaded to the 90°C ampacity.

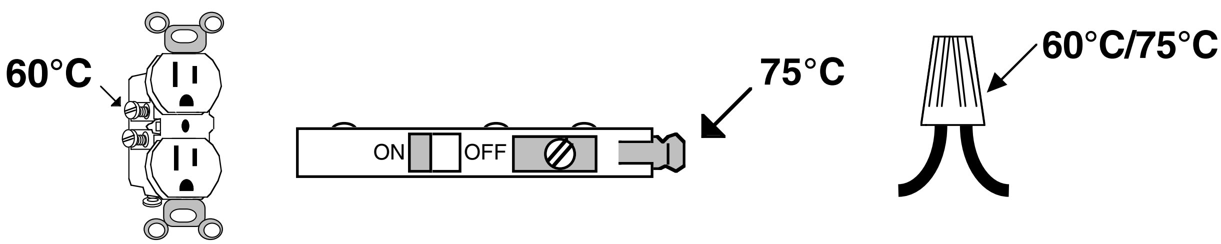
#10 THHN 40 ampacity
90°C - 194°F temperature rating

The THHN conductor is the most popular insulation used in circuits. Because of its thinner insulation, more conductors can be installed in a conduit compared to conductors with a thicker insulation.

Where the violation occurs is when the installer loads the THHN to the 90°C ampacity!

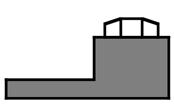
The only way a THHN could be loaded to a 90°C ampacity would be if every piece of electrical equipment (lugs, receptacle, switch, panelboard, overcurrent device, etc.) in the *entire* circuit is rated at 90°C.

The first thing the installer must be made aware of is that electrical equipment terminations are rated at 60°C, 75°C, or 60/75°C. If there is no marking on the equipment, it is 60°C for 100 amps or less. Over 100 amps is 75°C rated.



Circuit breakers are listed as suitable for 60°C only, 75°C only, or 60/75°C wire. Very little electrical equipment is tested for use with conductors operating over 75°C, although some large bolted pressure contact switches are suitable for conductors operating at 90°C.

When a conductor is chosen for the circuit, the electrician must know the termination ratings for the equipment in the *entire* circuit.



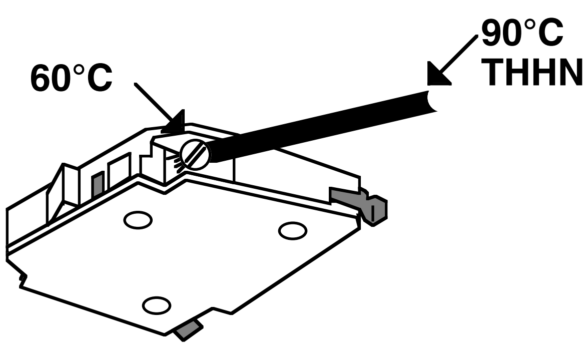
90°C RATED

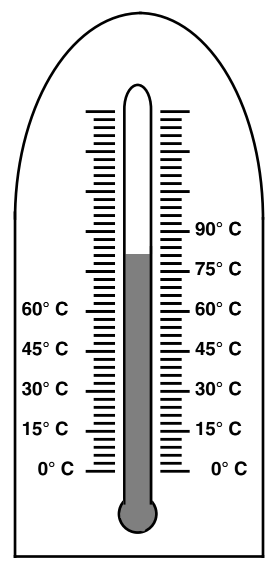
The lug may be rated for 90°C but this does not give permission to the installer to use a 90°C conductor at 90°C ampacity. Every electrical component in the entire circuit must be 90°C rated.

When terminals are tested at 60°C or 75°C, the use of 90°C conductors loaded to their higher ampacity ratings can damage the terminals on circuit breakers, switches, etc. Electrical equipment has experienced termination failures even when the load current did not exceed the current rating of the circuit breaker or switch, etc.

When a 60°C rated circuit breaker terminal is fed by a conductor operating at 90°C, there will be substantial heat conducted from the 90°C metal to the 60°C terminal that can damage the terminal over a period of time, even though the load current does not exceed the 60°C terminal rating and does not exceed the 90°C ampacity.

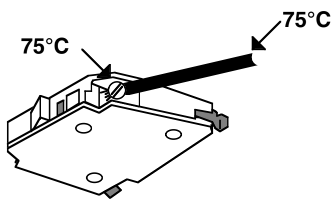
The definition of ampacity is the current in amperes a conductor can carry *continuously* under the conditions without exceeding its (insulation) temperature rating. The greater the ampacity of a higher-temperature rated conductor establishes the ability of the conductor insulation to withstand the higher heat being produced by the higher current through the wire. But, it is *wrong* to assume that the equipment the conductor is being connected to is also capable of withstanding this higher heat.

