UNIT
5

Raceway and Box Calculations

INTRODUCTION TO UNIT 5—RACEWAY AND BOX CALCULATIONS

Anyone who's ever pulled wire into a conduit understands the reason for maximum limits on the wire fill for raceways. Trying to pull too many conductors into a raceway can damage the conductor insulation due to the friction and mechanical abuse. We've all heard a joke about tying a wire-pulling rope onto the hitch of the service truck and "locking in the hubs." At least, we hope this is a joke and not an accurate recounting of an installation.

Chapter 9, Table 1 provides the maximum limits the *Code* recognizes for wire fill in terms of a percentage of the raceway's interior cross-sectional area. This unit explains those limits and provides instruction regarding the use of the associated tables in Chapter 9 to calculate conductor fill. How to use the tables in Annex C when all of the conductors in the raceway are the same size (total cross-sectional area including insulation) is also covered.

Wireway abuse results from disregarding the limits on the radius of bends required for making transitions into and out of the wireway, and the number of conductors and splices allowed. There are specific rules in the *NEC* to help plan wireway installations that are in compliance and much easier to work with.

The *Code* provides a limit to the number of conductors allowed in outlet boxes, based on Table 314.16(A). This limit is often joked about as being the "maximum number of conductors that can be installed in the outlet box while using the persuasion of your hammer handle." This method doesn't follow the *NEC's* guidance set forth in 314.16(B). In this unit, you'll learn how to properly calculate the maximum number of conductors and "conductor equivalents" to be installed in an outlet box. Be sure to read this material carefully so you'll understand what the *Code* means by "conductor equivalents."

An explanation of the sizing requirements of 314.28(A)(1) and (2) for larger pull boxes, junction boxes, and conduit bodies which enclose conductors 4 AWG and larger, rounds out the information provided here in Unit 5.

PART A—RACEWAY FILL

Introduction

Raceways must be large enough to avoid damaging the insulation when conductors are pulled into the raceway. Chapter 9 and Annex C of the *NEC* are the primary references for determining allowable conductor fill in raceways. For the most common condition, where multiple conductors of the same size are installed together in a raceway, the maximum number of conductors permitted can be determined from the tables in Annex C. For situations where conductors of different sizes are mixed together in a raceway, Chapter 9 contains the information necessary to calculate the required raceway size. Because different conductor types (THW, TW, THHN, and so forth) have different thicknesses of insulation, the number and size of conductors permitted in a given raceway often depend on the conductor type used.

Author's Comment: This unit is based on the use of solidly grounded ac systems, 600V or less, using 90ºC insulated copper conductors sized to 75ºC terminals unless otherwise specified.

5.1 Understanding the *NEC*, Chapter 9 Tables

Table 1—Conductor Percent Fill

The maximum percentage of allowable conductor fill is listed in Chapter 9, Table 1. It's based on common conditions where the length of the conductor and number of raceway bends are within reasonable limits [Chapter 9, Table 1, Note 1]. Figure 5–1

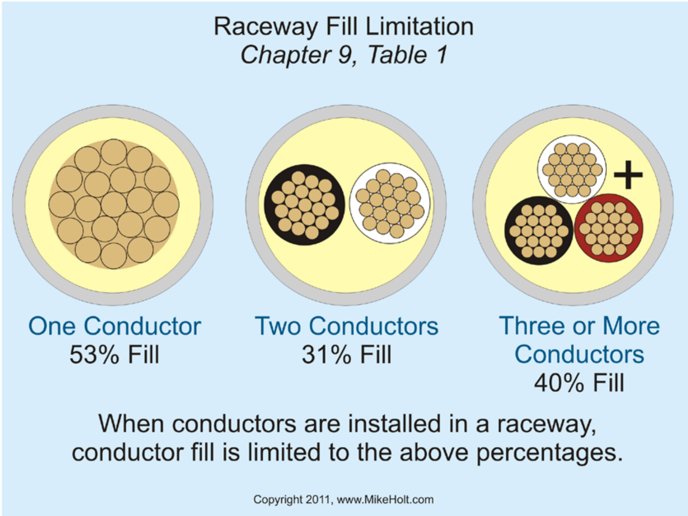

Figure 5–1

Notes to Tables, Note 1—Conductors all the Same Size

When all conductors in a conduit or tubing are the same size (total cross-sectional area including insulation), the number of conductors permitted in a raceway can be determined by simply looking at the tables located in Annex C—Raceway Fill Tables for Conductors and Fixture Wires of the Same Size.

Table 1 of Chapter 9, Maximum Percent Conductor Fill	
Number of Conductors	**Percent Fill Permitted**
1 conductor	53% fill
2 conductors	31% fill
3 or more conductors	40% fill
Raceway 24 inches or less	60% fill, Note 4

- Tables C.1 through C.12(a) are based on maximum percent fill as listed in Chapter 9, Table 1.
- Table C.1—Conductors and fixture wires in electrical metallic tubing (EMT)
- Table C.1(A)—Compact conductors in electrical metallic tubing (EMT)
- Table C.2—Conductors and fixture wires in electrical nonmetallic tubing (ENT)
- Table C.2(A)—Compact conductors in electrical nonmetallic tubing (ENT)
- Table C.3—Conductors and fixture wires in flexible metal conduit (FMC)
- Table C.3(A)—Compact conductors in flexible metal conduit (FMC)
- Table C.4—Conductors and fixture wires in intermediate metal conduit (IMC)
- Table C.4(A)—Compact conductors in intermediate metal conduit (IMC)
- Table C.5—Conductors and fixture wires in liquidtight flexible nonmetallic conduit (gray type) (LFNC-B)
- Table C.5(A)—Compact conductors in liquidtight flexible nonmetallic conduit (gray type) (LFNC-B)
- Table C.6—Conductors and fixture wires in liquidtight flexible nonmetallic conduit (orange type) (LFNC-A)
- Table C.6(A)—Compact conductors in liquidtight flexible nonmetallic conduit (orange type) (LFNC-A)

Author's Comment: The annex doesn't have a table for LFNC of the black type (LFNC-C).

- Table C.7—Conductors and fixture wires in liquidtight flexible metal conduit (LFMC)
- Table C.7(A)—Compact conductors in liquidtight flexible metal conduit (LFMC)
- Table C.8—Conductors and fixture wires in rigid metal conduit (RMC)
- Table C.8(A)—Compact conductors in rigid metal conduit (RMC)
- Table C.9—Conductors and fixture wires in rigid PVC conduit, Schedule 80
- Table C.9(A)—Compact conductors in rigid PVC conduit, Schedule 80
- Table C.10—Conductors and fixture wires in rigid PVC conduit, Schedule 40
- Table C.10(A)—Compact conductors in rigid PVC conduit, Schedule 40
- Table C.11—Conductors and fixture wires in Type A, rigid PVC conduit
- Table C.11(A)—Compact conductors in Type A, rigid PVC conduit
- Table C.12—Conductors and fixture wires in Type EB, PVC conduit
- Table C.12(A)—Compact conductors in Type EB, PVC conduit

► Annex C—Table C.1—EMT

Question: *How many 14 RHH conductors (without cover) can be installed in trade size 1 EMT?* **Figure 5–2**

(a) 13 *(b) 16* *(c) 19* *(d) 25*

Answer: *(b) 16 conductors [Annex C, Table C.1]*

Note 2 at the end of Annex C, Table C.1 indicates that an asterisk (*) with conductor insulation types RHH, RHW*, and RHW-2* means that these types don't have an outer covering. Insulation types RHH, RHW, and RHW-2 (without the asterisk) do have an outer cover. This is a cover (which may be a fibrous material) that increases the dimensions of the conductor more than the thin nylon cover encountered with conductors such as THHN.*

Question: *How many 8 THHN conductors can be installed in a trade size 3/4 EMT?* **Figure 5–3**

(a) 3 *(b) 5* *(c) 6* *(d) 8*

Answer: *(c) 6 conductors [Annex C, Table C.1]*

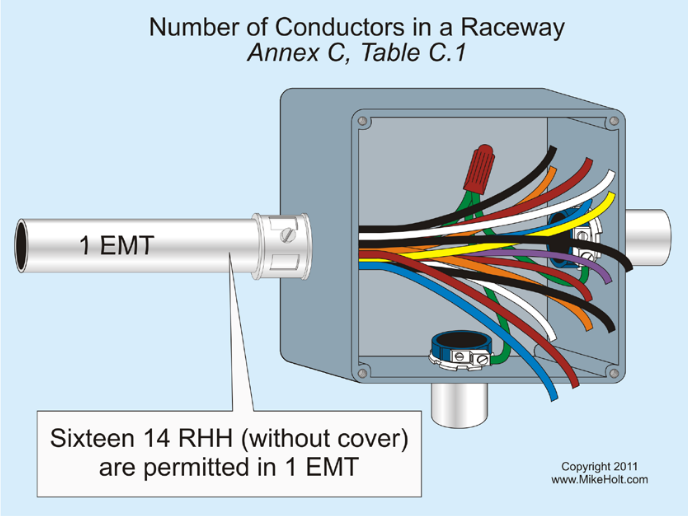

Figure 5–2

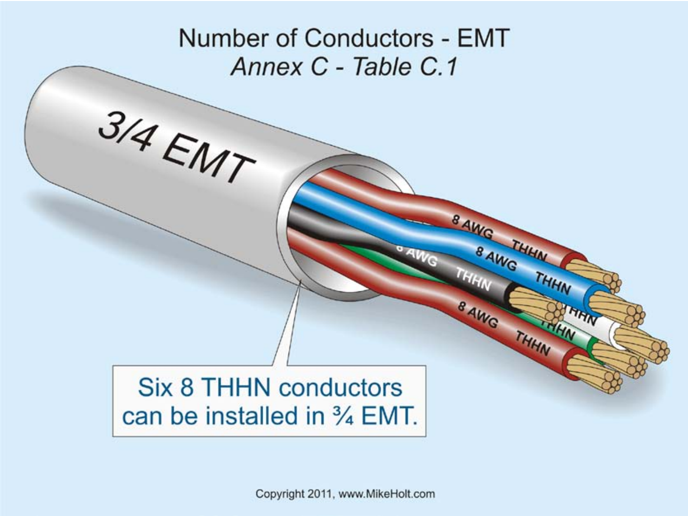

Figure 5–3

► Annex C—Table C.2A—Compact Conductors in ENT

Question: *How many 6 XHHW compact conductors can be installed in trade size 1¼ ENT?* **Figure 5–4**

(a) 6 *(b) 10* *(c) 13* *(d) 16*

Answer: *(b) 10 conductors [Annex C, Table C.2A]*

Compact stranding is the result of a manufacturing process where the standard conductor is compressed to the extent that the voids between the strands of wires are virtually eliminated [Annex C, Table C.1(a) footnote]. Unless the question specifically states compact conductors, assume that the conductors aren't the compact type.

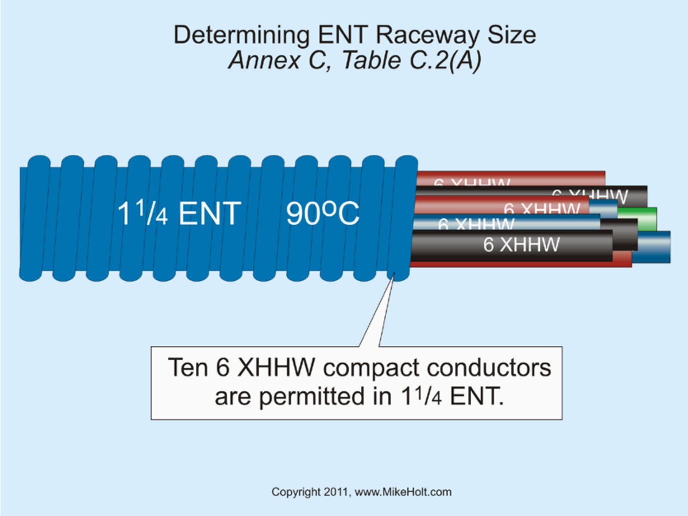

Figure 5–4

► Annex C—Table C.3—FMC

Question: *If trade size 1¼ FMC has three THHN conductors (not compact), what's the largest conductor permitted to be installed?* **Figure 5–5**

(a) 1 THHN (b) 1/0 THHN (c) 2/0 THHN (d) 3/0 THHN

Answer: *(a) 1 THHN [Annex C, Table C.3]*

It's common to see conductors with a dual insulation rating, such as THHN/THWN. This type of conductor can be used in a dry location at the THHN 90°C ampacity, or if used in a wet location, the THWN ampacity rating of the 75°C column of Table 310.15(B)(16) for THWN insulation types must be adhered to.

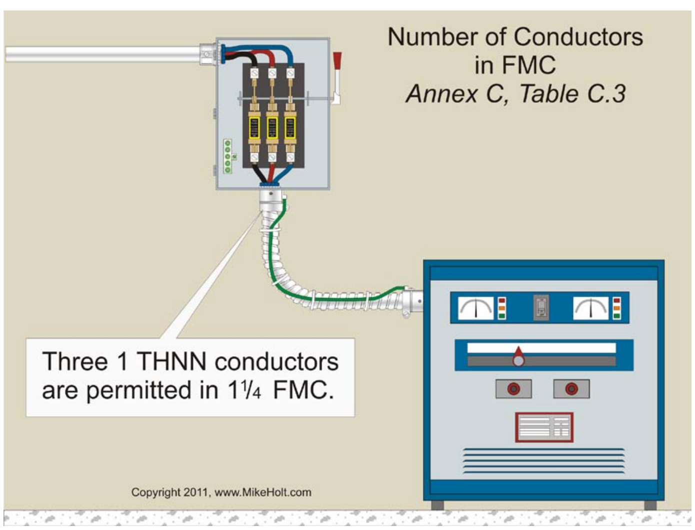

Figure 5–5

► Annex C—Table C.4—IMC

Question: *How many 4/0 RHH conductors with an outer cover can be installed in trade size 2 IMC?*

Note: *RHH insulation with an outer cover has no asterisk (*).*

(a) 1 conductor (b) 2 conductors
(c) 3 conductors (d) 4 conductors

Answer: *(c) 3 conductors [Annex C, Table C.4]*

► Annex C—Table C.7—Fixture Wire in LFMC

Question: *How many 18 TFFN conductors can be installed in trade size ¾ LFMC?* **Figure 5–6**

(a) 14 conductors (b) 26 conductors
(c) 30 conductors (d) 39 conductors

Answer: *(d) 39 conductors [Annex C, Table C.7]*

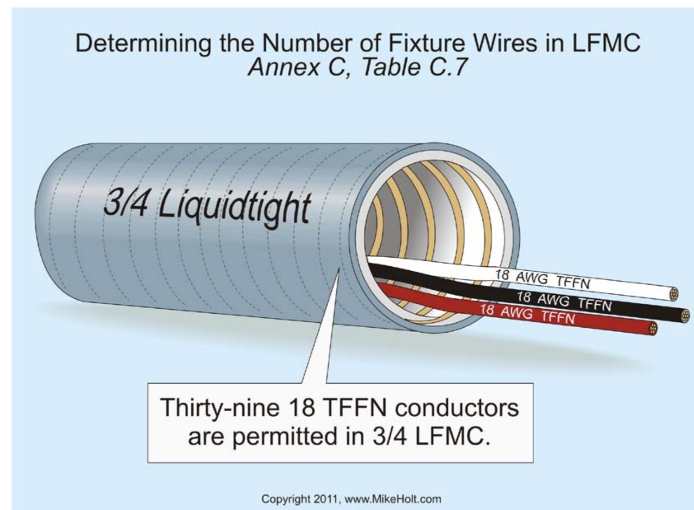

Figure 5–6

► Annex C—Table C.9—PVC Schedule 80

Question: *What's the smallest trade size PVC Schedule 80 raceway that can be used for the installation of a single 3/0 THHN as a grounding electrode conductor?* **Figure 5–7**

