Appendix N: Raychem® RHW and Raychem MC Pull Calculations

Introduction

When cables are pulled into raceways, cable tray, or open runs, they are likely to be subjected to physical stresses. The prime cause of physical stresses is the friction of the cable against the supporting and contact surfaces. If the supporting surface is straight and horizontal, this friction is caused by the weight of the cable in contact with this surface. If the surface is not horizontal, the weight of the cable also affects the pulling load, but is dependent upon the angle of inclination. This angle may add to or lessen the total pulling force, depending upon whether the pull is up or down.

When a cable is pulled around a bend, it is in contact against the inner arc of curvature of the bend. If any substantial amount of pulling force has been developed in the cable, the friction load due to the pressure at this point will greatly surpass that due solely to the weight of the cable. Thus, bends in the run increase the pulling load significantly.

Consider the following factors prior to installation to minimize the possibility of cable damage:

- Tensile strength of the conductors
- Method of attachment to the cable
- Sidewall pressure
- Estimated pulling tension
- Force required pulling the cable off the reel
- Coefficient of friction between the cable and adjacent surfaces
- Percentage of raceway area filled
- Bend radius

Each of these items is discussed in the following sections starting with tension calculations. Two tension calculations are required for each cable installation. The first calculation is the "Maximum Allowable Pulling Tension" for the particular cable to be installed. This value is dependent upon the method of attachment to the cable, the allowable sidewall bearing pressure, and the construction of the cable.

Secondly, knowing the weight of the cable and the details of the installation configuration, the "Estimated Pulling Tension" that may occur during installation can be calculated.

Maximum Allowable Pulling Tension

The maximum allowable pulling tension on the cable(s) is the lesser of the maximum allowable tension based on conductor strength (Tc), the maximum allowable tension based on sidewall pressure (Tp), and the limit based on the attachment method to the cable.

Conductor Tensile Strength

It is assumed that the method used to attach the cable to the pull rope transfers all forces to the conductor. The tensile strength of the conductor then becomes a limiting factor for the force that can be applied. This tension is determined by the following formula:

		Tc = K x F x kcmilT
Tc	=	Maximum allowable tension based on conductor tensile strength (pounds) See Table N.1.
K	=	Factor based on material strength; 8 for annealed copper
F	=	Factor to account for possible unequal tension distribution
kcmilT	=	The sum of the circular mil area of all conductors in thousand circular mils (kcmil)

The tension distribution factor (F) is 1 for a single or multiconductor cable, 0.8 when pulling more than one cable of equal conductor size, and 0.6 when pulling multiple cables of unequal conductor size. Ground conductors and armor should not be considered in these calculations.

When all conductors are the same size, the equation becomes:

		Tc = K x F x kcmil x N
kcmil	=	Circular mil area of one conductor in thousand circular mils (kcmil)
N	=	Total number of conductors pulled

Table N.1 Maximum tension based on copper conductor tensile strength limit

Conductor Size (AWG or Kcmil)	Equivalent Circular Mil Area (Kcmil)	One Conductor Tc (Pounds)	Three Conductor Tc (Pounds)	Four Conductor Tc (Pounds)
14	4.11	–	99	132
12	6.53	–	157	209
10	10.38	–	249	332
8	16.51	–	396	528
6	26.24	–	630	840
4	41.74	–	1,002	1,336
3	52.62	–	1,263	1,684
2	66.36	–	1,593	2,124
1	83.69	–	2,009	2,678
1/0	105.6	845	2,534	3,379
2/0	133.1	1,065	3,194	4,259
3/0	167.8	1,342	4,027	5,370
4/0	211.6	1,693	5,078	6,771
250	250	2,000	6,000	8,000*
350	350	2,800	8,400*	11,200*
500	500	4,000	12,000*	16,000*
750	750	6,000	18,000*	–

* Do not exceed cable attachment limit

Cable Attachment Limit

The maximum allowable tension is also limited by the device used to connect the cable to the pull rope. When pulling by gripping the conductors with a pulling eye or bolt, the maximum tension is usually limited to 10,000 pounds. This is dependent upon the pulling eye or bolt used and the method of application. The manufacturer's recommendations should be followed. When the insulated conductors are gripped with a properly sized and applied basket weave grip, the limit is 2000 pounds per grip.