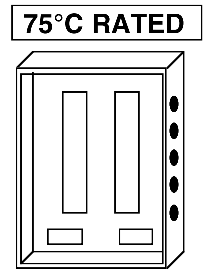




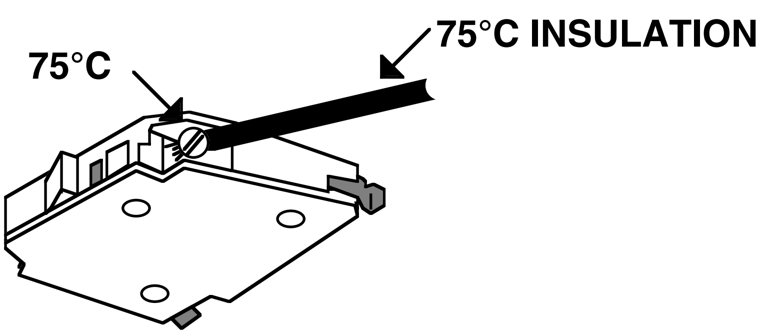
When two metallic parts are tightly connected having different operating temperatures (60°C - 90°C) the higher-temperature part (90°C) will give heat to the lower temperature part (60°C) and raise its temperature to above 60°C.

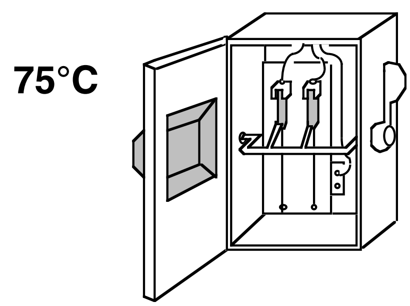
A 75°C temperature marking on a circuit breaker normally intended for wire sizes #14-#1 does not in itself allow the 75°C wire to be used at a 75°C ampacity unless the enclosure in which the circuit breaker is installed is also marked 75°C.





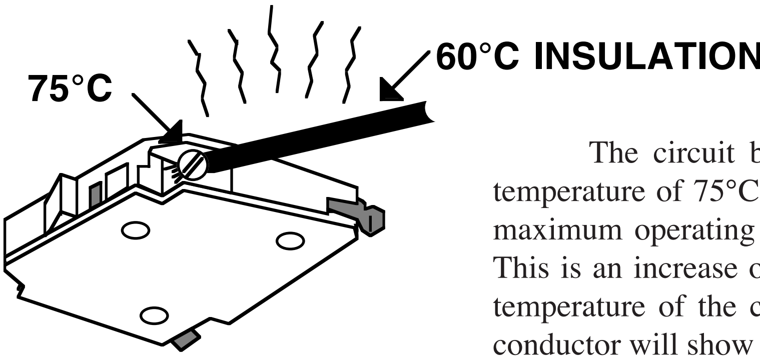
A conductor has *two* ends. Conductors must be sized by giving consideration to where each end will terminate and the temperature rating of the termination equipment.





If a termination is rated for 75°C, this means that the temperature at that termination may rise up to 75°C when the equipment is loaded to its full ampacity. If 60°C conductors were used, the additional heat at the termination above 60°C conductor insulation rating could result in insulation damage.

Often, manufacturers are asked when electrical equipment will be available with terminations that will allow THHN 90°C conductors to be loaded to the 90°C ampacity. The answer is complex and requires not only significant equipment redesign to handle the extra heat, but also significant changes in the product testing/listing standards would also have to occur.



The circuit breaker lug fully loaded will reach a temperature of 75°C which is 167°F. The 60°C conductor maximum operating temperature is 60°C which is 140°F. This is an increase of 27°F above the *maximum* operating temperature of the conductor. Over a period of time, the conductor will show signs of insulation damage such as the insulation becoming hard and brittle close to the termination.

The panelboard has a 150 amp circuit breaker with a temperature of 75°C. It requires a conductor with an ampacity of at least 150 amperes. Table 310.16 shown below lists the ampacities of different conductors. We must select a conductor with an ampacity of at least 150 from the *75°C column* which is a #1/0. A #1 THHN 90°C conductor also has an ampacity of 150. But, a #1 THHN *cannot* be loaded to the 150 ampacity because the equipment is only rated at 75°C. Using a #1 THHN conductor in this application would lead to possible overheating at the termination or premature opening of the circuit breaker. A 60°C insulated conductor is not acceptable regardless of the size since the temperature at the termination (75°C) could rise to a value greater than the insulation rating of 60°C.

