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Installation and Application Guide

for 600V Conductors

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Foreward

This guide discusses recommended or "best" practices for installing 600 volt conductors in conduit. The purpose of the guide is to identify those critical areas of design, pre-planning and cable pulling that result in a successful installation. Within these areas are numerous commonly overlooked practices that can result in a failed installation.

This guide is not intended to cover all aspects of cable installation, it is intended to provide guidelines and information on the more commonly misapplied techniques and equipment. There are four primary topics covered in this guide:

- Installation design and layout
- Evaluating a layout
- Proper setup
- Cable handling techniques and more

Every effort was made to keep these guidelines brief yet descriptive.

A NOTE FROM THE EDITOR…

Best practices are always a challenging topic. The issue is to achieve balance between reasonable and little known practices. As these best practices were developed we struggled with what is reasonable and what is considered unreasonable.

From years of experience in supporting wire and cable installations, we have concluded that the majority of wire installations in conduit can be classified as routine. This results in the unfortunate and inaccurate conclusion that all installations are routine. Southwire has found when best practices are not followed, the success of your installation is left to chance. When followed, these best practices virtually guarantee a successful installation.

These best practices are not new or novel; they have been well documented and used in industrial installations. Southwire Company's Power Cable Manual and Southwire Company's Power Cable Installation Guide provide clear instructions for proper installations in industrial environments. This guide now provides valuable installation information to contractors and engineers for use in residential, commercial and institutional installations.

Note: If you find you require more detailed information regarding your application contact your local Southwire sales representative or call Southwire directly at 1 888 NoLube 0 (888-665-8230) for assistance.

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Best Practices

1. PULL EVALUATION

a. Know the expected pull tensions and sidewall pressures prior to the pull. Make sure minimum bend radii will not be exceeded.
b. Never assume that an installation is routine.

2. PROOFING CONDUIT

a. Conduit must be free of all debris and damage.
b. Never assume the conduit is clean.

3. CLEAN ENTRY AND EXIT FROM CONDUIT SYSTEM

a. Rollers and sheaves are necessary for difficult pulls to eliminate damage when entering and exiting the conduit system.
b. Never assume that the crew can guide the conductors in and out of the conduit.

4. CONDUCTOR LUBRICATION

a. Applying lubricant is difficult, messy, and can be expensive on difficult pulls, often resulting in inadequate conductor lubrication.
b. Southwire Company's SIM Technology® products provide uniform pre-lubrication assuring the same or lower pulling tensions than when adding lubricants during installation.
c. Never assume lubrication will be done correctly. Specify Southwire SIM*pull*® products or specific lubrication system.

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Section 1. Cable and Conduit Selection

INSTALLATION ASSESSMENT CHECKLIST

The following is a recommended checklist for selecting the appropriate conductor and conduit based on the application and environment. This checklist also provides steps to evaluate your selection.

1) *Conductor Type:* Select a conductor type based on your application and the conductor ratings and listings.
2) *Conduit Size:* Determine the conductor size required based on your application and conductor ampacity.
3) *Reel Size:* Determine the maximum reasonable cable length that permits proper on site handling, accounting for weight and dimensions.
4) *Conduit Size:* Select conduit size based on required fill, clearance, jamming, and applicable codes and standards.
5) *Conduit Layout:* Determine an initial conduit layout based on NEC® compliance and reasonable expectations of pull length.
6) *Maximum Tension:* Calculate maximum allowable tension based on either cable stress or pulling device limitations.
7) *Jamming Probability:* Calculate weight correction factor (ω) and jamming ratio.
    a. Does the jamming ratio indicate a likelihood of conductor jamming? If so, increase the conduit size to alleviate this issue.
8) *Pulling Tension and Sidewall Pressure:* Calculate pulling tension (T) and sidewall pressure (SP) for each segment.
9) *Verify:* Compare calculated results to established limits.
10) *Redesign Pull:* If limits are exceeded, consider one or more of the following:
    a. Increase bend radii
    b. Decrease fill
    c. Reduce number of bends
    d. Reverse pull
    e. Pull in stages
    f. Decrease length of pull

CONDUCTOR TYPE

Choosing the appropriate conductor for the application will help provide a trouble-free installation for years to come. For outdoor and underground conduit applications the cable should be listed for wet locations. In underground conduit applications, where the cable is subject to immersion in water for extended periods of time, conventional wisdom is thicker insulations are better. <u>Further, conductors free from cuts and abrasions due to installation damage are less likely to fail prematurely in wet applications.</u>

Copper Conductors – Traditionally copper conductors are a popular choice in conduit feeder applications. Copper has a very high conductivity and therefore a smaller conductor size compared to aluminum for a given application. Copper also has a higher tensile strength when compared to aluminum conductors. The disadvantages of copper include weight and cost.

Aluminum Conductors – Aluminum has certain advantages over copper conductors. Aluminum conductors are 2.5 to 3 times lighter than the ampacity equivalent copper conductor. This means lower installation tensions and less likelihood of damaged cable during installation. Aluminum conductors are typically compact stranded which reduces the overall conductor diameter by 10% over concentric stranding. Meaning, although a larger conductor is needed for ampacity equivalency, the conduit fill penalty for that larger conductor is minimal. Aluminum is a reliable and cost effective conductor material. Trouble free installations are achieved when using listed aluminum conductors with listed connectors.

CONDUCTOR SIZE

Conductor sizing is usually determined by allowable ampacity. In the case of longer circuit lengths, conductor sizing may be determined by limiting voltage drop to an acceptable level.

Ampacity – When determining the allowable ampacity of a conductor it is important to account for any derating factors such as more than three current carrying conductors in a conduit or high ambient temperature. Ignoring the factors that require ampacity derating can result in overheating and premature failure of conductors. Further details on calculating allowable ampacities is given in Section 3 of this installation guide.

Voltage Drop – On longer circuit lengths, voltage drop may determine conductor size. Once a conductor has been sized based on allowable ampacity, including all derating factors a voltage drop calculation can determine if that conductor size is suitable. Generally a voltage drop of 3% or less will provide a system that operates properly and efficiently.

MAXIMUM REEL SIZES AND CONDUCTOR LENGTH

The conduit layout may be directly affected by the maximum available length or field handling limitations for the chosen conductor. The maximum reel size should be limited such that it can be properly handled in the field according to the practices in Section 2 of this Installation Guide. If necessary, additional splice locations should be included in the conduit layout to limit the maximum cable length required.

CONDUIT SIZING AND FILL RATIO

Conduit fill is the percentage of the area inside the conduit taken up by the conductor(s). Consult applicable codes, industry standards, and manufacturer's data for further information on fill. Dimensions for the various types of conduits can be found in Chapter 9 of the National Electrical Code.® NEC® conduit fill tables for various conduit types can be found in the annex of this guide.

$$\% \text{ Fill} = \left[\frac{d}{D}\right]^2 \cdot N \cdot 100$$

Where: d = outside diameter of the conductor in inches
D = inside diameter of the conduit in inches
N = number of conductors

Table 1 - Permitted Fill Ratio

Number of Conductors	Percent Fill
1	53%
2	31%
Over 2	40%

Based on NEC® Chapter 9 Table 1

CONDUIT LAYOUT

The initial conduit layout should comply with all NEC® requirements in that conduit type's respective article. All NEC® conduit articles limit the conduit layout to 360 degrees of bend between pull boxes. After performing a pull evaluation as described in this section it may be determined necessary to include additional pull boxes to limit pulling tension or sidewall pressures.

CONDUCTOR SUPPORT IN VERTICAL RACEWAYS

In vertical raceway applications, NEC® Article 300.19 requires that the conductors are supported and secured at intervals. The conductors should be supported at the specified intervals by one of the methods detailed in the NEC.® These intervals are determined by the size and weight of the conductor. Table 300.19(A) provides the required support and securing intervals by conductor type and size.

Table 2 - Support in Vertical Raceways

Wire Size	Aluminum	Copper
18 AWG – 8 AWG	**100 ft**	**100 ft**
6 AWG – 1/0 AWG	**200 ft**	**100 ft**
2/0 AWG – 4/0 AWG	**180 ft**	**80 ft**
> 4/0 AWG – 350 kcmil	**135 ft**	**60 ft**
> 350 kcmil – 500 kcmil	**120 ft**	**50 ft**
> 500 kcmil – 750 kcmil	**95 ft**	**40 ft**
> 750 kcmil	**85 ft**	**35 ft**

Based on NEC® Table 300.19(A)

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PULLING EVALUATION

The small details can make the difference between successful installations and having to remove damaged conductors. In preparing for a conductor pull, it is just as important to cover the small details as it is to assure that the conductor does not exceed maximum sidewall pressure, minimum bending radii or maximum pulling tensions. General field practices are provided to aid in preparing for large and small conductor installations.

Conductors installed in conduits have installation parameters, such as maximum pulling tensions, sidewall pressure, clearance, and jamming, which must be considered. These installations also involve some general considerations, such as field handling, storage, training of ends, and junction box sizes. These and other considerations can make the difference between a good installation and one resulting in damaged conductors.

Mechanical stresses during installation are generally more severe than those encountered while in service. The following information provides guidance in recognizing these conditions and provides a methodology to aid in keeping them within acceptable limits.

