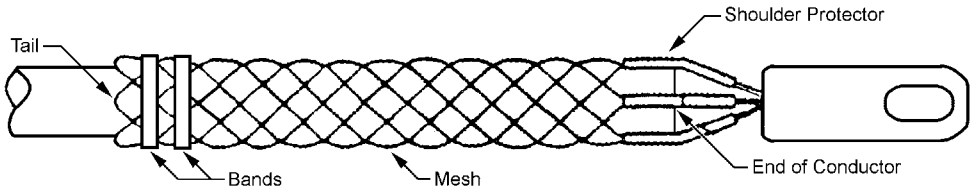
CABLE PULLING CALCULATIONS

Maximum Pulling Tensions for Installing Electrical Wire and Cables (Underground)

Cables of moderate size and length are pulled into ducts and conduit by using basket-type or Kellems grips. Pull cables using basket-style or Kellems grips on the cable insulation jacket unless it is necessary to pull directly on the conductor (see Case 2, below).



Kellems® K-Type Pulling Grip

One typically used, standard length Kellems K-Type pulling grip is designed to pull cables with diameters of 3.50 to 3.99 inches (Hubbell Catalog number 033-01-030). This grip is rated for 9,600 pounds work load and has an approximate breaking strength of 48,000 pounds. See the Table 5 on page 6 for other sizes of Kellems grips.

The following installation instructions accompany Kellems K-Type pulling grips (Hubbell):

1. Using black, vinyl electrical tape, tape the end of the conductor or cable bundle in two or three layers, tightly wrapped.
2. Assemble the grip so the cable end or cable bundle end is inserted up to the bend in the shoulder protectors (as shown above).
3. All slack should be ironed out of the mesh starting at the shoulder protectors and working back to the tail.
4. Two Punch-Lok® bands, each double wrapped, should be firmly attached approximately one inch and two inches from the grip's tail. Banding is required to insure maximum reliability and guard against accidental release.

Note: A Pengo Miller swivel is recommended for attachment to the grip's eye for release of torque during the pull.

Note: Do not run grips or swivel over bullwheels or winch drums while under tension.

Note: Do not use synthetic rope for pulling.

ORIGINATOR	STANDARDS COORDINATOR	STANDARDS SUPERVISOR	UNIT DIRECTOR
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The limits in the following examples must not be exceeded when pulling cable:

Case 1 – Pulling Grip, Head, or Eye Applied to Conductors

Aluminum: Maximum tension in pounds equals 0.006 times conductor size expressed in circular mils.

Copper: Maximum tension in pounds equals 0.008 times conductor size expressed in circular mils.

TABLE 1

Wire Size

AWG	Circular mils
6	26,250
2	66,370
1	83,690
2/0	105,530
4/0	211,600

Case 2 – Pulling Grip Applied to Insulation Jacket

Maximum tension shall not exceed 1,000 pounds. Case 1 limits shall not be exceeded.

Case 3 – Pulling Around a Bend

Maximum tension at a bend shall not exceed 500 times bend radius in feet. Cases 1 and 2 limits apply.

Case 4 – Pulling More Than One Conductor at a Time

Maximum tension shall not exceed the allowable sum of the individual tensions calculated above. Note that the maximum tension in this case may be much less than the individual sums, especially when pulling around a bend. Basket-type or Kellems grip tension is applied to the jacket, not the conductor.

FORMULAS FOR TENSION CALCULATIONS

Straight Sections – $T = L w f$

Where T = Pulling end tension

L = Section length

w = Cable weight per unit of length (see Table 4 on page 4)

f = Coefficient of friction 0.5 – Steel, clay

0.4 – PVC, transite

Curved Sections – $T_2 = T_1 e^{fa}$

Where T_1 = Feeding end tension

T_2 = Pulling end tension

e = 2.718

f = Coefficient of friction

a = Angle of bend, in radians (one radian = 57.3 degrees)