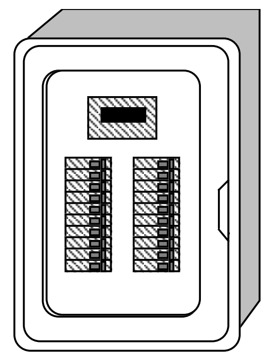
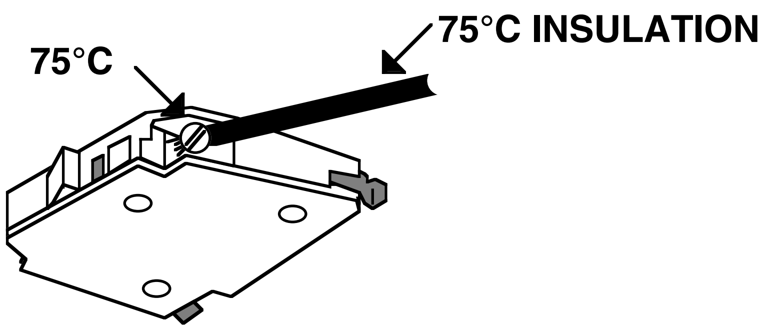
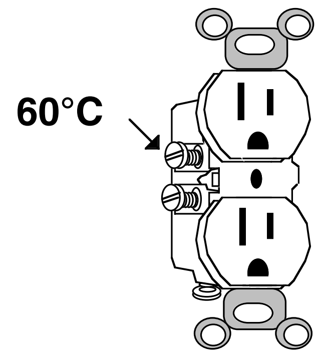


Table 310.16. Allowable Ampacities of Insulated Conductors

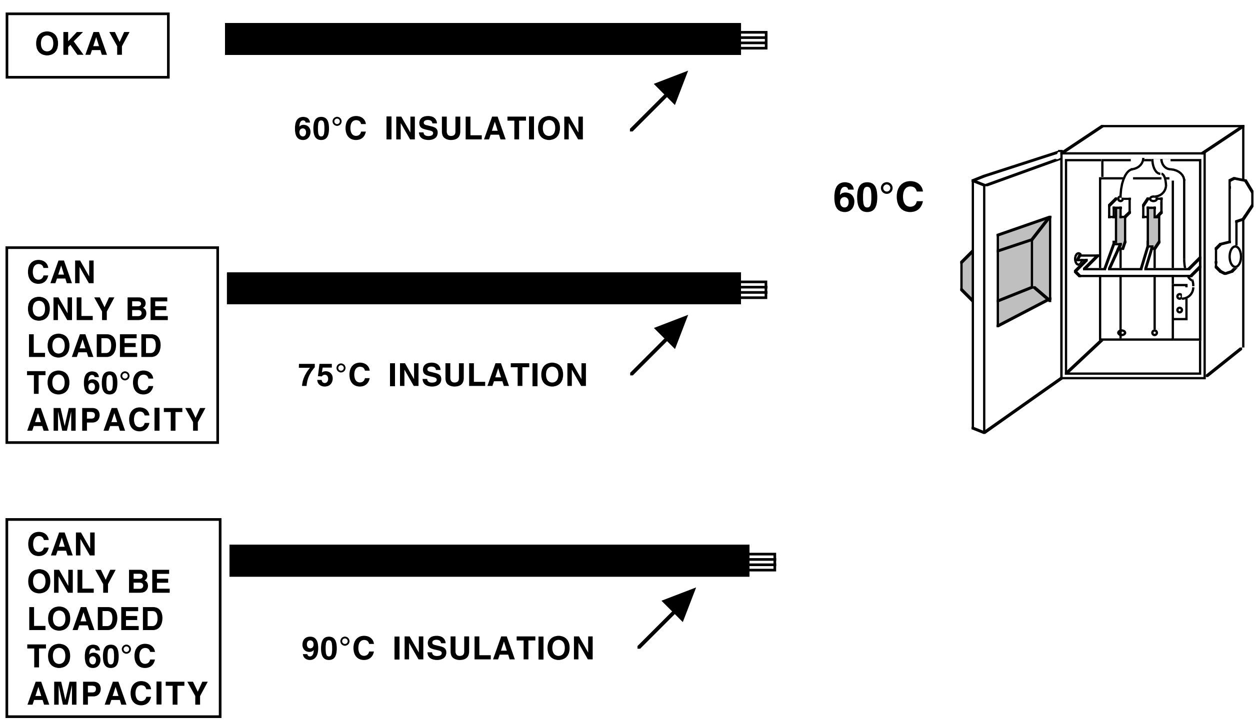
Size	Temperature Rating of Conductor. See Table 310.4(1).						Size
	60°C (140°F)	75°C (167°F)	90°C (194°F)	60°C (140°F)	75°C (167°F)	90°C (194°F)	
AWG kcmil	TYPES TW, UF	TYPES RHW, THHW, THW, THWN, XHHW, USE, ZW	TYPES TBS,SA, SIS, FEP, FEPB, MI, RHH, RHW-2, THHN, THHW, THW-2, THWN-2 USE-2, XHH XHHW, XHHW-2 ZW-2	TYPES TW, UF	TYPES RHW, THHW, THW, THWN, XHHW, USE	TYPES TBS, SA, SIS, THHN, THHW, THW-2, THWN-2, RHH, RHW-2, USE-2, XHH, XHHW, XHHW-2, ZW-2	AWG kcmil
	COPPER			ALUMINUM OR COPPER-CLAD ALUMINUM			
18**	....	....	14	....	....	....	....
16**	....	....	18	....	....	....	....
14**	15	20	25	....	....	....	....
12**	20	25	30	15	20	25	12**
10**	30	35	40	25	30	35	10**
8	40	50	55	35	40	45	8
6	55	65	75	40	50	55	6
4	70	85	95	55	65	75	4
3	85	100	115	65	75	85	3
2	95	115	130	75	90	100	2
1	110	130	145	85	100	115	1
1/0	125	150	170	100	120	135	1/0
2/0	145	175	195	115	135	150	2/0
3/0	165	200	225	130	155	175	3/0
4/0	195	230	260	150	180	205	4/0