(a) Trade size ½ (b) Trade size ¾
(c) Trade size 1 (d) Trade size 1¼

Answer: (b) Trade size 3/4 [Annex C, Table C.9]

Question: *If trade size 2 PVC Schedule 80 has three THHN compact conductors, what's the largest conductor permitted to be installed?*

(a) 1/0 THHN (b) 4/0 THHN
(c) 250 kcmil THHN (d) 300 kcmil THHN

Answer: (d) 300 kcmil THHN [Annex C, Table C.9(A)]

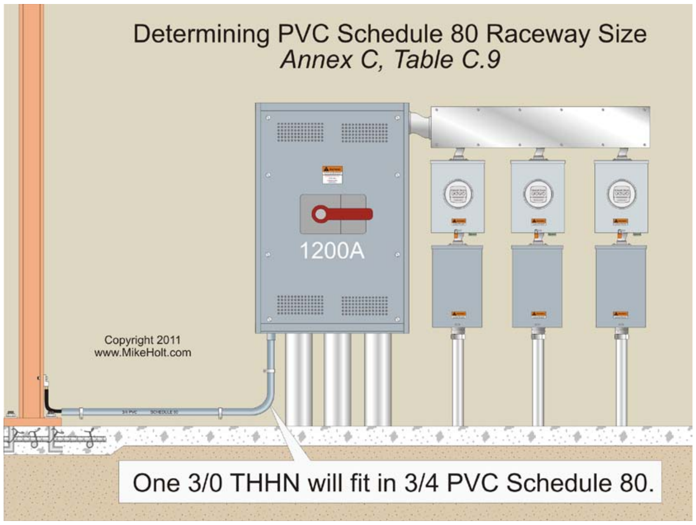

Figure 5–7

▶ Annex C—Table C.10—PVC Schedule 40

Question: *What's the smallest trade size PVC Schedule 40 raceway that can be used for the installation of four 1/0 THHN conductors?* Figure 5–8

(a) Trade size3/4 *(b) Trade size 1*
(c) Trade size 1 1/2 *(d) Trade size 2*

Answer: *(c) Trade size 1½ [Annex C, Table C.10]*

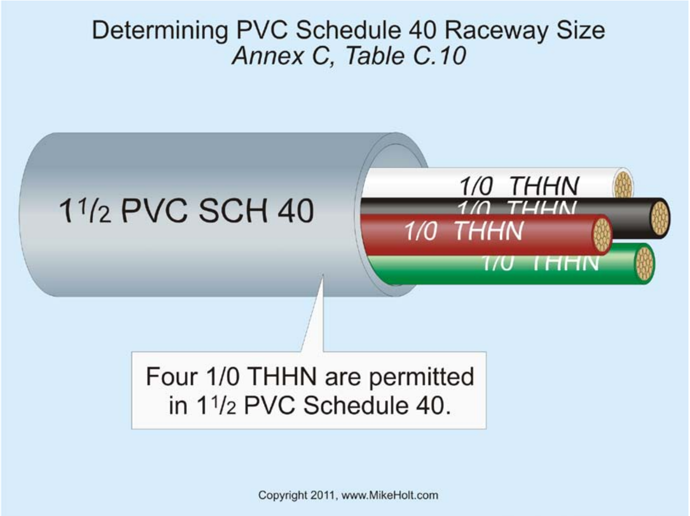

Figure 5–8

▶ Annex C—Table C.10(a)—Compact Conductors in PVC Schedule 40

Question: *If a trade size 2 PVC Schedule 40 raceway has three THHN compact conductors, what's the largest conductor permitted to be installed?*

(a) 1/0 THHN *(b) 4/0 THHN*
(c) 350 kcmil THHN *(d) 750 kcmil THHN*

Answer: *(c) 350 kcmil THHN [Annex C, Table C.10(A)]*

Notes to Tables, Note 2—Used for Physical Protection

The percentages listed in Table 1 apply only to complete raceway systems and aren't intended to apply to sections of raceways used to protect wiring from physical damage. Figure 5–9

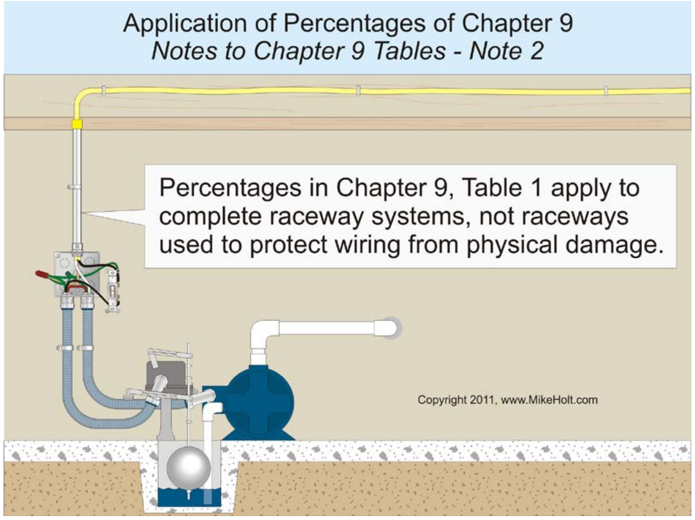

Figure 5–9

Notes to Tables, Note 3—Equipment Grounding Conductors

When equipment grounding and bonding conductors are installed in a raceway, the actual area of the conductor must be used to calculate raceway fill, Figure 5–10 . Chapter 9, Table 5 can be used to determine the cross-sectional area of insulated conductors and Chapter 9, Table 8 can be used to determine the cross-sectional area of bare conductors (see Chapter 9, Notes to Tables, Note 8).

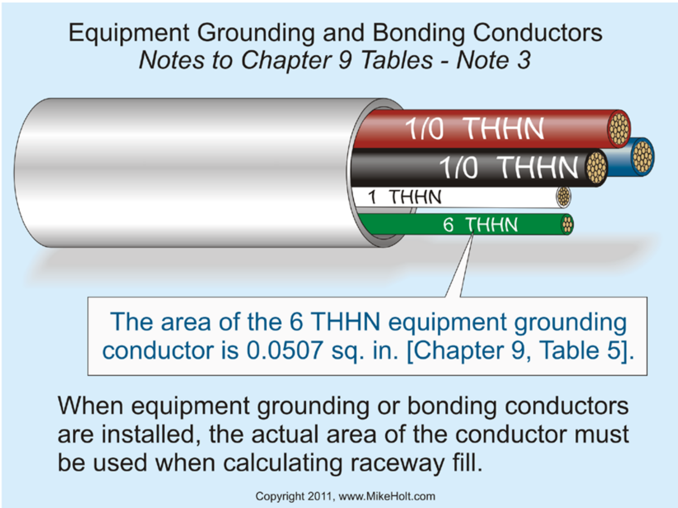

Figure 5–10

Notes to Tables, Note 4—Raceways not Exceeding 24 Inches

When a raceway doesn't exceed 24 in. in length, it's permitted to be filled to 60 percent of its total cross-sectional area as identified in Table 4 of Chapter 9. Figure 5–11

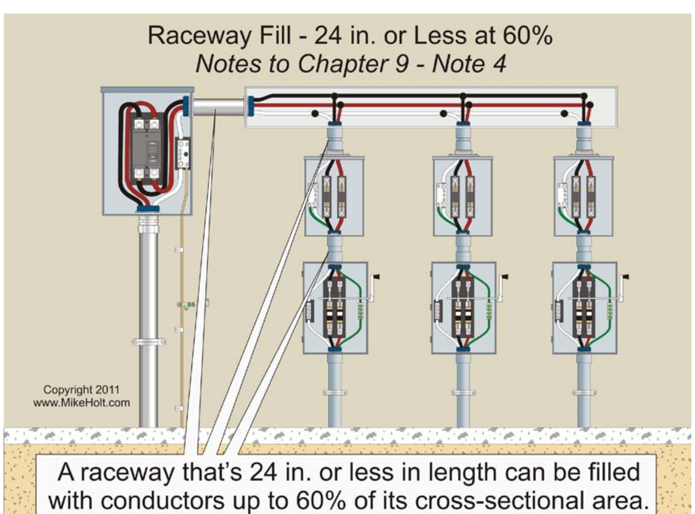

Figure 5–11

Notes to Tables, Note 5—Multiconductor Cables

For multiconductor cables, the actual cross-sectional area of the cable is to be used for raceway sizing. The cross sectional area of a circle is calculated by taking 3.14 x the square of the radius of the circle. Figure 5–12

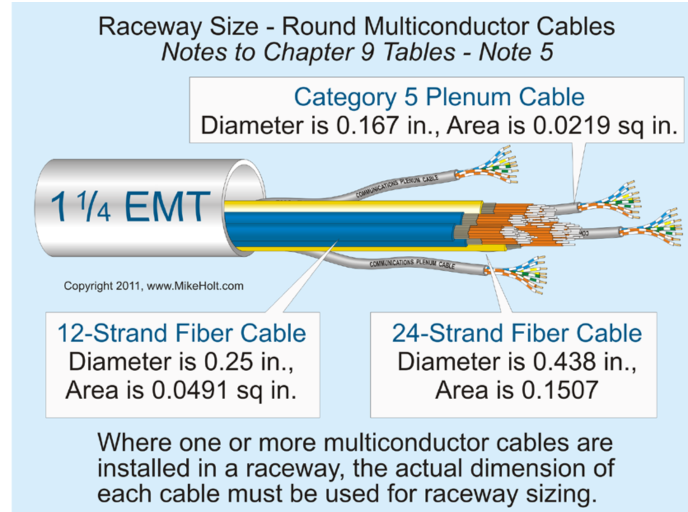

Figure 5–12

Question: *What Is the total are occupied in a raceway for the following cables?*

4 Category 5 plenum cables, dia = 0.167 in.
2 fiber cables, 24 strand, dia = 0.438 in.
3 fiber cables, 12 strand, dia = 0.25 in.

(a) 0.0254 (b) 0.1203 (c) 0.5363 (d) 0.9578

Answer: *(c) 0.5363 sq in.*

4 Cat 5 plenum cables, diameter = 0.167 in.
r = d/2 r = 0.167/2 = 0.0835 in.
Area = 3.14 x r^2
Area = 3.14 x 0.0835 in. x 0.0835 in.
Area = 0.0219 sq in. x 4 = 0.0876 sq in.

3 fiber cables, 12 strand, dia = 0.25 in.
r = d/2 r = 0.25/2 = 0.125 in.
Area = 3.14 x r^2
Area = 3.14 x 0.125 in. x 0.125 in.
Area = 0.0491 sq in. x 3 = 0.1473 sq in.

2 fiber cables, 24 strand, diameter = 0.438 in.
r = d/2 r = 0.438/2 = 0.219 in.
Area = 3.14 x r^2
Area = 3.14 x 0.219 in. x 0.219 in.
Area = 0.1507 sq in. x 2 = 0.3014 sq in.

Cat 5	*0.0876 sq in.*
12- strand	*0.1473 sq in.*
24-strand	*0.3014 sq in.*
	0.5363 sq in.

Notes to Tables, Note 6—Different Size Conductors

Use Table 4 and Table 5 when sizing raceways for conductors of different sizes. Table 4 provides the cross-sectional area of raceways, while Tables 5 and 5A give the cross-sectional areas of conductors. This is also the method to use when doing calculations for raceways of 24 in. and shorter, as Annex C doesn't account for the 60 percent fill allowance provided by Table 4. Figure 5–13

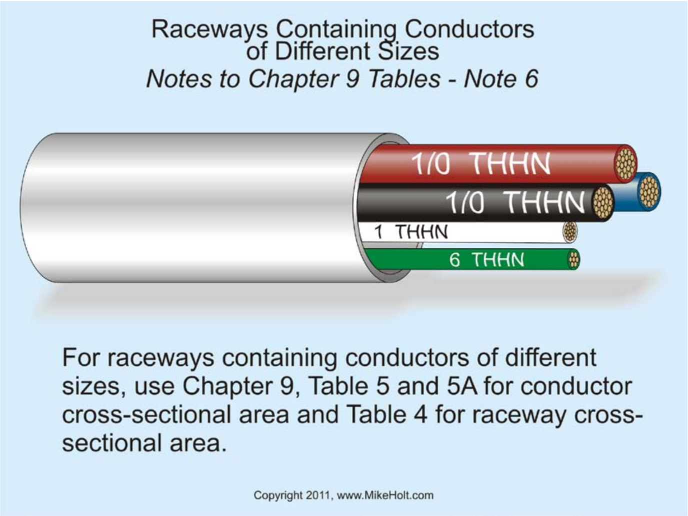

Figure 5–13

Notes to Tables, Note 7—Rounding

When the calculated number of conductors (all of the same size including insulation) results in 0.80 or more, the next higher whole number of conductors can be used.

Question: *How many 8 THHN conductors can be installed in a trade size 3/4 EMT?* Figure 5–14

(a) 3 (b) 5 (c) 6 (d) 8

Answer: *(c) 6 conductors*

8 THHN = 0.0366 sq in [Chapter 9 Table 5]

3/4 EMT 40% fill = 0.213 sq in. [Chapter 9 Table 4]

0.213 sq in./0.0366 sq in. = 5.82 conductors we are allowed to use 6 conductors per Chapter 9 Notes to Tables, Note 7

When the calculated number of conductors, all of the same size including insulation results in 0.80 or more, the next higher number of conductors can be used [Chapter 9, Notes to Tables, Note 7]

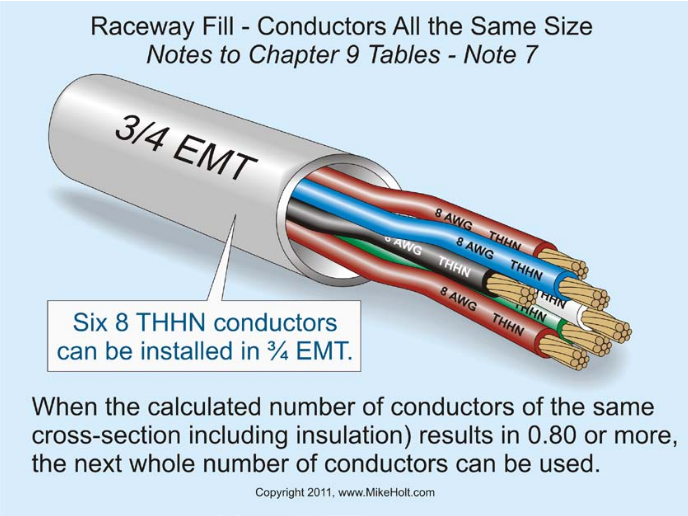

Figure 5–14

Notes to Tables, Note 8—Bare Conductors

The dimensions for bare conductors are listed in Chapter 9, Table 8. Figure 5–15

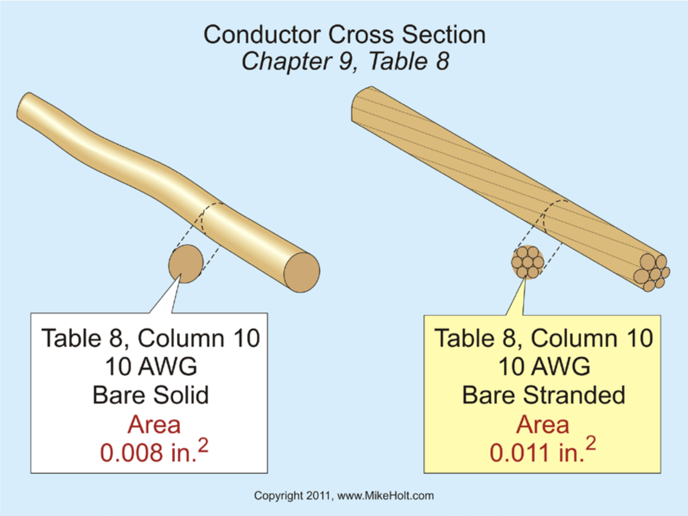

Figure 5–15

Notes to Tables, Note 9

A multiconductor cable or flexible cord is treated as a single conductor for calculating percentage conduit fill area. For cables with elliptical cross sections, the cross-sectional area is based on using the major diameter of the ellipse as the circle diameter.