Sidewall Pressure

When a cable is pulled around a bend, radial force is exerted on the insulation, armor, and jacket as the cable is pressed against the inner arc of the bend. This is referred to as sidewall pressure and is expressed as pounds per foot of radius.

Sidewall pressure is important in cable pulling calculations for two reasons. The first is its increase in the total pulling tension due to greater pressure between the cable and the bend. The second is its crushing effect upon the cable insulation and the possibility of permanent damage to the insulation and/or the cable armor if excessive sidewall pressures are permitted. Sidewall pressure is usually the determining factor when establishing maximum allowable pulling tension for large conductor sizes.

The maximum sidewall pressure for Raychem MC and RHW is normally 300 pounds per foot of radius. Tp is the maximum allowable cable tension based on the sidewall pressure limit.

The formula for maximum allowable cable tension for a single cable based on sidewall pressure is as follows:

		Tp = SWP x R
Tp	=	Maximum allowable tension which will not exceed the sidewall pressure limit in pounds* (see Table N.2)
SWP	=	Sidewall pressure limit in pounds per foot
R	=	Radius of bend in feet

* This value may be more limiting than the maximum tension Tc based on conductor strength. The lower value of the two governs.

Table N.2 Maximum tension (Tp) based on SWP limits for various sheave diameters

Sheave Inner Diameter (Inches)	Maximum Tension Based On SWP Limit: Tp (Pounds)	
	SWP = 400 Pounds/Foot	SWP = 300 Pounds/Foot
12	200	150
15	250	188
18	300	225
20	333	250
25	417	313
28	467	350
30	500	375
35	583	438
40	667	500
42	700	525
45	750	563
48	800	600
50	833	625
55	917	688
60	1,000	750
65	1,083	813

When pulling multiple cables together, additional forces may be encountered based on cable geometry. For these cases contact Tyco Thermal Controls Technical Support at (800) 545-6258 for additional information.

Estimated Pulling Tension

The installer should calculate estimated pulling tensions for all cables to be pulled, to ensure that the maximum allowable values established in the previous sections are not exceeded. The principle formulas used for these calculations are as follows:

The estimated pulling tension of one cable in a straight section of raceway may be calculated from the following formula that does not consider changes in elevation:

		$T = L \times W \times K$
T	=	Estimated pulling tension in pounds
L	=	Length of installation in feet
W	=	Weight of cable in pounds per foot
K	=	Coefficient of friction

Coefficient of Friction

The values used for coefficient of friction can vary from 0.1 to 0.8 depending upon many factors including the type of installation, raceway material, the type of cable jacket, and type of lubricant. For well lubricated conduit runs, the coefficient of friction can be as low as 0.3, but a value of 0.5 is generally used in calculations. For tray installations over well lubricated, properly installed sheaves, a value of 0.1 may be used to account for the tension increase as a result of cable sag between sheaves.

The estimated pulling tension of a cable in an inclined section of raceway may be calculated from the following simplified formula, where prior tension is the tension at the beginning of the incline and the multiplying factor (M) is tabulated below.

		T = L x W x M + (prior tension)
M	=	Multiplying factor for various values of coefficient of friction and angles of inclination as shown

Note, short downward bends may be neglected. For riser applications, contact Tyco Thermal Controls Technical Support at (800) 545-6258.

Table N.3 Multiplying factors (M)

	Angle from horizontal in degrees					
K	**15**	**30**	**45**	**60**	**75**	**90**
0.1	0.36	0.59	0.78	0.92	0.99	1.00
0.2	0.45	0.67	0.85	0.97	1.02	1.00
0.3	0.55	0.76	0.92	1.02	1.04	1.00
0.4	0.65	0.85	0.99	1.07	1.07	1.00
0.5	0.74	0.93	1.06	1.12	1.10	1.00

To calculate the tension out of a bend, the following formula may be used:

		T = T1 x F
T	=	Tension coming out of the bend in pounds
T1	=	Accumulated tension going into the bend in pounds
F	=	Friction factor for various values of coefficient of friction and bends as shown in Table N.4

Table N.4 Friction factors (F)

	Angle of bend in degrees					
K	**15**	**30**	**45**	**60**	**75**	**90**
0.1	1.03	1.05	1.08	1.11	1.14	1.17
0.2	1.05	1.11	1.17	1.23	1.30	1.37
0.3	1.08	1.17	1.27	1.37	1.48	1.60
0.4	1.11	1.23	1.37	1.52	1.69	1.87
0.5	1.14	1.30	1.48	1.69	1.92	2.19

Note: For large cables where bends close to the minimum bend radius are contemplated, additional force may be required to bend the cable.