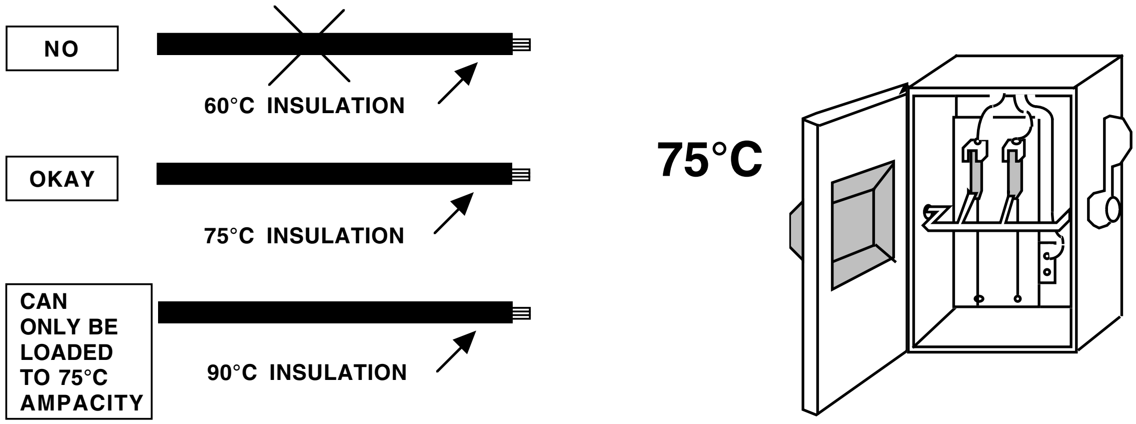
A circuit breaker is rated 75°C and the receptacle to which the branch circuit conductor is connected is rated 60°C. The conductor must have an insulation rating of at least 75°C (due to the rating of the breaker), and the conductor must be sized based on the ampacity of a 60°C conductor (due to the rating of the receptacle).

