



PDHonline Course E276 (2 PDH)

Conduit Fill Calculations

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Introduction:

The purpose of this course is to explain conduit fill, which is just one of the factors to be considered in conduit sizing. There are other aspects to be considered, as listed in the sidebar. Additional information is also available in *PDH Course E122 Conduit System Design* by Ralph Fehr, Ph.D, PE.

The tables presented in this document are available as a separate file, if you have difficulty reading the tables in this document.

One of the reasons to limit conduit fill is to allow air to circulate within the conduit and thereby permit some cooling of the conductors. Conduit fill calculations, also known as raceway fill calculations or conductor fill calculations, are performed to determine the minimum conduit size required for a given set of conductors. Drawings often describe a circuit as 3-#12, #12 Gnd, ¾" C., without mentioning the type of conductors or the type of conduit. Typically, the construction specification is where the conductor type and conduit type are called out for each type of application. The reason we have to know the type of conductor and conduit is because the physical dimensions are different for different types of conductors and conduits. Different types of conductors with different types of insulation will have different outside diameters for the same wire size. See Figure 6 for the different diameters of a 4/0 AWG conductor with four different insulation types. Table 5 from Chapter 9 of the NEC gives the approximate diameters and areas of different types of conductors, a portion of which is presented as Table 7 in this document, which shows THHW, THHN, THWN, and XHHW. Different types of conduits will have different internal diameters for the same conduit size. Table 4 from Chapter 9 of the NEC gives the nominal internal diameters and cross-sectional areas for different conduit types and sizes. Portions of these values are reproduced in Tables 2 through 6 in this document for EMT, IMC, RMC, Schedule 40 PVC, and Schedule 80 PVC. See Figure 5 for an illustration of the different dimensions of a 1" conduit of these five different types.

Conduit fill is often explained by using an example in which all of the conductors are the same size and type. Sometimes, all of the conductors within a conduit are the same size (such as 12 AWG) and type (such as THHN), but often the conductors will be of different sizes, and occasionally there will be more than one type of conductor in the same conduit. Annex C in the NEC gives the maximum number of conductors of the same size that will be permitted in various types and sizes of conduit. Annex C is based on the general case of all of the conductors being the same sizes and type, so Annex C has not been reproduced in this document, since we are

These topics are not covered in this short course:

- *Jam ratio – see FPN No. 2 to Table 1 in Chapter 9 of the NEC.*
- *The de-rating of conductor ampacity based on the number of current-carrying conductors in the same conduit.*
- *Compact conductors (Table 5A in the NEC).*
- *Cable pulling tension.*
- *Conduit bending radius.*
- *Selecting the proper type of conduit and conductor for a given application.*
- *Sizing of boxes and conduit bodies.*
- *Sizing of wireways.*

considering specific cases in which the conductors might be different sizes and types. You can use the techniques from this course to verify the values shown in Annex C, but be sure to consider Note 7 to the tables in Chapter 9 of the NEC, as explained later.

Occasionally, a circuit will run through more than one type of conduit. A common example of this is a circuit that runs in galvanized rigid steel (GRS, sometimes called RGS) above grade, then transitions to Schedule 40 PVC below grade, then back into GRS when it comes above grade again. The conduit fill calculations would be slightly different for the two types of conduit.

Conduit fill calculations are relatively simple and straightforward, but certain details must be known about the conduit and the conductors. There can be only one unknown from the following five pieces of information in order to perform the calculations to match the conduit size with the conductors:

- Size of conduit, such as 3"
- Type of conduit, such as Schedule 40 PVC
- Conductor quantities, such as 3-#12 THWN
- Conductor sizes, such as 3-#12 THWN
- Conductor types, such as 3-#12 THWN.

For multiconductor cables, the last two topics listed above are replaced by using the overall or outside diameter of the cable (it doesn't matter what the sizes and types of the internal conductors are). This document will use different formats interchangeably to describe conductor sizes, such as #12 and 12 AWG. With regard to formulas and calculations in this document, we will be using the asterisk (*) for multiplication and the forward slash (/) for division. Since we will be discussing diameter (d), rather than radius (r), in this document, the familiar expression for the area of a circle will be shown as $A = \pi * d^2 / 4$, rather than $A = \pi * r^2$.

Conduit Fill Tables from the NEC:

NEC Table 1 in Chapter 9 gives guidelines for conduit fill, which are represented in Table 1 in this document.

Qty. of Conductors	Percent of Cross Section
1	53
2	31
Over 2	40

It might seem from a quick glance at Table 1 that the installation of 2 conductors is being treated unfairly, since 2 conductors can only take up 31% of the conduit cross-sectional area while 3 conductors can take up 40% of the area and 1 conductor can go all the way up to 53%. The low value of 31% is based partly on geometry, as illustrated in Figure 2, where it is clear that 2 conductors sized to take up a total of 53% of the conduit cross-sectional area won't even fit in the conduit. Similarly, 2 conductors sized at 40% fill would be pretty crowded in the conduit and might prove difficult to pull.