► NM cable in EMT Example

Question: *What size EMT is needed for one 12-2 w/G NM cable that measures 7⁄16 on the major diameter?* **Figure 5–16**

(a) Trade size ½ *(b) Trade size ¾*
(c) Trade size 1 *(d) Trade size 1¼*

Answer: *(a) Trade size ½*

Area = 3.14 x r²

D = 7⁄16 in.
D = 0.4375 in.

R = D/2
R = 0.4375 in./2
R = 0.22 in.

Area = 3.14 x 0.22 in. x 0.22 in.
Area = 0.1520 sq in.

Use the one wire column (53%) of Chapter 9, Table 4 for EMT:

Trade size ½ EMT provides 0.161 sq in., which is larger than 0.1520 sq in. and will meet the minimum requirement.

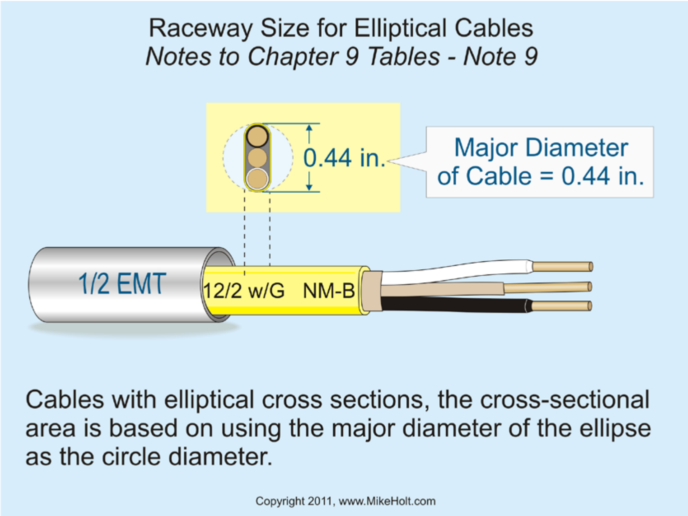

Figure 5–16

Notes to Tables—Raceway Cross-Sectional Area

The sixth column of this table (Total Area 100%) gives the total cross-sectional area in square inches of the raceway. There are also 31% (2 wires), 40% (3 or more wires), 53% (1 wire), and 60% (nipple) cross-sectional area columns based on the number of conductors in accordance with Chapter 9, Table 1.

► Raceway Cross-Sectional Area Example 1

Question: *What's the cross-sectional area of permitted conductor fill for a trade size 1 EMT raceway 30 inches long that contains four conductors?* **Figure 5–17**

(a) 0.346 sq in. *(b) 1.013 sq in.*
(c) 2.067 sq in. *(d) 3.356 sq in.*

Answer: *(a) 0.346 sq in.*
[Chapter 9, Notes to Tables, Note 4 and Table 4, 40% column]

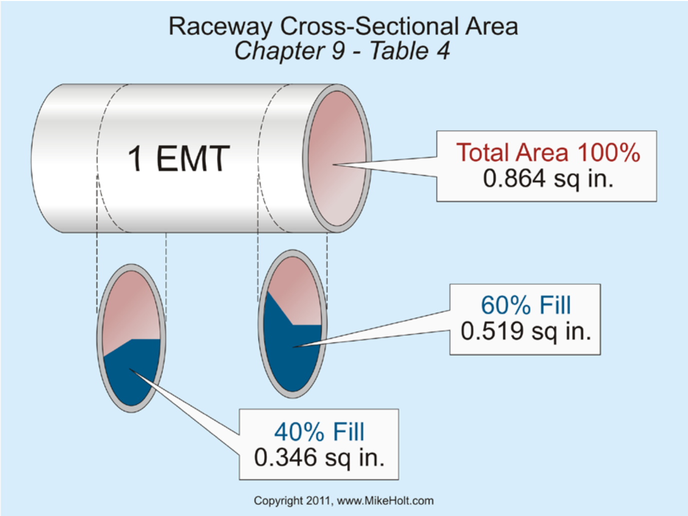

Figure 5–17

► Raceway Cross-Sectional Area Example 2

Question: *What's the cross-sectional area of permitted conductor fill for a trade size 2 EMT raceway that's 20 inches long?* **Figure 5–18**

(a) 1.342 sq in. *(b) 2.013 sq in.*
(c) 2.067 sq in. *(d) 3.356 sq in.*

Answer: *(b) 2.013 sq in.*
Reminder: For a raceway 24 in. and shorter, use the 60% column [Chapter 9, Notes to Tables, Note 4 and Table 4, 60% column]

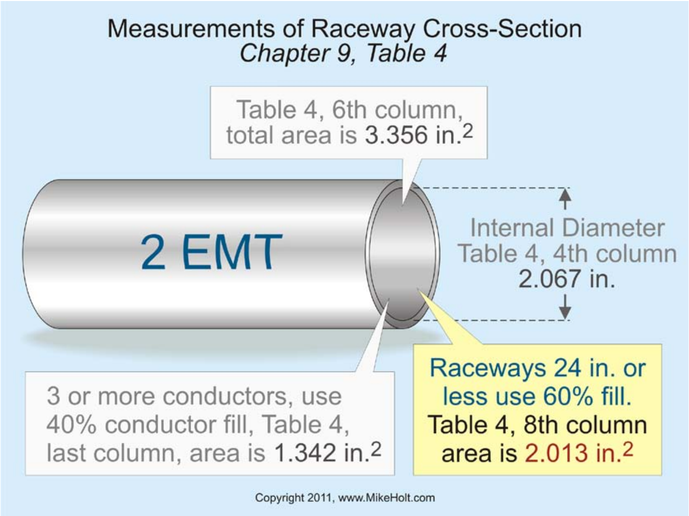

Figure 5–18

▶ Raceway Cross-Sectional Area Example 3

Question: *What's the cross-sectional area of permitted conductor fill for a trade size 2 EMT raceway 30 inches long that contains four conductors? See* **Figure 5–18**.

(a) 1.342 sq in.	*(b) 2.013 sq in.*
(c) 2.067 sq in.	*(d) 3.356 sq in.*

Answer: *(a) 1.342 sq in.*
[Chapter 9, Table 1 and Table 4, 40% column]

▶ Raceway Cross-Sectional Area Example 4

Question: *What's the minimum size EMT raceway required for three conductors with a wire fill of 0.25 sq in.?*

(a) Trade size ½	*(b) Trade size 1*
(c) Trade size 1¼	*(d) Trade size 1½*

Answer: *(b) Trade size 1*

▶ Raceway Cross-Sectional Area Example 5

Question: *What's the minimum size Schedule 80 PVC raceway required for three conductors with a wire fill of 0.35 sq in.?*

(a) Trade size ½	*(b) Trade size 1*
(c) Trade size 1¼	*(d) Trade size 1½*

Answer: *(c) Trade size 1¼*

Table 5—Dimensions of Insulated Conductors and Fixture Wires

Chapter 9, Table 5 lists the cross-sectional area of insulated conductors and fixture wires (see **Table 5–1**).

▶ Table 5—THHN

Question: *What's the cross-sectional area for one 10 THHN conductor?* **Figure 5–19**

(a) 0.0097 sq in.	*(b) 0.0172 sq in.*
(c) 0.0211 sq in.	*(d) 0.0278 sq in.*

Answer: *(c) 0.0211 sq in.*

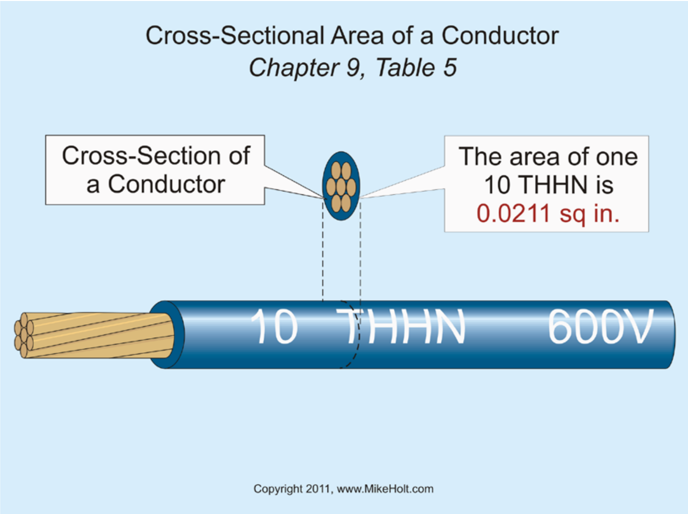

Figure 5–19

▶ Table 5—RHW With an Outer Cover

Question: *What's the cross-sectional area for one 10 RHW conductor with an outer cover?*

(a) 0.0172 sq in.	*(b) 0.0206 sq in.*
(c) 0.0278 sq in.	*(d) 0.0437 sq in.*

Answer: *(d) 0.0437 sq in.*

Table 5–1: Commonly Used Conductor Cross-Sectional Area						
Column 1	RHH/RHW With Cover	RHH/RHW Without Cover	TW or THW	THHN THWN	XHHW	BARE Stranded Conductors
	Chapter 9, Table 5					Chapter 9 Table 8
	Column 2	Column 3	Column 4	Column 5	Column 6	
Size AWG/kcmil	Approximate Cross-Sectional Area – Square Inches					
14	0.0293	0.0209	0.0139	0.0097	0.0139	0.004
12	0.0353	0.0260	0.0181	0.0133	0.0181	0.006
10	0.0437	0.0333	0.0243	0.0211	0.0243	0.011
8	0.0835	0.0556	0.0437	0.0366	0.0437	0.017
6	0.1041	0.0726	0.0726	0.0507	0.0590	0.027
4	0.1333	0.0973	0.0973	0.0824	0.0814	0.042
3	0.1521	0.1134	0.1134	0.0973	0.0962	0.053
2	0.1750	0.1333	0.1333	0.1158	0.1146	0.067
1	0.2660	0.1901	0.1901	0.1562	0.1534	0.087
0	0.3039	0.2223	0.2223	0.1855	0.1825	0.109
00	0.3505	0.2624	0.2624	0.2233	0.2190	0.137
000	0.4072	0.3117	0.3117	0.2679	0.2642	0.173
0000	0.4754	0.3718	0.3718	0.3237	0.3197	0.219

► Table 5—RHH Without an Outer Cover

Question: *What's the cross-sectional area for one 10 RHH without an outer cover?*

(a) 0.0117 sq in. *(b) 0.0252 sq in.*
(c) 0.0278 sq in. *(d) 0.0333 sq in.*

Answer: *(d) 0.0333 sq in.*

The note at the end of Table 5 states that conductor Types RHH, RHW, and RHW-2 without outer coverings are identified on the table with an asterisk (*).

Author's Comment: The difference in the insulation thickness between RHH and THHN can be determined from Table 310.104(A) Conductor Applications and Insulations. You will find that 10 RHH has an insulation thickness of 45 mils while 10 THHN has an insulation thickness of 20 mils.

Table 5A—Dimensions of Compact Insulated Conductors

Chapter 9, Table 5A, lists the cross-sectional areas for compact copper and aluminum building wires. These conductors use specially shaped strands so that the overall size of the conductor is more compact. The outer covering is marked as a compact conductor.

► Table 5—THHN Compact Conductors

Question: *What's the cross-sectional area for one 1 THHN compact conductor?*

(a) 0.0117 sq in. *(b) 0.1352 sq in.*
(c) 0.2733 sq in. *(d) 0.5216 sq in.*

Answer: *(b) 0.1352 sq in.*

► Table 5—Compact Conductors

Question: *What's the cross-sectional area for one 4/0 XHHW compact conductor?*

(a) 0.0117 sq in. *(b) 0.1352 sq in.*
(c) 0.2733 sq in. *(d) 0.5216 sq in.*

Answer: *(c) 0.2733 sq in.*

Table 8—Conductor Properties

Chapter 9, Table 8 contains conductor properties such as the cross-sectional area in circular mils, the number of strands per conductor, the cross-sectional area in square inches for bare conductors, and the direct-current resistance at 75ºC for both copper and aluminum conductors.

► Bare Conductor—Cross-Sectional Area

Question: *What's the cross-sectional area for one 10 AWG bare stranded conductor?* **Figure 5–20**

(a) 0.008 sq in. *(b) 0.011 sq in.*
(c) 0.038 sq in. *(d) a or b*

Answer: *(b) 0.011 sq in. [Chapter 9, Table 8]*

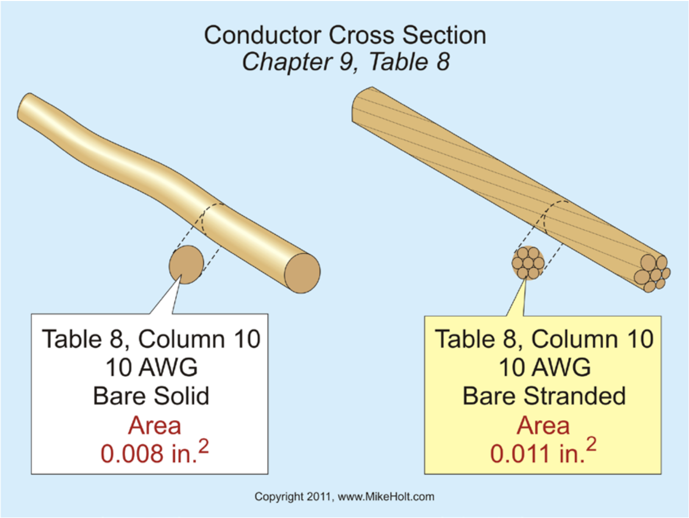

Figure 5–20

5.2 Raceway Calculations

Annex C—Tables 1 through 12 can't be used to determine raceway sizing when conductors of different sizes are installed in the same raceway. When this situation is encountered, use the following steps to determine the raceway size and nipple size:

Step 1: Determine the cross-sectional area (in square inches) for each conductor from Chapter 9, Table 5 for insulated conductors and from Chapter 9, Table 8 for bare conductors.

Step 2: Determine the total cross-sectional area for all conductors.

Step 3: Size the raceway according to the percent fill as listed in Chapter 9, Table 1. Chapter 9, Table 4 includes the various types of raceways with columns representing the allowable percentage fills; such as 40 percent for three or more conductors, and 60 percent for raceways 24 in. or less in length. Be careful when selecting the raceway from Chapter 9, Table 4 as this table is divided up into numerous tables for each raceway type, and you must choose the correct section of the table for the type of raceway for which you're performing the calculations.

► Raceway Size

Question: *What's the minimum size Schedule 40 PVC raceway required for three 500 kcmil THHN conductors, one 250 kcmil THHN conductor, and one 3 THHN conductor.* **Figure 5–21**

(a) Trade size 2 *(b) Trade size 2½*
(c) Trade size 3 *(d) Trade size 3½*

Answer: *(c) Trade size 3*

Step 1: Determine the cross-sectional area of the conductors [Chapter 9, Table 5].

500 THHN 0.7073 sq in. x 3 wires = 2.1219 sq in.
250 THHN 0.3970 sq in. x 1 wire = 0.3970 sq in.
3 THHN 0.0973 sq in. x 1 wire = 0.0973 sq in.

Step 2: Total cross-sectional area of all conductors = 2.6162 sq in.

Step 3: Size the conduit at 40 percent fill [Chapter 9, Table 1] using Chapter 9, Table 4 (be sure to select the table for PVC Schedule 40). Trade size 3 Schedule 40 PVC has an allowable cross-sectional area of 2.907 sq in. for over two conductors in the 40 percent column.

