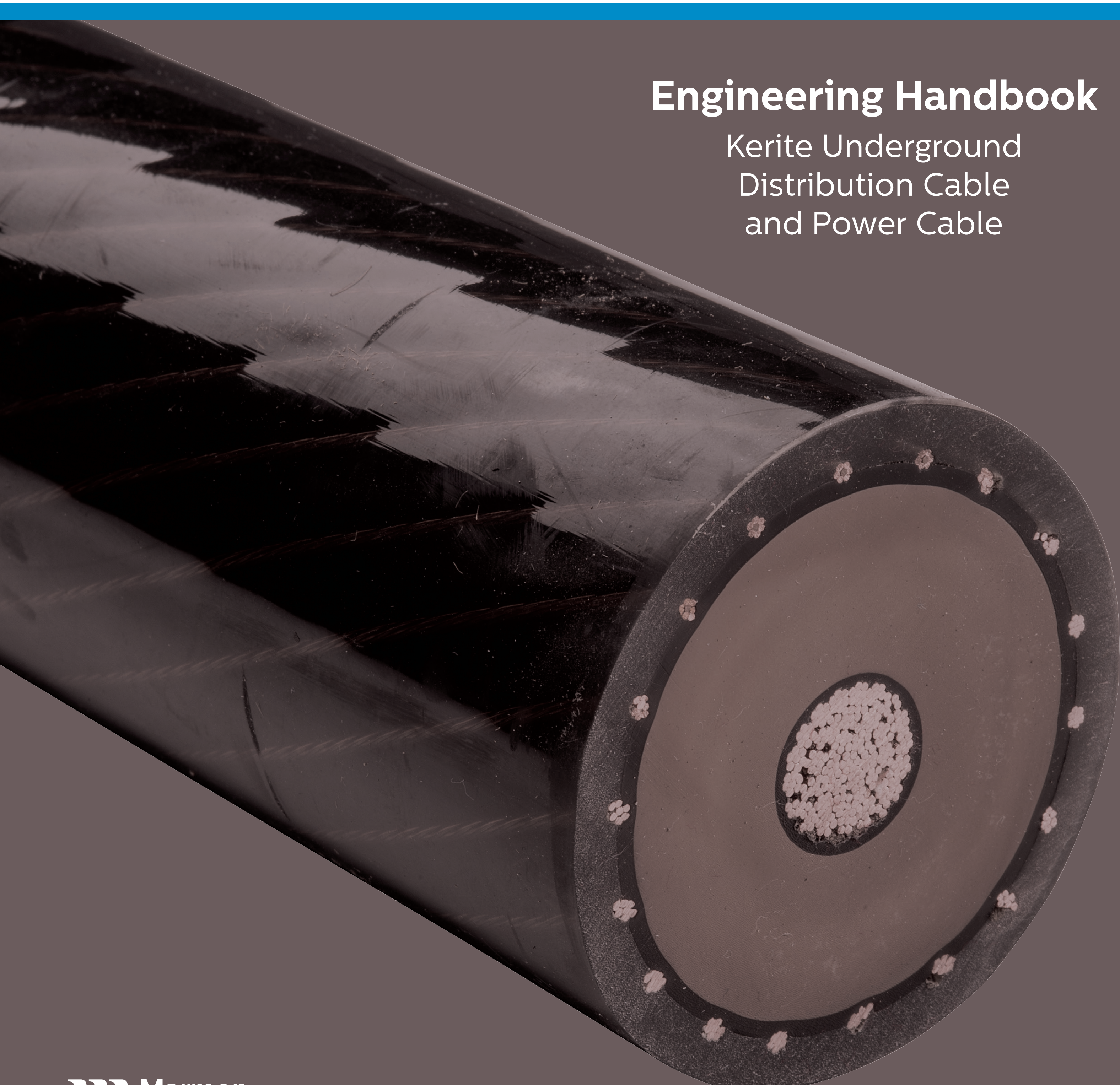
POWER CABLE

Hendrix® kerite®

Engineering Handbook

Kerite Underground Distribution Cable and Power Cable



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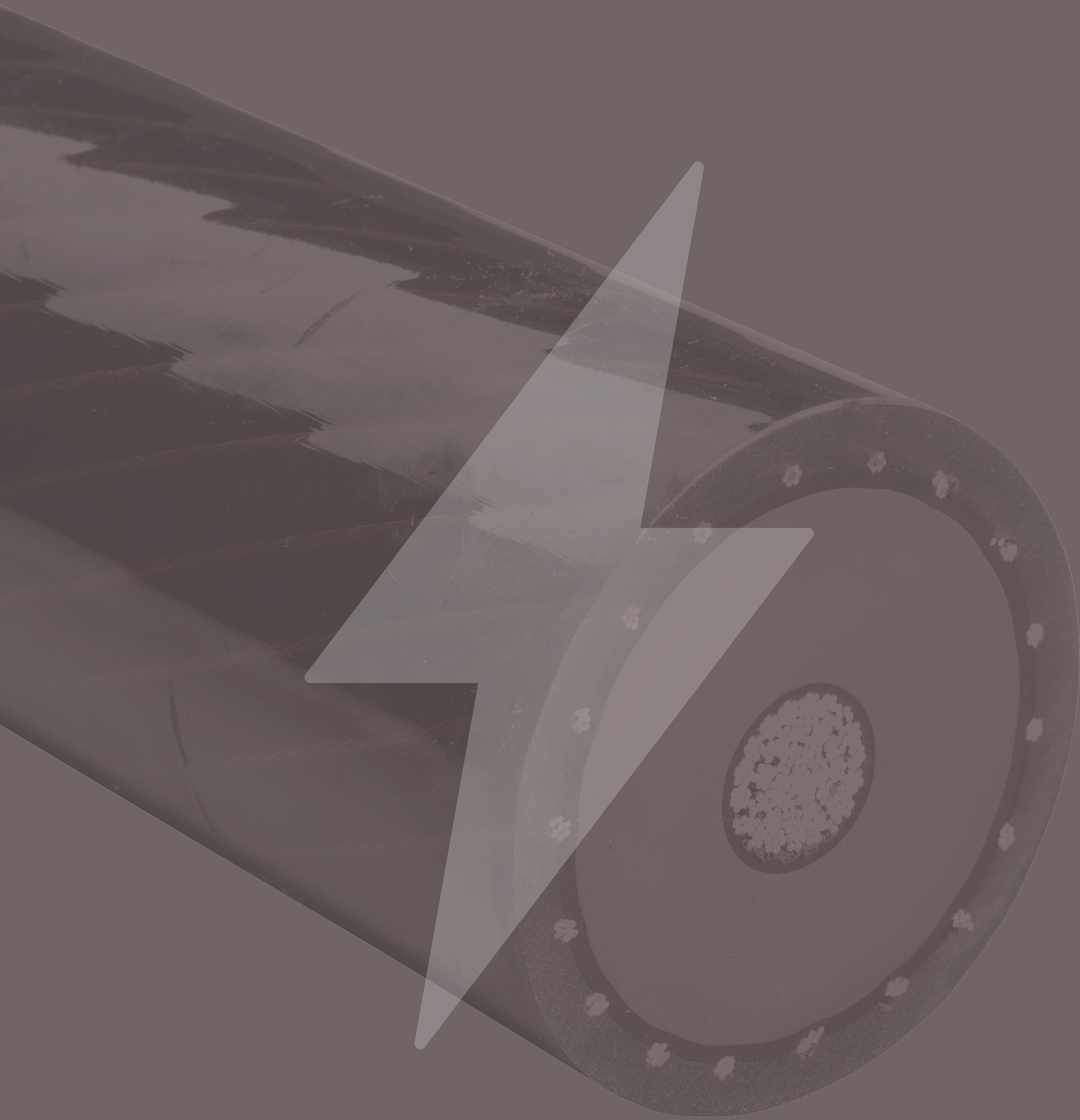

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Introduction

The Kerite Cable Engineering Handbook is a guide for the proper design and installation of medium and high voltage cable by distribution and transmission engineers at utilities and consulting engineering practices. Section One from Page 3 through Page 8 has cable design and application data. Section Two covers cable installation from Page 9 through Page 18.

Section One – Cable Design and Application

Section One explains cable design based on requirements for power and amperage ratings, cable dimensions, and fault current carrying capability. The selection of the appropriate cable for a particular application is essential so the cable gives excellent service over the life of the installation. Consideration must be given to both electrical and mechanical requirements.