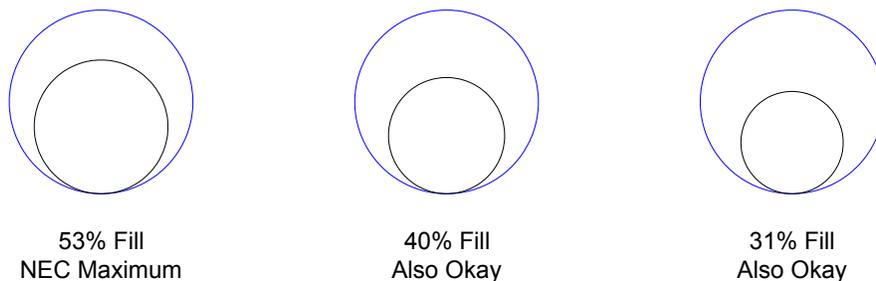
A lesser-used conduit application is a nipple between two panels or enclosures, which is shown with 60% fill in Tables 2 through 6. A nipple is a section of conduit that is 24" or less in length and is used to allow one or more cables to travel between boxes, cabinets, or similar enclosures. The conduit fill in these nipples is allowed to be up to 60% (obviously, this wouldn't work for two conductors). This is Note 4 to the tables in Chapter 9 in the NEC, as described next.

The notes to the tables in Chapter 9 are important, and some of them are paraphrased here:

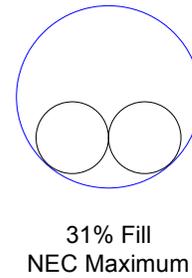
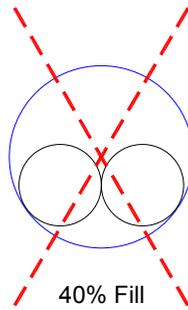
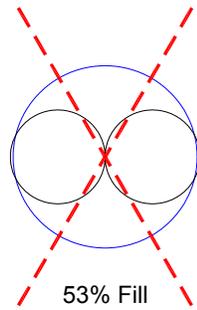
Notes to Tables in Chapter 9 of the NEC:

- (3) Equipment grounding conductors shall be included in conduit fill calculations.
- (4) Conduit nipples are permitted to be filled up to 60%.
- (5) For cables not included in the tables in Chapter 9, such as multiconductor cables, the actual dimensions of the cables shall be used in conduit fill calculations.
- (7) If all of the conductors are the same physical size (cross-sectional area), the next-higher whole number can be used when the calculation results in a decimal remainder of 0.8 or larger.
- (9) A multiconductor cable shall be treated as a single conductor for calculating conduit fill. For cables that have elliptical cross-sections, the cross-sectional area calculation shall be based on using the major diameter (the longer dimension) of the ellipse as the circle diameter.

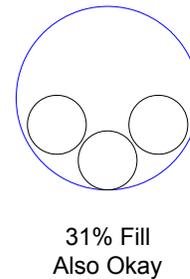
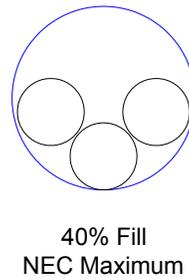
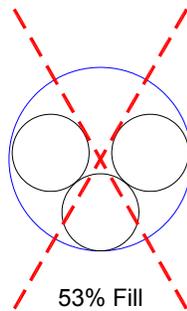
Figures 1, 2, and 3, and 4 illustrate and compare conduit fill for 1, 2, 3, and 4, 5, & 6 conductors. The case of 60% fill for nipples is not included in these four illustrations.



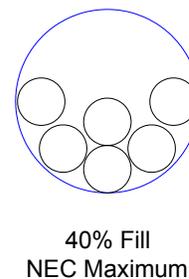
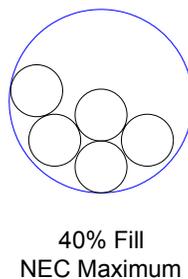
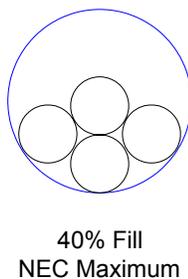
One Conductor
Figure 1



Two Conductors
Figure 2



Three Conductors
Figure 3



Four, Five, & Six Conductors
Figure 4

Conduit Types:

Electrical Metallic Tubing (EMT) as shown in Table 2 is thin-walled. When it is used, it is typically in protected locations, such as inside of hollow walls or above suspended ceilings.

Intermediate Metal Conduit (IMC) as shown in Table 3 is called intermediate because it is between EMT and RMC in wall thickness and strength. IMC is sometimes used in place of RMC, where approved.

Rigid Metal Conduit (RMC) as shown in Table 4 could be either aluminum or galvanized rigid steel (GRS) and has thicker walls than IMC. RMC is arguably the most popular all-purpose type of conduit for above-grade (above-ground) conduit systems.

