The following data is intended as a general guide to aid individuals with the installation of cables inside ducts, raceways or conduit. These recommendations are based upon a study sponsored by the ICEA (Insulated Cable Engineers Association). The information contained herein is not a comprehensive set of instructions. An engineer or technician experienced with installations should be consulted for particular applications where out-of-the-ordinary conditions exist or could be encountered.

**PREFACE**

Before installing cables, it is recommended that the routing be thoroughly inspected to avoid bends and/or pulling tensions that exceed specified limits. Good design of the duct, raceway or conduit itself along with the routing is essential to ensure damage-free installation and the full service life of all components.

**MAXIMUM PULLING TENSION ON A CABLE**

For cable equipped with pulling eye or pulling bolt, the formula shown below is used to calculate the maximum allowable pulling tension on the cable for the entire routing.

\[
T_m = K \times n \times CMA
\]  
(Formula 1)

Where:
- \(T_m\) = maximum pulling tension (lbs.) (see Appendix A for calculated tensions)*
- \(K\) = constant
  - 0.008 for copper conductors
  - 0.006 for aluminum conductors
- \(n\) = number of conductors
- \(CMA\) = circular mil area for one conductor

*This value is the maximum tension that can be placed on the cable or, if pulling more than one conductor at a time, group of cables. In some cases this could exceed the limitations of the pulling equipment being used. The specifications set forth by the pulling equipment manufacturer (if available) should be compared to this value, and the lower of the two should govern.

**CABLE GRIP TENSION**

When cable grip is used over non lead-jacketed cable, the pulling tension should not exceed 1,000 lbs or 1,000 lbs. per grip (when used with multi-conductor cables) and also the tension calculated in Formula 1.

**CALCULATED PULLING TENSION – straight section of conduit**

\[
T_s = L \times W \times f
\]  
(Formula 2)

Where:
- \(T_s\) = pulling tension at end of straight section, lbs.
- \(L\) = length of straight section, feet
- \(W\) = weight of cable, lbs./ft.
- \(f\) = coefficient of friction (if unknown, use 0.5)

**CALCULATED PULLING TENSION – curved (bent) section of conduit**

\[
T_b = T_s \times e^{fa}
\]  
(Formula 3)

Where:
- \(T_b\) = pulling tension at end of bend, lbs.
- \(T_s\) = pulling tension at end of straight section entering the bend, lbs.
- \(e\) = naperian log base (2.718)
- \(f\) = coefficient of friction (if unknown, use 0.5)
a = angle of bend (radians)  
(See Table 1 with e$^{fa}$ values for common angles and Tables 2 & 3 for minimum bend radii)

MAXIMUM SIDEWALL PRESSURE AT BENDS
Sidewall pressure is caused by the tension in the cable acting horizontally and the weight of the cable acting vertically. Generally, the maximum sidewall pressure should not exceed 300 lbs/foot of radius, i.e., the tension of a cable immediately as it leaves a bend must not be greater than 300 times the bend radius (in feet). Shown below are formulas to calculate the maximum allowable tension at a bend and the actual sidewall pressure.

**Bend radii for training cable into final position (no tension on the cable) are shown in Tables 2 & 3. There are no published limits for bend radii when pulling cable (when the cable is under tension), however Superior-Essex recommends doubling the minimum bend radii shown on Tables 2 & 3 when pulling cable through conduit.**

\[
T_{bm} = 300 \times r \quad \text{(Formula 4)}
\]

Where:
- $T_{bm}$ = maximum allowable pulling tension at bend, lbs.
- $r$ = bend radius, feet

\[
P = \frac{T_b}{r} \quad \text{(Formula 5)}
\]

Where:
- $P$ = actual sidewall pressure on cable, lbs./ft.
- $T_b$ = pulling tension at and of bend, lbs.
- $r$ = bend radius, feet

The maximum allowable pulling tension at bend ($T_{bm}$) is the limit that the calculated pulling tension ($T_b$) should be compared to. If $T_b$ is greater than $T_{bm}$, the possibility of redesign or re-routing should be considered.