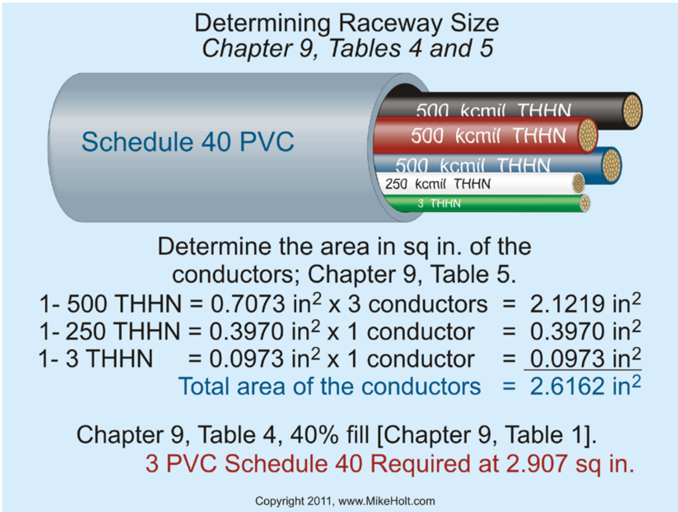

Figure 5–21

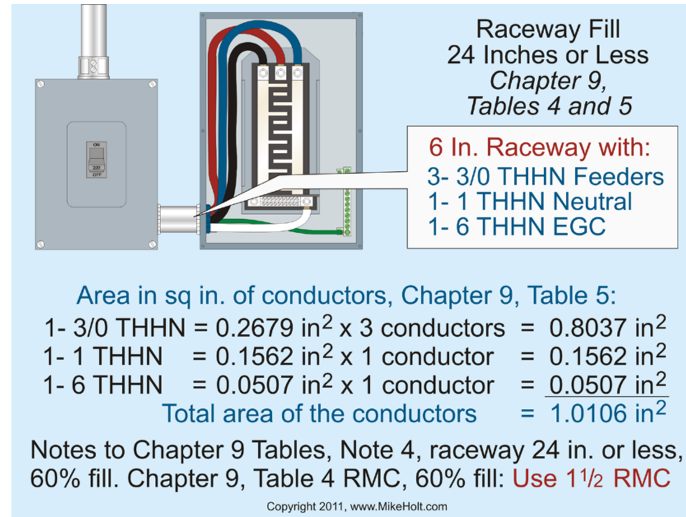

Figure 5–22

▶ Raceway 24 in. or Less in Length

Question: *What size RMC 24 in. or less in length is required for three 3/0 THHN conductors, one 1 THHN conductor, and one 6 THHN conductor?* Figure 5–22

(a) Trade size ½ *(b) Trade size 1*
(c) Trade size 1½ *(d) Trade size 2*

Answer: *(c) Trade size 1½*

Step 1: Determine the cross-sectional area of the conductors [Chapter 9, Table 5].

3/0 THHN 0.2679 sq in. x 3 wires = 0.8037 sq in.
1 THHN 0.1562 sq in. x 1 wire = 0.1562 sq in.
6 THHN 0.0507 sq in. x 1 wire = 0.0507 sq in.

Step 2: Total cross-sectional area of the conductors = 1.0106 sq in.

Step 3: Size the conduit at 60 percent fill [Chapter 9, Table 1, Note 4] using Chapter 9, Table 4.

Trade size 1¼ nipple = 0.0916 sq in., too small
Trade size 1½ nipple = 1.243 sq in., just right
Trade size 2 nipple = 2.045 sq in., larger than required

5.3 Wireways

Wireways are commonly used where access to the conductors within the raceway is required to make terminations, splices, or taps to several devices at a single location. Their high cost precludes their use for other than short distances, except in some commercial or industrial occupancies where the wiring is frequently revised.

Author's Comment: Both metal wireways [376] and nonmetallic wireways [378] are often called "troughs" or "gutters" in the field. Gutters are not really the same thing as a wireway, and are covered by Article 366. Gutters are typically part of a factory fabricated switchgear, and the product installed in the field is a wireway.

Definition—Metal Wireway [376.2]

A sheet metal raceway with hinged or removable covers for housing and protecting electric conductors and cable, and in which conductors are placed after the wireway has been installed. Figure 5–23

Conductors—Maximum Size [376.21]

The maximum size conductor permitted in a wireway must not be larger than that for which the wireway is designed.

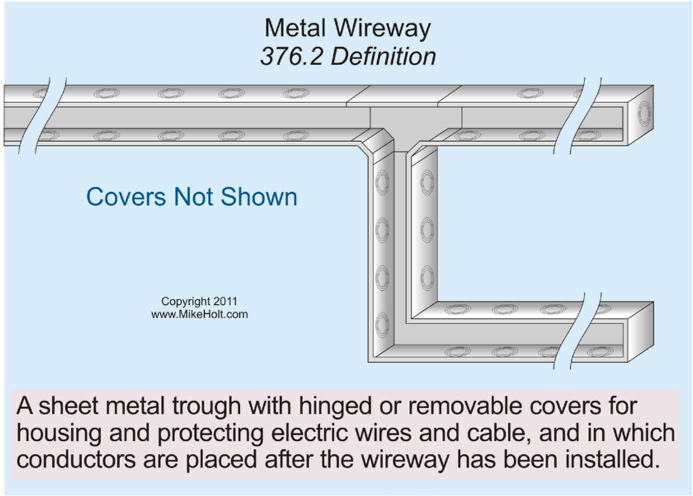

Figure 5–23

Number of Conductors and Ampacity [376.22]

(a) Number of Conductors. The maximum number of conductors permitted in a wireway is limited to 20 percent of the cross-sectional area of the wireway. Figure 5–24

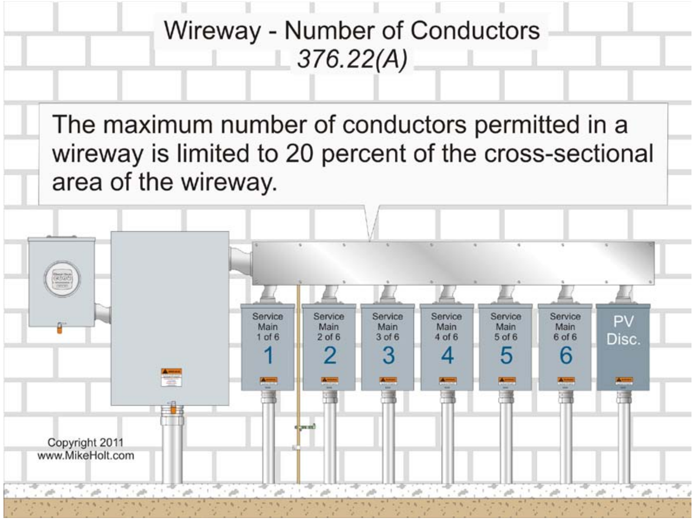

Figure 5–24

▶ Wireway Cross-Sectional Area

Question: *What's the cross-sectional area of a 6 in. x 6 in. wireway?*

(a) 6 sq in. (b) 16 sq in. (c) 36 sq in. (d) 66 sq in.

Answer: *(c) 36 sq in.*

The cross-sectional area is found by multiplying height by depth: 6 in. x 6 in. = 36 sq in.

▶ Wireway Allowable Conductor Fill Area

Question: *What's the maximum allowable conductor fill in square inches for a 6 in. x 6 in. wireway?*

(a) 5 sq in. (b) 6.50 sq in. (c) 7.20 sq in. (d) 8.90 sq in.

Answer: *(c) 7.20 sq in.*

36 sq in. x 0.20 = 7.20 sq in. [376.22(A)]

▶ Wireway Conductor Fill

Question: *What's the maximum number of 500 kcmil THHN conductors that can be installed in a 6 in. x 6 in. wireway?* Figure 5–25

(a) 4 (b) 6 (c) 10 (d) 20

Answer: *(c) 10*

36 sq in. x 0.20 = 7.20 sq in. [376.22(A)]

500 kcmil THHN = 0.7073 sq in. [Chapter 9, Table 5]

Maximum Allowable Area/Area per Conductor = Number of Conductors

7.20 sq in./0.7073 sq in. = 10.17 conductors

10 conductors can be installed.

Note: *Conductor ampacity adjustment for bundling isn't required because there are fewer than 30 current-carrying conductors [376.22(B)].*

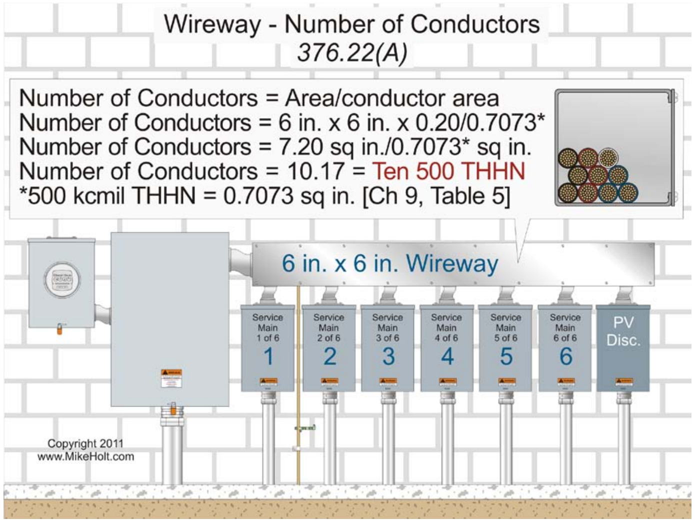

Figure 5–25

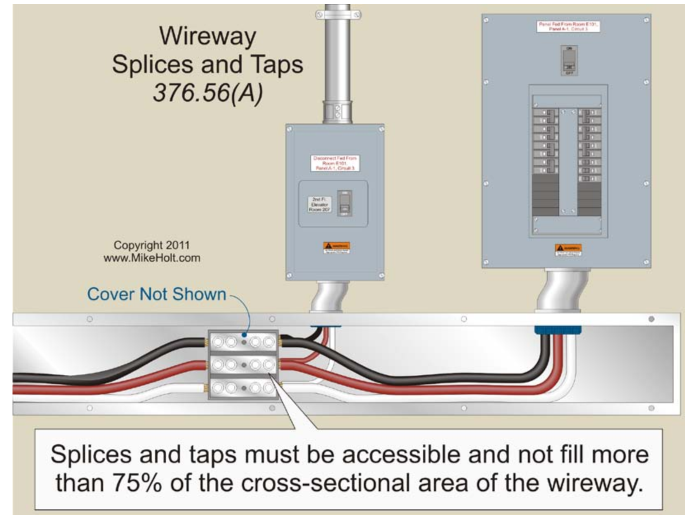

Figure 5–26

▶ Wireway Conductor Fill

Question: *What size wireway is required for three 500 kcmil THHN, one 250 kcmil THHN, and four 4/0 THHN conductors?*

(a) 4 in. x 4 in.	*(b) 6 in. x 6 in.*
(c) 8 in. x 8 in.	*(d) 10 in. x 10 in.*

Answer: *(b) 6 in. x 6 in.*

Find the conductor area [Chapter 9, Table 5]

500 kcmil THHN = 0.7073 sq in. x 3 = 2.1219 sq in.
250 kcmil THHN = 0.3970 sq in.
4/0 THHN = 0.3237 sq in. x 4 =1.2948 sq in.
Total Conductor Area = 3.8137 sq in.

The wireway must not be filled to over 20 percent of its cross-sectional area [376.22(A)]. Twenty percent is equal to one-fifth, so we can multiply the required conductor area by five to find the minimum square inch area required.

Conductor Area x 5 = Required Wireway Minimum Area
3.8137 sq in. x 5 = 19.07 sq in.

A 6 in. x 6 in. wireway has a cross-sectional area of 36 sq in. and will be large enough.

Wireway Splices and Taps. Splices and taps must not fill more than 75 percent of the wiring space at any cross section [376.56]. Figure 5–26 and 5–27

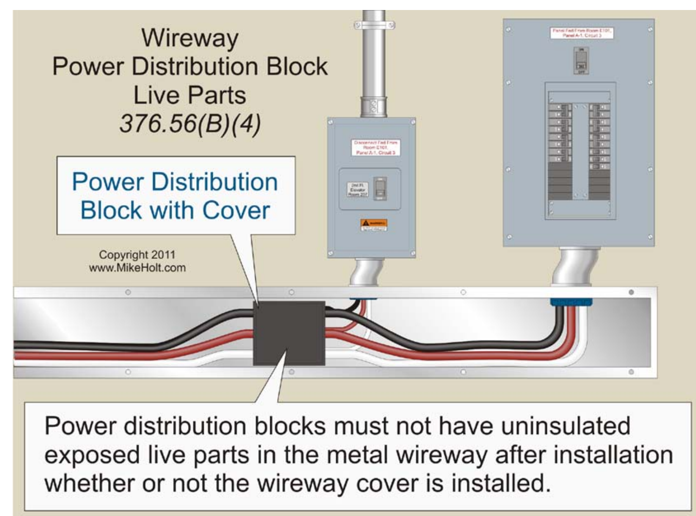

Figure 5–27

Sizing for Conductor Bending Radius. Where conductors are bent within a metal wireway, the wireway must be sized to meet the bending radius requirements contained in Table 312.6(A), based on one wire per terminal [367.23(A)]. Figure 5–28

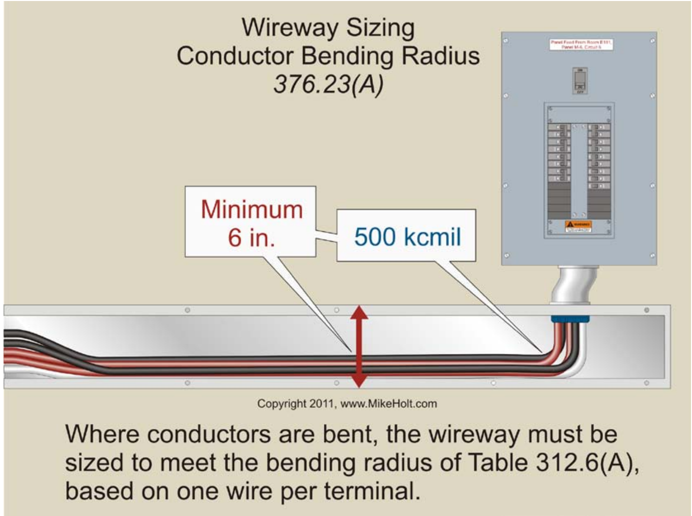

Figure 5–28

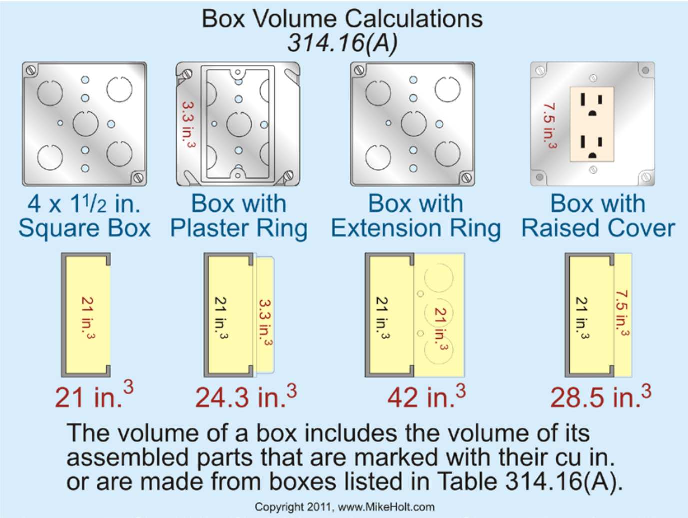

Figure 5–29

5.4 Tips for Raceway Calculations

Tip 1: Take your time.

Tip 2: Use a ruler or a straightedge when using tables, and highlight key words and important sections.

Tip 3: Watch out for different types of raceways and conductor insulations, particularly RHH/RHW with or without an outer cover.

Tip 4: Watch for the difference between conductors and compact conductors.