Rigid Nonmetallic Conduit (RNC) Schedule 40 PVC as shown in Table 5 has thicker walls than RMC, but it is made out of polyvinyl chloride (PVC), not metal. Schedule 40 PVC is often used for underground duct banks for telephone, data, and power. The wall thickness values in this table are based on the average wall thickness, but many conduit catalogs show only the minimum wall thickness, which would give a different value for the internal diameter and area.

Rigid Nonmetallic Conduit (RNC) Schedule 80 PVC as shown in Table 6 has thicker walls than Schedule 40 PVC and the thickest walls of all of the conduit types discussed in this document. Schedule 80 PVC is often used for the riser to bring an electrical service underground from a pole to below grade, which then goes to a building or a pad-mounted transformer. The wall thickness values in this table are based on the average wall thickness, but many conduit catalogs show only the minimum wall thickness, which would give a different value for the internal diameter and area.

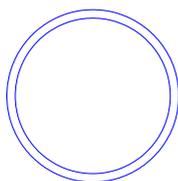
Outside Diameter = 1.163"
Wall Thickness = 0.057"
Internal Diameter = 1.049"
Internal Area = 0.864 sq. in.

Outside Diameter = 1.29"
Wall Thickness = 0.093"
Internal Diameter = 1.105"
Internal Area = 0.959 sq. in.

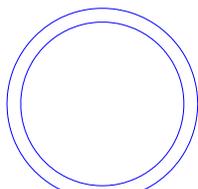
Outside Diameter = 1.315"
Wall Thickness = 0.126"
Internal Diameter = 1.063"
Internal Area = 0.887 sq. in.

Outside Diameter = 1.315"
Wall Thickness = 0.143"
Internal Diameter = 1.029"
Internal Area = 0.832 sq. in.

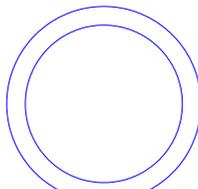
Outside Diameter = 1.315"
Wall Thickness = 0.19"
Internal Diameter = 0.936"
Internal Area = 0.688 sq. in.



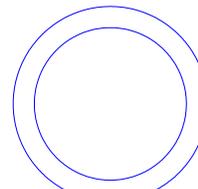
1" EMT



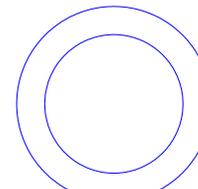
1" IMC



1" RMC



1" Sch. 40 PVC



1" Sch. 80 PVC

Relative Dimensions of Various 1" Conduit Types
Figure 5

The cross-sectional area for each conduit is calculated from the internal diameter for that type and size of conduit. The overall diameter and the thickness of the conduit wall are not important for conduit fill calculations, although they do determine the internal diameter, and have been shown for reference on Tables 2 through 6. The rows are shaded as a visual aid.

TABLE 2 - Electrical Metallic Tubing (EMT) - Dimensions and % Fill

Conduit Nominal Size (inch)	Nominal Outside Diam. (inch)	Nominal Wall Thickness (inch)	Nominal Internal Diam. (inch)	100% of Internal Area (in ²)	Nipples: 60% of Internal Area (in ²)	1 Wire: 53% of Internal Area (in ²)	2 Wires: 31% of Internal Area (in ²)	3+ Wires: 40% of Internal Area (in ²)
1/2	0.706	0.042	0.622	0.304	0.182	0.161	0.094	0.122
3/4	0.922	0.049	0.824	0.533	0.320	0.283	0.165	0.213
1	1.163	0.057	1.049	0.864	0.519	0.458	0.268	0.346
1-1/4	1.510	0.065	1.380	1.496	0.897	0.793	0.464	0.598
1-1/2	1.740	0.065	1.610	2.036	1.221	1.079	0.631	0.814
2	2.197	0.065	2.067	3.356	2.013	1.778	1.040	1.342
2-1/2	2.875	0.072	2.731	5.858	3.515	3.105	1.816	2.343
3	3.500	0.072	3.356	8.846	5.307	4.688	2.742	3.538
3-1/2	4.000	0.083	3.834	11.545	6.927	6.119	3.579	4.618
4	4.500	0.083	4.334	14.753	8.852	7.819	4.573	5.901

TABLE 3 - Intermediate Metal Conduit (IMC) - Dimensions and % Fill

Conduit Nominal Size (inch)	Nominal Outside Diam. (inch)	Nominal Wall Thickness (inch)	Nominal Internal Diam. (inch)	100% of Internal Area (in ²)	Nipples: 60% of Internal Area (in ²)	1 Wire: 53% of Internal Area (in ²)	2 Wires: 31% of Internal Area (in ²)	3+ Wires: 40% of Internal Area (in ²)
1/2	0.815	0.078	0.660	0.342	0.205	0.181	0.106	0.137
3/4	1.029	0.083	0.864	0.586	0.352	0.311	0.182	0.235
1	1.290	0.093	1.105	0.959	0.575	0.508	0.297	0.384
1-1/4	1.638	0.095	1.448	1.647	0.988	0.873	0.510	0.659
1-1/2	1.883	0.100	1.683	2.225	1.335	1.179	0.690	0.890
2	2.360	0.105	2.150	3.630	2.178	1.924	1.125	1.452
2-1/2	2.857	0.150	2.557	5.135	3.081	2.722	1.592	2.054
3	3.476	0.150	3.176	7.922	4.753	4.199	2.456	3.169
3-1/2	3.971	0.150	3.671	10.584	6.351	5.610	3.281	4.234
4	4.466	0.150	4.166	13.631	8.179	7.224	4.226	5.452