Calculations should be made to indicate whether the pull looks easy or impossible, making the decision to pull an obvious choice. When a marginal situation is encountered, the entire pull should be reviewed. This review may include more rigorous calculations or trial pulls. A final decision should be made based on installation factors known to the end user and installer.

The sizes of the conduit are determined based on the calculations of the clearances, jamming, and fill. Pulling tensions may then be evaluated by determining the maximum tension based on the pulling device used and the maximum tension that can be applied to the conductors. The lesser of these two values is the maximum allowable tension (T_m).

The pulling tension (T) required to pull the conductor through the conduit is then calculated and compared to the maximum allowable tension. If the pulling tension exceeds the allowable tension, then conditions should be changed to ensure a successful pull. After calculating pulling tensions, sidewall pressures (SP) may be calculated.

For further study on this subject, AEIC Publication G5-90 and IEEE Standard 1185 present additional details.

Maximum Allowable Tension on Pulling Devices – The allowable tension stated by the manufacturer of a pulling device should not be exceeded. General guidelines for pulling device allowable pulling tensions are provided below.

Pulling Eye – 10,000 pounds or the manufacturer’s published rating, whichever is less.

Basket Grip – Traditional practices limit the allowable tension of a basket grip to 1,000 pounds. Under specific conditions this limit can be safely exceeded.

Other Means – Field-fabricated devices such as “mare’s tails” have been commonly used. Extreme care should be taken while using these means as the maximum allowable pulling tension of such devices is generally unknown.

Maximum Allowable Tension of Conductors – The metallic core of the conductor is generally the only member that can bear the pulling forces without damage. Do not use metallic shielding wires, tapes, braids or armor not designed for the purpose in pulling tension calculations.

Variable definitions for the following equations and examples:

T_c = tension on each conductor, in pounds
S = allowable stress from Table 3, in pounds/cmil
A = area of each conductor, in cmil
N = number of conductors
T_{device} = maximum allowable tension on device in pounds
T_{total} = maximum allowable tension of multiple conductors pulled together in pounds

Table 3 – Conductor Stress

Maximum Allowable Conductor Stress	
Metal	**lb/cmil**
Copper	0.008
Aluminum 1350 Alloy	0.008
Aluminum 8000 Series Alloy	0.006

Table 4 - Conductor Area

Size (AWG)	cmil	Size (kcmil)	cmil
14	4,110	250	250,000
12	6,530	300	300,000
10	10,380	350	350,000
8	16,510	400	400,000
7	20,820	450	450,000
6	26,240	500	500,000
5	33,090	550	550,000
4	41,740	600	600,000
3	52,620	650	650,000
2	66,360	700	700,000
1	83,690	750	750,000
1/0	105,600	800	800,000
2/0	133,100	900	900,000
3/0	167,800	1000	1,000,000
4/0	211,600	1200	1,200,000

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Single Conductors:

$T_c = S \cdot A$ *pounds*

Example:
Single Type THHN conductor, 4/0 AWG copper

$T_c = (0.008) \cdot (211{,}600)$ *pounds*
$T_c = 1{,}693$ *pounds*

Multiple Conductors (three or less conductors):

$T_{total} = N \cdot T_c$ *pounds*

Example:
Two Type THHN conductors, 4/0 AWG copper

$T_{total} = (2) \cdot (1{,}693)$ *pounds*
$T_{total} = 3{,}386$ *pounds*

Multiple Conductors (more than three conductors):

$T_{total} = (0.8)\, N \cdot T_c$ *pounds*

Example:
Four Type THHN conductors, 6 AWG copper

$T_c = (0.008) \cdot (26{,}240)$ *pounds*
$T_c = 210$ *pounds*

$T_{total} = (0.8) \cdot (4) \cdot (210)$ *pounds*
$T_{total} = 672$ *pounds*

CAUTION:
Pulling different conductor sizes at the same time is not recommended if the conductor size or other characteristics are significantly different. If you must pull different size conductors, it must be done with care. For example, if a run requires three 350 kcmil and three 8 AWG single conductors, it would be preferable, though not necessarily ideal, to pull the three 350 kcmil single conductors and one 3 conductor 8 AWG cable at the same time. Pulling additional conductors into an existing conduit system is generally not recommended. If this must be done, extreme caution must be taken. Of special concern is the cutting action of the tensioned pulling rope.

CALCULATING PULLING TENSIONS

The following equations allow the user to calculate the expected pulling tension of a conductor in a conduit pull. These calculations only provide an estimate to assist the user in determining the feasibility of the installation in question. Many factors affect the actual tensions and sidewall pressures one might see in an average pull. The coefficient of friction between a conductor exterior (jacket/sheath) and conduit varies with the type of jacket or sheath, type and condition of conduit, type and amount of pulling lubricant used, conductor temperature, and ambient temperature. High ambient temperatures (80°F and above) can increase the coefficient of dynamic friction for conductors having a nonmetallic jacket. Pulling lubricants must be compatible with conductor components and be applied while the conductor is being pulled. Pre-lubrication of the conduit is recommended by some lubricant manufacturers. Southwire's SIM*pull* THHN® requires no pulling lubricant.

INCOMING TENSION

Incoming tension will greatly affect the overall tension in a conductor pull. This tension is multiplied throughout the conductor pull and therefore has a great affect on the overall pulling tension. It is important to estimate the incoming tension as accurately as possible when calculating the expected pulling tension.

Feeding Off Reel Horizontally – When the conductor(s) are fed off the reel horizontally for some distance, the following equation should be used to approximate the tension required to remove the conductor from the reel:

$T_{in} = 25 \cdot W$ *pounds*
where: W = total cable assembly weight, in pounds/foot

Feeding Off Reel Vertically – When the conductor reel must be positioned directly below the conduit, the following equation should be used to approximate the tension required to pull the conductor into the conduit:

$T_{in} = W \cdot L$ *pounds*
where: W = total cable assembly weight, in pounds/foot
L = straight vertical section length, in feet

The tension can now be approximated for pulling the conductor into a conduit from a horizontal position when the reel is placed directly under the conduit. To estimate the tension entering the conduit when the reel must be placed away from and below the entrance to the tray, use the equation for feeding off the reel vertically where the height (L) is the vertical distance between the reel and conduit. To allow for bending forces as the conductor comes off the reel, the minimum tension added should be $25 \cdot W$.

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COEFFICIENTS OF FRICTION

The coefficient of dynamic friction (μ) is a measure of the friction between a moving conductor and the conduit. The coefficient of friction can have a large impact on the tension calculation. It can vary from 0.1 to 1.0 with lubrication and can exceed 1.0 for unlubricated pulls. Typical values for the coefficient of friction are presented in Table 5. Pulls should never be stopped and restarted because the coefficient of static friction will always be higher than the coefficient of dynamic friction.

Table 5 – Typical Coefficients of Dynamic Friction (μ) for Cables with an Adequate Cable Lubrication* During a Pull

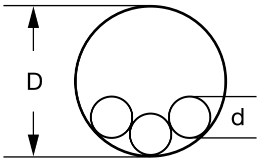
Cable Outer Jacket or Insulation	Conduit Type	
	EMT	PVC
TYPE THHN/THWN (Nylon)	0.28*	0.24*
SIM*pull* THHN® †**	0.28	0.24
Type XHHW, Type USE, Type RHH/RHW (XLPE)	0.25*	0.14*

† Lubrication not required with Southwire SIM*pull* THHN® products
* Values based on Polywater® Pull Planner™ 2000
** SIM*pull* THHN® can approach a coefficient of friction of 0.15. However, for the purpose of evaluation, the more conservative values stated above are appropriate.

The coefficient of friction between a conductor exterior (jacket/sheath) and conduit varies with the type of jacket or sheath, type and condition of conduit, type and amount of pulling lubricant used, conductor temperature, and ambient temperature. High ambient temperatures (80° F and above) can increase the coefficient of dynamic friction for conductors having a nonmetallic jacket. Pulling lubricants must be compatible with conductor components and be applied while the conductor is being pulled. Pre-lubrication of the conduit is recommended by lubricant manufacturers to achieve the best results.

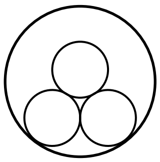
CONDUCTOR CONFIGURATION

The configuration of three single-conductors in a conduit is determined by the ratio of the conduit inner diameter (D) to the outer diameter (d) of one of the single conductors (D/d ratio).



Cradled

$\frac{D}{d} \geq 2.5$



Triangular

$\frac{D}{d} < 2.5$

Figure 1
Configuration of Three Single Conductors

A cradled configuration develops when three single-conductors are pulled into a conduit where the D/d ratio is 2.5 or greater. A triangular configuration develops when three single-conductors are pulled into a conduit where the D/d ratio is less than 2.5. These conductors may be pulled from individual reels, tandem reels, or a single reel with parallel wound conductors.