<table>
<thead>
<tr>
<th><strong>TABLE 1</strong></th>
<th><strong>VALUES OF $e^{fa}$ FOR COMMON ANGLES</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>BEND ANGLE (°)</strong></td>
<td><strong>$e^{fa}$</strong></td>
</tr>
<tr>
<td>15</td>
<td>1.20</td>
</tr>
<tr>
<td>30</td>
<td>1.44</td>
</tr>
<tr>
<td>45</td>
<td>1.73</td>
</tr>
<tr>
<td>60</td>
<td>2.08</td>
</tr>
<tr>
<td>75</td>
<td>2.50</td>
</tr>
<tr>
<td>90</td>
<td>3.00</td>
</tr>
</tbody>
</table>
TABLE 2
MINIMUM BEND RADIi FOR NON-SHIELDED/NON-ARMORED POWER CABLES

<table>
<thead>
<tr>
<th>Thickness of Conductors (inches)</th>
<th>Cable O.D. (inches)</th>
<th>Minimum Bending Ratios as a Multiple of Cable O.D.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0 to 1.000”</td>
<td>1.001” to 2.000”</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>0 to 0.169</td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td>0.169 and larger</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Values taken from ICEA S-95-658

TABLE 3
SUGGESTED MINIMUM BEND RADIi FOR PORTABLE JACKETED CABLES

<table>
<thead>
<tr>
<th>Cable Type</th>
<th>Minimum Bend Radius as a Multiple of Cable O.D.</th>
</tr>
</thead>
<tbody>
<tr>
<td>THERMOSET-JACKETED 0-5kV</td>
<td>6</td>
</tr>
<tr>
<td>THERMOSET-JACKETED 5+kV</td>
<td>8</td>
</tr>
<tr>
<td>CONTROL CABLE (7 conductor &amp; over)</td>
<td>20</td>
</tr>
<tr>
<td>FLAT-TWIN CABLES</td>
<td>USE MINOR O.D. TO DETERMINE MINIMUM BEND RADIUS</td>
</tr>
</tbody>
</table>

EXAMPLE – 1/0 AWG THHN, cable weight = 0.37 lbs./ft.

MAXIMUM PULLING TENSION, \( T_m \)
\[
T_m = 0.008 \times 1 \times 105600 = 846 \text{ lbs}
\]
**PULLING FROM POINT “H” (FEEDING IN FROM “A”)**

- Tension @ A = Zero
- Tension @ B (Ts₁) = 200 x .37 x .5 = 37 lbs
- Tension @ C (Tb₁) = 37 x 1.48 = 55 lbs
- Tension @ D (Ts₂) = 55 + [70 x .37 x .5] = 68 lbs
- Tension @ E (Tb₂) = 68 x 2.19 = 149 lbs
- Tension @ F (Ts₃) = 149 + [100 x .37 x .5] = 168 lbs
- Tension @ G (Tb₃) = 168 x 1.48 = 249 lbs
- Tension @ H (Ts₄) = 249 + [50 x .37 x .5] = 258 lbs

P = T / L

- P₇₋₈ = 55 / 10 = 5.5 lbs/ft
- P₈₋₉ = 149 / 10 = 14.9 lbs/ft
- P₉₋₁₀ = 249 / 10 = 24.9 lbs/ft
- P₁₀₋₁₁ = 160 / 10 = 16.0 lbs/ft

**PULLING FROM POINT “A” (FEEDING IN FROM “H”)**

- Tension @ H = Zero
- Tension @ G (Ts₁) = 50 x .37 x .5 = 9 lbs
- Tension @ F (Tb₁) = 9 x 1.48 = 13 lbs
- Tension @ E (Ts₂) = 13 + [100 x .37 x .5] = 32 lbs
- Tension @ D (Tb₂) = 32 x 2.19 = 70 lbs
- Tension @ C (Ts₃) = 70 + [70 x .37 x .5] = 83 lbs
- Tension @ B (Tb₃) = 83 x 1.48 = 123 lbs
- Tension @ A (Ts₄) = 123 + [200 x .37 x .5] = 160 lbs

P = T / L

- P₁₋₂ = 13 / 10 = 1.3 lbs/ft
- P₂₋₃ = 70 / 10 = 7 lbs/ft
- P₃₋₄ = 123 / 10 = 12.3 lbs/ft

P = T / L

Pulling from either direction will not result in the tension or sidewall pressure exceeding the limits (846 lbs & 300 lbs/ft). However, pulling from point “A” (feeding the cable from “H”) will result in approximately 40% less tension being placed on the cable. Therefore, it is most desirable to pull from point “A”.