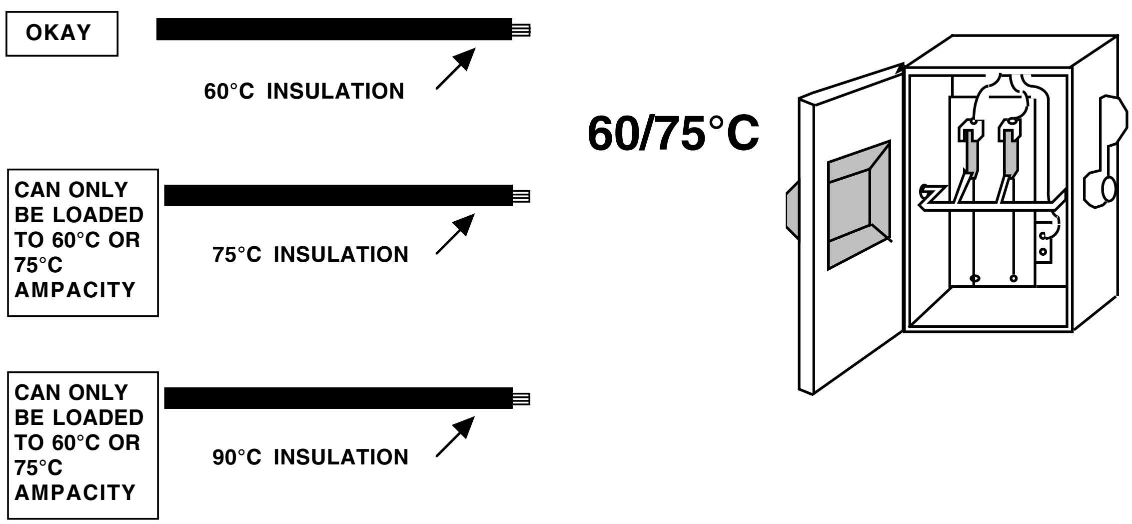


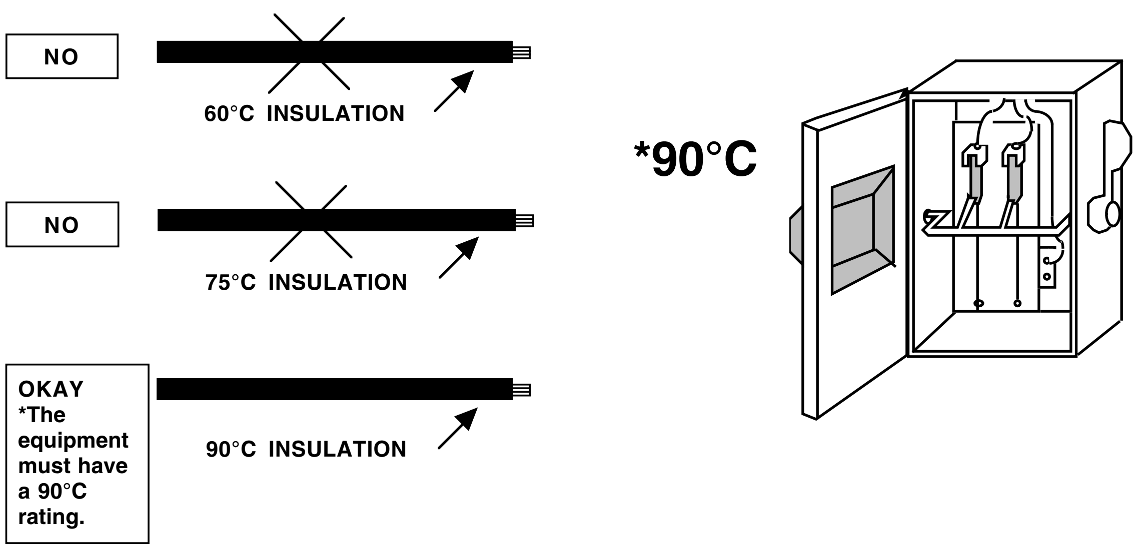


The general rule is 100 amps or less is wire sizes #14 - #1 with 60°C ampacity and for over 100 amps, the wire sizes are #1/0 and larger with 75°C ampacity. But, there are two exceptions: (1) Conductors with higher temperature ratings such as 75°C can be used but at the ampacity of the equipment temperature rating as shown above. (2) Equipment termination provisions can be used with higher rated conductors at the ampacity of the higher rated conductors, provided the equipment is listed at the higher rating. This means a 20 amp receptacle can be rated 75°C even though it is 100 amps or less.



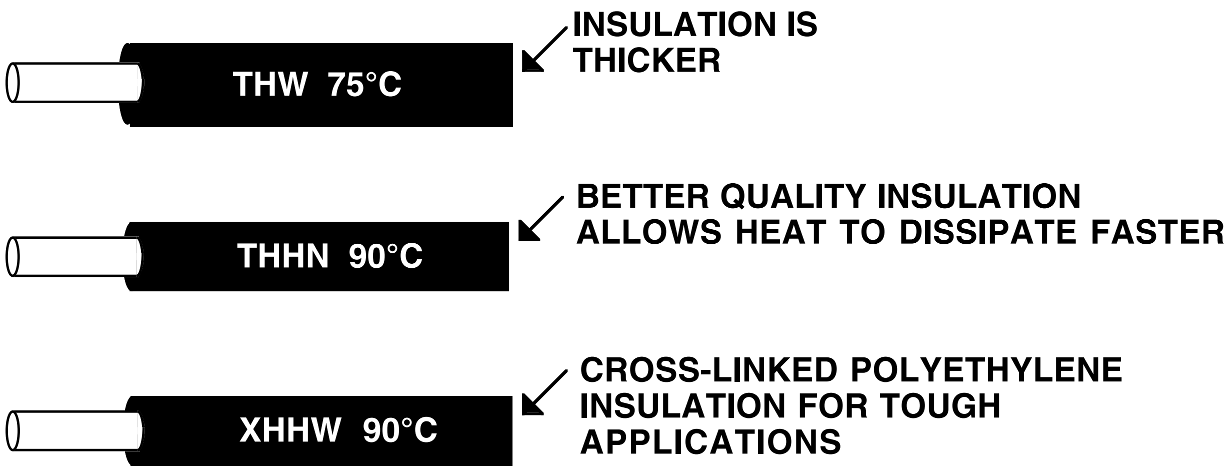

NO
60°C INSULATION
OKAY
75°C INSULATION
CAN ONLY BE LOADED TO 75°C AMPACITY
90°C INSULATION
75°C


OKAY
60°C INSULATION
CAN ONLY BE LOADED TO 60°C OR 75°C AMPACITY
75°C INSULATION
CAN ONLY BE LOADED TO 60°C OR 75°C AMPACITY
90°C INSULATION
60/75°C


NO
60°C INSULATION
NO
75°C INSULATION
OKAY *The equipment must have a 90°C rating.
90°C INSULATION
*90°C

