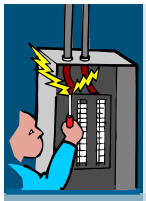

City of Republic—Community Development Department

Electrical Box Fill Calculations

REVISION DATE: DECEMBER 2016

Calculating Box Fill

Calculate conductor equivalents to prevent box fill violations per 2012 IRC.

Box fill isn't just the number of wires in the box — it's the total volume of the conductors, devices, and fittings in a box.

Every outlet box has a specific amount of space for conductors, devices, and fittings. We call that the box volume. You calculate box volume per 2012 IRC Section E3905.12.1.1 and box fill per 2012 IRC Section E3905.12.2.1, but make sure your E3905.12.1.1 box volume is greater than or equal to your E3905.12.2.1 box fill.

Box Volume

2012 IRC Table E3905.12.1 seems to make it simple to determine the volume of a box, but don't get too excited. You can use Table E3905.12.1 only if the box contains no switches, receptacles, luminaire studs, luminaire hickeys, internal cable clamps, or equipment-grounding conductors. This is rarely the case.

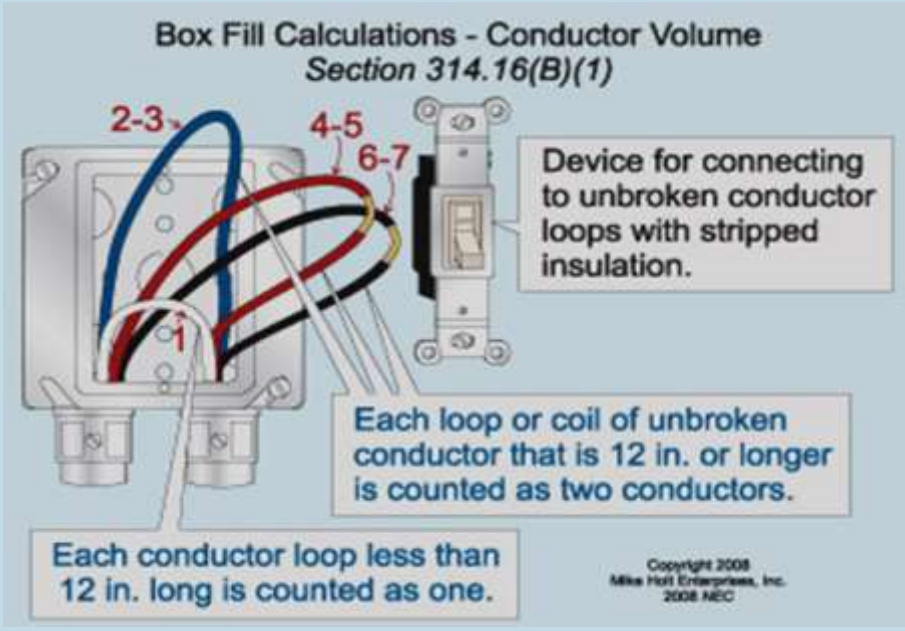

Figure 1—To Calculate Conductor Volume, Use the Guidelines Above for Certain Box Fill Calculations

If Table E3905.12.1 is inapplicable for your installation, which it typically will be, how do you calculate box volume? It's a matter of adding up individual volumes of assembled parts per section E3905.12.2.

Start with the box itself. If the box is not a standard size, the volume will be marked on the box by the manufacturer per section E3905.12.1.2. Then, add to it the sum of the individual volumes of the assembled parts, such as plaster rings, extension rings, etc. Include only those parts that are marked with their volumes in cubic inches per section E3905.12.2 or included in IRC Table E3905.12.1

Conductor Volume

Calculating conductor volume is a matter of adding up individual conductor fill volumes and conductor equivalent volume fills — and there are five such volumes. After you calculate all five volumes using E3905.12.2.1 through E3905.12.2.5, add them up using the equivalent volumes found on Table E3905.12.2.1. The number you get is the total conductor volume. In no case can this exceed the box volume per section E3905.12.1.