CONDUCTOR JAMMING

Jamming is the wedging of three or more conductors when pulled into a conduit. This usually occurs because of crossovers when the conductors twist or are pulled around bends. The jam ratio is the ratio of the conduit inner diameter (D) and the conductor outside diameter (d).

$$\text{Jam Ratio} = \frac{D}{d}$$

The probability for jamming is presented in Figure 2

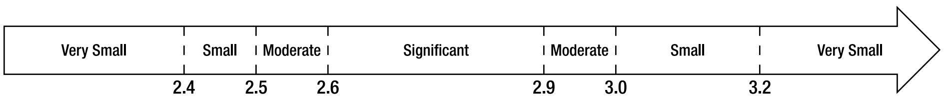


Figure 2
Jamming Probabilities Using the Jam Ratio

WEIGHT CORRECTION FACTOR

The configuration of conductors can affect conductor tension. A weight correction factor (ω) is used in the tension equations to account for this effect. The value for the weight correction factor is determined from the equations that follow:

Single Conductor:
$\omega = 1$

Three Conductors (Triangular):

$$\omega = \frac{1}{\sqrt{1-\left(\frac{d}{(D-d)}\right)^2}}$$

Three Conductors (Cradled):

$$\omega = 1+\frac{4}{3}\cdot\left[\frac{d}{(D-d)}\right]^2$$

Four Conductors or More (Complex):
$\omega = 1.4$

Note: When pulling two conductors it is suggested that the conservative three-conductor (triangular) factor be used for calculations.

Variable definitions for the following equations and examples:

T_{in} = tension into a section in pounds
T_{out} = tension out of a section in pounds
ω = weight correction factor, dimensionless
μ = coefficient of dynamic friction, dimensionless
W = total cable assembly weight on pounds/foot
L = straight section length in feet
θ = straight section angle from horizontal in radians
ϕ = bend section angle in radians
R = bend section radius in feet
e = 2.71 natural logarithm base

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Horizontal Straight Section:

$T_{out} = \omega\ \mu\ W\ L + T_{in}$

Inclined and Vertical Straight Section:

Pulling Up:
$T_{out} = WL(\sin\theta + \omega\cos\theta) + T_{in}$ *pounds*

Pulling Down:
$T_{out} = -WL(\sin\theta - \mu\cos\theta) + T_{in}$ *pounds*

Approximation for Bends – The equations for calculating pulling tensions through bends with the varying orientations and gravitational pulling directions are complicated. For this reason, it is common practice to use an approximation for all bends.

Elbows and Bends (Approximation):

$T_{out} = T_{in} \cdot e^{\omega\mu\phi}$

SIDEWALL PRESSURE

Sidewall pressure is the vector force that exists on the cable as it is pulled through a bend. Because the surface area of the bend is smaller in small radius bends, that force is concentrated over a much smaller area. Most of the time sidewall pressure is the limiting factor in a cable pull.

Sidewall pressure is calculated as follows:

For one single-conductor cable or multiple-conductor cable under a common jacket

$$SP = \frac{T}{R}$$

For three single-conductor cables, cradled

$$SP = (3\omega - 2) \cdot \frac{T}{(3R)}$$

For three single-conductor cables, triangular

$$SP = \omega \cdot \frac{T}{(2R)}$$

where: T = tension coming out of the bend in pounds
R = bend radius, in feet
ω = weight correction factor, dimensionless
SP = sidewall pressure in pounds/foot

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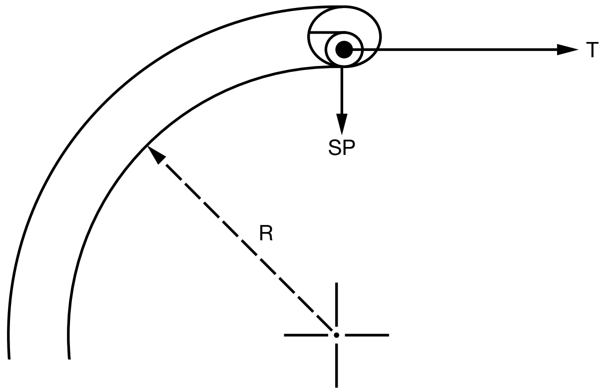

Figure 3
Sidewall Pressure Factors

Table 6 - Maximum Allowable Sidewall Pressure

Cable Type	SP lbs/ft
600V Nonshielded Control Cable (Type TC Cable)	300
600V & 1kV Nonshielded Power Cable (Types THHN, THWN, USE, RHH, and RHW)	1000

BEND RADIUS

The minimum allowable bend radii of non-shielded conductors are typically expressed as a multiplier of the conductor outside diameter. The general guidelines for conductor training bend radii are given in Table 7.

Table 7 – Minimum Bend Radius

Cable Diameter Inches	Bend Radius as a Multiplier of the Cable OD
Up to 1.000	4
1.001 - 2.000	5
2.001 and Over	6

In some cases specific guidelines exist for certain conductors such as USE. The NEC® Article 338 requires the minimum bend radius for USE not exceed 5 times the conductor outside diameter.

The minimum allowable bend radii above are for conductors being permanently trained into final position. While pulling, it is necessary to use larger radius rollers and conduit bends to help minimize sidewall pressures and limit excessive pulling tensions.

Section 2. Setup and Installation

INSTALLATION CHECKLIST

1) *Conduit Free of Debris:* Was the conduit proofed using a mandrel to remove any debris and ensure the conduit is free from obstructions?
2) *Rollers and Sheaves Properly Installed:* Are the rollers and sheaves the appropriate size to meet the minimum bending radius of the conductor and limit excessive sidewall pressures?
3) *Tugger Properly Setup:* Must the conductor be pulled across a roller on the tugger? If so, is the roller on the tugger of sufficient size for the conductor's minimum bend radius and sidewall pressure?
4) *Reels Damage Free:* Have the conductor reels been inspected for damage during shipping?
5) *Conductors Freely Payoff Reel:* Are the conductor reels setup in an area that permits the conductor to payoff freely?
6) *Pull Rope Properly Attached:* Is the appropriate pulling device, based on the expected pulling tensions, installed properly on the conductor ends?
7) *Conductor Lubrication*: If not using Southwire's SIM*pull* THHN,® has the conductor been sufficiently lubricated?
8) *Proper Terminations:* Are the equipment terminations properly sized and rated for the conductor?

CONDUIT PROOFING

Obstructions in the conduit will increase installation tensions and difficulties, and in worst cases make the pull impossible to accomplish. Further, debris in conduit is often a contributing factor in damaged conductors.

Proofing – The process of proofing the conduit can be accomplished as the pulling rope is being pulled into the conduit. A rubber duct swab to proof the duct is recommended. If a wire brush mandrel is needed to dislodge an obstruction, attach the wire brush mandrel to the pull line. Behind the wire brush mandrel trail the rubber duct swab by approximately 4 to 6 feet with a sturdy rope section. Attach the pull rope to the trailing end of the rubber duct swab. While pulling in the pull rope the wire brush mandrel (if needed) will loosen stuck debris and the rubber duct swab will extract that debris. Now you can execute the conductor pull confident the conduit is clear of potentially damaging debris.

INSTALLING ROLLERS AND SHEAVES

Using the correct rollers and sheaves and placing them correctly can be the difference in a good installation and damaged conductors. Proper placement of sheave wheels, pulleys and rollers help protect the conductors and will reduce the installation time.

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Placement – First, determine the number and location of rollers, sheave wheels or radius roller assemblies that are required based on the conductor minimum bend radius and support needed. Be sure that sheaves and rollers are mounted securely to withstand the required pulling forces. Sheave wheels, pulleys and rollers must be maintained and lubricated to reduce friction.

Many times the conductor(s) are pulled across a pulley or sheave as it exits the conduit run. It is easy to ignore this pulley during the evaluation of the pull. However, this can be the most critical pulley as cable tensions usually increase toward the end of the cable pull. Be sure this pulley is large enough not to exceed the cable bend radius or the allowable sidewall pressure.

Pulley sizes and count – Wherever pulleys and sheaves are required, it is important to account for bend radius and sidewall pressures. The pulley and sheaves should at least be larger than the minimum bending radius of the cable, and large enough to minimize the sidewall pressures at that point in the pull.

On occasion it may be necessary to have multiple pulleys in large pull boxes, manholes and vaults. The pulleys should be of sufficient number and arranged such that the cable is supported and transitions easily into or out of the conduit. Arranging the pulleys or sheaves in such a manner will decrease overall pulling tensions and result in quicker and easier pulls.

Sheave wheel sizes and types – When pulling conductors around sheaves, large sheave diameters will reduce the amount of sidewall pressure created at each bend. If you have a large bending radius you may not be able to find a radius roller large enough to meet the required bending radius required for this installation. Large conductors may require the use of radius rollers, in which multiple wheels mounted together provide the required bend radius. The individual sheaves in such a roller assembly should have a minimum inside radius of 1.25 in. Sheave or radius rollers should be located every 20 degrees of bend.

NOTE: *Never use a three-sheave assembly on a 90-degree bend to pull conductors.*

Table 8 – Multi-Roller Sheave Assemblies

Bending Angle (degrees)	Number of Sheaves
0 - 20	1
21 - 40	2
41 - 60	3
61 - 80	4
81 - 90	5

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PREPARING CONDUCTORS FOR INSTALLATION

Package Inspection – Preplanning is an important part of every pull. The conductor package should be checked for the following prior to beginning the pull.

