

## How to Calculate Conduit Fill

Conduit fill is the amount of a conduit's cross-sectional area that is occupied by a cable or cables, based on the cable outside diameter and the conduit inside diameter. In practice, it is limited as a ratio, typically expressed as a percentage, and enforced by code, standard, or best practice to help assure system safety and performance. The ratio can be used to determine appropriate conduit size or determine how many cables can be placed in an existing conduit. The maximum recommended ratio can be affected by several factors, including application type, number of cables in the conduit, and the number of conduit bends. The following table provides maximum recommended fill for many standard conduit sizes at the maximum fill ratio specified by the United States National Electrical Code (NEC) for domains within its scope. This also assumes no more than two 90° bends between pull points. Guidance is also provided below on how to calculate conduit fill. Other codes, standards or practices may dictate other maximum fill ratios, but the methodology remains the same.

Conduit Trade Size Designator <sup>1</sup> English (Metric)	CONDUIT		MAXIMUM OCCUPANCY RECOMMENDED			MINIMUM RADIUS OF BENDS	
	Internal Diameter in (mm)	Cross-Sectional Area in <sup>2</sup> (mm <sup>2</sup> )	1 Cable = 53% Fill in <sup>2</sup> (mm <sup>2</sup> )	2 Cables = 31% Fill in <sup>2</sup> (mm <sup>2</sup> )	3+ Cables = 40% Fill in <sup>2</sup> (mm <sup>2</sup> )	Layers of Steel within Sheath in (mm)	Other Sheath in (mm)
½ (16)	0.62 (15.7)	0.30 (195)	0.16 (103)	0.09 (60)	0.12 (78)	6 (160)	4 (100)
¾ (21)	0.82 (20.9)	0.53 (345)	0.28 (183)	0.16 (107)	0.21 (138)	8 (210)	5 (130)
1 (27)	1.05 (26.6)	0.87 (559)	0.46 (296)	0.27 (173)	0.35 (224)	11 (270)	6 (160)
1¼ (35)	1.38 (35.1)	1.51 (973)	0.80 (516)	0.47 (302)	0.60 (389)	14 (350)	8 (210)
1½ (41)	1.61 (40.9)	2.05 (1,322)	1.09 (701)	0.64 (410)	0.82 (529)	16 (410)	10 (250)
2 (53)	2.07 (52.5)	3.39 (2,177)	1.80 (1,154)	1.05 (675)	1.36 (871)	21 (530)	12 (320)
2½ (63)	2.47 (62.7)	4.82 (3,106)	2.56 (1,646)	1.49 (963)	1.93 (1,242)	25 (630)	25 (630)
3 (78)	3.07 (77.9)	7.45 (4,794)	3.95 (2,541)	2.31 (1,486)	2.98 (1,918)	31 (780)	31 (780)
3½ (91)	3.55 (90.1)	9.96 (6,413)	5.28 (3,399)	3.09 (1,988)	3.98 (2,565)	36 (900)	36 (900)
4 (103)	4.03 (102.3)	12.83 (8,268)	6.80 (4,382)	3.98 (2,563)	5.13 (3,307)	40 (1,020)	40 (1,020)
5 (129)	5.05 (128.2)	20.15 (12,984)	10.68 (6,882)	6.25 (4,025)	8.06 (5,194)	50 (1,280)	50 (1,280)
6 (155)	6.07 (154.1)	29.11 (18,760)	15.43 (9,943)	9.02 (5,816)	11.64 (7,504)	60 (1,540)	60 (1,540)

<sup>1</sup>Identifier only; not an actual dimension

### Sizing a Conduit

#### Step 1

The first step in sizing a conduit is to determine the number of cables to be placed in the conduit. This will determine the maximum fill allowance (see table above).

NUMBER OF CABLES IN CONDUIT	MAXIMUM FILL
1	53%
2	31%
3 or more	40%

## Step 2

Next, determine the cross sectional area (A) of cable(s) being placed in the conduit via the following equation:

$$A = \frac{\pi D^2}{4} \text{ or } A = 0.79D^2$$

If there is more than one cable being placed in the conduit, simply add up the results of the calculations as follows:

$$A_T = 0.79D^2 (\text{Cable 1}) + 0.79D^2 (\text{Cable 2}) + 0.79D^2 (\text{Cable 3}) + 0.79D^2 (\text{Cable 4}) + \dots$$

## Step 3

Finally, determine the number of bends in the conduit. If more than two 90° conduits per pull section, subtract 15% from the total cross-sectional area (see examples below) for each one above two. It is recommended that no more than two 90° bends be placed in a single section of conduit.

## Example 1

Suppose two RG-6 Quad Shield (QS) coaxial cables and two 4-pair Unshielded Twisted Pair (UTP) cables are to be placed in a conduit with no bends. The outside diameter (OD) of each RG-6 QS coax is 0.30 inch and the OD of each UTP is 0.20 inch.