TABLE 4 - Rigid Metal Conduit (RMC) [GRS & Aluminum] - Dimensions and % Fill

Conduit Nominal Size (inch)	Nominal Outside Diam. (inch)	Nominal Wall Thickness (inch)	Nominal Internal Diam. (inch)	100% of Internal Area (in ²)	Nipples: 60% of Internal Area (in ²)	1 Wire: 53% of Internal Area (in ²)	2 Wires: 31% of Internal Area (in ²)	3+ Wires: 40% of Internal Area (in ²)
1/2	0.840	0.104	0.632	0.314	0.188	0.166	0.097	0.125
3/4	1.050	0.107	0.836	0.549	0.329	0.291	0.170	0.220
1	1.315	0.126	1.063	0.887	0.532	0.470	0.275	0.355
1-1/4	1.660	0.133	1.394	1.526	0.916	0.809	0.473	0.610
1-1/2	1.900	0.138	1.624	2.071	1.243	1.098	0.642	0.829
2	2.375	0.146	2.083	3.408	2.045	1.806	1.056	1.363
2-1/2	2.875	0.193	2.489	4.866	2.919	2.579	1.508	1.946
3	3.500	0.205	3.090	7.499	4.499	3.974	2.325	3.000
3-1/2	4.000	0.215	3.570	10.010	6.006	5.305	3.103	4.004
4	4.500	0.225	4.050	12.882	7.729	6.828	3.994	5.153
5	5.563	0.245	5.073	20.212	12.127	10.713	6.266	8.085
6	6.625	0.266	6.093	29.158	17.495	15.454	9.039	11.663

TABLE 5 - Rigid PVC Conduit (RNC) Schedule 40 - Dimensions and % Fill

Conduit Nominal Size (inch)	Nominal Outside Diam. (inch)	Nominal Wall Thickness (inch)	Nominal Internal Diam. (inch)	100% of Internal Area (in ²)	Nipples: 60% of Internal Area (in ²)	1 Wire: 53% of Internal Area (in ²)	2 Wires: 31% of Internal Area (in ²)	3+ Wires: 40% of Internal Area (in ²)
1/2	0.840	0.119	0.602	0.285	0.171	0.151	0.088	0.114
3/4	1.050	0.123	0.804	0.508	0.305	0.269	0.157	0.203
1	1.315	0.143	1.029	0.832	0.499	0.441	0.258	0.333
1-1/4	1.660	0.150	1.360	1.453	0.872	0.770	0.450	0.581
1-1/2	1.900	0.155	1.590	1.986	1.191	1.052	0.616	0.794
2	2.375	0.164	2.047	3.291	1.975	1.744	1.020	1.316
2-1/2	2.875	0.215	2.445	4.695	2.817	2.488	1.455	1.878
3	3.500	0.229	3.042	7.268	4.361	3.852	2.253	2.907
3-1/2	4.000	0.240	3.521	9.737	5.842	5.161	3.018	3.895
4	4.500	0.251	3.998	12.554	7.532	6.654	3.892	5.022
5	5.563	0.274	5.016	19.761	11.856	10.473	6.126	7.904
6	6.625	0.297	6.031	28.567	17.140	15.141	8.856	11.427

TABLE 6 - Rigid PVC Conduit (RNC) Schedule 80 - Dimensions and % Fill

Conduit Nominal Size (inch)	Nominal Outside Diam. (inch)	Nominal Wall Thickness (inch)	Nominal Internal Diam. (inch)	100% of Internal Area (in ²)	Nipples: 60% of Internal Area (in ²)	1 Wire: 53% of Internal Area (in ²)	2 Wires: 31% of Internal Area (in ²)	3+ Wires: 40% of Internal Area (in ²)
1/2	0.840	0.157	0.526	0.217	0.130	0.115	0.067	0.087
3/4	1.050	0.164	0.722	0.409	0.246	0.217	0.127	0.164
1	1.315	0.190	0.936	0.688	0.413	0.365	0.213	0.275
1-1/4	1.660	0.203	1.255	1.237	0.742	0.656	0.383	0.495
1-1/2	1.900	0.212	1.476	1.711	1.027	0.907	0.530	0.684
2	2.375	0.231	1.913	2.874	1.725	1.523	0.891	1.150
2-1/2	2.875	0.293	2.290	4.119	2.471	2.183	1.277	1.647
3	3.500	0.318	2.864	6.442	3.865	3.414	1.997	2.577
3-1/2	4.000	0.337	3.326	8.688	5.213	4.605	2.693	3.475
4	4.500	0.357	3.786	11.258	6.755	5.967	3.490	4.503
5	5.563	0.398	4.768	17.855	10.713	9.463	5.535	7.142
6	6.625	0.458	5.709	25.598	15.359	13.567	7.935	10.239

Conductor Types:

There are many types of insulated conductors. A few of the more common types will be considered in the document.