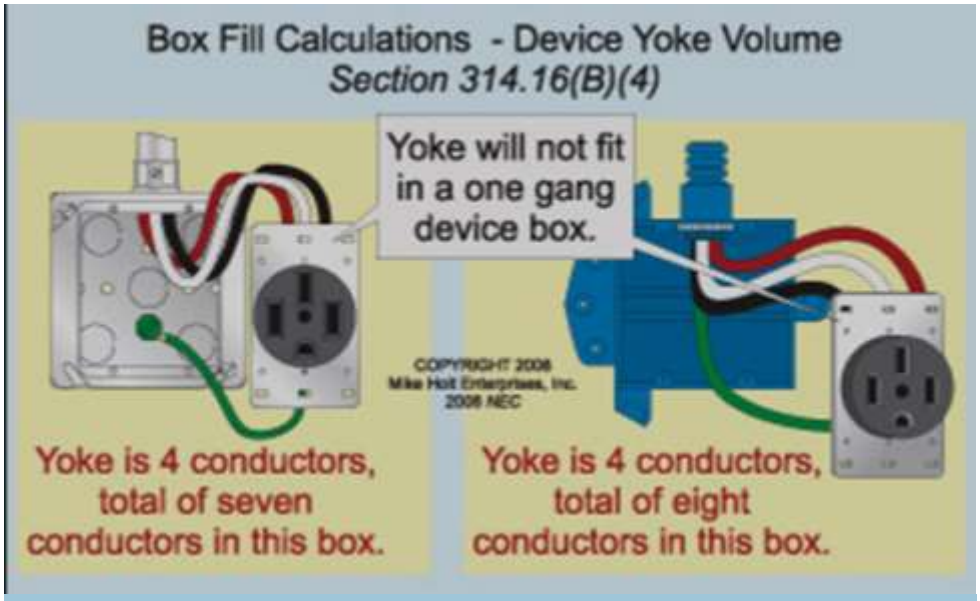

Figure 2—Each Multi-Gang Device Yoke Counts as Two Conductor Volumes for Each Gang, Based on the Largest Conductor That Terminates on the Device

In this process, you don't need to count raceway and cable fittings (including locknuts and bushings), wire connectors, or cable connectors with their clamping mechanism outside of the box. Nor do you need to count conductors that originate and terminate within the outlet box (such as equipment-bonding jumpers and pigtails) per section E3905.12.1.

Using Table E3905.12.2.1, calculate each of the five following conductor equivalent volumes:

1. **Conductor volume**

   Each unbroken conductor that runs through a box, as well as each conductor that terminates in a box, is counted as a single conductor volume. Each loop or coil of unbroken conductor having a length of at least twice the minimum length required for free conductors in section E3406.10.3 must be counted as two conductor volumes. Conductors that originate and terminate within the box (e.g., pigtails) aren't counted at all (**Fig. 1**).

   You can omit equipment-grounding conductors and up to four 16 AWG and smaller fixture wires from box fill calculations, if they enter the box from a domed luminaire or similar canopy (e.g., a ceiling paddle fan canopy) per section E3905.12.2.1 Exception.

2. **Cable clamp volume**

   One or more internal cable clamps count as a single conductor volume, based on the largest conductor that enters the box. Cable connectors that have their clamping mechanism outside the box aren't counted.

3. **Support fitting volume**

   Each luminaire stud or luminaire hickey counts as a single conductor volume, based on the largest conductor that enters the box.

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.

   A multi-gang device yoke that's too wide for mounting in a single gang box, as described in Table E3905.12.1, is counted as two conductor volumes for each gang, based on the largest conductor that terminates on the device (**Fig. 2**).

5. **Equipment-grounding conductor volume**

   All equipment-grounding conductors in a box count as a single conductor volume, based on the largest equipment-grounding conductor that enters the box.