The primary electrical requirement is the selection of an insulation with outstanding electrical characteristics when manufactured and retention of those characteristics throughout the life of the cable installation. Vital insulation characteristics include discharge resistance, transient attenuation, superior wet performance and long service life. Kerite's DR-EPR™ insulation design is based on decades of field experience as well as extensive testing. A minimum cable life of forty years is typical when the cable is properly installed. When Kerite cable is installed and tested by Kerite Cable Services, longer warranties are available.

Section Two – Cable Installation

The cable's ultimate life is optimized by taking proper care during installation. Section Two covers all topics for correctly installing Kerite cable, from selecting conduit and duct sizes, pulling tensions, minimum bending radius, proper cable support and field testing the installed cable.

Conductor Selection

For most applications the selection of copper versus aluminum is an economic decision. As conductor sizes increase the difference in initial cost favors aluminum. The diameter of the aluminum cable becomes increasingly larger than copper for similar ampacity because of aluminum's lower conductivity. Larger diameter cables may require larger ducts, conduits, and racks/trays potentially offsetting initial cable cost savings.

The selection of a conductor size is mainly dependent on the amount of current it must carry and the installation type. The following table of electrical formulas can be used for determining amperage in a particular circuit.

Electrical Formulas

To Find	Direct Current	Alternating Current	
		Single-Phase	Three-Phase
Amperes (Given Horsepower)	$\frac{HP \times 1000}{E \times Eff}$	$\frac{HP \times 746}{E \times Eff \times PF}$	$\frac{HP \times 746}{1.73 \times E \times Eff \times PF}$
Amperes (Given Kilowatts)	$\frac{KW \times 1000}{E}$	$\frac{KW \times 1000}{E \times PF}$	$\frac{KW \times 1000}{1.73 \times E \times PF}$
Amperes (Given Kilovolts)	$\frac{KVA \times 1000}{E}$	$\frac{KVA \times 1000}{E}$	$\frac{KVA \times 1000}{1.73 \times E \times PF}$
Kilowatts	$\frac{I \times E}{1000}$	$\frac{I \times E \times PF}{1000}$	$\frac{I \times E \times 1.73 \times PF}{1000}$
Kilovolt Amperes	$\frac{I \times E}{1000}$	$\frac{I \times E}{1000}$	$\frac{I \times E \times 1.73}{1000}$
Horsepower (Output)	$\frac{I \times E \times Eff}{746}$	$\frac{I \times E \times Eff \times PF}{746}$	$\frac{I \times E \times 1.73 \times Eff \times PF}{746}$

Where:
I = Amperes
E = Phase-to-Phase Volts
Eff = Efficiency Expressed as a Decimal (85% = 0.85),
PF = Power Factor Expressed as a Decimal (95% = 0.95)

KW = Kilowatts
KVA = Kilovolt Amperes
HP = Horsepower

Conductor Selection

Conductor Size (AWG/kcmil)	Standing (No.xMils)	Diameter (inch)	Circular Mil Area (kcmil)	Area (mm²)	Aluminum Conductors Weight (lbs/kft)	Aluminum Conductors DC Resistance @ 25°C (Ω/kft)	Copper Conductors Weight (lbs/kft)	Copper Conductors DC Resistance @ 25°C (Ω/kft)
	Class B Stranded Conductors							
6	7 x 61.2	0.178	26.2	13.3	25	0.6740	81	0.4109
4	7 x 77.2	0.225	41.7	21.1	39	0.4242	129	0.2580
2	7 x 97.4	0.283	66.4	33.6	62	0.2661	205	0.1621
1	19 x 66.4	0.313	83.7	42.4	78	0.2111	258	0.1285
1/0	19 x 74.5	0.352	105.6	53.5	99	0.1672	326	0.1020
2/0	19 x 83.7	0.395	133.1	67.4	125	0.1326	411	0.0811
4/0	19 x 105.5	0.498	211.6	107	199	0.0836	653	0.0510
250	37 x 82.2	0.558	250	127	234	0.0708	772	0.0431
350	37 x 97.3	0.661	350	177	328	0.0505	1081	0.0308
500	37 x 116.2	0.789	500	253	469	0.0354	1544	0.0216
750	61 x 110.9	0.968	750	380	703	0.0236	2316	0.0144
1000	61 x 128.0	1.117	1000	507	937	0.0176	3088	0.0108
1250	91 x 117.2	1.250	1250	633	1172	0.0141	3859	0.0086
1500	91 x 128.4	1.370	1500	760	1408	0.0118	4631	0.0072
1750	127 x 117.4	1.480	1750	887	1643	0.0101	5403	0.0062
2000	127 x 125.5	1.583	2000	1013	1877	0.0088	6175	0.0054
	Solid Conductors							
2	–	0.259	66.4	33.6	61.1	0.261	201	0.1594
1	–	0.289	83.7	42.4	77.1	0.207	253	0.1263
1/0	–	0.325	105.6	53.5	97.2	0.164	320	0.1002
2/0	–	0.365	133.1	67.5	122.5	0.130	403	0.0795
	Compact Conductors							
250	–	0.520	250	127	235	0.0707	772	0.0431
350	–	0.616	350	177	329	0.0505	1080	0.0308
500	–	0.736	500	253	469	0.0354	1542	0.0216
750	–	0.908	750	380	704	0.0236	2316	0.0144
1000	–	1.060	1000	507	939	0.0177	3086	0.0108