THHW is rated at 75°C for wet locations and 90°C for dry locations and has no outer covering on its insulation.

THHN is rated at 90°C for dry and damp locations and has a nylon jacket over its insulation.

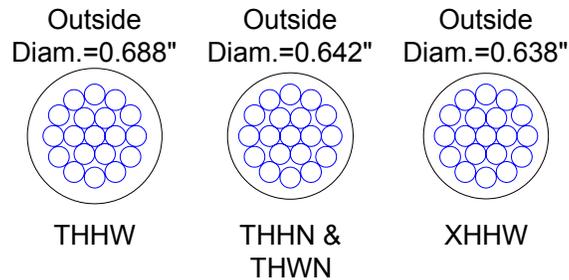
THWN is rated at 75°C for dry and wet locations and has a nylon jacket over its insulation.

XHHW is rated at 75°C for wet locations and 90°C for dry and damp locations and has no outer covering on its insulation.

The type of conductor required is usually defined in the construction specifications and by the type of installation – wet, damp, or dry. For example, wires installed in below-grade (underground) conduits must be rated for wet locations, since underground conduits will

invariably contain water, eventually. THHN, therefore, is not suitable for below-grade conduit runs, since it is not rated for wet locations.

Figure 6 shows that the diameters are slightly different for different types of conductors of the same wire size or gage. In the case illustrated, XHHW is slightly thinner than THHN/THWN, which is a little thinner than THHW. The large outer circle in Figure 6 represents the outside diameter of the conductor and the smaller circles inside represent the small strands of wire inside of the insulation. Looking at Table 7, THHN and THWN have matching diameters in all sizes.



Relative Dimensions of
Various 4/0 AWG Conductor Types
Figure 6

Conductor type XHHW is not always thinner than conductor type THHN/THWN – it depends on the wire size. Look at Table 7. In sizes 14 through 6 AWG, for example, XHHW is thicker than THHN/THWN. Table 7 in this document is based on Table 5 of Chapter 9 in the NEC. The rows are shaded as a visual aid.

Conduit Fill Calculations:

Let's start with a simple example of 3-#10 (THHN) in a GRS conduit. These examples will be for conduit runs, not nipples, unless nipples are specifically mentioned.

EXAMPLE 1

Find the minimum galvanized rigid steel (GRS) conduit size for 3-#10 (THHN).

To calculate the minimum conduit size, we add up the cross-sectional areas of the conductors from Table 7. We are dealing with THHN conductors, therefore:

$$(3) * 0.0211 \text{ in}^2 = 0.0633 \text{ in}^2$$

A Note About 1-1/4" (1.25") Conduit:

Some people might argue that 1-1/4" conduit is not a standard size, while others might disagree. If 1-1/4" conduit is not readily available, then 1-1/2" conduit is obviously the choice. The availability of 1-1/4" varies with geographic location and has changed over the years.

TABLE 7 - Dimensions of Insulated Conductors			
Type	Size (AWG or KCMIL)	Approximate Diameter (inch)	Approximate Area (in²)
THHW	14	0.133	0.0139
	12	0.152	0.0181
	10	0.176	0.0243
	8	0.236	0.0437
	6	0.304	0.0726
	4	0.352	0.0973
	3	0.380	0.1134
	2	0.412	0.1333
	1	0.492	0.1901
	1/0 or 0	0.532	0.2223
	2/0 or 00	0.578	0.2624
	3/0 or 000	0.630	0.3117
	4/0 or 0000	0.688	0.3718
	250	0.765	0.4596
	300	0.820	0.5281
	350	0.871	0.5958
	400	0.918	0.6619
500	1.003	0.7901	
THHN & THWN	14	0.111	0.0097
	12	0.130	0.0133
	10	0.164	0.0211
	8	0.216	0.0366
	6	0.254	0.0507
	4	0.324	0.0824
	3	0.352	0.0973
	2	0.384	0.1158
	1	0.446	0.1562
	1/0 or 0	0.486	0.1855
	2/0 or 00	0.532	0.2223
	3/0 or 000	0.584	0.2679
	4/0 or 0000	0.642	0.3237
	250	0.711	0.3970
	300	0.766	0.4608
	350	0.817	0.5242
	400	0.864	0.5863
500	0.949	0.7073	
XHHW	14	0.133	0.0139
	12	0.152	0.0181
	10	0.176	0.0243
	8	0.236	0.0437
	6	0.274	0.0590
	4	0.322	0.0814
	3	0.350	0.0962
	2	0.382	0.1146
	1	0.442	0.1534
	1/0 or 0	0.482	0.1825
	2/0 or 00	0.528	0.2190
	3/0 or 000	0.580	0.2642
	4/0 or 0000	0.638	0.3197
	250	0.705	0.3904
	300	0.760	0.4536
	350	0.811	0.5166
	400	0.858	0.5782
500	0.943	0.6984	

Since we have three conductors, we can use up to 40% of the conduit fill, as shown in Table 1. We could either look at the 40% fill column in Table 4 for the smallest value greater than 0.0633 in², or calculate the 100% fill value by dividing 0.0633 in² by 40%, such as:

$0.0633 \text{ in}^2 / 0.4 = 0.15825 \text{ in}^2$, which is the minimum 100% conduit fill value.