PART B—OUTLET BOX FILL CALCULATIONS [314.16]

Introduction

Boxes must be of sufficient size to provide free space for all conductors. An outlet box is generally used for the attachment of devices and luminaires and has a specific amount of space (volume) for conductors, devices, and fittings. The volume taken up by conductors, devices, and fittings in a box must not exceed the box fill capacity. The volume of a box is the total volume of its assembled parts, including plaster rings, industrial raised covers, and extension rings. The total volume includes only those parts that are marked with their volumes in cubic inches [314.16(A)] or included in Table 314.16(A) of the *NEC*. Figure 5–29

5.5 Sizing Box—Conductors All the Same Size [Table 314.16(A)]

When all of the conductors in an outlet box are the same size (insulation doesn't matter), Table 314.16(A) can be used to:

(1) Determine the number of conductors permitted in the outlet box, or

(2) Determine the size outlet box required for the given number of conductors.

Author's Comment: If the outlet box contains switches, receptacles, luminaire studs, luminaire hickeys, manufactured cable clamps, or equipment grounding conductors, then we must make an allowance for these items, which is not reflected in Table 314.16(A) .

► Outlet Box Size

Question: *What's the minimum depth for a 4 in. square outlet box which contains six 12 THHN conductors and three 12 THW conductors?* Figure 5–30

(a) 4 x 1¼ in. square *(b) 4 x 1½ in. square*
(c) 4 x 2⅛ in. square *(d) 4 x 2⅛ in. with extension*

Answer: *(b) 4 x 1½ in. square*

Table 314.16(a) permits nine 12 AWG conductors; the insulation type isn't a factor when calculating box fill.

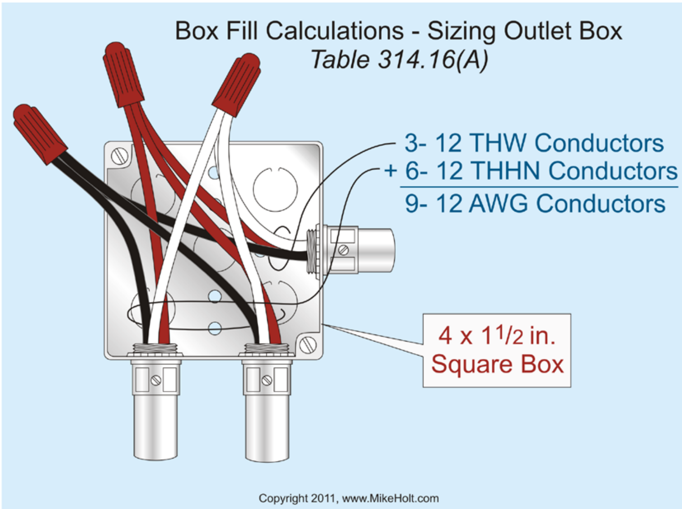

Figure 5–30

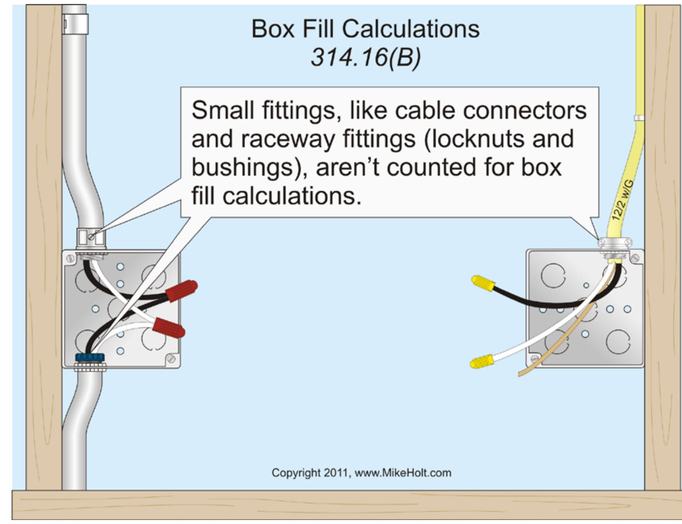

Figure 5–31

► Number of Conductors in an Outlet Box

Question: *Using Table 314.16(A), how many 14 THHN conductors are permitted in a 4 x 1½ in. round box?*

(a) 7 conductors *(b) 9 conductors*
(c) 10 conductors *(d) 11 conductors*

Answer: *(a) 7 conductors*

5.6 Conductor Equivalents

Box Fill Calculations [314.16(B)].

The calculated conductor volume determined by (1) through (5) and Table 314.16(B) are added together to determine the total volume of the conductors, devices, and fittings. Raceway and cable fittings, including locknuts and bushings, aren't counted for box fill calculations. Figure 5–31

Table 314.16(B) Volume Allowance Required per Conductor	
Conductor AWG	**Volume cu in.**
18	1.50
16	1.75
14	2.00
12	2.25
10	2.50
8	3.00
6	5.00

(1) Conductor Volume. Each unbroken conductor that runs through a box and each conductor that terminates in a box is counted as a single conductor volume in accordance with Table 314.16(B). Each loop or coil of unbroken conductor having a length of at least twice the minimum length required for free conductors in 300.14 must be counted as two conductor volumes. Conductors that originate and terminate within the box, such as pigtails, aren't counted at all. Figures 5–32 and 5–33

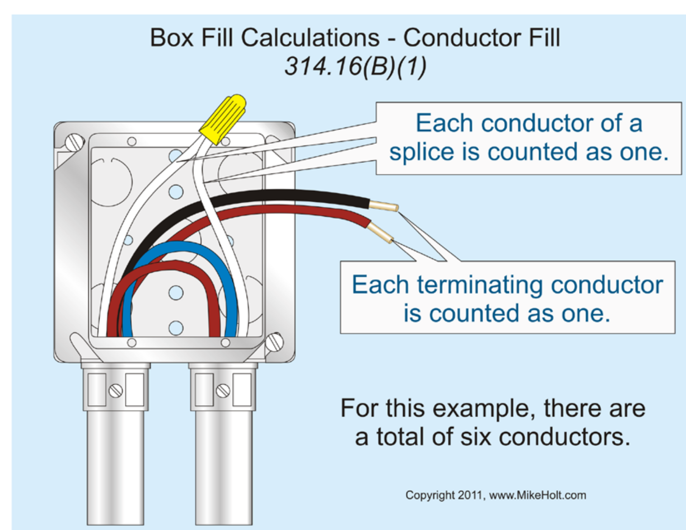

Figure 5–32

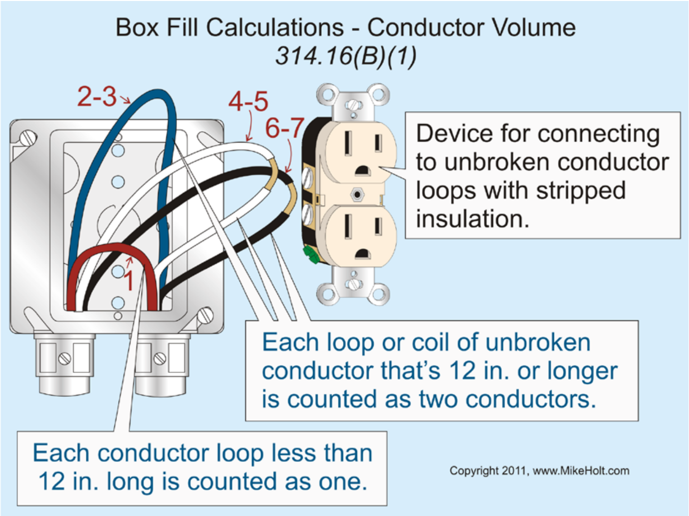

Figure 5–33

Author's Comment: According to 300.14, at least 6 in. of free conductor, measured from the point in the box where the conductors enter the enclosure, must be left at each outlet, junction, and switch point for splices or terminations of luminaires or devices.

Exception: Equipment grounding conductors, and up to four 16 AWG and smaller fixture wires, can be omitted from box fill calculations if they enter the box from a domed luminaire or similar canopy, such as a ceiling paddle fan canopy. Figure 5–34

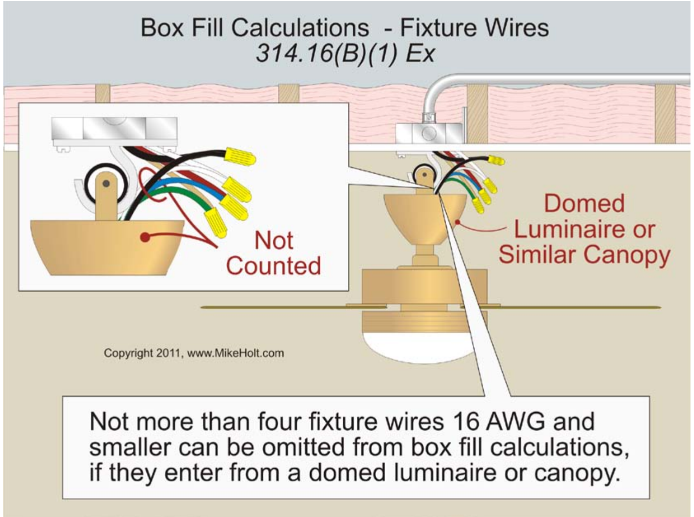

Figure 5–34

(2) Cable Clamp Volume. One or more internal cable clamps count as a single conductor volume in accordance with Table 314.16(B), based on the largest conductor that enters the box. Cable connectors that have their clamping mechanism outside the box aren't counted. Figure 5–35

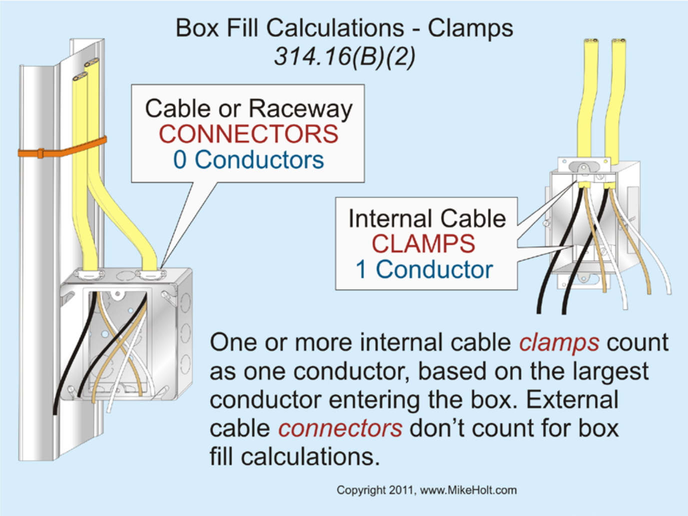

Figure 5–35

(3) Support Fitting Volume. Each luminaire stud or luminaire hickey counts as a single conductor volume in accordance with Table 314.16(B), based on the largest conductor that enters the box. Figure 5–36

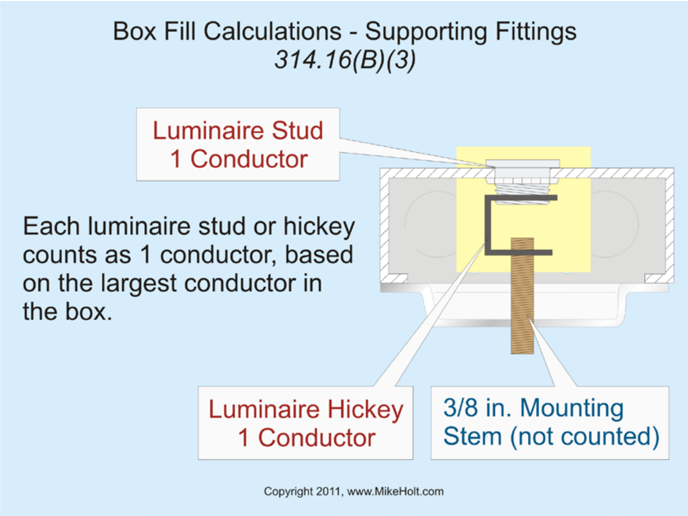

Figure 5–36

(4) Device Yoke Volume. Each single gang device yoke (regardless of the ampere rating of the device) counts as two conductor volumes based on the largest conductor that terminates on the device in accordance with Table 314.16(B). Figure 5–37

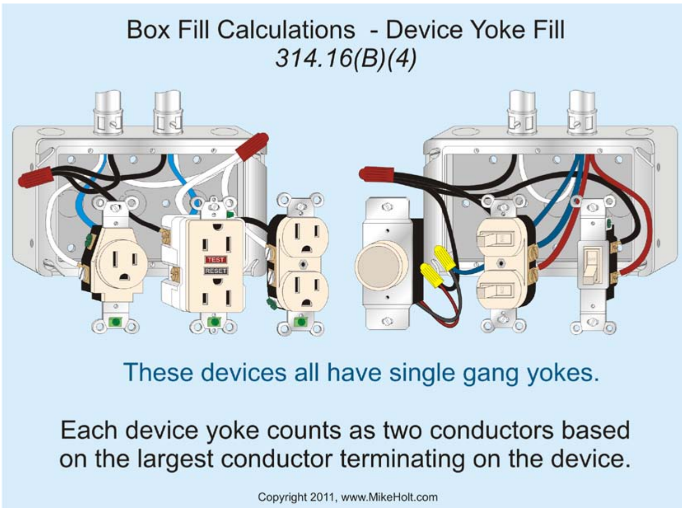

Figure 5–37

Each multigang device yoke counts as two conductor volumes for each gang based on the largest conductor that terminates on the device in accordance with Table 314.16(B). Figure 5–38

Author's Comment: A device that's too wide for mounting in a single gang box is counted based on the number of gangs required for the device.

Question: *If a range receptacle that requires 2 gangs for mounting is fed by three 6 AWG conductors In a raceway system where the raceway is the equipment grounding conductor, and a 1.30 cu in. plaster ring is installed on a metal 4 11/16 square box, how deep must the box be?*

(a) 1 ¼ in. (b) 1 ½ in.
(c) 2 ⅛ in. (d) none of these is deep enough

Answer: *(c) 2 ⅛ in.*

6 AWG = 5.00 cu in. [Table 314.16(B)]
5.00 cu in. x 7 = 35.00 cu in.
4 11/16 sq x 2 1/8 deep box = 42.00 cu in. [Table 314.16(A)]
42.00 + 1.30 cu in. = 43.30 cu in.

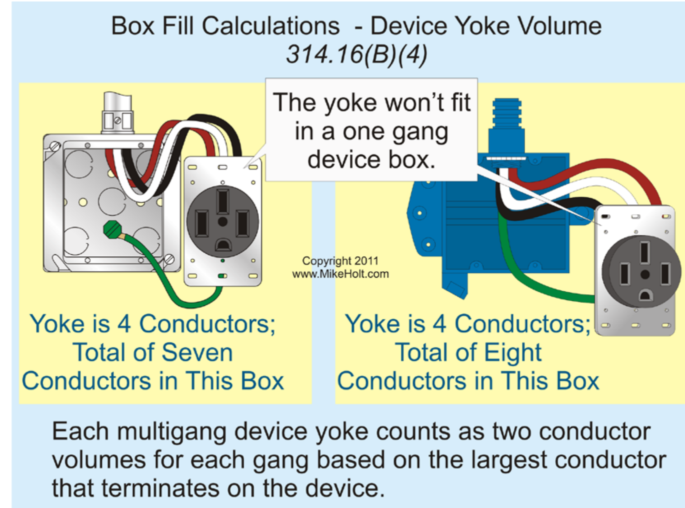

Figure 5–38

(5) Equipment Grounding Conductor Volume. All equipment grounding conductors in a box count as a single conductor volume in accordance with Table 314.16(B), based on the largest equipment grounding conductor that enters the box. Insulated equipment grounding conductors for receptacles having insulated grounding terminals (isolated ground receptacles) [250.146(D)] count as a single conductor volume in accordance with Table 314.16(B). Figure 5–39

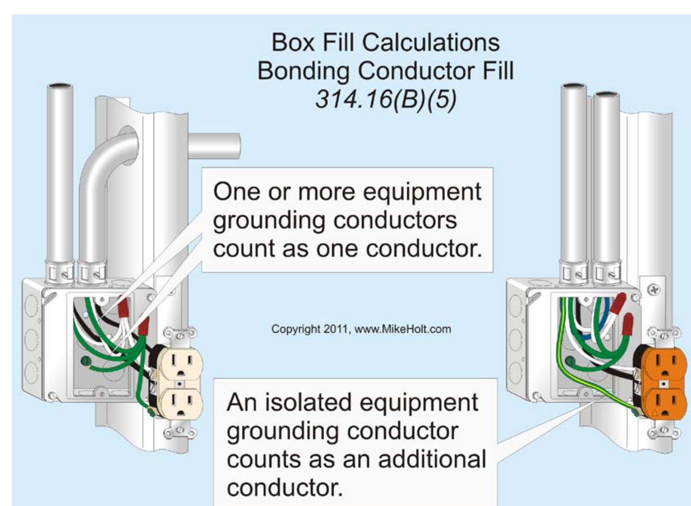

Figure 5–39

What Isn't Counted

Wire connectors, cable connectors, raceway fittings, and conductors that originate and terminate within the outlet box (such as equipment bonding jumpers and pigtails) aren't counted for box fill calculations [314.16(A)].