TABLE 2

CONDUCTOR APPLIED TENSION
Maximum Pulling Tensions, Grip, Head, or Eye

Cable Description	Maximum Tension	
	Pounds	Kilograms
3-1/C, 750 kcmil, 28kV Cu. and 1-4/0 Cu. Neut	19,692	8,932
3-1/C, 500 kcmil, 28kV Cu. and 1-4/0 Cu. Neut	13,692	6,210
3-2/C, 350 kcmil, 28 kV	6,300	2,863
3-2/C, #1 Al., 28 kV	1,500	684
2-2/C, #1 Al., 28 kV	1,000	456
1-2/C, #1 Al., 28 kV	500	228
500 kcmil, Quadruplex, 600V Al.	11,100	5,045
500 kcmil, Triplex, 600V Al.	8,100	3,674
350 kcmil, Quadruplex, 600V Al.	6,569	3,433
350 kcmil, Triplex, 600V Al.	5,469	2,480
#4/0, Quadruplex, 600V Al.	4,442	2,014
#4/0, Triplex, 600V Al.	3,172	1,439
3-#1, 600V Al.	1,500	684
#6, Duplex, 600V Al.	315	142

TABLE 3

VALUES FOR e^{fa}
Coefficients of Friction Are for Non-Lubricated Cables

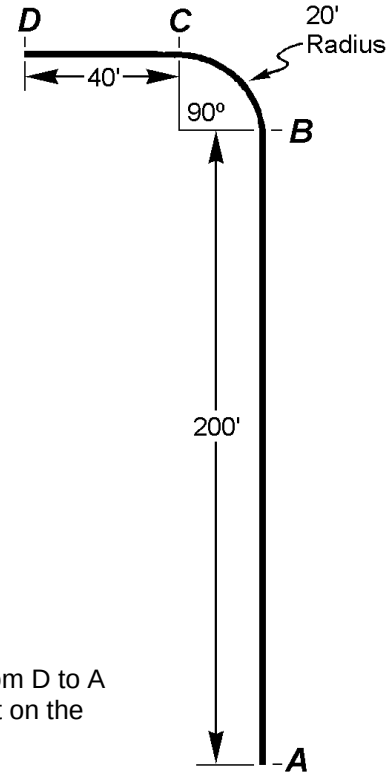
a (degrees)	15	30	45	60	75	90	105	120
e^{fa} (f = 0.5)	1.14	1.30	1.48	1.69	1.92	2.19	2.50	2.85
e^{fa} (f = 0.4)	1.11	1.25	1.37	1.52	1.69	1.87	2.08	2.31

Note that no calculations have included any effects of sloping runs. Generally, it is best to pull downhill and feed the end closest to any bends.

Cable must not stop part way through. Once a pull has begun, it must be completed.

Case 4 Example

A 3-conductor, 500 kcmil, copper, RINJ cable weighing 6.4 pounds per foot is to be pulled in the duct shown below. Find the tension pulling from A to D and from D to A. Must the cable be pulled with tension applied to the conductors, or will a basket or Kellems grip on the insulation work?



PULLING FROM A to D

Tension A to B	200 x 0.5 x 6.4	=	640 lbs
Tension A to C			640 x 2.20 = 1410 lbs
Tension C to D	40 x 0.5 x 6.4	=	128 lbs
Total Tension A to D			128 + 1410 = 1538 lbs

PULLING FROM D to A

Tension D to C	40 x 0.5 x 6.4	=	128 lbs
Tension D to B			128 x 2.20 = 282 lbs
Tension B to A	200 x 0.5 x 6.4	=	640 lbs
Total Tension D to A			640 + 282 = 922 lbs

Pulling on the conductors allows a maximum tension of:

0.008 x 500,000 x 3 = 12,000 lbs.

Pulling on the insulation with Kellems grips allows a maximum tension of 1000 lbs.

The maximum tension allowed at the bend is: 20 x 500 = 10,000 lbs.

Pulling from A to D requires that pulling be done with the conductors. Pulling from D to A allows a basket or Kellems grip on the insulation. The radius bend has no effect on the tension limits.

TABLE 4

See also Construction Guideline E6-1/NGE-70

CABLE WEIGHTS (w)		
Conductor	**Weight (lbs. per foot)**	**Weight (Kg per meter)**
500 kcmil Quad 600V Al.	2.233	3.323
500 kcmil Tx. 600V Al.	1.700	2.530
350 kcmil Quad 600V Al.	1.588	2.363
350 kcmil Tx. 600V Al.	1.266	1.884
#4/0 Quad 600V Al.	0.997	1.484
#4/0 Tx. 600V Al.	0.695	1.034

Case 5 – Pulling Up a Vertical Riser

The pulling tension is calculated the same as for a horizontal run except the total weight of the vertical portion of the cable is **ADDED** to the calculated tensions to determine the actual tension required to pull the cable.

Case 6 – Pulling Down a Vertical Riser

This pulling tension is calculated the same as above but the weight of the vertical portion to the cable is **SUBTRACTED** from the calculated tensions. If the run is long or the cable weight is high, the actual tension will be negative. This means a hold-back or brake will be required for permanent support for the cable.