Using 0.15825 in², we look at Table 4 in the 100% column and see that we could use a ½” conduit. Many construction specifications, however, limit the smallest conduit size to ¾”. If that were the case, we would have to choose ¾” conduit to match the construction specification, even though ½” meets the NEC requirement for conduit fill. **END OF EXAMPLE**

Let’s try another example with two different wire sizes.

EXAMPLE 2

Find the minimum Schedule 80 PVC conduit size for 3-500 KCMIL, 1/0 AWG Gnd, all conductors XHHW.

Looking at Table 7 for XHHW conductors, we have:

$$(3) * 0.6984 \text{ in}^2 = 2.0952 \text{ in}^2$$

$$(1) * 0.1825 \text{ in}^2 = 0.1825 \text{ in}^2$$

$$\text{Adding together: } 2.2777 \text{ in}^2$$

Looking at the 40% column of Table 6 for Schedule 80 PVC, we find that we need a minimum conduit size of 3”. **END OF EXAMPLE**

Consider another example.

EXAMPLE 3

What would be the minimum size of Schedule 80 PVC for 3-8 AWG, 2-10 AWG, all THWN?

$$(3) * 0.0366 \text{ in}^2 = 0.1098 \text{ in}^2$$

$$(2) * 0.0211 \text{ in}^2 = 0.0422 \text{ in}^2$$

$$\text{Adding together: } 0.152 \text{ in}^2$$

Looking at the 40% column of Table 6 for Schedule 80 PVC, we find that we need a minimum conduit size of ¾”. **END OF EXAMPLE**

EXAMPLE 4

What would be the minimum size of EMT for 2-8 AWG THWN?

$$(2) * 0.0366 \text{ in}^2 = 0.0732 \text{ in}^2$$

Since there are two conductors, we look at the 31% column from Table 2 and find that the minimum conduit size is ½”, but always check with the construction specification with regard to minimum conduit size. **END OF EXAMPLE**

EXAMPLE 5

What would be the minimum size of Schedule 40 PVC for one 3/0 AWG ground XHHW?

The overall area for an XHHW 3/0 AWG conductor is 0.2642 in². Looking at the 53% column in Table 5 for Schedule 40 PVC, we find that we need a minimum conduit size of 3/4".

END OF EXAMPLE

EXAMPLE 6

What would be the minimum size of Schedule 40 PVC for 5-3/0 AWG XHHW?

$$(5) * 0.2642 \text{ in}^2 = 1.321 \text{ in}^2$$

Look at the 40% column of Table 5. Does this mean that we have to go up to 2-1/2" Sch. 40 conduit, since 2" Sch. 40 conduit only provides 1.316 in²? Since all of the conductors are the same physical size, we might be able to use Note 7 to the tables in Chapter 9 of the NEC, which says we can round up the number of conductors permitted if we come up with a decimal remainder of 0.8 or more. Therefore, looking at 2":

$$1.316 \text{ in}^2 / 0.2642 \text{ in}^2 = 4.98 \text{ conductors}$$

Note 7 says we can round this value up to 5 conductors, so 2" Schedule 40 PVC conduit would meet the NEC requirements for conduit fill. END OF EXAMPLE

Would the outcome of the above example be the same for Schedule 80 PVC?

EXAMPLE 7

The 40% column of Table 6 for 2" Schedule 80 PVC tells us that the allowable conduit fill would be 1.15 in², which is less than the value of 1.321 in² that we calculated for the same conductors in Example 6. Can we use Note 7 to the tables in Chapter 9? Let's see:

$$1.15 \text{ in}^2 / 0.2642 \text{ in}^2 = 4.35 \text{ conductors}$$

Since the decimal remainder of 4.35 is 0.35, we can't use Note 7, which specifies a minimum decimal remainder of 0.8. What size Schedule 80 conduit would we need? To accommodate the 1.321 in² of conductors, Table 6 says we need a 2-1/2" conduit. END OF EXAMPLE

Let's say that there is an existing 1-1/2" Schedule 40 PVC conduit running below grade (underground) between two buildings. How many 12 AWG XHHW conductors can be placed in this existing conduit while meeting the NEC maximum conduit fill limitation?

EXAMPLE 8

Assuming three or more conductors will fit, we look at the 40% column of Table 5 to see that 1-1/2" Schedule 40 PVC can be filled up to 0.794 in² for three or more conductors. The outside diameter of one 12 AWG XHHW conductor is 0.0181 in². Dividing the available area by the area of one conductor gives us:

$$0.794 \text{ in}^2 / 0.0181 \text{ in}^2 = 43.867 \text{ conductors.}$$

Since all of the conductors are the same size, Note 7 allows us to round this number up to 44 conductors. **END OF EXAMPLE**

Let's look at an example with a nipple used to run wires between two panels.