TOTAL CONDUCTORS

What is the total number of conductors used for the box fill calculations in **Fig. 3**?
Switch and conductors: five — 14 AWG*
Receptacles and conductors: four — 14 AWG**
Equipment-grounding conductor: one — 14 AWG
Cable clamps: one — 14 AWG
Total = 11 — 14 AWG
* two conductors for the device and three conductors terminating
** two conductors for the device and two conductors terminating

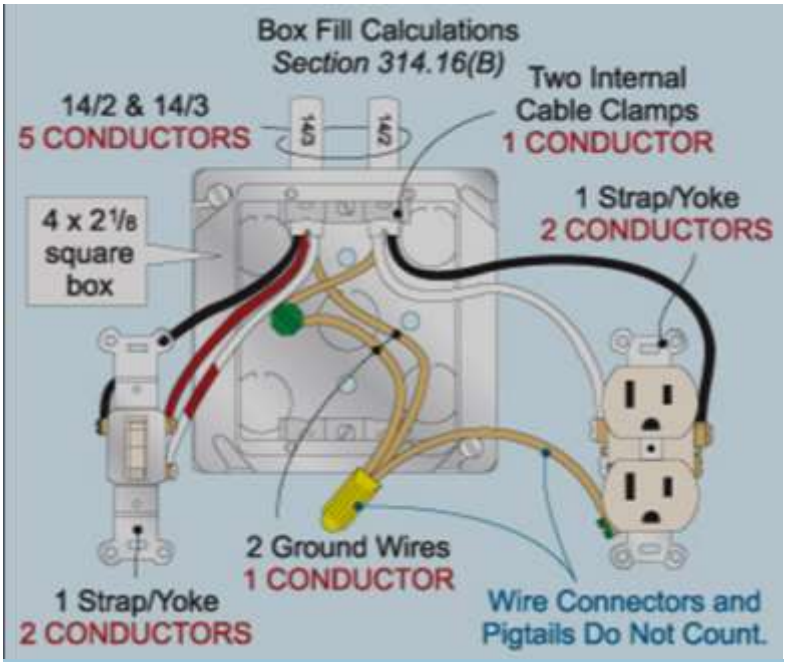

Figure 3—The Box has the Equivalent of Eleven 14 AWG Conductors

Each 14 AWG counts as two cubic inches [Table E3905.12.2.1]. Therefore, 11 conductors × two cubic inches = 22 cubic inches.

If the cubic inch volume of the mud ring is not stamped on it or given in the problem, we cannot include it in the box volume. Without knowing the mud ring volume, a 4-inch-square by 2⅛-inch-deep box would be the minimum required for this example.

BOX SIZING

To determine the size of the outlet box when the conductors are of different sizes, 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 E3905.12.2.1 through E3905.12.2.5.

Step 3: Size the box by using Table E3905.12.1.