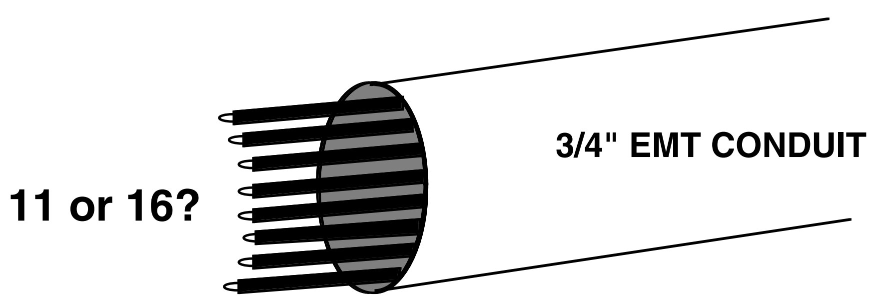
ADVANTAGES OF 90° C CONDUCTORS

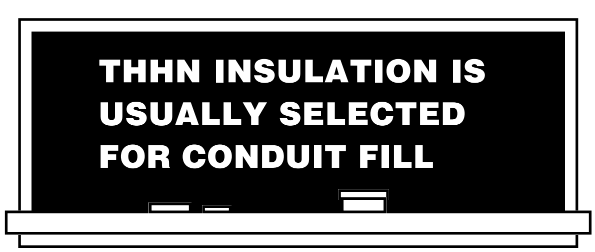
As you have seen, different types of insulations have different ampacities and temperature ratings. Insulation also changes the size of the conductor and this is important when considering conduit fill.

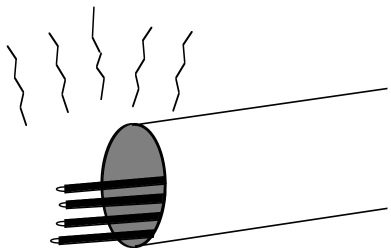


A #12 THW has a thicker insulation .0181 sq.in. compared to the thinner insulation of a #12 THHN at .0133 sq.in.

You could install 11 - #12 THW's in a 3/4" EMT conduit or 16 - #12 THHN's.







Code Table 310.15(C)(1) states the number of conductors is the total number of conductors in the raceway or cable, including spare conductors. The count shall be adjusted in accordance with 310.15(E) and (F). The count shall not include conductors that are connected to electrical components that cannot be simultaneously energized.

That where the number of current-carrying conductors in a raceway or cable exceeds *three,* the allowable ampacity must be reduced to compensate for the increased heating effect due to reduced ventilation of an enclosed group of closely spaced conductors.

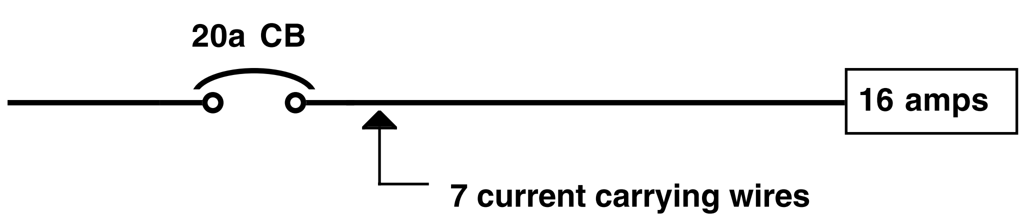
Adjustment Factors.

(a) More than Three Current Carrying Conductors in a Raceway or Cable. Where the number of conductors in a raceway or cable exceeds three, the ampacities shall be reduced as shown in the following table:

Table 310.15(C)(1) Number of Conductors	Percent of Values in Tables 310.16 through Table 310.19 as Adjusted for Ambient Temperature if Necessary
4 through 6	80
7 through 9	70
10 through 20	50
21 through 30	45
31 through 40	40
41 and above	35

Selecting THHN 90°C insulation is an advantage in designing when applying the derating factors (correction factor and/or adjustment factor) to the normal ampacity of the conductor.

Example: The circuit is installed in a conduit that has a total of seven current carrying conductors. The equipment in the circuit has a rating of 60°C.



The Code requires the normal ampacity to be reduced for the seven current carrying conductors.

A #12 TW ampacity is 20 x 70% =14 amps the maximum current permitted.

A #12 THW ampacity is 25 x 70% = 17.5 amps is the maximum current permitted.

A #12 THHN has a normal ampacity of 30 x 70% = 21 amps is the maximum current permitted on the conductor. A #12 TW with a derated ampacity of 14 amps would be permitted to be protected by the next higher size breaker which is 15 amp **not a 20 amp.** A #12 THW with a derated ampacity of 17.5 is considered protected by the next higher size breaker which is a 20 amp. The advantage of a #12 THHN is it has a derated ampacity of 21 which is above the breaker rating of 20 amps. The THHN insulation eliminates any chance of overload damage to the insulation.