1) Check the conductor(s) for:
   a. Correct size and type
   b. Shipping damage
   c. Special instructions

2) Check the reel(s) for:
   a. Damage
   b. Protruding nails or staples that might damage conductor

Reel Setup – The cable reels should be setup to payoff in line if possible to facilitate and uniform conductor bundle entering the conduit. The reels should be supported by properly maintained quality reel stands to ensure even payoff. Incoming tensions will be magnified throughout the pull, and for this reason it is important to limit the cable tension as it enters the conduit. The cable should feed straight into the conduit by hand or, for larger conductors, over a large diameter sheave. The reel payoff should be assisted by hand or cable feeder to limit incoming tensions in the cable pull. When using SIM*pull*® products with a cable feeder, the feeder may need to be adjusted to eliminate cable slip.

Pull Rope – The pulling rope used shall be of adequate strength to pull the maximum allowable conductor pulling tensions. If PVC elbows are used, care should be taken not to damage the elbows with the pulling line. The use of flat strap, MuleTape® or Double-braided composite pulling line is recommended to avoid the pulling line burning through the elbows on difficult pulls. Polypropylene pulling ropes tend to have higher stretch and more prone to conduit burn-thru on difficult pulls.

The pulling rope should be attached by a means that is suitable for the expected pulling tensions.

Low Tension Devices – Wire mesh pulling grips are typically limited to 1,000 pound pulling tension. Under no circumstance should the manufacturer published tensile rating for the device be exceeded.

Other field fabricated pulling means are commonly used when pulling cable. These means should not be used in high tension pulls, and extreme care should be taken when using such means to pull cable as they have unproven tensile capabilities.

High Tension Devices – Pulling eyes should be used when the expected pulling tensions are greater than 800-1000 pounds. Again, under no circumstance should the manufacturer published tensile rating for the device be exceeded.

CABLE LUBRICATION

Reducing the coefficient of friction is the primary factor in the selection of a lubricant. Compatibility of the lubricant with cable and conduit is extremely important. The lubricant should not have any deleterious effects on the conduit or on the physical or electrical properties of the cable insulation, or jacket materials.

An estimate of the quantity of required lubricant can be determined:

$$Q = 0.0015 \cdot L \cdot D$$

where: Q = Quantity in gallons
L = The conduit length in feet
D = The inside diameter of the conduit in inches

Southwire Company's SIM*pull*® products provide uniform pre-lubrication eliminating the need for messy lubricants while assuring the same or lower pulling tensions as when adding lubricants during the installation.

PULLING CONDUCTORS

With the proper setup based on a thorough evaluation and clean conduit, it is expected the pull will be successful. If at all possible, the pull should be accomplished in a single slow pull. Starting and stopping a pull is not ideal since it can take considerably more force to start the pull again.

There are times that adjustments will need to be made during the pull. For this reason, it is important to have good means of communications among the various members of the pulling team. This allows the pull to be suspended in the event a problem arises or an adjustment must be made to pulleys, payoffs, etc.

Proper Conductor Handling – It is important to always take care when handling cable reels and conductors. Mishandling of cable reels and conductors can damage the conductor resulting in an electrical installation that does not operate properly or fails prematurely. Although the following points do not reflect every possible mishandling situation, they do represent some of the more commonly overlooked situations.

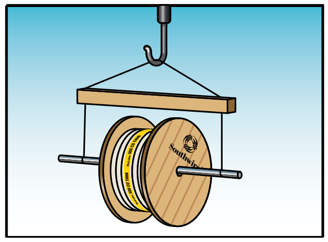
Cold Weather Concerns – Low temperatures can be a concern when installing conductors. Conductors should be handled more carefully and pulled more slowly during cold weather. If conductors must be installed during cold weather, approaching freezing, it is important to make sure the core temperature of the reel is sufficiently warm to prevent damaging the insulation system. The conductor should be kept in heated storage for at least 24 hours prior to installation to enable the conductor to warm up throughout the reel. Conductors should not be installed at ambient temperatures lower than:

Table 9 – Minimum Conductor Installation Temperatures

Insulation or Jacket	Minimum Installation Temperature	
Type THHN/THWN, THW (PVC)	-10°C	14°F
Type MV-105 (EPR)	-40°C	-40°F
Types XHHW, USE, RHH, and RHW (XLPE)	-40°C	-40°F

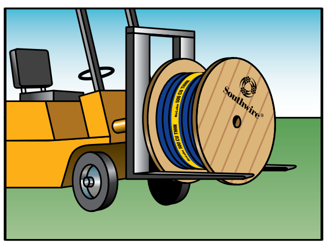
Handling and Storage of Reels – It is important to properly store and handle conductors on the reel. Below is a list of general guidelines to follow when moving and storing reels.

1) Unloading equipment should not come in contact with the conductor or its protective covering.
2) If a crane is used to unload cable, a shaft through the arbor hole or a cradle supporting both reel flanges should be used.

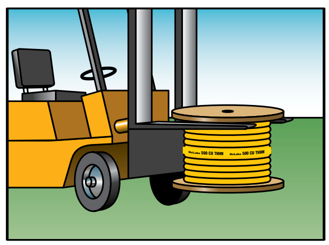


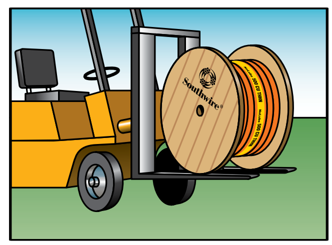
Proper Reel Handling Techniques

3) Forklifts must lift the reel by contacting both flanges.



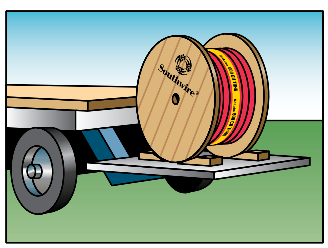
Proper Reel Handling Techniques



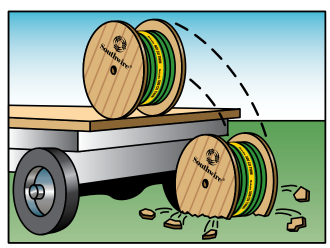


Improper Reel Handling Techniques

4) Ramps must be wide enough to support both reel flanges.



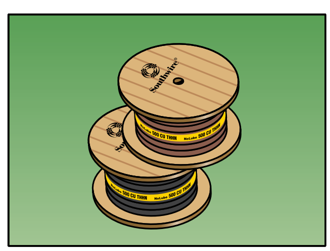
Proper Reel Handling Techniques



Improper Reel Handling Techniques

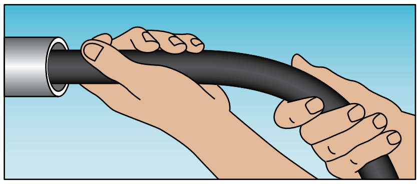
5) Store reels on hard surface so that the flanges will not sink and allow reel weight to rest on cable.

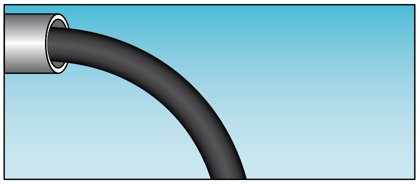
Proper Reel Handling Techniques



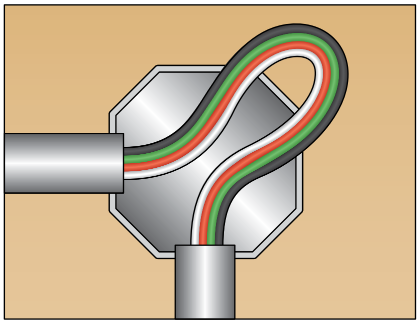
Improper Reel Handling Techniques

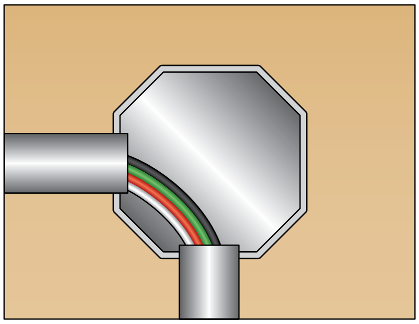
6) Reels should be stored out of harm's way. Consider both physical and environmental hazards.
7) Conductor ends must always be sealed to prevent the entrance of moisture, etc.
8) Remove temporary lashing.
9) While pulling, in order to eliminate sharp bends and crossovers, always have a person feed the cable(s) straight into the conduit by hand or, for larger conductors, over a large diameter sheave.


Proper


Improper

10) Do not pull conductors directly across short, sharp angles. After pulling completely out of one side of the enclosure, feed conductors into the other side of the enclosure and pull that segment.


Proper


Improper

Caution: Minimum bending radii must be maintained.

VERTICAL INSTALLATIONS

Proper precautions must be taken to keep conductors from free falling during vertical installations. Never assume that adequate tension exists between the conductors and conduit to keep the conductors from falling. In vertical installations, conductors are typically placed at the top of the installation so they can be pulled from the top down, greatly reducing or eliminating pulling tension on the conductors. The following steps should always be taken to make sure the conductors are secure at all times. The solution would come in two parts:

Support During Installation – Securing the reel during installation and supplemental braking is recommended on vertical installations. Installers should not rely solely on a reel brake during vertical installations. Reel braking can fail for various reasons. Therefore, the conductors should also have some type of alternate braking mechanism. If the reel brake mechanism fails, the alternate system can stop the conductors, keeping them from free-falling to the ground. Continue to test your braking mechanisms as you progress through the pull.