EXAMPLE 9

What size GRS nipple would be required for 6-4/0 AWG XHHW, 2-6 AWG THHN Gnd?

$$(6) * 0.3197 \text{ in}^2 = 1.9182 \text{ in}^2 \text{ [XHHW]}$$

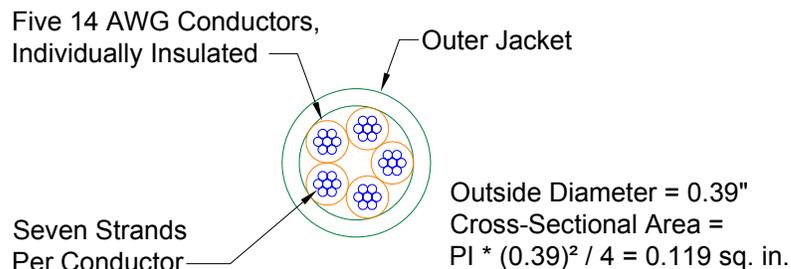
$$(2) * 0.0507 \text{ in}^2 = 0.1014 \text{ in}^2 \text{ [THHN]}$$

$$\text{Adding together: } 2.0196 \text{ in}^2$$

Looking at the 60% column of Table 4 for Rigid Metal Conduit (RMC), we find that we need a minimum conduit size of 2". Since the conductors are different diameters, there is no need to consider using Note 7. **END OF EXAMPLE**

A multiconductor cable, which has multiple insulated conductors within a common jacket, is treated as a single conductor for the purpose of conduit fill calculations. Notes 5 and 9 to the tables in Chapter 9 of the NEC mention multiconductor cables specifically.

Consider a 5/C #14 tray cable, as illustrated in Figure 7, for the next example.



**Multiconductor 5/C #14 THHN/THWN
Tray Cable (Type TC)
Figure 7**

EXAMPLE 10

What size GRS conduit would be required for one 5/C #14 tray cable?

One cable is 0.119 in² and the 53% column of Table 4 says 1/2" conduit would meet the conduit fill requirement. **END OF EXAMPLE**

EXAMPLE 11

What size Schedule 80 PVC conduit would be required for two 5/C #14 tray cables?

Two cables would be $2 * 0.119 \text{ in}^2 = 0.238 \text{ in}^2$. It might seem that the 31% column of Table 6 tells us that 1-1/4" conduit would be required, but let's see if we can use Note 7, since both of the cables are the same physical size. The 31% column of Table 6 at 1" says we have 0.213 in^2 to work with, and if we divide that by the area of one cable we get $0.213 \text{ in}^2 / 0.119 \text{ in}^2 = 1.79$ which can be rounded up to 1.8, since that is all the accuracy that we need. Therefore, 1" conduit would meet the maximum conduit fill. **END OF EXAMPLE**

EXAMPLE 12

How many 5/C #14 tray cables would fit in a 2" galvanized rigid steel (GRS) conduit?

Assuming more than two cables will fit, a 2" GRS (RMC) conduit has a 40% area of 1.363 in^2 (from Table 4), and the cross-sectional area of one cable is 0.119 in^2 , therefore:

$1.363 / 0.119 = 11.5$, so the answer is 11. **END OF EXAMPLE**

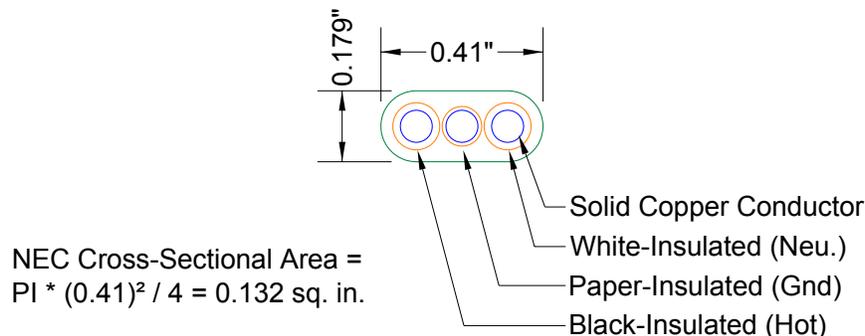
EXAMPLE 13

How many 5/C #14 tray cables would fit in a 2" aluminum nipple running from one box to another?

A 2" aluminum (RMC) conduit has a 60% area of 2.045 in^2 (from the 60% column for nipples on Table 4), and the cross-sectional area of one cable is 0.119 in^2 , therefore:

$2.045 / 0.119 = 17.2$, so the answer is 17. **END OF EXAMPLE**

Nonmetallic-sheathed (NM) cable is also known as Romex® cable. This type of multiconductor cable is used in a large percentage of residential wiring and is typically run without conduit. In the following examples, we will consider a 2-conductor with ground NM cable because of its elliptical cross-section (see Figure 8) and examine how that would affect conduit fill calculations. Note 9 to the tables in Chapter 9 of the NEC says that we have to use the major diameter (0.41") to calculate the circle to get the cross-sectional area of $\pi * (0.41)^2 / 4 = 0.132 \text{ in}^2$ for this type of cable.