DERATED AMPACITY = 14

#12 TW 20 ampacity
60°C - 140°F temperature rating

DERATED AMPACITY = 17.5

#12 THW 25 ampacity
75°C - 167°F temperature rating

DERATED AMPACITY = 21

#12 THHN 30 ampacity
90°C - 194°F temperature rating

Example: A branch circuit has a noncontinuous load of 29 amps. The circuit is installed in a conduit that has a total of four current carrying conductors. The equipment in the circuit has a rating of 60°C.

A #10 TW ampacity is 30 x 80% =24 amps the maximum current permitted. A #10 TW would violate the Code in this example as the load is 29 amps.

A #10 THW ampacity is 35 x 80% = 28 amps is the maximum current permitted. A #10 THW would also be a violation as the load is 29 amps.

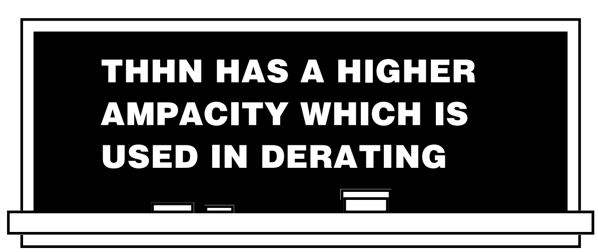
A #10 THHN has a normal ampacity of 40 x 80% = 32 amps is the maximum current permitted on the conductor. Next go to the 60°C column and select a conductor that will carry the 29 amp load. A #10 THHN can be used in this condition. The THHN conductor can safely carry 32 amps without damage to the *conductor insulation*. But, the 60°C column shows a #10 conductor cannot be loaded to more than 30 amps without possible damage to the *termination*.

Otherwise you would have to use a #8 TW (40a x 80% = 32a) or a #8 THW (50a x 80% = 40a). By selecting THHN insulation you can use a smaller #10 conductor.

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

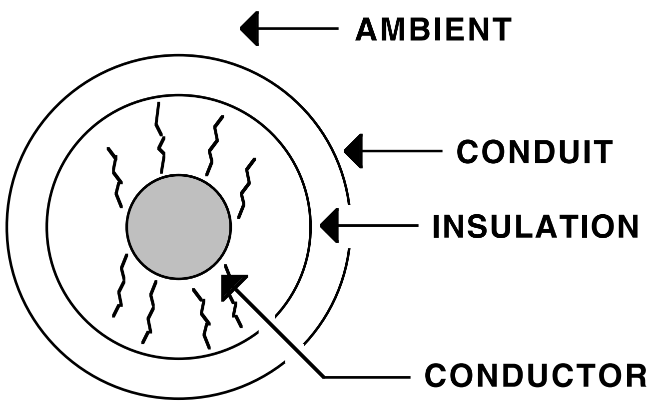
#10 THW 35 ampacity
75°C - 167°F temperature rating

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



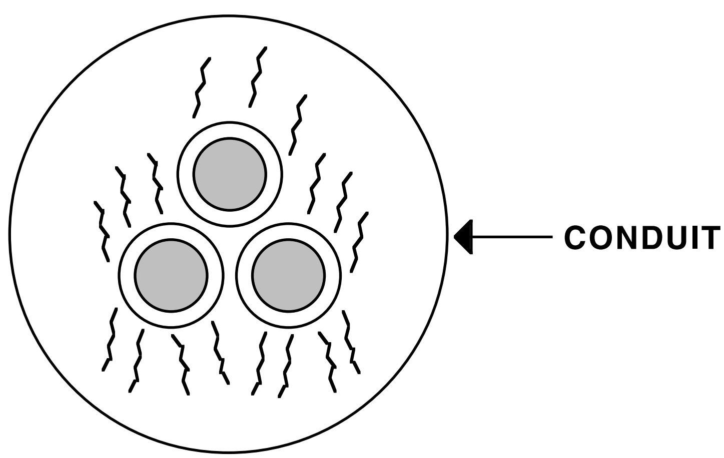
Summary

Table 310.16 gives ampacities under two conditions: There are **not** more than three current-carrying conductors in a raceway or cable and the raceway or cable containing the conductors is operating in an ambient temperature **not** exceeding 30°C of 86°F.

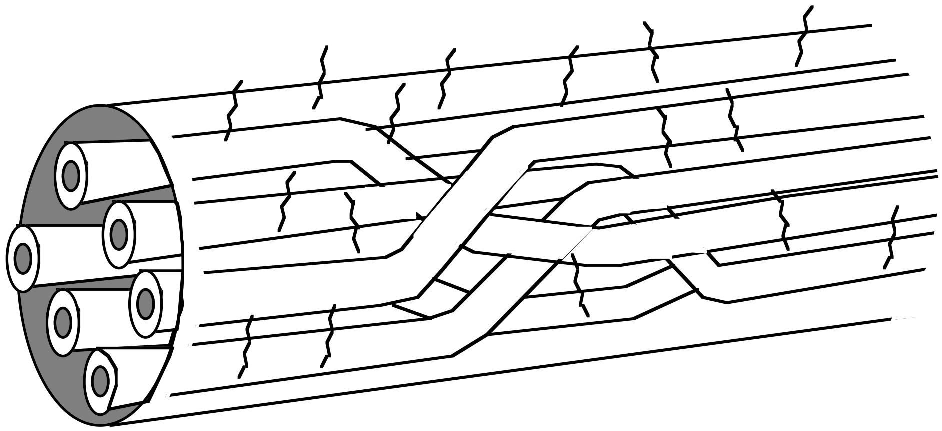


The current flowing through the conductor produces heat (I^2R). This heat must dissipate through the insulation into the raceway or cable. From the raceway or cable, the heat must dissipate into the ambient.