Support Immediately After Installation – Once the cable has been pulled, the conductors should be secured in several locations as soon as possible. Conductors should never be secured by only the braking mechanisms at the top of the pull. When securing with a clamp, basket grip or wedge grip, it's important that properly applied electrical tape or friction tape be used under the device to hold the conductors in place.

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Permanent Support – After the conductors are installed, they must be supported per NEC® 300.19 Supporting Conductors in Vertical Raceways. The installation must meet the maximum spacing intervals and support methods in NEC® 300.19. Properly applied electrical or friction tape under the device is important to ensure long-term support.

TERMINATING CONDUCTORS

Proper termination of the conductors is directly related to system reliability. It is imperative that properly rated devices are used. This became apparent in the 1960s when aluminum wiring was terminated to devices rated for copper conductors. The result was unreliable electrical systems. AA-8000 series aluminum paired with UL listed terminations has resulted in proven reliable residential and commercial installations for over 30 years. What follows is some history and best practices for aluminum conductor termination.

Aluminum Connectors – With the advent of AA-8000 series aluminum alloy, listed aluminum terminations are as reliable as copper. When aluminum was first used for commercial and residential wiring in the 1960s, manufacturers used the same EC 1350 electrical grade aluminum used by utilities. The same properties that make this alloy great for transmission applications made it a poor choice for the commercial terminations of the times.

The solution would come in two parts:

1) A new aluminum alloy that possessed the properties to perform well in commercial and residential terminations was needed. Southwire was the first to introduce such an alloy in 1968 and called it triple e™ (now called AlumFlex,™ emphasizing its ease of installation). Later the National Electrical Code® required the use of 8000 series aluminum alloy and Underwriters Laboratory (UL) required that all aluminum building wire, with the exception of single-rated USE, be manufactured with AA-8000 series aluminum.

2) Listed connectors were another important factor in reliable aluminum conductor terminations. In the 1960s, terminal lugs were not tested or designed for use with aluminum wire. Today's listed connectors are designed and tested for use with AA-8000 series aluminum alloy. This ensures complete compatibility of materials, such as brass set screws instead of steel.

When terminating aluminum conductors, there are several practices one should be aware of to ensure a quality connection that will remain trouble free.

1) Always use a connector that is listed for use with aluminum wire.

2) The following is recommended but not required. Always follow the connector manufacturer's instructions
   a. The surface of the conductor should be wire-brushed to break any aluminum oxide barrier leaving a clean surface for the connection.
   b. The use of anti-oxidant compound, joint compound, is not required unless the connector's manufacturer requires it. However, the use of a listed joint compound is always a good practice.

3) Always tighten set-screw type connectors to the manufacturer's recommended torque.

4) Most importantly, **do not re-torque the terminations** as part of routine maintenance. As with copper conductors, repeated tightening of any set-screw connections can result in the eventual "biting" through the conductor causing the termination to fail.

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Section 3. Design and Application Guidelines

SPECIFYING CONDUIT PROOFING

Cable is commonly damaged due to debris left in the conduit during installation. Prior to pulling the conductors, it is considered good practice to proof the conduit system. The purpose of proofing the conduit system is to ensure the conduit is intact, not crushed or disjointed, and the conduit is clear from debris that could damage the conductor jacket or insulation. This is accomplished with the use of wire brush mandrels, duct swabs and mandrels.

Wire Brush Mandrel – A wire brush mandrel consists of a length of brush approximately the size of the conduit inner diameter with stiff steel bristles and an eye on each end for attaching the pull ropes. This wire brush mandrel is pulled through the duct to break up any debris deposits that might exist in the conduit run. If an obstruction is felt the brush can be pulled back and forth repeatedly to break up the obstruction.

Rubber Duct Swab – A rubber duct swab typically consists of a series of rubber discs approximately the size of the conduit inner diameter on a length of steel cable with an eye on each end for attaching pull ropes. The rubber duct swab is pulled through the duct to extract loose debris from the duct that may damage conductor jackets or insulations. It is imperative that the appropriate size swab is used to ensure its effectiveness. The use of a swab will also locate damage ducts that would cause the conductors to bind and increase pulling tensions.

Test Mandrels – Test mandrels are solid slugs that represent a conduit fill of 80% or more. The mandrel is pulled through the conduit to locate obstructions that would prevent the conductors from being pulled in. A mandrel may not be necessary when a rubber duct swab is used as either would indicate an obstruction while a rubber duct swab is the correct choice for removing debris.

By specifying the conduit to be proofed prior to installing the cable, designers and engineers increase the likelihood of an installation free of damaged cable, and as a result a more reliable installation.

Unless there is reason to believe the conduit is damaged, the recommended conduit proofing practice is to use a rubber duct swab. A duct swab will remove any loose debris and will help identify any severe obstructions in the conduit. If an obstruction is located, it may be necessary to dislodge the obstruction with a wire brush mandrel and follow with a duct swab to remove the loosened debris.

AMPACITY CONSIDERATIONS

Copper is assigned a conductivity of 100%. The conductivity of all other metals is compared to copper. The conductivity of aluminum is approximately 62% of that of copper.

It is commonly accepted that comparable current-carrying copper and aluminum conductors are separated by two AWG sizes. For example, an 8 AWG copper and 6 AWG aluminum conductor can carry the same amount of current.

Conductors larger than those listed in the American Wire Gage system are sized based on their circular-mil area. The rule of two sizes larger for aluminum conductors versus copper may not work for the circular-mil sizes of conductors. The best solution is to consult the appropriate NEC® ampacity table for the correct size aluminum conductor to replace a copper conductor.

A copy of NEC® Table 310.16 is included in the annex of this manual on page 36.

GROUNDING CONSIDERATIONS

The equipment grounding conductor in conduit and conductor installations should be sized based on the over current protection device per Table 250.122 of the NEC®.

For conductors in parallel runs, the equipment grounding conductor in each conduit should be sized to match on the upstream overcurrent protection device rating based on Table 250.122 in the NEC®. Table 250.122 is included in the annex of this guide for convenience on page 34.

Section 4. Annexes

ANNEX A. TYPE THHN CONDUCTOR SPECIFICATION

26 05 19 WIRE AND CABLE TYPE THHN

PART 1 GENERAL

1.1 SPECIFICATION INCLUDES

1.1.1 Cable Type: Type THHN/THWN for use as services, feeders and branch circuits.

1.1.2 General Applications: Type THHN/THWN cable may be used in the following general applications per the National Electrical Code®

- 1.1.2.1 In Conduit
- 1.1.2.2 In Cable Tray
- 1.1.2.3 For Services
- 1.1.2.4 For Feeders
- 1.1.2.5 For Branch Circuits
- 1.1.2.6 Wet or Dry Locations

1.2 SUBMITTALS

1.2.1 Product Data: Submit manufacturer's product data confirming that materials comply with specified requirements and are suitable for the intended application.

1.2.2 Installation Instructions: Manufacturer's installation instructions shall be included in submittal. Industry guides may supplement the manufacturer's instructions.

1.3 REQUIREMENTS

1.3.1 Underwriters Laboratories: Type THHN cable shall meet the following Underwriters Laboratories (UL) standards and listings.

- 1.3.1.1 UL 83 Thermoplastic-Insulated Wires and Cables
- 1.3.1.2 UL 1063 UL Standard for Safety Machine-Tool Wires and Cables
- 1.3.1.3 UL listed sunlight resistant in black sizes 2 AWG and larger
- 1.3.1.4 Sizes 1/0 AWG and larger listed for CT USE
- 1.3.1.5 Sizes 14 through 1 AWG shall be rated VW-1
- 1.3.1.6 Sizes 8 AWG and larger shall be rated THWN-2

1.3.2 ASTM Standards: Type THHN cable shall meet all applicable ASTM standards.

1.3.3 Federal Specifications: Type THHN cable shall meet Federal Specification A-A-59544.

PART 2 PRODUCTS

2.1 MANUFACTURER

2.1.1 Southwire Company, One Southwire Drive, Carrollton, Georgia, 30119
Website: www.southwire.com

2.1.2 Senator Wire and Cable, 102 City Hall Ave., Carrollton, Georgia, 30117
Website: www.southwire.com

2.2 CABLE CONSTRUCTION

2.2.1 Conductor: The conductor shall be soft annealed copper.

2.2.2 Insulation: The insulation shall be high-heat and moisture resistant PVC.

2.2.3 Jacket: The jacket shall be abrasion, moisture, gasoline and oil resistant nylon or listed equivalent with:

2.2.4 Self-Lubricating Jacket: Jackets on conductor sizes 1/0 AWG and larger shall be SIM*pull*® or equivalent having integrated self-lubrication such that the cable coefficient of friction is less than or equal to 0.17.