► Number of Conductors

Question: *What's the total number of conductors used for the box fill calculations in* **Figure 5–40**?

(a) 5 conductors	*(b) 7 conductors*
(c) 9 conductors	*(d) 11 conductors*

Answer: *(d) 11 conductors*

Switch and conductors	*5 – 14 AWG †*
Receptacles and conductors	*4 – 14 AWG ††*
Equipment grounding conductor	*1 – 14 AWG*
Cable clamps	*+ 1 – 14 AWG*
Total	*11 – 14 AWG*

†two conductors for the device and three conductors terminating
††two conductors for the device and two conductors terminating

Each 14 AWG counts as 2 cu in. [Table 314.16(B)].

11 conductors x 2 cu in. = 22 cu in.

If the cubic inch volume of the mud ring isn't stamped on it, or given in the problem, we can't include it in the box volume. Without knowing the mud ring volume, a 4 in. square by 2⅛ in. deep box is the minimum required for this example.

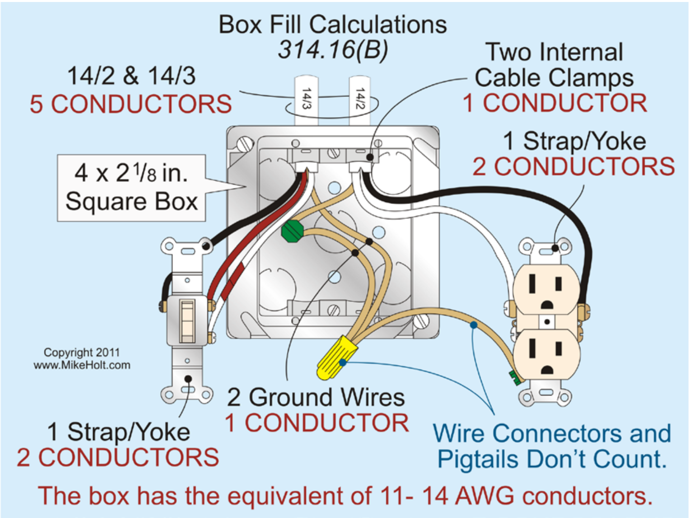

Figure 5–40

5.7 Outlet Box Sizing [314.16(B)]

To determine the size of the outlet box when the conductors are of different sizes (insulation isn't a factor), follow these steps:

Step 1: Determine the number and size of conductor equivalents in the box.

Step 2: Determine the volume of the conductor equivalents from Table 314.16(B).

Step 3: Size the box by using Table 314.16(A).

► Example: Calculating Different Size Conductors

Question: *What's the minimum depth 4 in. square outlet box required for one 14/3 w/G Type NM cable that terminates on a 3-way switch, and one 12/2 w/G Type NM cable that terminates on a receptacle? The box has internally installed cable clamps.* **Figure 5–41**

(a) 4 x 1¼ in. square	*(b) 4 x 1½ in. square*
(c) 4 x 2⅛ in. square	*(d) any of these*

Answer: *(c) 4 x 2⅛ in. square*

Step 1: Determine the number of each size conductor.

14 AWG

14/3 NM =	*3 – 14 AWG*
Switch	*+ 2 – 14 AWG*
Total	*5 – 14 AWG*

12 AWG

12/2 NM	*2 – 12 AWG*
Cable clamp	*1 – 12 AWG*
Receptacle	*2 – 12 AWG*
Equipment grounding conductor	*+ 1 – 12 AWG*
Total	*6 – 12 AWG*

All equipment grounding conductors count as one conductor, based on the largest equipment grounding conductor entering the box [314.16(B)(5)].

Step 2: Determine the volume of the conductors [Table 314.16(B)].

14 AWG	*2 cu in. each*
2 cu in. x 5 conductors	*10 cu in.*
12 AWG	*2.25 cu in. each*
2.25 cu in. x 6 conductors	*13.50 cu in.*
Total Volume	*10 cu in. + 13.50 cu in.*
Total Volume	*23.50 cu in.*

Step 3: Select the outlet box from Table 314.16(A).

4 x 2⅛ in. square, 30.30 cu in. meets the minimum cu in. requirements

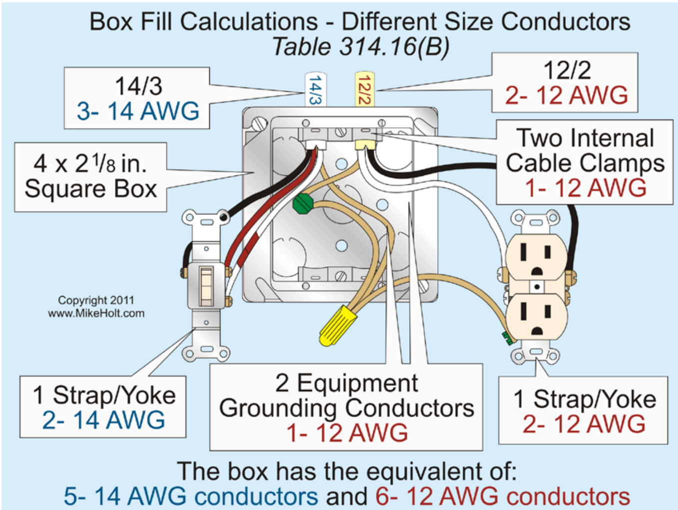

Figure 5–41

▶ Domed Fixture Canopy [314.16(B)(1) Ex]

Question: *A round 4 x ½ in. box has a total volume of 7 cu in. and has factory-installed internal cable clamps. Can this pancake box be used with a lighting luminaire that has a domed canopy? The branch-circuit wiring is 14/2 w/G NM cable, and the luminaire has two 16 AWG fixture wires and one 16 AWG ground wire.* **Figure 5–42**

(a) Yes (b) No

Answer: *(b) No*

The box is limited to 7 cu in., and the conductor equivalents total 8 cu in. [314.16(B)(1) Ex].

Step 1: Determine the number and size of conductors within the box.

Fixture wires, including the fixture equipment grounding conductor aren't counted when the fixture has a domed canopy.

14/2 NM	*2 – 14 AWG*
Cable clamps	*1 – 14 AWG*
Ground wire	*+ 1 – 14 AWG*
Total	*4 – 14 AWG conductors*

Step 2: Determine the volume of the conductors [Table 314.16(B)].

14 AWG = 2 cu in.

Four 14 AWG conductors = 4 wires x 2 cu in. = 8 cu in.

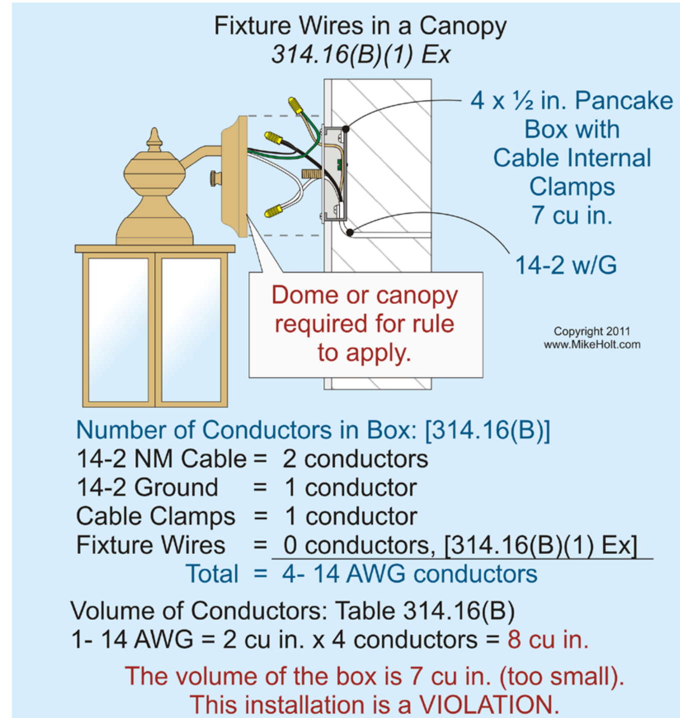

Figure 5–42

▶ Conductors Added to an Existing Box

Question: *How many 14 AWG conductors can be pulled through a 4 x 2 ⅛ in. square box that has a plaster ring of 3.60 cu in.? The box already contains two receptacles, five 12 AWG conductors, and one 12 AWG equipment grounding conductor.* **Figure 5–43**

(a) 4 conductors (b) 5 conductors
(c) 6 conductors (d) 7 conductors

Answer: *(b) 5 conductors*

Step 1: Determine the number and size of the existing conductors.

Two Receptacles (2 yokes x 2 conductors)	*4 – 12 AWG conductors*
Five 12 AWG	*5 – 12 AWG conductors*
One equipment grounding conductor	*+ 1 – 12 AWG conductors*
Total	*10 – 12 AWG conductors*

Step 2: Determine the volume of the existing conductors [Table 314.16(B)].

12 AWG conductor = 2.25 cu in.
10 wires x 2.25 cu in. = 22.50 cu in.

Step 3: Determine the space remaining for the additional 14 AWG conductors.

Remaining space = Total space less the area required for existing conductors

Total space = 30.30 cu in. (box) [Table 314.16(A)] + 3.60 cu in. (ring) = 33.90 cu in.

Remaining space = 33.90 cu in. – 22.50 cu in. (ten 12 AWG conductors)

Remaining space = 11.40 cu in.

Step 4: Determine the number of 14 AWG conductors permitted in the spare space.

Conductors added = Remaining space/added conductors' volume

Conductors added = 11.40 cu in./2 cu in. = 5.70 [Table 314.16(B)]

Conductors added = 5
(Rounding up doesn't apply to box fill.)

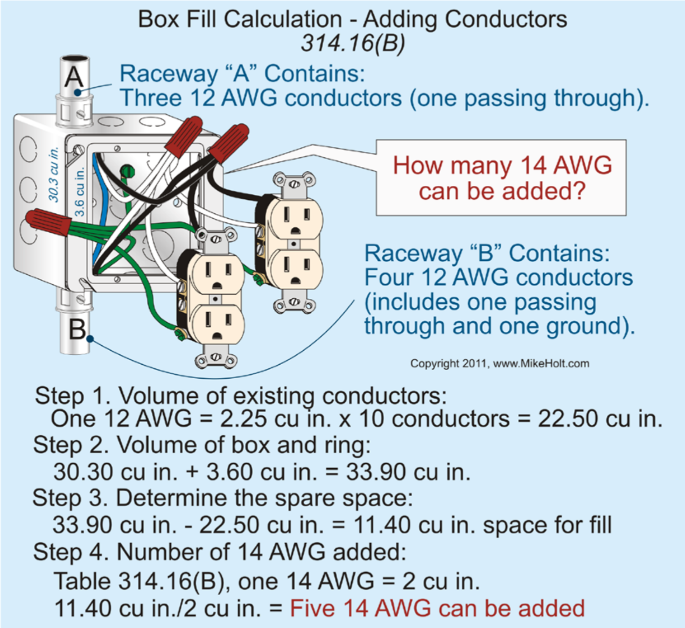

Figure 5–43

Tips for Outlet Box Sizing

Tip 1: If conductors are the same size, add them together and size the box using the AWG size columns of Table 314.16(A).

Tip 2: If the box contains different sizes of conductors, use Table 314.16(B) to find the area of each conductor, add them up, and size the box from Table 314.16(A) using the cu in. column.

Tip 3: Practice sizing boxes on the jobsite or in your own home, or by drawing out a picture problem to solve.

PART C—PULL BOXES, JUNCTION BOXES, AND CONDUIT BODIES

Introduction

Pull boxes, junction boxes, and conduit bodies must be sized to permit conductors to be installed so that the conductor insulation isn't damaged. For conductors 4 AWG and larger, pull boxes, junction boxes, and conduit bodies must be sized in accordance with 314.28 of the *NEC*. Figure 5–44

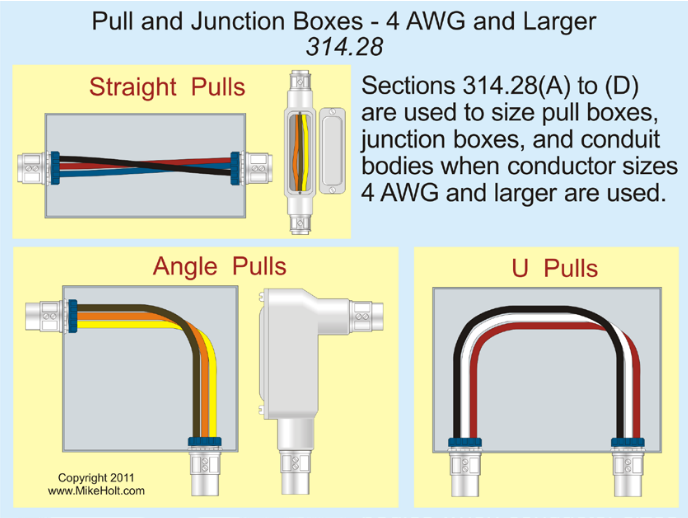

Figure 5–44

5.8 Pull/Junction Box Sizing Requirements

Boxes and Conduit Bodies for Conductors 4 AWG and Larger [314.28]

Boxes and conduit bodies containing conductors 4 AWG and larger that are required to be insulated must be sized so the conductor insulation won't be damaged.

(A) Minimum Size. For raceways containing conductors 4 AWG or larger, the minimum dimensions of boxes and conduit bodies must comply with the following:

(1) Straight Pulls. The minimum distance from where the conductors enter to the opposite wall must not be less than eight times the trade size of the largest raceway. Figure 5–45

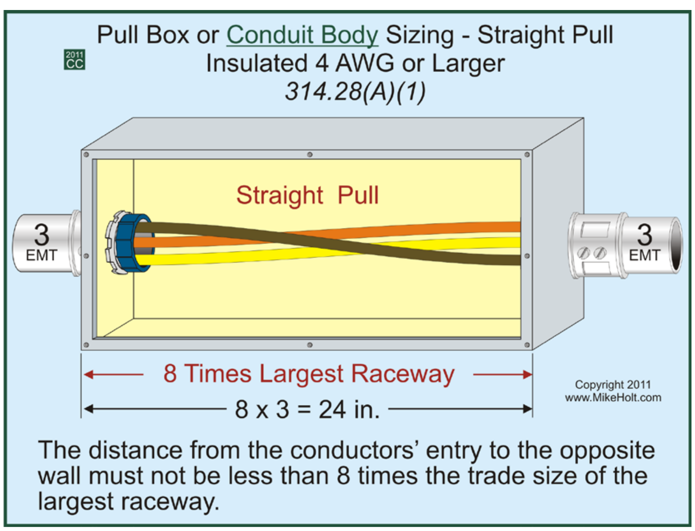

Figure 5–45

(2) Angle Pulls, U Pulls, or Splices.