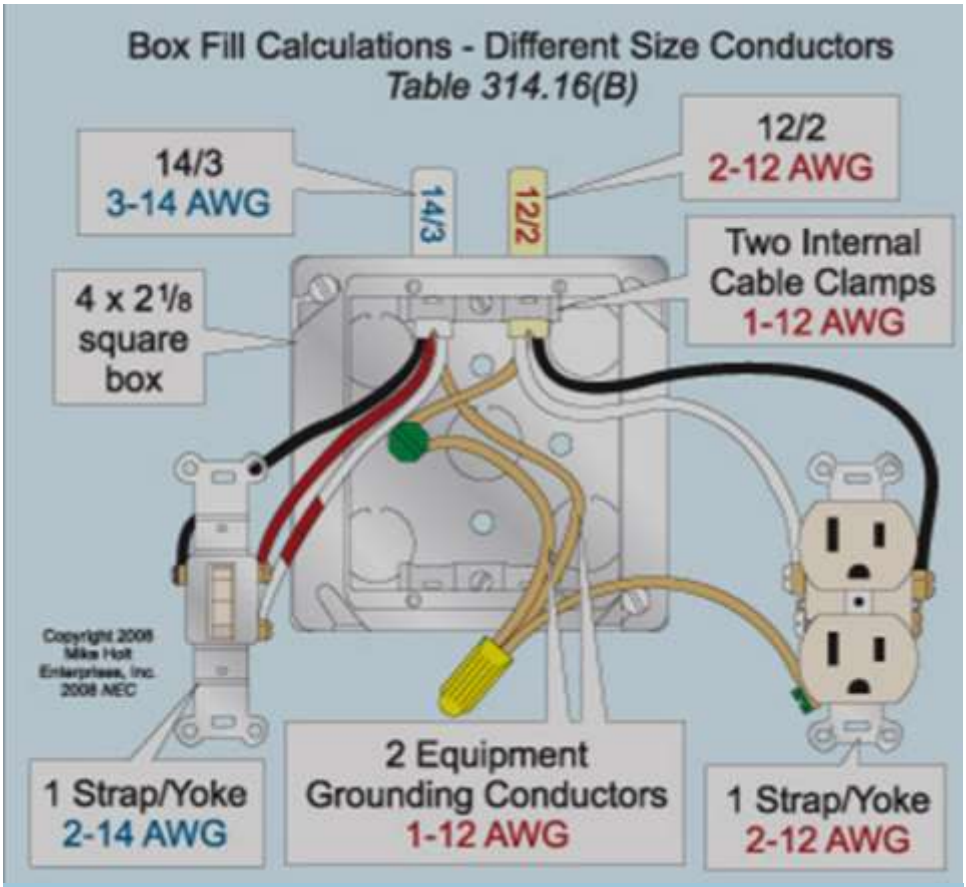

Figure 4—The Box has the Equivalent of Five 14 AWG Conductors and Six 12 AWG Conductors

Let's work an example. What is the minimum size square outlet box required for one 14/3 Type NM cable that terminates on a 3-way switch, and one 12/2 Type NM cable that terminates on a receptacle? The box has internally installed cable clamps (**Fig. 4**).

Step 1: Determine the number of each size conductor.

14 AWG
14/3 NM = three — 14 AWG
Switch = two — 14 AWG
Total = five — 14 AWG

12 AWG
12/2 NM = two — 12 AWG
Cable clamp = one — 12 AWG
Receptacle = two — 12 AWG
Equipment-grounding conductor = one — 12 AWG
Total = six — 12 AWG

All equipment-grounding conductors count as one conductor, based on the largest equipment-grounding conductor entering the box per section E3905.12.2.5.

Step 2: Determine the volume of the conductors [Table E3905.12.2.1].

14 AWG = two cubic inches each
2 cubic inches × five conductors = 10 cubic inches

12 AWG = 2.25 cubic inches each
2.25 cubic inches × six conductors = 13.50 cubic inches
Total volume = 10 cubic inches + 13.50 cubic inches
Total volume = 23.50 cubic inches

Step 3: Select the outlet box from Table E3905.12.1.

4 × 2⅛ square, 30.30 cubic inches meets the minimum cubic inch requirements.

GETTING IT RIGHT

Sometimes, you already have a box in place and need to make sure you don't overfill it. This could easily be the case during remodeling/retrofit work, or following a change order on new construction. Other times, you know how many conductors will go in a given run, and you need to make sure you install a big enough box. Either way, you calculate box volume and conductor volume. However, you can summarize the whole process this way:

- If conductors are the same size, add them together and size the box using the AWG size columns of Table E3905.12.1. Your conductor equivalents will all be the same size as the conductors.
- If the box contains different sizes of conductors, use Table E3905.12.2.1 to find the area of each conductor, add them up, and size the box from Table E3905.12.1 using the cubic inch column.

But remember:

- Calculating box volume is a matter of adding up individual volumes of assembled parts per section E3905.12.1.
- Calculating conductor volume is a matter of adding up individual conductor equivalent volumes per sections E3905.12.2.1 through E3905.12.2.5.

If box fill exceeds box volume, then you need to reduce the number of conductors or use a larger box.

Keep in mind that these are *minimum* requirements. There's no penalty for using a box that's too big, other than the additional cost of that box versus a smaller one. It's typically more cost-effective on a project to use a smaller quantity of box sizes and have a few that are oversized than to calculate the exact minimum needed a every point and try to match them all up in the field.