PART 3 INSTALLATION

3.1 INSTALLATION

3.1.1 Manufacturer's Instructions: Type THHN cable shall be installed per the manufacturer's published installation instructions. Industry guides may supplement the manufacturer's instructions.

3.1.2 Field Support: Manufacturer shall provide, when requested, field engineering support for Type THHN cable installation.

3.1.3 Manufacturer: Type THHN cable for circuits, feeders and services shall be supplied from a single manufacturer.

3.1.4 Minimum Bend Radius: Bends in Type THHN shall be made so that the cable will not be damaged.

3.2 SPECIFIC USES

3.2.1 Type THHN cable may be used in conduit, raceways and cable trays for services, feeders and branch circuits as specified in the applicable section of the NEC®.

3.3 USES NOT PERMITTED

3.3.1 Type THHN cable shall not be used in direct burial applications.

3.4 AMPACITY

3.4.1 The ampacity of Type THHN cable shall be determined in accordance with Article 310.15 of the National Electrical Code® The installation should not exceed the temperature ratings of the terminations and equipment.

ANNEX B. TYPE XHHW CONDUCTOR SPECIFICATION

26 05 19 WIRE AND CABLE TYPE XHHW-2

PART 1 GENERAL

1.4 SPECIFICATION INCLUDES

1.4.1 Cable Type: Type XHHW for use as services, feeders and branch circuits.
1.4.2 General Applications: Type XHHW cable may be used in the following general applications per the National Electrical Code®
- 1.4.2.1 In Conduit
- 1.4.2.2 In Cable Tray
- 1.4.2.3 For Services
- 1.4.2.4 For Feeders
- 1.4.2.5 For Branch Circuits
- 1.4.2.6 Wet or Dry Locations

1.5 SUBMITTALS

1.5.1 Product Data: Submit manufacturer's product data confirming that materials comply with specified requirements and are suitable for the intended application.
1.5.2 Installation Instructions: Manufacturer's installation instructions shall be included in submittal. Industry guides may supplement the manufacturer's instructions.

1.6 REQUIREMENTS

1.6.1 Underwriters Laboratories: Type XHHW cable shall meet the following Underwriters Laboratories (UL) standards and listings.
- 1.6.1.1 UL 44 Thermoset – Insulated Wires and Cables
- 1.6.1.2 UL listed sunlight resistant in black sizes 2 AWG and larger
- 1.6.1.3 Sizes 1/0 AWG and larger listed for CT USE
- 1.6.1.4 Sizes 14 through 8 AWG shall be rated SIS
- 1.6.1.5 All sizes shall be rated XHHW-2

1.6.2 ICEA Standards: Type XHHW cable shall meet all construction requirements of ICEA S-95-658 (NEMA WC 70) – Nonshielded 0-2 kV Cables.
1.6.3 ASTM Standards: Type XHHW cable shall meet all applicable ASTM standards.
1.6.4 Federal Specifications: Type XHHW cable shall meet Federal Specification A-A-5954.

PART 2 PRODUCTS

2.3 MANUFACTURER

2.3.1 Southwire Company, One Southwire Drive, Carrollton, Georgia, 30119
Website: www.southwire.com
2.3.2 Senator Wire and Cable, 102 City Hall Ave., Carrollton, Georgia, 30117
Website: www.southwire.com

2.4 CABLE CONSTRUCTION

2.4.1 Conductor: The conductor shall be soft annealed copper.
2.4.2 Insulation: Insulation shall be abrasion, moisture, and heat resistant cross-linked polyethylene.
2.4.3 Alternate Construction: Type XHHW-2 shall be listed CT USE by request.

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PART 3 INSTALLATION

3.5 INSTALLATION

3.5.1 Manufacturer's Instructions: Type XHHW cable shall be installed per the manufacturer's published installation instructions. Industry guides may supplement the manufacturer's instructions.

3.5.2 Field Support: Manufacturer shall provide, when requested, field engineering support for Type XHHW cable installation.

3.5.3 Manufacturer: Type XHHW cable for circuits, feeders and services shall be supplied from a single manufacturer.

3.5.4 Minimum Bend Radius: Bends in Type XHHW shall be made so that the cable will not be damaged.

3.6 SPECIFIC USES

3.6.1 Type XHHW cable may be used in conduit, raceways and cable trays for services, feeders and branch circuits as specified in the applicable section of the NEC.®

3.7 USES NOT PERMITTED

3.7.1 Type XHHW cable shall not be used in direct burial applications.

3.8 AMPACITY

3.8.1 The ampacity of Type XHHW cable shall be determined in accordance with Article 310.15 of the National Electrical Code.® The installation should not exceed the temperature ratings of the terminations and equipment.

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ANNEX C. PRODUCT DATA SHEETS

SIM*pull* THHN®

- 600 Volts. Copper Conductor. Thermoplastic Insulation/SIM Nylon Sheath
- Heat, Moisture, Gasoline, and Oil Resistant[1] Rated MTW and THWN-2*
- Sizes Through 500 kcmil Listed T90 Nylon or TWN 75
- Sizes Through 500 kcmil Listed FT1
- Size1/0 and Larger Listed for CT Use
- Black Sizes Listed Sunlight Resistant
- SIM Technology® for Easier Pulling

Applications Suitable for use as follows:

Southwire SIM*pull*® Type THHN or THWN-2* conductors are primarily used in conduit and cable trays for services, feeders, and branch circuits in commercial or industrial applications as specified in the National Electrical Code[2]. When used as Type THHN, or T90 Nylon, conductor is suitable for use in dry locations at temperatures not to exceed 90°C. When used as Type THWN-2* or TWN75, conductor is suitable for use in wet or dry locations at temperatures not to exceed 90°C or not to exceed 75°C when exposed to oil or coolant. When used as Type MTW, conductor is suitable for use in wet locations or when exposed to oil or coolant at temperatures not to exceed 60°C or dry locations at temperatures not to exceed 90°C (with ampacity limited to that for 75°C conductor temperature per NFPA 79). Voltage for all applications is 600 volts. This cable may be installed without the need for pulling lubricant.

Standards and References

Southwire SIM*pull*® Type THHN or THWN-2* or MTW (also AWM) meets or exceeds all applicable ASTM specifications, UL Standard 83, UL Standard 1063 (MTW), CSA, Federal Specification A-A-59544, and requirements of the National Electrical Code.®

Construction

Southwire SIM*pull*® Type THHN or THWN-2* or MTW copper conductors are annealed (soft) copper, compressed strand, insulated with a tough heat and moisture resistant polyvinyl chloride (PVC), over which a SIM (SLIKQwik™ Infused Membrane) nylon (polyamide) or UL-listed equal jacket is applied. Available in black, white, red, blue, green, yellow, brown, orange and gray. Some colors subject to economic order quantity. Conductor sizes 2 AWG and larger listed and marked sunlight resistant in black only.

[1]Oil and gasoline resistant II as defined by Underwriters Laboratories
[2]2008 Edition
*rated -2 for 8 AWG and larger only

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WEIGHTS, MEASUREMENTS AND PACKAGING

CONDUCTOR		INSULATION THICKNESS (mils)	JACKET THICKNESS (mils)	NOMINAL O.D. (mils)		APPROX. NET WEIGHT PER 1000 FT. (lbs)		ALLOWABLE AMPACITIES*			STANDARD PACKAGE
SIZE (AWG or kcmil)	NUMBER OF STRANDS			SOL.	STR.	SOL.	STR.	60°C	75°C	90°C	
14	19	15	4	102	109	15	16	15	15	15	DNF
12	19	15	4	119	128	23	24	20	20	20	DNF
10	19	20	4	150	161	37	38	30	30	30	DQF
8	19	30	5	--	213	--	62	40	50	55	F
6	19	30	5	--	249	--	95	55	65	75	E
4	19	40	6	--	318	--	152	70	85	95	C
3	19	40	6	--	346	--	188	85	100	110	BC
2	19	40	6	--	378	--	234	95	115	130	C
1	19	50	7	--	435	--	299	110	130	150	B
1/0	19	50	7	--	474	--	371	125	150	170	B
2/0	19	50	7	--	518	--	461	145	175	195	B
3/0	19	50	7	--	568	--	574	165	200	225	B
4/0	19	50	7	--	624	--	717	195	230	260	B
250	37	60	8	--	694	--	850	215	255	290	B
300	37	60	8	--	747	--	1011	240	285	320	B
350	37	60	8	--	797	--	1173	260	310	350	B
400	37	60	8	--	842	--	1333	280	335	380	B
500	37	60	8	--	926	--	1653	320	380	430	B
600	61	70	9	--	1024	--	1985	355	420	475	C
750	61	70	9	--	1126	--	2462	400	475	535	C
1000	61	70	9	--	1275	--	3254	455	545	615	C

Solid construction available in sizes 14 through 10 AWG as Types THHN or THWN or AWM only.
Sizes 14 through 6 AWG also suitable for 105°C appliance wiring material (AWM).
Sizes 14 and 12 AWG contain four 500 ft. spools per carton. Size 10 AWG contains two 500 ft. spools per carton.
*Allowable ampacities shown are for general use as specified by the National Electrical Code® 2008 Edition, section 310.15. Unless the equipment is marked for use at higher temperatures, the conductor ampacity shall be limited to the following:
60°C – When terminated to equipment for circuits rated 100 amperes or less or marked for size 14 through 1 AWG conductors. MTW wet locations or when exposed to oil or coolant.
75°C – When terminated to equipment for circuits rated over 100 amperes or marked for conductors larger than size 1 AWG. THWN-2 when exposed to oil or coolant. MTW dry locations.
90°C – THHN dry locations. THWN-2 wet or dry locations. For ampacity derating purposes.

