

JAMMING

Jamming is the wedging of three or more cables as they are pulled into a conduit. This usually occurs as a result of cross-overs 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):

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

Probability of Jamming (Jamming Probability Using Jam Ratio)

very small	small	moderate	significant	moderate	small	very small
2.3	2.6	2.8	3.0	3.1	3.2 and higher	

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

These factors apply to the minimum values for the radii to which insulated cables may be bent for permanent training during installation. In all cases the minimum radii specified refers to the inner surface of the cable and not to the axis of the cable, and the specified factors apply only as noted. Additional constructions are covered under the appendix of ICEA S-93-639, ICEA S-95-658, and ICEA S-96-659.

A. Power Cables Without Metallic Shielding or Without Armor

The minimum bending radii for both single and multiple conductor cable are as follows:

Overall Diameter of Cable in Inches		
1.000 and Less	1.001 to 2.000	2.001 and Over
4	5	6

CONDUIT FILL

Conduit Fill is the percentage of area inside the conduit taken up by the cable(s). consult applicable codes, industry standards and manufacturers data for further information on fill. Add ground conductor if applicable.

$$\text{Fill} = [d/D]^2 \cdot N \cdot 100 \text{ percent}$$

where: d = outside diameter of the cable in inches
D = inside diameter of the conduit in inches
N = number of cables

Trade Size	Area Sq. in.	40% Area Sq. In.	53% Area Sq. In.	ID In.	OD In.
2	3.36	1.34	1.78	2.067	2.37
2-1/2	4.79	1.92	2.54	2.469	2.87
3	7.38	2.95	3.91	3.068	3.50
3-1/2	9.90	3.96	5.25	3.548	4.00
4	12.72	5.09	6.74	4.026	4.50
5	20.00	8.00	10.60	5.047	5.56
6	28.89	11.60	15.30	6.065	6.62

B. Single and Multi-Conductor Armored and/or Shielded

CABLE CONSTRUCTION		Overall Diameter of Cable in Inches	
		Inches 1.50 & Less	Inches 1.51 & Larger
Minimum Bending Radius as a Multiple of Cable Diameter			
ARMOR	Single and Multi-Conductor Non-Shielded	7	7
	Single Conductor Tape Shielded	12	15
	Multi-Conductor with Individually Tape Shielded Conductor	12/7*	12/7*
	Multi-Conductor with Overall Tape Shield	12	12
NON-ARMOR	Single Conductor Tape Shielded	12	12
	Multi-Conductor with Individually Tape Shielded Conductor	12/7*	12/7*
URD	Single Conductor	8	8
	Multi-Conductor	8/5**	8/5**

*12 x individual shielded conductor diameter, or 7 x overall cable diameter whichever is greater

**8 x individual shielded conductor diameter, or 5 x overall cable diameter whichever is greater

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.

A. Maximum Pulling Tension on a Cable:

(Not for vertical lifting with one end suspension)
With pulling eye attached to copper conductors:

$$T_m = 0.008 \times n \times \text{CM}$$

where:

T_m = maximum tension, pounds
 n = number of conductors
CM = cir-mil area of each conductor

WHEN THREE CONDUCTORS ARE PULLED TOGETHER, USE CALCULATED TENSION FOR TWO CONDUCTORS. IF MORE THAN THREE, THE MAXIMUM PULLING TENSION SHOULD BE REDUCED BY 20%

B. Maximum Permissible Pulling Length for Straight Pulls:

$$L_m = (T_m) / (FW)$$

where:

L_m = pulling length, feet (straight section)
 T_m = maximum tension, pounds
 F = coefficient of friction (per type of lubricant)
 W = weight of cable per foot, pounds

C. Pulling Tension Calculation in Ducts:

1. For straight duct sections, the pulling tension equals the length of the duct multiplied by the weight per foot of cable and the coefficient of friction (per type of lubricant).
2. For curved sections, the following formula applies:

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

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 (per type of lubricant)
 a = angle of bend in radians (1 radian = 57.3°)

COEFFICIENT OF FRICTION

The coefficient of dynamic friction (μ) is a measure of the friction between a moving cable 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. Stopping and restarting a pull should be avoided where possible, because the coefficient of static friction will always be higher than the coefficient of dynamic friction.

Typical coefficients of Dynamic Friction (μ), Adequate Cable Lubrication During Pull

Cable Exterior	Type of Conduit		
	M	PVC	PVC
PVC - Polyvinyl Chloride	0.4	0.35	0.5
PE - Low Density HMW Polyethelene	0.35	0.35	0.5
Nylon	0.4	0.35	0.5
CPE	0.5	0.5	0.7

NOTES:

(A) These represent conservative values. For more exact information contact lubrication suppliers.

(B) Conduit Codes:

M = metallic, steel or aluminum

PVC = polyvinyl chloride, thin wall or heavy schedule 40

FIB = fiber conduit-Orangeburg or Nocrete

The coefficient of friction between a cable 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, cable temperature and ambient temperature. High ambient temperatures can increase the coefficient of dynamic friction for cable having a nonmetallic jacket.

CABLE SIDEWALL PRESSURE

The maximum pulling tension in pounds shall not exceed 500 times the radius of curvature of the bend expressed in feet.