2012 IRC Table E3905.12.1 – Maximum Number of Conductors in Metal Boxes [a]

Box Dimensions (inches trade size and type)	Maximum Capacity (cubic inches)	Maximum Number of Conductors[a]						
		18 Awg	16 Awg	14 Awg	12 Awg	10 Awg	8 Awg	6 Awg
4 × 1 1/4 round or octagonal	12.5	8	7	6	5	5	4	2
4 × 1 1/2 round or octagonal	15.5	10	8	7	6	6	5	3
4 × 2 1/8 round or octagonal	21.5	14	12	10	9	8	7	4
4 × 1 1/4 square	18.0	12	10	9	8	7	6	3
4 × 1 1/2 square	21.0	14	12	10	9	8	7	4
4 × 2 1/8 square	30.3	20	17	15	13	12	10	6
4 11/16 × 1 1/4 square	25.5	17	14	12	11	10	8	5
4 11/16 × 1 1/2 square	29.5	19	16	14	13	11	9	5
4 11/16 × 2 1/8 square	42.0	28	24	21	18	16	14	8
3 × 2 × 1 1/2 device	7.5	5	4	3	3	3	2	1
3 × 2 × 2 device	10.0	6	5	5	4	4	3	2
3 × 2 × 2 1/4 device	10.5	7	6	5	4	4	3	2
3 × 2 × 2 1/2 device	12.5	8	7	6	5	5	4	2
3 × 2 × 2 3/4 device	14.0	9	8	7	6	5	4	2
3 × 2 × 3 1/2 device	18.0	12	10	9	8	7	6	3
4 × 2 1/8 × 1 1/2 device	10.3	6	5	5	4	4	3	2
4 × 2 1/8 × 1 7/8 device	13.0	8	7	6	5	5	4	2
4 × 2 1/8 × 2 1/8 device	14.5	9	8	7	6	5	4	2
3 3/4 × 2 × 2 1/2 masonry box/gang	14.0	9	8	7	6	5	4	2
3 3/4 × 2 × 3 1/2 masonry box/gang	21.0	14	12	10	9	8	7	4

a. Where volume allowances are not required by Sections E3905.12.2.2 through E3905.12.2.5

2012 IRC Table E3905.12.2.1 – Volume Allowance Required per Conductor

Size of Conductor (AWG)	Free Space Within Box for Each Conductor (Cubic Inches)
18	1.50
16	1.75
14	2.00
12	2.25
10	2.50
8	3.00
6	5.00

The City of Republic is located in Greene County in the southwest corner of the State of Missouri approximately ten miles from the City of Springfield, forty-five miles from Branson, and within a two-hour drive to the states of Oklahoma, Kansas, and Arkansas.

Republic began its existence in 1871 and soon thrived due in large part to the Frisco Railroad, which ran through town. Early accounts of the City indicate the existence of grain elevators within the City, a blacksmith shop and livery stable, as well as a tomato factory and cheese factory. A flourmill was built in 1890 and soon became the largest in the Middle West and carried the slogan "The World is our Field." It is unknown how the City achieved the name "Republic" but it is believed the first postmaster may have named the town. During 1904 and 1905, iron ore was mined and shipped from Republic's limekiln located south of town. Due to the fertile, gentle rolling land of this area, Republic became known as one of the major fruit producers in the Midwest, producing apples, peaches, grapes, strawberries, and tomatoes. As was common in southwest Missouri, many early citizens worked as strawberry pickers and shipped the fruit by railcar every season.

The City of Republic is fortunate to have a broad economic base. The City has several retail shops, grocery stores, factories, etc. Republic is a great place for locating a business due to the strong residential base, which provides a large pool of qualified, available work force. Republic is a pleasant place to work without the difficulties of traffic jams and limited parking. The City has no earnings tax and has ample quality office and retail space available. The City's close proximity to Springfield makes it desirable for many.

The City of Republic has an excellent school system that believes all students should be able to manage change, become lifelong learners, and participate in the democratic process. The City has been fortunate enough to strive toward a progressive future while at the same time keeping some of its traditional characteristics. While the City has seen extensive growth over the last few years, city officials are anticipating a steady, continued increase in its development.

Community Development Department

REPUBLIC
MISSOURI
GROWING TOGETHER

We're on the Web!

http://www.republicmo.com/378/Builders-Resources