Case 7 – Supports for Vertical Risers (Non-Armored)

All vertical cable runs require a permanent support. Short lengths (i.e., pole risers) may be supported with Kellems grips. Use the following process to calculate the maximum length (see example).

1. Select grip by wire size and note its breaking strength (See Table 5). Divide by 10 (Safety Factor). Divide this by the weight per foot of the cable times the length to find the **maximum** length the grip will support.
2. Use the conductor size in circular mils times $\pi/4$ times 24,000 (breaking strength of copper) and divide by a safety factor of 7 to determine the allowable supporting tension. (Multiply by three for three conductors.) Divide this result by the weight per foot of cable to find the **MAXIMUM** length of this cable that can be supported. Note the maximum allowable tension is 1000 lbs. for any cable. Divide this by the lbs/ft of cable weight to find this maximum. Use the smaller of the above 3 to find the safe maximum support length. **Note:** On all cable grip supports use two Punch Lok bands to secure the bottom of the grip and prevent slipping.

Case 7 Example

Cable:	#1 XLP 3cc cu 15 kV	3/0 XLP 3cc Cu 15 kV
Diameter over Jacket	2.01 to 2.25 inches	2.31 to 2.45 inches
Weight:	2.25 lbs/ft	3.37 lbs/ft
Grip No. (Kellems):	022-07-005	022-07-006
Breaking Lbs:	8050#	8050#
Grip Limit:	$\frac{8050}{(2.25)\ (10)} = 358$ feet	$\frac{8050}{(3.37)\ (10)} = 238$ feet
Cable Limit:	$\frac{(\pi/4)\ (83{,}690)\ (24{,}000)\ (3)}{(2.25)\ (7)\ (10^6)} = 300$ft	$\frac{(\pi/4)\ (167{,}800)\ (24{,}000)\ (3)}{(3.37)\ (7)\ (10^6)} = 402$ft
Maximum Cable Tension 1000# (see Case 2):	1000/2.25 = 444ft	1000/3.37 = 297ft
Maximum Length:	300 feet	238 feet

Case 8 – Supports for Armored Cable Risers

Armored cable is supported by its armor wires using an O.Z. fitting that is threaded on to the upper end of the vertical conduit run (No. FT5040, Stock No. 731142). This conduit **MUST** be rigid galvanized steel, encased in concrete, to provide support.

Case 8 Example

Cable:	2/0, XLP, 3cc, Cu, 15 kV, Armored
Armor:	40 Strands, 165 mils diameter
Weight:	6.95 lbs/ft
Armor Strength:	50,000 lbs/square inch

$$\text{Allowable Length} = \frac{(\pi/4)\ (\text{Armor Diameter})^2\ (\text{Number of Strands})\ (50{,}000)}{(7)\ (6.95)}$$

$$= \frac{(\pi/4)(0.165)^2\ (40)(50{,}000)}{(7)\ (6.95)} = 879 \text{ feet MAXIMUM}$$

References:
Okonite Company: Bulletin #EHB-98, Page 40-46
Okonite Company: “Installation Practices foe Cable Raceway Systems,” 1998
Okonite Company: “Cable Installation Design Limits”
IEEE Guide for Installation Methods for Generating Station Cables, IEEE Std 1185-1994
Construction Guideline E6-1/NGE-70

TABLE 5

Kellems® K-Type Pulling Grip, Standard Length

Hubbell Cat. No.	Cable Diameter Range, Inches	Work Load, Lbs.*	Approx. Breaking Strength, Lbs.
033-01-011	0.50 – 0.61	1,120	5,600
033-01-012	0.62 – 0.74	1,360	6,800
033-01-024	0.75 – 0.99	1,920	9,600
033-01-025	1.00 – 1.49	3,280	16,400
033-01-026	1.50 – 1.99	3,280	16,400
033-01-027	2.00 – 2.49	5,440	27,200
033-01-019	2.50 – 2.99	6,600	33,000
033-01-029	3.00 – 3.49	8,200	41,000
033-01-030	3.50 – 3.99	9,600	48,000
033-01-031	4.00 – 4.49	9,600	48,000
033-01-039	4.50 – 4.99	9,600	48,000
033-01-047	5.00 – 5.99	9,600	48,000
033-01-045	6.00 – 6.99	9,600	48,000

* Safety factor of 5 is per Kellems technical information.