STANDARD PACKAGE CODES

- B – 1000 ft. reel
- C – 500 ft. reel
- D – 2500 ft. spool
- E – 1000 ft. spool
- F – 500 ft. spool
- N – 2000 ft. carton
- Q – 350 ft. carton

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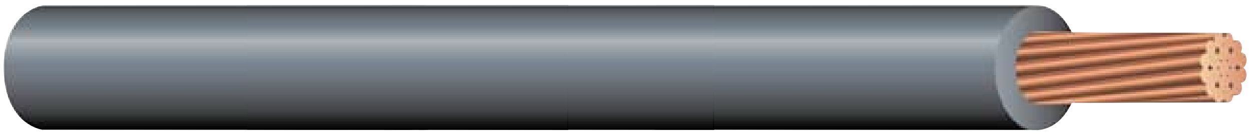
LISTED

Southwire®

XHHW

- 600 Volt. Copper Conductor
- Cross-Linked Polyethylene (XLP) Insulation
- High-Heat and Moisture Resistant
- Sizes 14 Through 8 AWG Also Rated SIS
- Black Sizes 2 AWG and Larger Sunlight Resistant



Applications Suitable for use as follows:

Southwire Type XHHW-2 conductors are primarily used in conduit or other recognized raceways for services, feeders and branch circuit wiring, as specified in the National Electrical Code.®[1] XHHW-2 conductors may be used in wet or dry locations at temperatures not to exceed 90°C. Voltage rating for XHHW-2 conductors is 600 volts.

Standards and References

Southwire Type XHHW-2 conductors meet or exceed UL Standard 44, Federal Specification A-A-59544, and requirements of the National Electrical Code.®

Type XHHW-2 meets and exceeds all construction requirements of ICEA S-95-658 (NEMA WC 70) – Nonshielded 0-2 kV Cables, with testing frequencies based on UL requirements.

Construction

Southwire Type XHHW-2 copper conductors are annealed (soft) copper. Insulation is an abrasion, moisture, and heat resistant cross-linked polyethylene (XLP). Sizes 14, 12, and 10 AWG available in black, white, red, blue, yellow, green, orange, brown, purple, and gray. Conductor sizes 2 AWG and larger listed and marked sunlight resistant in black only. Colors available in sizes 8 AWG and larger. Not CT rated.

Alternate Construction

Southwire Type XHHW-2 copper conductors are also available in sizes 1/0 AWG and larger rated for cable tray use and sunlight resistant. Specify XHHW-2 for CT Use when requesting quote or ordering.

[1] 2008 Edition

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WEIGHTS, MEASUREMENTS AND PACKAGING								
CONDUCTOR		INSULATION THICKNESS (mils)	NOMINAL O.D. (mils)	ALLOWABLE AMPACITIES*			APPROX. NET WEIGHT PER 1000 FT. (lbs)	STANDARD PACKAGE
SIZE/CONST. (AWG or kcmil)	NO. STRANDS			60°C	75°C	90°C		
14	7	30	130	15	15	15	18	A
12	7	30	147	20	20	20	26	A
10	7	30	171	30	30	30	40	A
8	7	45	232	40	50	55	66	B
6	7	45	267	55	65	75	99	B
4	7	45	314	70	85	95	149	B
2	7	45	370	95	115	130	230	B
1	19	55	434	110	130	150	292	B
1/0	19	55	473	125	150	170	363	B
2/0	19	55	517	145	175	195	452	B
3/0	19	55	567	165	200	225	565	B
4/0	19	55	623	195	230	260	705	B
250	37	65	691	215	255	290	835	B
300	37	65	744	240	285	320	995	B
350	37	65	794	260	310	350	1155	B
400	37	65	839	280	335	380	1314	B
500	37	65	923	320	380	430	1633	B
600	61	80	1029	355	420	475	1966	C
700	61	80	1098	385	460	520	2283	C
750	61	80	1131	400	475	535	2441	C
1000	61	80	1280	455	545	615	3230	C

*Allowable Ampacities:
Allowable ampacities shown are for general use as specified by the National Electrical Code,® 2008 Edition, section 310.15. Unless the equipment is marked for use at higher temperatures the conductor ampacities shall be limited to the following:
60 °C – When terminated to equipment for circuits rated 100 amperes or less or marked for 14 through 1 AWG conductors.
75 °C – When terminated to equipment for circuits rated over 100 amperes or marked for conductors larger than 1 AWG.
90 °C – Wet or dry locations. For ampacity derating purposes

STANDARD PACKAGE CODES

A – 2500 ft. reel
B – 1000 ft. reel
C – 500 ft. spool

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ANNEX D. FIELD TESTING

Safety – Even low potential testing has inherent hazards to personnel and equipment. Thus safety rules are applicable for both high voltage and low voltage testing.

Before conducting tests on any cable system, verify the cable system is properly de-energized. If the cable system has been previously energized, you must follow the prescribed rules for conducting the switching necessary to de-energize, lock-out, tag, and ground the cable system.

Insulation Resistance Testing – The most common method of field testing for 600 volt cable is to use a megohm meter. This test provides a measure of insulation resistance as a function of applied voltage and resulting leakage current.

The insulation resistance is read in megohms. The test set reads the total circuit resistance and therefore it is useful to normalize the results using the following formula.

$$IR = (L \cdot R \cdot F) / 1{,}000$$

where: L = the length of the conductor in feet
R = the resistence in megohms read from the Megger
F = the temperature correction factor from Table 10

This provides results in megohms for 1,000 feet of conductor which is useful when testing circuits of varying lengths.

Interpretation of Results – Industry practice recognizes tests with a dc potential of 500 or 1000 volts dc. The insulation resistance reading should be taken after 1 minute to allow the reading to stabilize.

For spot short time readings, IR readings should be evaluated with respect to the test conditions to determine if the results should be considered acceptable. IR readings can vary greatly depending on the environmental conditions. Conditions such as humidity, moisture in the conduits, and leftover residue on the conductor from pulling compounds are among some of the factors that influence IR readings and make detection of problems more difficult. The following 2 to 50 Megohm Rule is a good indicator to use for evaluating IR readings:

Acceptable: A megohm meter reading of 50 megohms or higher should be considered acceptable.

Investigate: A megohm meter reading of 2 to 50 megohms may be used for deciding when to investigate the cable installation. In most cases, a 2 to 50 megohm reading does not indicate the insulation quality. Therefore, 2 to 50 megohms should not be specified as a pass/fail value. These readings are usually associated with long circuit lengths, moisture, or contamination. Ends of conductors that are dirty or damp may need to be cleaned and dried.

Unacceptable: Readings less than 2 megohms will most likely indicate damaged insulation or severe test conditions.

Table 10 – Temperature Correction Factors for Insulation Resistance Calculations

ºF	TYPES XHHW/RHH/RHW/USE	TYPE THHN
50º	0.73	0.56
55º	0.86	0.75
60º	1.00	1.00
65º	1.17	1.34
70º	1.36	1.79
75º	1.59	2.40
80º	1.86	3.21
85º	—	4.30

ANNEX E. REFERENCE MATERIALS

NEC® Table 250.122 - Minimum Size Equipment Grounding Conductors for Grounding Raceway and Equipment

RATING OR SETTING OF AUTOMATIC OVERCURRENT DEVICE IN CIRCUIT AHEAD OF EQUIPMENT, CONDUIT, ETC., NOT EXCEEDING (AMPERES)	SIZE (AWG OR kcmil)	
	COPPER	ALUMINUM OR COPPER-CLAD ALUMINUM*
15	14	12
20	12	10
30	10	8
40	10	8
60	10	8
100	8	6
200	6	4
300	4	2
400	3	1
500	2	1/0
600	1	2/0
800	1/0	3/0
1000	2/0	4/0
1200	3/0	250
1600	4/0	350
2000	250	400
2500	350	600
3000	400	600
4000	500	800
5000	700	1200
6000	800	1200

Note: Where necessary to comply with 250.4 (A)(5) or (B)(4), the equipment grounding conductor shall be sized larger than given in this table.
*See installation restrictions in 250.120.