**To find the cross-sectional area of any cable use the following equation:**

$$A = 0.79D^2 \text{ where } D = \text{outside diameter (OD) of the cable}$$

**So, for this example, the calculation for each cable type would be as follows:**

$$\text{Coax: } 0.79D^2 = 0.79 \times 0.30^2 = 0.07 \text{ in}^2$$

$$\text{UTP: } 0.79D^2 = 0.79 \times 0.20^2 = 0.03 \text{ in}^2$$

**Simply add the results for all 4 cables as follows:**

$$\text{Coax} + \text{Coax} + \text{UTP} + \text{UTP} = \text{total cross-sectional area}$$

$$0.07 + 0.07 + 0.03 + 0.03 = 0.20 \text{ in}^2$$

Because 3 or more cables are being placed in the conduit, the maximum fill is 40%. In the table, go to the column marked "3+ Cables = 40% Fill". This column states the maximum allowed occupancy for each trade size conduit. For 1/2" conduit, the maximum occupancy is 0.12 in<sup>2</sup>, which is less than the 0.20 in<sup>2</sup> required, and is therefore unsuitable for the application. For a 3/4" conduit, the maximum occupancy is 0.21 in<sup>2</sup>, being greater than 0.20 in<sup>2</sup>, and therefore the minimum appropriate size for this application.

## Example 2

Now suppose that the same two RG-6 QS coax and two 4-pair UTP cables are placed in a conduit that includes three 90° bends.

### Calculations

The total cross-sectional area of the cables is still 0.20 in<sup>2</sup>. However, since there are three 90° bends, the acceptable fill must be reduced by 15% for each bend above two to find the proper maximum fill. This is done via the following calculations:

$$\begin{array}{r}
 100\% \\
 -15\% \quad (\text{extra } 90^\circ \text{ bend}) \\
 \hline
 85\% \\
 \times 40\% \quad (\text{proper fill for 3 or more cables}) \\
 \hline
 34\% \quad (\text{new fill requirement})
 \end{array}$$

Now the new maximum fill is 34%. Since there is no column for 34%, calculate the available space in the conduit manually. Finding the proper trade size, in an example such as this, is a matter of trial and error. From the table, ¾" conduit has an area of 0.53 in<sup>2</sup> and 1" conduit has an area of 0.87 in<sup>2</sup>.

To calculate the maximum occupancy for these conduits, use the following equation:

$$\begin{array}{l}
 \text{Area} \times 34\% = \text{maximum occupancy} \\
 \text{For } \frac{3}{4}": \quad 0.53 \times 34\% = 0.18 \text{ in}^2 \\
 \text{For } 1": \quad 0.87 \times 34\% = 0.30 \text{ in}^2
 \end{array}$$

The maximum occupancy for a ¾" conduit is 0.18 in<sup>2</sup>, which is less than the 0.20 in<sup>2</sup> required, and is therefore unsuitable for the application. The maximum occupancy for a 1" conduit is 0.30 in<sup>2</sup>, being greater than 0.20 in<sup>2</sup>, and therefore the minimum appropriate size for this application.

## Example 3

Suppose you had five Low Voltage (LV) control cables and five LV instrumentation cables that are placed in a 4" conduit with no bends. The OD of each of the LV control cables is 0.527 inch and the LV instrumentation cable is 0.506 inch.

To find the cross-sectional area of any cable use the following equation:

$$A = 0.79D^2 \text{ where } D = \text{outside diameter (OD) of the cable}$$

So, for this example, the calculation for each cable type would be as follows:

$$\begin{array}{l}
 \text{LV Control:} \quad 0.79D^2 = 0.79 \times 0.527^2 = 0.22 \text{ in}^2 \\
 \text{LV Instrumentation:} \quad 0.79D^2 = 0.79 \times 0.506^2 = 0.20 \text{ in}^2
 \end{array}$$

Simply add the results for all 10 cables as follows:

$$\begin{array}{l}
 (\text{LV Control} \times 5) + (\text{LV Instrumentation} \times 5) = \text{total cross-sectional area} \\
 (0.22 \times 5) + (0.20 \times 5) = 2.1 \text{ in}^2
 \end{array}$$

Because 3 or more cables are being placed in the conduit, the maximum fill is 40%. In the table, go to the column marked "3+ Cables = 40% Fill". This column states the maximum allowed occupancy for each trade size conduit. For 2" conduit, the maximum occupancy is 1.36 in<sup>2</sup>, which is less than the 2.1 in<sup>2</sup> required, and is therefore unsuitable for the application. For a 3" conduit, the maximum occupancy is 2.98 in<sup>2</sup>, being greater than 2.1 in<sup>2</sup>, and therefore the minimum appropriate size for this application.

## Summary

This document is intended as a guideline for calculating conduit fill. The examples provided are based on NEC requirements and do not take into account all factors that may affect conduit fill. When sizing conduits for new runs, consideration should be given to providing allowance for future cabling needs.