**GENERAL GUIDELINES FOR CABLE PULLING**

**PREPARATION:**
1. Establish the direction of the pull based on safe pulling tensions and sidewall pressure calculations.
2. Select the correct size pulling eyes, bolts or grips.
3. Locate feeder reels, spools, etc. such that the tension at the feeding end is minimized.
4. Use pulling equipment that provides smooth speed control.
5. Choose a pulling rope that has the required tensile strength.
6. Prior to pulling, make sure the conduit is clean and free of dirt, water, scale, etc.
7. For long and/or heavy pulls, pre-lubricate the conduit and pull rope, particularly when using PVC.
8. Install a dynamometer.

**CABLE PULLING:**
1. Apply pulling lubricant (compound) liberally during the installation.
2. If possible, utilize two-way communication at both ends of the run, particularly on long runs.
3. Accelerate slowly and smoothly to a constant pulling speed.
4. Avoid letting the cable stop part way through the pull. The friction is greatly increased when re-starting a pull.

**AFTER PULLING:**
1. Seal the ends of the installed cable to prevent moisture from getting inside the cable.
2. High voltage testing is recommended both before and after the installation.
### Calculated Maximum Pulling Tensions

<table>
<thead>
<tr>
<th>Gauge Size</th>
<th>Single Conductor</th>
<th>Three Conductor</th>
<th>Four Conductor</th>
</tr>
</thead>
<tbody>
<tr>
<td>18</td>
<td>13</td>
<td>39</td>
<td>52</td>
</tr>
<tr>
<td>16</td>
<td>21</td>
<td>62</td>
<td>83</td>
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<tr>
<td>14</td>
<td>33</td>
<td>99</td>
<td>132</td>
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<tr>
<td>12</td>
<td>52</td>
<td>157</td>
<td>209</td>
</tr>
<tr>
<td>10</td>
<td>83</td>
<td>249</td>
<td>332</td>
</tr>
<tr>
<td>8</td>
<td>132</td>
<td>396</td>
<td>528</td>
</tr>
<tr>
<td>6</td>
<td>210</td>
<td>630</td>
<td>840</td>
</tr>
<tr>
<td>4</td>
<td>334</td>
<td>1,002</td>
<td>1,336</td>
</tr>
<tr>
<td>3</td>
<td>421</td>
<td>1,263</td>
<td>1,684</td>
</tr>
<tr>
<td>2</td>
<td>531</td>
<td>1,593</td>
<td>2,124</td>
</tr>
<tr>
<td>1</td>
<td>670</td>
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</tr>
<tr>
<td>1/0</td>
<td>846</td>
<td>2,539</td>
<td>3,386</td>
</tr>
<tr>
<td>2/0</td>
<td>1,065</td>
<td>3,194</td>
<td>4,259</td>
</tr>
<tr>
<td>3/0</td>
<td>1,342</td>
<td>4,027</td>
<td>5,370</td>
</tr>
<tr>
<td>4/0</td>
<td>1,693</td>
<td>5,078</td>
<td>6,771</td>
</tr>
<tr>
<td>250</td>
<td>2,000</td>
<td>6,000</td>
<td>8,000</td>
</tr>
<tr>
<td>300</td>
<td>2,400</td>
<td>7,200</td>
<td>9,600</td>
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<tr>
<td>350</td>
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<td>450</td>
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</tr>
<tr>
<td>750</td>
<td>6,000</td>
<td>18,000</td>
<td>24,000</td>
</tr>
<tr>
<td>1000</td>
<td>8,000</td>
<td>24,000</td>
<td>32,000</td>
</tr>
</tbody>
</table>

These values are the maximum tensions that can be placed on the cable or, if pulling more than one conductor at a time, group of cables. In some cases these values could exceed the limitations of the pulling equipment being used. The specifications set forth by the pulling equipment manufacturer (if available) should be compared to this value, and the lower of the two should govern.

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**EDITOR: STEVE ECKARDT**

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