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ARTICLE 358 – ELECTRICAL METALLIC TUBING (EMT)

	NOMINAL INTERNAL DIAMETER		TOTAL AREA 100%		60%		1 WIRE 53%		2 WIRES 31%		OVER 2 WIRES 40%	
TRADE SIZE	mm.	in.	mm.^{2}	in.^{2}	mm.^{2}	in.^{2}	mm.^{2}	in.^{2}	mm.^{2}	in.^{2}	mm.^{2}	in.^{2}
1/2	15.8	0.622	196	0.304	118	0.182	104	0.161	61	0.094	78	0.122
3/4	20.9	0.824	343	0.533	206	0.320	182	0.283	106	0.165	137	0.213
1	26.6	1.049	556	0.864	333	0.519	295	0.458	172	0.268	222	0.346
1 1/4	35.1	1.380	968	1.496	581	0.897	513	0.793	300	0.464	387	0.598
1 1/2	40.9	1.610	1314	2.036	788	1.221	696	1.079	407	0.631	526	0.814
2	52.5	2.067	2165	3.356	1299	2.013	1147	1.778	671	1.040	866	1.342
2 1/2	69.4	2.731	3783	5.858	2270	3.515	2005	3.105	1173	1.816	1513	2.343
3	85.2	3.356	5701	8.846	3421	5.307	3022	4.688	1767	2.742	2280	3.538
3 1/2	97.4	3.834	7451	11.545	4471	6.927	3949	6.119	2310	3.579	2980	4.618
4	110.0	4.334	9521	14.753	5712	8.852	5046	7.819	2951	4.573	3808	5.901

ARTICLE 344 – RIGID METAL CONDUIT (RMT)

	NOMINAL INTERNAL DIAMETER		TOTAL AREA 100%		60%		1 WIRE 53%		2 WIRES 31%		OVER 2 WIRES 40%	
TRADE SIZE	mm.	in.	mm.^{2}	in.^{2}	mm.^{2}	in.^{2}	mm.^{2}	in.^{2}	mm.^{2}	in.^{2}	mm.^{2}	in.^{2}
3/8	-	-	-	-	-		-	-	-	-	-	-
1/2	16.1	0.632	204	0.314	122	0.188	108	0.166	63	0.097	81	0.125
3/4	21.2	0.836	393	0.549	212	0.329	187	0.291	109	0.170	141	0.220
1	27.0	1.063	573	0.887	344	0.532	303	0.470	177	0.275	229	0.355
1 1/4	35.4	1.394	984	1.526	591	0.916	522	0.809	305	0.473	394	0.610
1 1/2	41.2	1.624	1333	2.071	800	1.243	707	1.098	413	0.642	533	0.829
2	52.9	2.083	2198	3.408	1319	2.045	1165	1.0806	681	1.056	879	1.363
2 1/2	63.2	2.489	3137	4.866	1882	2.919	1663	2.579	972	1.508	1255	1.946
3	78.5	3.090	4840	7.499	2904	4.499	2565	3.974	1500	2.325	1936	3.000
3 1/2	90.7	3.570	6461	10.010	3877	6.006	3424	5.305	2003	3.103	2584	4.004
4	102.9	4.050	8316	12.882	4990	7.729	4408	6.828	2578	3.994	3326	5.153
5	128.9	5.073	13050	20.212	7830	12.127	6916	10.713	4045	6.266	5220	8.085
6	154.8	6.093	18821	29.158	11292	17.495	9975	15.454	5834	9.039	7528	11.663

ARTICLES 352 AND 353 – RIGID PVC CONDUIT (RNC), SCHEDULE 40, AND HDPE CONDUIT

	NOMINAL INTERNAL DIAMETER		TOTAL AREA 100%		60%		1 WIRE 53%		2 WIRES 31%		OVER 2 WIRES 40%	
TRADE SIZE	mm.	in.	mm.²	in.²	mm.²	in.²	mm.²	in.²	mm.²	in.²	mm.²	in.²
3/8	-	-	-	-	-	-	-	-	-	-	-	-
1/2	15.3	0.602	184	0.285	110	0.171	97	0.151	57	0.088	74	0.114
3/4	20.4	0.804	327	0.508	196	0.305	173	0.269	101	0.157	131	0.203
1	26.1	1.029	535	0.832	321	0.499	284	0.441	166	0.258	214	0.333
1 1/4	34.5	1.360	935	1.453	561	0.872	495	0.770	290	0.450	374	0.581
1 1/2	40.4	1.590	1282	1.986	769	1.191	679	1.052	397	0.616	513	0.794
2	52.0	2.047	2124	3.294	1274	1.975	1126	1.744	658	1.020	849	1.316
2 1/2	62.1	2.445	3029	4.695	1817	2.817	1605	2.488	939	1.455	1212	1.878
3	77.3	3.042	4693	7.268	2816	4.361	2487	3.852	1455	2.253	1877	2.907
3 1/2	89.4	3.521	6277	9.737	3766	5.842	3327	5.161	1946	3.018	2511	3.895
4	101.5	3.998	8091	12.554	4855	7.532	4288	6.654	2508	3.892	3237	5.022
5	127.4	5.016	12748	19.761	7649	11.856	6756	10.473	3952	6.126	5099	7.904
6	153.2	6.031	18433	28.567	11060	17.140	9770	15.141	5714	8.856	7373	11.427

NEC® TABLE 300.19(A) SPACINGS FOR CONDUCTOR SUPPORTS

SIZE OF WIRE	SUPPORT OF CONDUCTORS IN VERTICAL RACEWAYS	CONDUCTORS			
		ALUMINUM OR COPPER-CLAD ALUMINUM		COPPER	
		m.	ft.	m.	ft.
18 AWG – 8 AWG	Not greater than	30	100	30	100
6 AWG – 1/0 AWG	Not greater than	60	200	30	100
2/0 AWG – 4/0 AWG	Not greater than	55	180	25	80
> 4/0 AWG – 350 kcmil	Not greater than	41	135	18	60
> 350 kcmil – 500 kcmil	Not greater than	36	120	15	50
> 500 kcmil – 750 kcmil	Not greater than	28	95	12	40
> 750 kcmil	Not greater than	26	85	11	35

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Table 310-16 Allowable Ampacities of Insulated Conductors Rated 0 Through 2000 Volts, 60°C Through 90°C (140°F Through 194°F), Not More Than Three Current-Carrying Conductors in Raceway, Cable, or Earth (Directly Buried), Based on Ambient Temperature of 30°C (86°F)

	TEMPERATURE RATING OF CONDUCTOR (SEE TABLE 310.13)						
	60°C (140°F)	75°C (167°F)	90°C (194°F)	60°C (140°F)	75°C (167°F)	90°C (194°F)	
	TYPES TW, UF	TYPES RHW, THHW, THW, THWN, XHHW, USE, ZW	TYPES TBS, SA, SIS, FEP, FEPB, MI, RHH, RHW-2, THHN, THHW, THW-2, THWN-2, USE-2, XHH, XHHW, XHHW-2, ZW-2	TYPES TW, UF	TYPES RHW, THHW, THW, THWN, XHHW, USE	TYPES TBS, SA, SIS, THHN, THHW, THW-2, THWN-2, RHH, RHW-2, USE-2, XHH, XHHW, XHHW-2, ZW-2	
SIZE AWG OR KCMIL	COPPER			ALUMINUM OR COPPER-CLAD ALUMINUM			SIZE AWG OR KCMIL
18	-	-	14	-	-	-	-
16	-	-	18	-	-	-	-
14*	20	20	25	-	-	-	-
12*	25	25	30	20	20	25	12*
10*	30	35	40	25	30	35	10*
8	40	50	55	30	40	45	8
6	55	65	75	40	50	60	6
4	70	85	95	55	65	75	4
3	85	100	110	65	75	85	3
2	95	115	130	75	90	100	2
1	110	130	150	85	100	115	1
1/0	125	150	170	100	120	135	1/0
2/0	145	175	195	115	135	150	2/0
3/0	165	200	225	130	155	175	3/0
4/0	195	230	260	150	180	205	4/0
250	215	255	290	170	205	230	250
300	240	285	320	190	230	255	300
350	260	310	350	210	250	280	350
400	280	335	380	225	270	305	400
500	320	380	430	260	310	350	500
600	355	420	475	285	340	385	600
700	385	460	520	310	375	420	700
750	400	475	535	320	385	435	750
800	410	490	555	330	395	450	800
900	435	520	585	355	425	480	900
1000	455	545	615	375	445	500	1000
1250	495	590	665	405	485	545	1250
1500	520	625	705	435	520	585	1500
1750	545	650	735	455	545	615	1750
2000	560	665	750	470	560	630	2000

	CORRECTION FACTORS						
AMBIENT TEMPS. (°C)	FOR AMBIENT TEMPERATURES OTHER THAN 30°C (86°F) MULTIPLY THE ALLOWABLE AMPACITIES SHOWN ABOVE BY THE APPROPRIATE FACTOR SHOWN BELOW.						AMBIENT TEMP. (°F)
21-25	1.08	1.05	1.04	1.08	1.05	1.04	70-77
26-30	1.00	1.00	1.00	1.00	1.00	1.00	78-86
31-35	0.91	0.94	0.96	0.91	0.94	0.96	87-95
36-40	0.82	0.88	0.91	0.82	0.88	0.91	96-104
41-45	0.71	0.82	0.87	0.71	0.82	0.87	105-113
46-50	0.58	0.75	0.82	0.58	0.75	0.82	114-122
51-55	0.41	0.67	0.76	0.41	0.67	0.76	123-131
56-60	-	0.58	0.71	-	0.58	0.71	132-140
61-70	-	0.33	0.58	-	0.33	0.58	141-158
71-80	-	-	0.41	-	-	0.41	159-176

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NOTES:

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