Estimated Sidewall Pressure

The sidewall pressure acting upon a single cable at a bend may be estimated from the following equation:

		P = T/R
P	=	Sidewall pressure on the cable in pounds per foot
T	=	Estimated tension out of the bend in pounds
R	=	Radius of the bend in feet

Back Tension

The force required to pull a cable off the reel is generally referred to as back tension. This is normally taken to be zero, since the cable is fed off the reel. This value may be negative, and light braking may be applied to control the flow of cable to avoid feeding at too great a rate. For downward pulls, considerable braking may be required.

Minimum Bending Radius

In establishing the minimum allowable bend radius for a cable it must be considered that two distinct cases occur. There are bends which occur during pulling (in which case the cable is under tension and is subsequently straightened after leaving the bend) and a bend made as part of the permanent training in position (in which case the cable is not under tension and is usually only bent once). Obviously, for pulling cable under tension, the radius should be as large as practical to minimize the danger of flattening the armor or other damage occurring. For permanent training, when no subsequent straightening or re-bending is required, the minimum allowable radius can be smaller.

Guidelines for the minimum allowable radius of bend have been established for these conditions:

1. The ***minimum training radius***, is used where no tension is applied to the cable (i.e., permanent training), and
2. The ***minimum pulling radius***, is used where tension is applied to the cable.

Table N.5 Minimum pulling and training radii

Cable Type	Cable Diameter Range (Inches)	Minimum Training Radius	Minimum Pulling Radius
Raychem MC	All sizes	7 X	10 X
Cores	1.000 and less	4 X	8 X
Cores	1.000 to 2.000	5 X	10 X

The minimum bending radii listed in ICEA standards and the NEC/CEC are for permanent training. These values along with recommendations for pulling radii are provided in Table N.5 for both Raychem MC and RHW cables. The bending radius values for RHW may be used for the individual conductors of the MC Cable after the armor and inner jacket are removed and the conductors are separated. For cases not shown, please call Tyco Thermal Controls Technical Support at (800) 545-6258.

Worldwide Headquarters
Tyco Thermal Controls
307 Constitution Drive
Menlo Park, CA 94025-1164
USA
Tel: (800) 545-6258
Tel: (650) 216-1526
Fax: (800) 527-5703
Fax: (650) 474-7711
info@tycothermal.com
www.tycothermal.com

Canada
Tyco Thermal Controls
250 West St.
Trenton, Ontario
Canada K8V 5S2
Tel: (800) 545-6258
Fax: (800) 527-5703

Latin America
Tyco Thermal Controls
7433 Harwin Drive
Houston, TX 77036
United States
Tel: (713) 868-4800
Tel: (713) 735-8645
Fax: (713) 868-2333

Europe, Middle East, Africa (EMEA)
Tyco Thermal Controls
Romeinse Straat 14
3001 Leuven
België / Belgique
Tel: +32 16 213 511
Fax: +32 16 213 603

Asia Pacific
Tyco Thermal Controls
20F, Innovation Building,
1009 Yi Shan Rd,
Shanghai 200233,
P.R.China
Tel: +86 21 2412 1688
Fax: +86 21 5426 2937 / 5426 3167

tyco
Thermal Controls

Important: *All information, including illustrations, is believed to be reliable. Users, however, should independently evaluate the suitability of each product for their particular application. Tyco Thermal Controls makes no warranties as to the accuracy or completeness of the information, and disclaims any liability regarding its use. Tyco Thermal Controls' only obligations are those in the Tyco Thermal Controls Standard Terms and Conditions of Sale for this product, and in no case will Tyco Thermal Controls or its distributors be liable for any incidental, indirect, or consequential damages arising from the sale, resale, use, or misuse of the product. Specifications are subject to change without notice. In addition, Tyco Thermal Controls reserves the right to make changes—without notification to Buyer—to processing or materials that do not affect compliance with any applicable specification.*