**12/2 Nonmetallic-Sheathed Conductor
Type CU-NM-B or Romex SIMpull®
Figure 8**

In one way, it makes sense to use the longer diameter of the ellipse to calculate the cross-sectional area, since we won't be able to control which way the long and short diameters will be oriented as the cable twists through the conduit.

EXAMPLE 14

What size Schedule 40 PVC conduit would be required for one 12/2 NM cable?

One NM cable has an NEC cross-sectional area of 0.132 in^2 . Looking at the 53% column of Table 5 indicates that a 1/2" conduit at 0.151 in^2 would meet the NEC requirement for conduit fill. Even though 1/2" conduit would meet this requirement, it would actually be difficult to pull this jacketed solid-conductor cable through any 1/2" conduit fittings. To re-state this, 1/2" conduit would meet the NEC requirements, but it would make everyone's life easier to use 3/4" or larger conduit, since this is solid wire, not stranded. [END OF EXAMPLE](#)

EXAMPLE 15

What size Schedule 40 PVC conduit would be required for two 12/2 NM cables?

The cross-sectional area for two cables would be $2 * 0.132 \text{ in}^2 = 0.264 \text{ in}^2$. Looking at the 31% column of Table 5 might tell us that 1-1/4" conduit would be required, but let's check to see if Note 7 will allow us to use 1" conduit. The 1" 31% column of Table 5 says we have 0.258 in^2 to work with, and if we divide that by the area of one cable, we get $0.258 \text{ in}^2 / 0.132 \text{ in}^2 = 1.95$. Therefore, 1" conduit would meet the conduit fill requirement. [END OF EXAMPLE](#)

EXAMPLE 16

What size IMC nipple would be required for two 5/C #14 tray cables and three 12/2 NM cables?

The area of the two 5/C cables is $2 * 0.119 \text{ in}^2 = 0.238 \text{ in}^2$

The area of the three 12/2 NM cables is $3 * 0.132 \text{ in}^2 = 0.396 \text{ in}^2$

Adding the two areas together, $0.238 + 0.396 = 0.634 \text{ in}^2$

Looking at the 60% column of Table 3 indicates 1-1/4" conduit would meet the conduit fill requirement. See Figure 9 for an illustration of this example. The conductors are not all the same physical size, so there is no need to consider Note 7. [END OF EXAMPLE](#)

EXAMPLE 17

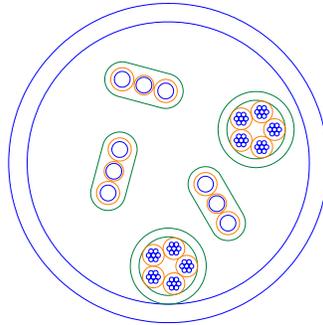
Find the minimum aluminum conduit size for 3-500 KCMIL (XHHW), #3 Gnd (THHW).

$(3) * 0.6984 \text{ in}^2 = 2.0952 \text{ in}^2$ [XHHW]

$(1) * 0.1134 \text{ in}^2 = 0.1134 \text{ in}^2$ [THHW]

Adding together: 2.2086 in^2

Looking at the 40% column of Table 4 tells us that we need a 3" conduit. [END OF EXAMPLE](#)



(2) 5/C #14 & (3) 12/2 NM Cables
In 1-1/4" IMC Nipple
Figure 9

In Closing:

Conduit fill calculations are fairly simple, but they require a certain minimal amount of information. If all of the conductors are the same size, Note 7 to the tables in Chapter 9 of the NEC might allow a smaller conduit size to be selected. Conduit fill calculations are only one of many factors to consider in sizing conduits.

Abbreviations:

- 5/C – Five-conductor cable.
- AWG – American Wire Gage.
- C.M. – Circular Mils – a measurement of cross-sectional area that is equal to the area of a circle that is 0.001” (one mil) in diameter.
- EMT – Electrical Metallic Tubing.
- IMC – Intermediate Metallic Conduit.
- KCMIL – Thousand (K) circular (C) mil (MIL) – formerly known as MCM.
- MCM – Thousand (M) circular (C) mil (M) – now more-commonly known as KCMIL.
- NM – Nonmetallic-sheathed cable.
- NEC – National Electrical Code (NFPA 70) [the 2005 edition was used for this write-up].
- PVC – Polyvinyl Chloride, a type of conduit material that is often called plastic.
- RMC – Rigid Metal Conduit.
- RNC – Rigid Nonmetallic Conduit.
- THHN – Conductor type, see text.
- THHW – Conductor type, see text.
- THWN – Conductor type, see text.
- XHHW – Conductor type, see text.

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