- Angle Pulls. This occurs when conductors enter a wall and leave through a wall that is located 90 degrees from the entry wall. The distance from the raceway entry to the opposite wall must not be less than six times the trade size of the largest raceway, plus the sum of the trade sizes of the remaining raceways on the same wall and row. Figure 5–46

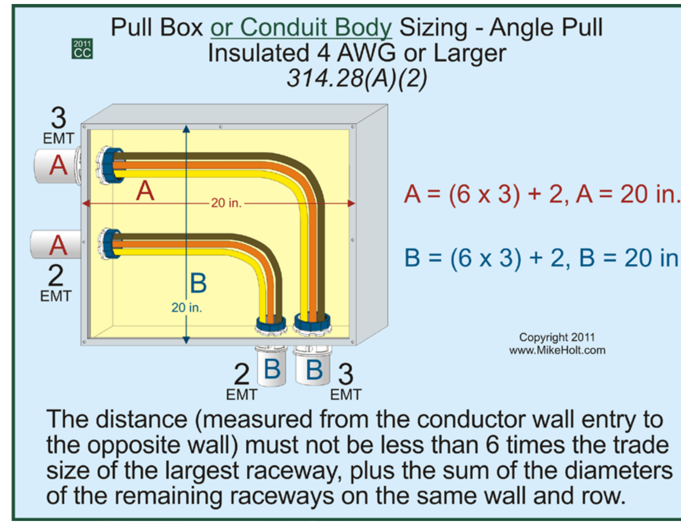

Figure 5–46

- U Pulls. When a conductor enters and leaves from the same wall, the distance from where the raceways enter to the opposite wall must not be less than six times the trade size of the largest raceway, plus the sum of the trade sizes of the remaining raceways on the same wall and row. Figure 5–47

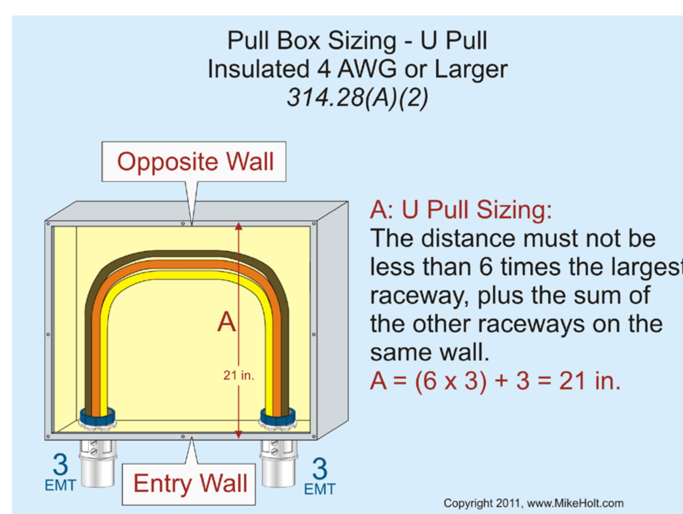

Figure 5–47

- Splices. When conductors are spliced, the distance from where the raceways enter to the opposite wall must not be less than six times the trade size of the largest raceway, plus the sum of the trade sizes of the remaining raceways on the same wall and row. Figure 5–48

- Distance Between Raceways. The distance between raceways enclosing the same conductor must not be less than six times the trade size of the largest raceway, measured from the raceways' nearest edge-to-nearest edge. Figure 5–50

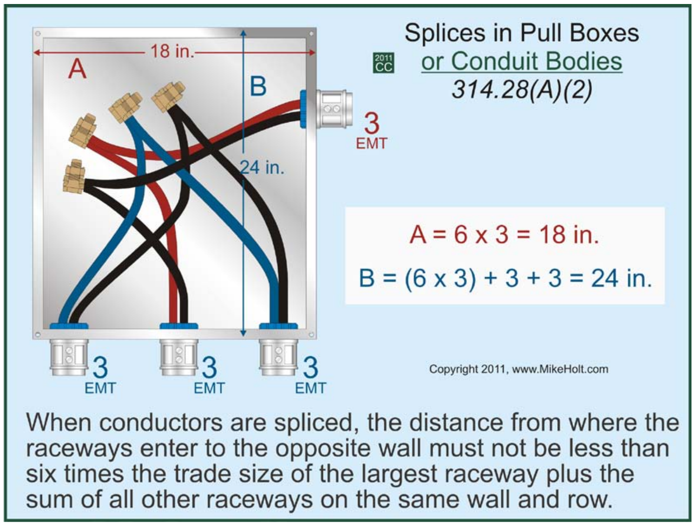

Figure 5–48

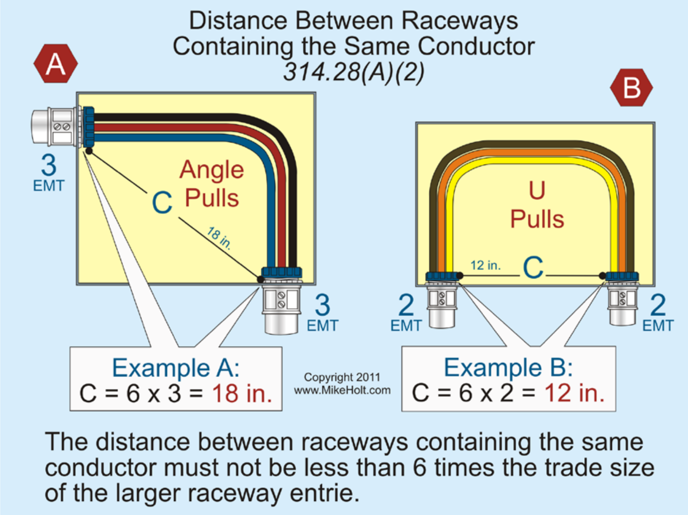

Figure 5–50

- Rows. Where there are multiple rows of raceway entries, each row is calculated individually and the row with the largest distance must be used. Figure 5–49

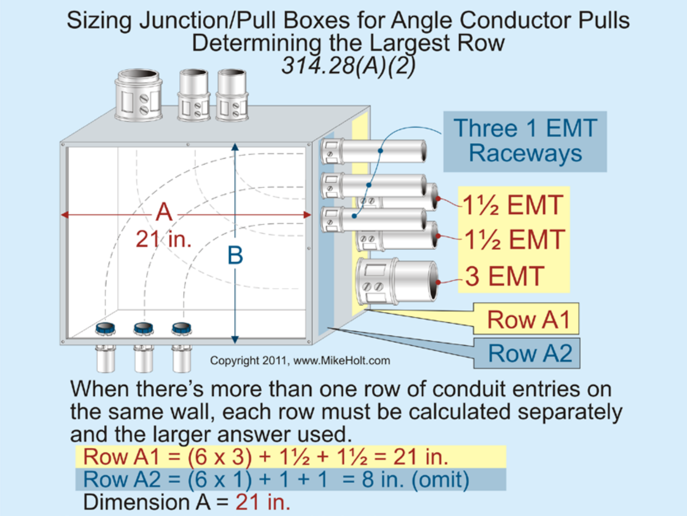

Figure 5–49

Exception: When conductors enter an enclosure with a removable cover, such as a conduit body or wireway, the distance from where the conductors enter to the removable cover must not be less than the bending distance as listed in Table 312.6(A) for one conductor per terminal. Figure 5–51

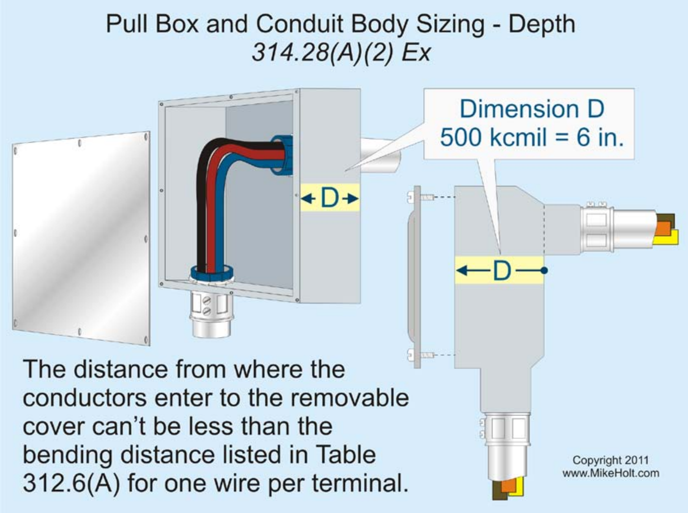

Figure 5–51

5.9 Pull/Junction Box Sizing Tips

When sizing pull and junction boxes, follow these suggestions:

Step 1: Always draw out the problem.

Step 2: Calculate the HORIZONTAL distance(s):

- Left to right straight calculation
- Right to left straight calculation
- Left to right angle or U pull calculation
- Right to left angle or U pull calculation

Step 3: Calculate the VERTICAL distance(s):

- Top to bottom straight calculation
- Bottom to top straight calculation
- Top to bottom angle or U pull calculation
- Bottom to top angle or U pull calculation

Step 4: Calculate the distance between raceways enclosing the same conductors.

5.10 Pull Box Examples

Pull Box Sizing

A junction box contains two trade size 3 raceways on the left side and one trade size 3 raceway on the right side. The conductors from one of the trade size 3 raceways on the left wall are pulled through the trade size 3 raceway on the right wall. The conductors from the other trade size 3 raceways on the left wall are pulled through a trade size 3 raceway at the bottom of the pull box.

► Horizontal Dimension

Question: *What's the horizontal dimension of this box?* Figure 5–52

(a) 18 in. (b) 21 in. (c) 24 in. (d) 30 in.

Answer: *(c) 24 in. [314.28]*

Left to right straight pull	*8 x 3 in. = 24 in.*
Right to left straight pull	*8 x 3 in. = 24 in.*
Left to right angle pull	*(6 x 3 in.) + 3 in. = 21 in.*
Right to left angle pull	*No calculation*

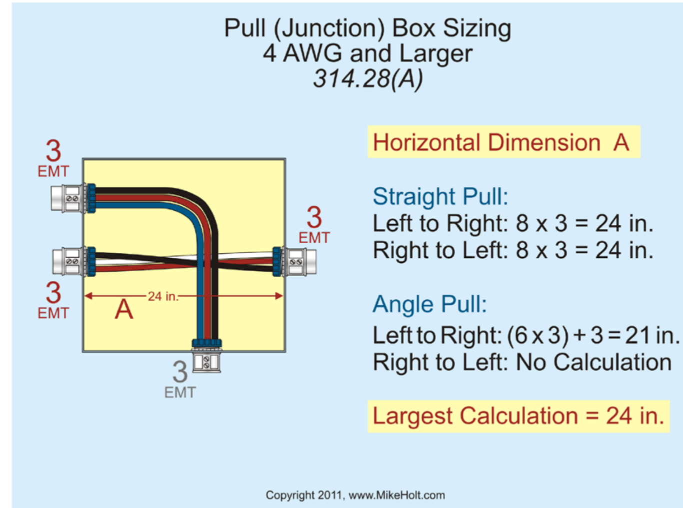

Figure 5–52

► Vertical Dimension

Question: *What's the vertical dimension of this box?* Figure 5–53

(a) 18 in. (b) 21 in. (c) 24 in. (d) 30 in.

Answer: *(a) 18 in. [314.28]*

Top to bottom straight	*No calculation*
Bottom to top straight	*No calculation*
Top to bottom angle	*No calculation*
Bottom to top angle	*6 x 3 in. = 18 in.*

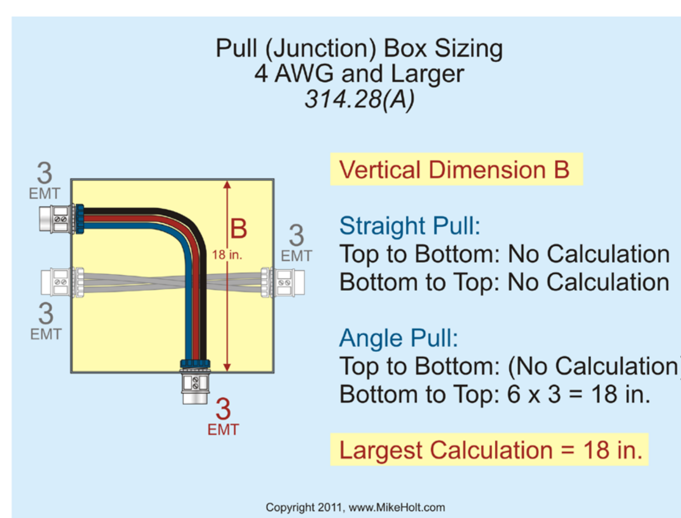

Figure 5–53

► Distance Between Raceways

Question: *What's the minimum distance between the two trade size 3 raceways that contain the same conductors?* **Figure 5–54**

(a) 18 in. *(b) 21 in.* *(c) 24 in.* *(d) 30 in.*

Answer: *(a) 18 in. [314.28]*

6 x 3 in. = 18 in.

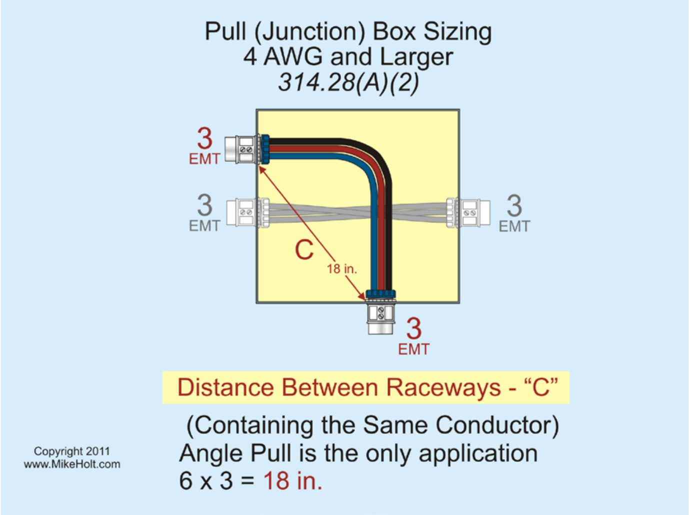

Figure 5–54

Pull Box Sizing

A pull box contains a trade size 2 and trade size 3 raceway on the left side, a trade size 3 raceway on the top, and a trade size 2 raceway on the right side. The trade size 2 raceways are a straight pull and the trade size 3 raceways are an angle pull.