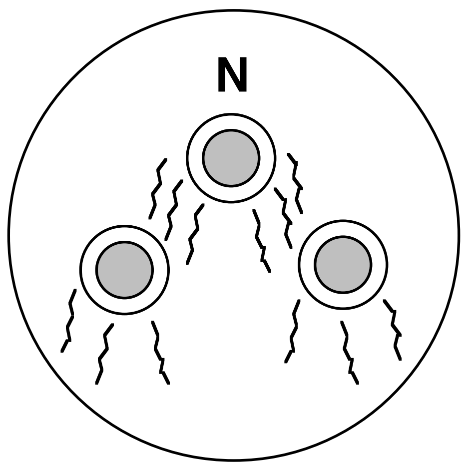
You can see from the illustration how the conductor material, size, insulation type, and ambient temperature decide the allowable ampacity of a conductor.



The above diagram shows three current-carrying conductors with the heat being released from the circumference of the conductors to the conduit.



The above illustration shows a conduit with six current-carrying conductors. **All** of the conductors are not close to the conduit wall to dissipate the heat. This condition requires the ampacity of each conductor to be reduced per Table 310.15(C)(1). Conductors installed in **parallel** require reducing the ampacity per T. 310.15(C)(1). Section 310.10(G)(1) states: Conductors installed in parallel shall comply with the provisions of 310.10(G)(2) through (G)(4).



310.15(E)(1): A **neutral** conductor which carries only the unbalanced current from the other conductors, as in the case of normally balanced circuits of three or more conductors, **shall not be counted** when applying the provisions of T. 310.15(C)(1).

Example: If the load is balanced, the current in the neutral is zero, and the two ungrounded conductors will run cooler because the neutral conductor is in intimate contact with them throughout the circuit and will serve to carry off part of the heat.

Using #4 THW copper conductors, 100 feet in length each. From Table 8, Chapter 9, the resistance of a #4 uncoated copper conductor is 0.308 ohms per thousand feet. 0.308 x .100 feet = 0.0308 ohm per conductor.

Let's say the circuit is balanced with each ungrounded conductor carrying a load of 60 amps. Heat = I^2R 60a x 60a x 0.0308 x 2 conductors = 221.76 watts.

Now assume the load is **not** balanced, the ungrounded conductor Line 1 carries 80 amps, Line 2 carries 40 amps, and the neutral carries the **unbalanced** of 40 amps.

The heat loss would be:

Line 1 =	80a x 80a x 0.0308 ohm =	197.12 watts
Line 2 =	40a x 40a x 0.0308 ohm =	49.28 watts
Neutral =	40a x 40a x 0.0308 ohm =	49.28 watts
		295.68 watts

The total of 295.68 watts is **more** than the loss of 221.76 watts in the case of the balanced load. Therefore, the balanced load is the best condition for heat. Any amount of load **imbalance** will only make heat conditions worse.

Any conductor in a raceway or cable has one of six possible values of ampacity, depending on the conditions of application.

The six conditions of ampacity using a #4 THW copper conductor as an example:

Condition 1. Ambient temperature is 30°C. Not more than three current-carrying conductors in raceway or cable. Under these conditions, #4 THW copper conductor has an ampacity of 85, as shown in Table 310.16.

Condition 2. Ambient temperature is 25°C which is **below** 30°C. Not more than three current-carrying conductors in raceway or cable. Under these conditions the value of 85 amps from Table 310.16 must be multiplied by the factor from "Ampacity Correction Factors" Table 310.15(B)(1)(1). For THW insulation at 25°C the correction factor is 1.05. 85 ampacity x 1.05 = 89.25 **increased** ampacity.

Condition 3. Ambient temperature is 45°C which is **above** 30°C. Not more than three current-carrying conductors in raceway or cable. Under these conditions the value of 85 amps must be multiplied by the correction factor of .82 per T. 310.15(B)(1)(1). 85 ampacity x .82 = 69.7 reduced ampacity.

Condition 4. Ambient temperature is 30°C. **Four** current-carrying conductors in raceway or cable. As required by T.310.15(C)(1), the value of 85 amps must be multiplied by 80% to determine the conductor ampacity. 85 ampacity x 80% = 68 reduced ampacity.