INSTALLATION INFORMATION

JAMMING

Jamming is the wedging of three or more cables as they are pulled into a conduit. This usually occurs as a result of crossovers when the cables are twisted or are pulled around bends in the conduit. Jam ratio is defined as the ratio of conduit inner diameter (D) to the cable outside diameter (d).

Jam Ratio = D/d

Probability of Jamming

Jamming probability using the jam ratio

<2.3	Very small
2.3 – 2.6	Small
2.6 – 2.8	Moderate
2.8 – 3.0	Significant
3.0 – 3.1	Moderate
3.1 – 3.2	Small
3.2 and up	Very small

The oval cross section of conduit bends was accounted for with a 5% factor. Note: Measured cable diameters should be used to determine the jam ratio since actual cable diameters vary from published values.

MINIMUM BENDING RADII

Single Conductor 600 Volt Power Cables (without metallic shielding) for conductor insulation 155 mils and less are as shown below. These should be used for training cable into final position (when there is no tension on the cable). When pulling cable through conduit (when cable is under tension), the minimum bending radius should be at least double the minimum bend radius shown below.

OD of Cable	Minimum Bending Radius as a Multiple of Cable Diameter
1.000” and less	4
1.001” – 2.000”	5

MAXIMUM PULLING TENSIONS

The following recommendations are based on a study sponsored by the ICEA. These recommendations may be modified if experience and more exact information so indicate. For a pull of any complexity, it is recommended that a program such as Pull-Planner™ 3000 sold by American Polywater be used to calculate pulling tensions and side wall pressures.

1. **Maximum Pulling Tension on a Cable**
   With pulling eye attached to copper conductors:

T=0.008 x n x CMA

Where: ***T***=maximum tension in pounds
N= number of conductors
CMA=circular mil area of each conductor (see Table 1)

When more than three conductors are pulled together, the maximum pulling tension should be reduced by 20%.

2. **Maximum Permissible Pulling Length:**

L= (T)/(fxW)

Where: ***L***=pulling length, feet (straight section)
T=maximum tension, pounds
f=coefficient of friction (see Table 2)
W=weight of cable per foot, pounds

3. **Calculated Pulling Tension (straight section of conduit)**
   For straight duct sections, the pulling tension equals the length of the duct multiplied by the weight per foot of the cable and the coefficient of friction (per type of cable and lubricant).

$T_s = L \times W \times f$

Where: T_s = pulling tension at end of straight section in lbs.
L = length of straight section in feet

W = weight of cable in lbs. /ft.
f = coefficient of friction (see Table 2)

4. **Calculated Pulling Tension (curved or bent section of conduit)**
   For curved sections, the following formula applies:

$T_c = T_1 \times e^{fa}$

Where: T_c = tension exiting curved section, pounds
T_1 = tension entering curved section, pounds
e = Napierian logarithm base (2.718)
f = coefficient of friction (see Table 2)
a = angle of bend in radians (1 radian = 57.3°)

5. Cable Sidewall Pressure at Bends

Sidewall pressure (SP) is caused by the tension in the cable acting horizontally and the weight of the cable acting vertically. The sidewall pressure should not exceed the value shown in the table below.

Cable Type	Maximum Allowable Sidewall Pressure (SP) – lbs./ft.
600 Volt & 1kV Nonshielded Power Cable (i.e. THHN/THWN, USE, RHH/RHW, etc)	1000

For a single conductor cable: SP = T_c /R (R is the radius of the bend in feet)

For three single conductor cables, cradled: SP = (3wf – 2)*T_c/(3R)

For three single conductor cables, triangular: SP = wf*T_c/(3R)

Where: T_c = tension exiting bend in pounds
R = bend radius in feet
wf = weight correction factor (see below)
SP = sidewall pressure in pounds/ft.

Weight Correction Factor – The configuration of conductors will affect conductor tension and the weight correction factor (wf) is used to account for this. The wf is calculated as follows:

Single Conductor: wf = 1

Three Conductors (triangular): wf = 1/ Sqrt (1-(d/D-d)) [D = conduit ID, d = conductor OD]

Three Conductors (cradled): wf = 1 + 4/3*(d/(D-d))^2

Four Conductors or more: wf = 1.4

INSTALLATION GUIDE AT LOW AMBIENT TEMPERATURES

Low temperatures can cause problems during installation due to temporary brittleness of the insulation and jacketing materials. When installing wire during cold weather, cable must be handled more carefully and should be pulled more slowly. The wire should be kept in a heated environment for at least 24 hours prior to the installation. It is not recommended that wire be installed at ambient temperatures below the following.

TABLE 3

Jacket / Insulation Type	Minimum Installation Temperature	
PVC	-10°C	14°F
XLPE	-25°C	-13°F
Nylon	-4°C	25°F

"MEGGER" (INSULATION RESISTANCE TESTING)

Megger testing is a commonly used method of assuring that 600 volt cables have been installed in conduit without damage to the insulation. DC voltages of 500 or 1000 volts are acceptable to use. Megger readings may vary considerably due to ambient conditions. Humidity, moisture in the conduit, and residue from pulling lube will affect the megger reading. These should be taken into account. The length of the run and the ambient temperature will also affect the reading but adjustments can be made using the formula below to normalize these factors.

IR (insulation resistance per 1000 feet) = (L / 1000) X R X CF

Where: L = length of the conductor in feet
R = megger reading in megohms
CF = temperature correction factor (see table)

Insulation Resistance Temperature Correction Factor (CF)	
Temperature in °F	THHN
45	0.24
50	0.39
55	0.62
60	1.00
65	1.61
70	2.59
75	4.18
80	6.73
85	10.8

"MEGGER" (INSULATION RESISTANCE TESTING) - Continued

After the selected voltage (500 or 1000 volts DC) is applied for 1 minute, the reading in megohms is taken from the megger. If the normalized reading is 50 megohms or greater, the reading is considered passing. If the normalized reading is from 2 to 50 megohms, the cable installation should be examined closely. Readings in this range are often accompanied by long runs or moisture or contamination that causes current leakage near the bared conductor ends. A reading in this range usually does not mean that the conductor insulation is damaged or defective. Readings in this range should be confirmed and evaluated by an experienced electrical testing specialist. A normalized reading of less than 2 megohms is considered failing if the testing conditions have been scrutinized to assure that current leakage due to moisture or contamination near the bare conductor ends and test leads is not present.

TABLE 1

CIRCULAR MIL AREAS				
AWG	**CMA**		**Kcmil**	**CMA**
12	6,530		250	250,000
10	10,380		300	300,000
8	16,510		350	350,000
6	26,240		400	400,000
4	47,470		500	500,000
3	52,620		600	600,000
2	66,360		750	750,000
1	83,690		1000	1,000,000
1/0	105,600			
2/0	133,100			
3/0	167,800			
4/0	211,600			

TABLE 2

Use if exact numbers for cable type and lubricant are not known

TYPICAL COEFFICIENTS OF FRICTION WITH ADEQUATE CABLE LUBRICATION DURING THE PULL		
	Type of Conduit	
Cable Type	Steel or Aluminum	PVC
THHN/THWN-2 w/added lube	0.28	0.24
XHHW-2 w/added lube	0.28	0.24
SLiPWire™ THHN/THWN-2*	0.15	0.15
SLiPWire™ XHHW-2*	0.16	0.16

* Lubrication not required with Cerro Wire SLiPWire™ products.

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