► Horizontal Dimension

Question: *What's the horizontal dimension of the box?* **Figure 5–55**

(a) 20 in. *(b) 24 in.* *(c) 28 in.* *(d) 30 in.*

Answer: *(a) 20 in. [314.28(A)(2)]*

Left to right straight pull	*8 x 2 in. = 16 in.*
Right to left straight pull	*8 x 2 in. = 16 in.*
Left to right angle pull	*(6 x 3 in.) + 2 in. = 20 in.*
Right to left angle pull	*No calculation*

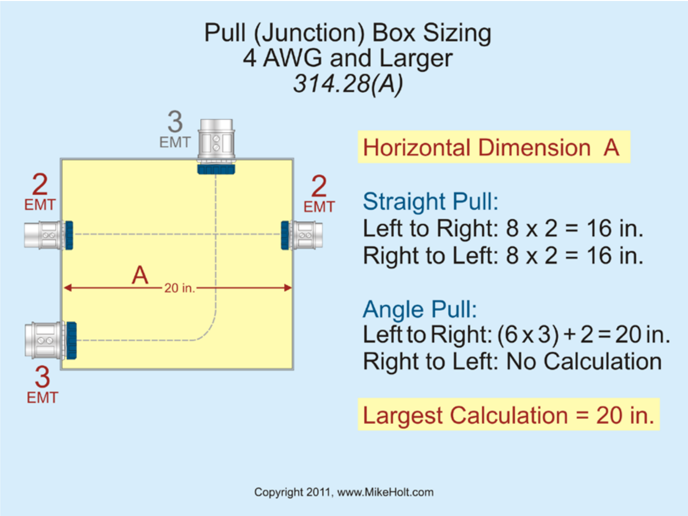

Figure 5–55

► Vertical Dimension

Question: *What's the vertical dimension of the box?* **Figure 5–56**

(a) 14 in. *(b) 18 in.* *(c) 21 in.* *(d) 26 in.*

Answer: *(b) 18 in. [314.28(A)(2)]*

Top to bottom straight	*No calculation*
Bottom to top straight	*No calculation*
Top to bottom angle	*6 x 3 in. = 18 in.*
Bottom to top angle	*No calculation*

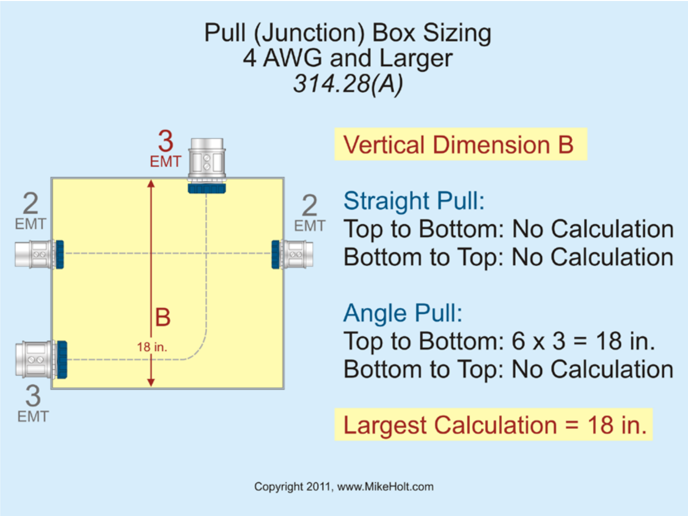

Figure 5–56

▶ **Distance Between Raceways**

Question: *If the two trade size 3 raceways contain the same conductors, what's the minimum distance between these raceways?* **Figure 5–57**

(a) 18 in. *(b) 21 in.* *(c) 24 in.* *(d) 30 in.*

Answer: *(a) 18 in. [314.28(A)(2)]*
6 x 3 in. = 18 in.

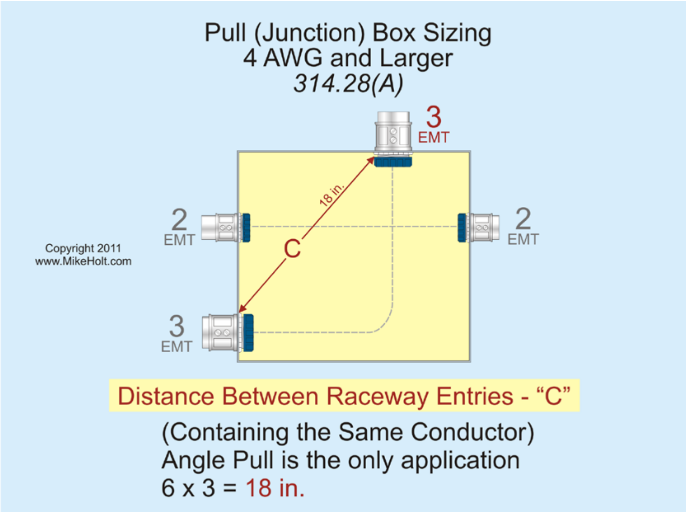

Figure 5–57

Summary

1. Slow down and take your time on these calculations. It's easy to make simple mistakes.
2. Pull box calculations can be tricky—remember which wall you're working on.
3. Box calculations become more familiar with more practice. Use practical field examples to practice calculations.
4. Draw up some sample pull boxes and calculate them for practice.

CONCLUSION TO UNIT 5—RACEWAY AND BOX CALCULATIONS

The importance of protecting conductor insulation during installation is understood by every electrician. The principles covered in this unit have gone far toward helping you achieve that goal.

In this unit, you learned how to use the tables in Chapter 9 of the *NEC* when completing raceway fill calculions. First, the area of the conductor is found, using Chapter 9, Table 5 for insulated conductors or Chapter 9, Table 8 for bare conductors. Then after totaling the cross-sectional areas of all the conductors, the raceway trade size from Chapter 9, Table 4 is selected using the available cross-sectional area of the raceway. Take your time when working out these calculations to select the correct insulation type and the correct raceway for your problem.

Annex C provides a quicker method for sizing raceways than the Chapter 9 Tables when the conductors are all the same AWG size, and the same size in cross-sectional area (including the insulation). There are numerous tables in Annex C (based on the raceway type) that can be used to reduce the time spent in calculations, so once again be sure to take your time and be certain you're using the correct table.

Metal wireways must be sized using the requirements of Article 376. The maximum fill for wireways isn't just how much you can squeeze into them. There are specific limits on conductor cross-sectional area, number of conductors, and wire-bending radius. Following the rules of Article 376 will provide a much safer installation and takes the mystery out of sizing wireways.

Maintaining proper outlet box fill is important as you rough-in the installation. There are a number of details that were covered in determining the correct box size to be used that will be important on an exam. Be sure to remember what items are counted in box fill calculations, and review the information if necessary.

Junction box and pull box calculations only come into play when the conductors are 4 AWG and larger. Straight pulls, angle pulls, and U pulls were all covered in this unit, as well as an often forgotten requirement that applies to two raceways that contain the same conductors. Always draw out a problem involving junction or pull boxes so that you'll be able to visualize it and properly apply the calculations you've learned.

UNIT
5

Practice Questions

Please use the 2011 *Code* book to answer the following questions, which are based on the 2011 *NEC.*

PRACTICE QUESTIONS FOR UNIT 5—RACEWAY AND BOX CALCULATIONS

PART A—RACEWAY FILL

5.1 Understanding the *NEC*, Chapter 9 Tables

1. When all the conductors are the same size (total cross-sectional area including insulation), the number of conductors permitted in a raceway can be determined by simply looking at the Tables in _____ of the *NEC*.

   (a) Chapter 9
   (b) Annex B
   (c) Annex C
   (d) Annex D

2. When equipment grounding conductors are installed in a raceway, the actual area of the conductor must be used when calculating raceway fill.

   (a) True
   (b) False

3. When a raceway doesn't exceed 24 in. in length, the raceway is permitted to be filled to _____ percent of its cross-sectional area.

   (a) 31
   (b) 40
   (c) 53
   (d) 60

4. How many 16 TFFN conductors can be installed in trade size ¾ electrical metallic tubing?

   (a) 26
   (b) 29
   (c) 30
   (d) 40

5. How many 6 RHH conductors (without outer cover) can be installed in trade size 1¼ electrical nonmetallic tubing?

   (a) 7
   (b) 13
   (c) 16
   (d) 25

6. How many 1/0 XHHW conductors can be installed in trade size 2 flexible metal conduit?

   (a) 6
   (b) 7
   (c) 13
   (d) 16

7. How many 12 RHH conductors (with outer cover) can be installed in a trade size 1 IMC raceway?

   (a) 4
   (b) 5
   (c) 7
   (d) 11

8. Three THHN compact conductors are needed in a trade size 2 rigid metal conduit. What's the largest compact conductor that can be installed?

   (a) 4/0 AWG
   (b) 250 kcmil
   (c) 350 kcmil
   (d) 500 kcmil

9. The actual area of conductor fill is dependent on the raceway size and the number of conductors installed. If there are three or more conductors installed in a raceway, the total area of conductor fill is limited to _____ percent.

(a) 31
(b) 40
(c) 53
(d) 60

10. What's the cross-sectional area in square inches for a 10 THW conductor?

(a) 0.0172 sq in.
(b) 0.0243 sq in.
(c) 0.0252 sq in.
(d) 0.0278 sq in.

11. What's the cross-sectional area in square inches for a 14 RHW conductor (without an outer cover)?

(a) 0.0172 sq in.
(b) 0.0209 sq in.
(c) 0.0252 sq in.
(d) 0.0278 sq in.

12. What's the cross-sectional area in square inches for a 10 THHN conductor?

(a) 0.0117 sq in.
(b) 0.0172 sq in.
(c) 0.0211 sq in.
(d) 0.0252 sq in.

13. What's the cross-sectional area in square inches for a 12 RHH conductor (with an outer cover)?

(a) 0.0117 sq in.
(b) 0.0252 sq in.
(c) 0.0327 sq in.
(d) 0.0353 sq in.

14. What's the cross-sectional area in square inches for an 8 AWG bare solid conductor?

(a) 0.013 sq in.
(b) 0.027 sq in.
(c) 0.038 sq in.
(d) 0.045 sq in.

5.2 Raceway Calculations

15. The number of conductors permitted in a raceway is dependent on the _____.

(a) area of the raceway
(b) percent area fill as listed in Chapter 9, Table 1
(c) area of the conductors as listed in Chapter 9, Tables 5 and 8
(d) all of these

16. A 200A feeder installed in Schedule 80 PVC has three 3/0 THHN conductors, one 2 THHN conductor, and one 6 THHN conductor. What size raceway is required?

(a) A trade size 2 raceway.
(b) A trade size 2½ raceway.
(c) A trade size 3 raceway.
(d) A trade size 3½ raceway.

17. What size rigid metal conduit is required for three 4/0 THHN conductors, one 1/0 THHN conductor, and one 4 THHN conductor when the raceway is 24 in. or less in length?

(a) A trade size 1½ rigid metal conduit.
(b) A trade size 2 rigid metal conduit.
(c) A trade size 2½ rigid metal conduit.
(d) A trade size 3 rigid metal conduit.

18. An existing trade size ¾ rigid metal conduit that does not exceed 24 in. in length contains four 10 THHN conductors and one 10 AWG (bare stranded) ground wire. How many additional 10 THHN conductors can be installed?

(a) 5
(b) 7
(c) 9
(d) 11

5.3 Wireways

19. What's the cross-sectional area of a 4 in. x 4 in. wireway?

    (a) 6 sq in.
    (b) 16 sq in.
    (c) 36 sq in.
    (d) 66 sq in.

20. What's the maximum allowable sq in. of conductor fill for a 4 in. x 4 in. wireway?

    (a) 2.40 sq in.
    (b) 3.20 sq in.
    (c) 5.30 sq in.
    (d) 12 sq in.

21. What's the maximum number of 400 kcmil THHN conductors that can be installed in a 6 in. x 6 in. wireway?

    (a) 4
    (b) 6
    (c) 10
    (d) 12

PART B—OUTLET BOX FILL CALCULATIONS [314.16]

5.5 Sizing Box—Conductors All the Same Size [Table 314.16(A)]

22. What size box is the minimum required for six 14 THHN conductors and three 14 THW conductors?

    (a) A 4 x 1¼ square box.
    (b) A 4 x 1½ round box.
    (c) A 4 x 1¼ round box.
    (d) A 4 x 2⅛ square box.

23. How many 10 AWG conductors are permitted in a 4 x 1½ square box?

    (a) 8 conductors
    (b) 9 conductors
    (c) 10 conductors
    (d) 11 conductors

5.6 Conductor Equivalents

24. Table 314.16(A) doesn't take into consideration the volume of _____.

    (a) switches and receptacles
    (b) luminaire studs and hickeys
    (c) internal cable clamps
    (d) all of these

25. When determining the number of conductors for box fill calculations, which of the following statements is(are) true?

    (a) A luminaire stud or hickey is considered as one conductor for each type, based on the largest conductor that enters the outlet box.
    (b) Internal factory cable clamps are considered as one conductor for one or more cable clamps, based on the largest conductor that enters the outlet box.
    (c) The single gang device yoke is considered as two conductors, based on the largest conductor that terminates on the strap (device mounting fitting).
    (d) all of these

26. When determining the number of conductors for box fill calculations, which of the following statements is(are) true?

    (a) Each conductor that runs through the box without a splice or leaving a loop long enough to splice is considered as one conductor.
    (b) Each conductor that originates outside the box and terminates in the box is considered as one conductor.
    (c) Wirenuts, cable connectors, raceway fittings, and conductors that originate and terminate within the outlet box (equipment bonding jumpers and pigtails) aren't counted for box fill calculations.
    (d) all of these

27. It's permitted to omit one equipment grounding conductor and not more than _____ that enter a box from a luminaire canopy.

    (a) five fixture wires
    (b) four 16 AWG fixture wires
    (c) four 18 AWG fixture wires
    (d) b and c

28. Can a round 4 x ½ in. box marked as 8 cu in. with manufactured cable clamps supplied with 14/2 W/G NM be used with a luminaire that has two 18 TFN conductors and a canopy cover?

(a) Yes
(b) No

5.7 Outlet Box Sizing [314.16(B)]

29. What size outlet box is required for one 12/2 W/G NM cable that terminates on a switch, one 12/3 W/G NM cable that terminates on a receptacle, and the box has manufactured cable clamps?

(a) A 4 x 1¼ square box.
(b) A 4 x 1½ square box.
(c) A 4 x 2⅛ square box.
(d) A 3 x 2 x 3½ device box

30. How many 14 AWG conductors can be pulled through a 4 x 1½ square box with a plaster ring marked 3.60 cu in.? The box already contains two duplex receptacles, five 14 AWG conductors, and two grounding conductors.

(a) one conductor
(b) two conductors
(c) three conductors
(d) four conductors

PART C—PULL BOXES, JUNCTION BOXES, AND CONDUIT BODIES

5.8 Pull/Junction Box Sizing Requirements

31. When conductors 4 AWG and larger are installed in boxes and conduit bodies, the enclosure must be sized according to which of the following requirements?

(a) The minimum distance for straight pull calculations from where the conductors enter to the opposite wall must not be less than eight times the trade size of the largest raceway.
(b) The distance for angle pull calculations from the raceway entry to the opposite wall must not be less than six times the trade size diameter of the largest raceway, plus the sum of the diameters of the remaining raceways on the same wall and row.
(c) The distance between raceways enclosing the same conductor(s) must not be less than six times the trade size diameter of the largest raceway.
(d) all of these

32. When conductors enter an enclosure opposite a removable cover, the distance from where the conductors enter to the removable cover must not be less than ______.

(a) six times the largest raceway
(b) eight times the largest raceway
(c) a or b
(d) none of these

The following information applies to the next three questions.

A junction box contains two trade size 2½ raceways on the left side and one trade size 2½ raceway on the right side. The conductors from one trade size 2½ raceway (on the left wall) are pulled through the raceway on the right wall. The other trade size 2½ raceway conductors (on the left wall) are pulled through a trade size 2½ raceway at the bottom of the pull box.

33. What's the minimum distance from the left wall to the right wall?

(a) 18 in.
(b) 20 in.
(c) 21 in.
(d) 24 in.

34. What's the minimum distance from the bottom wall to the top wall?

(a) 15 in.
(b) 18 in.
(c) 21 in.
(d) 24 in.

35. What's the minimum distance between the raceways that contain the same conductors?

(a) 15 in.
(b) 18 in.
(c) 21 in.
(d) 24 in.

The following information applies to the next three questions.

A junction box contains two trade size 2 raceways on the left side, and two trade size 2 raceways on the top.

36. What's the minimum distance from the left wall to the right wall?

(a) 14 in.
(b) 21 in.
(c) 24 in.
(d) 28 in.

37. What's the minimum distance from the bottom wall to the top wall?

(a) 14 in.
(b) 18 in.
(c) 21 in.
(d) 24 in.

38. What's the minimum distance between the trade size 2 raceways that contain the same conductors?

(a) 12 in.
(b) 18 in.
(c) 21 in.
(d) 24 in.