Short Circuits

On power systems with particularly high KVA capacity, the available short circuit current must be considered in the selection of the conductor size and the cable shield design. The graphs on the following pages show the maximum currents Kerite cables and shields can carry for various periods of time without degradation to the insulation system and jackets.

Fault Currents

When calculating the time a conductor can carry a particular fault current, or determining the fault current which can be carried for a specific time, it is conservatively assumed that the total heat generated is stored in the conductor, for the brief duration of the short circuit, without any dissipation of heat to the environment.

Either the allowable fault current (I), the allowable duration of time (t), or the cross sectional area (A) of metal necessary to sustain a particular fault can be computed when two of the three variables are known.

$$I = \sqrt{\frac{k \times A^2}{t}}$$

A = Total cross-sectional area of concentric neutral, tape shield, or phase conductor (circular mils)
I = Fault current (amperes)
t = Duration of fault (seconds)
k = Constant for conductor or shield material with fixed initial and final temperatures

The k value in the above equation can be obtained in the following table:

	Shield Material		Conductor Material			
	Copper	Cupro-Nickel	Copper (HV)	Aluminum (HV)	Copper (MV)	Aluminum (MV)
k Value	6.258×10^{-3}	0.560×10^{-3}	5.215×10^{-3}	2.341×10^{-3}	4.627×10^{-3}	2.077×10^{-3}
Starting Temp	65°C		90°C		105°C	
Max Final Temp	250°C					

The first graph on the following page shows the time a conductor can carry a particular fault current. To determine the fault current for safe operation of a tape shield, the cross-sectional area (A) in the above equation for fault current for safe operation of a conductor should be replaced as follows:

$$A = 4 \times T_T \times D_S \times \sqrt{\frac{50}{100 - P_{LAP}}}$$

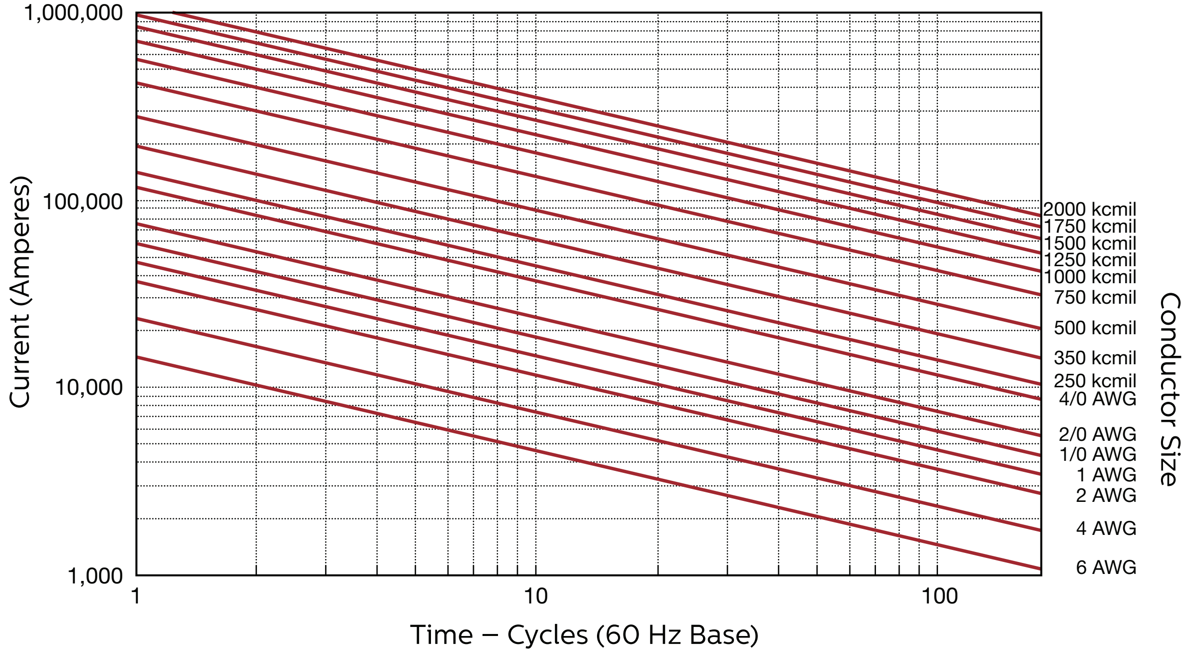
A = Cross-sectional area of tape (including lap conduction)
T_T = Thickness of the tape (mils)
D_S = Diameter of the shield (mils)
P_{LAP} = Percentage of tape overlap (percent)

	Area for Round Concentrics	Area for Flat Straps
14	4110	4110
12	6530	6530
10	10380	10380
9	13090	N/A

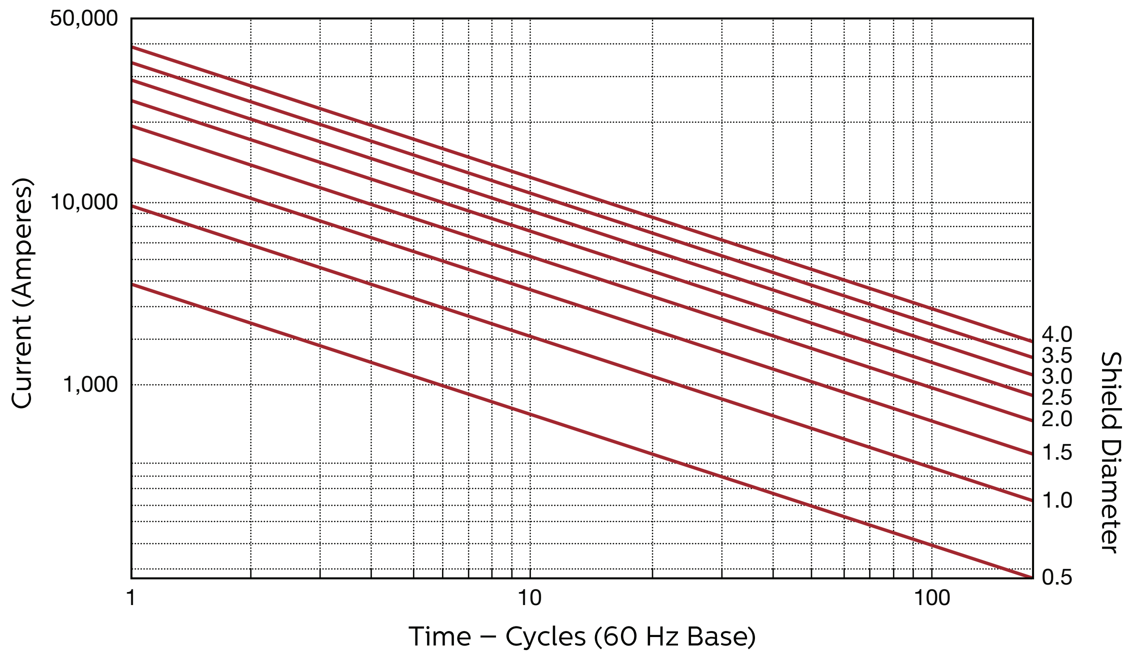
The second graph on the following page shows the time a tape shield can carry a particular fault current. For fusing (tape reaching its melting temperature), the same graph may be used as follows:

1. To find the time to fusing for a particular current, enter chart with current, find safe time and multiply by 4.93 to get time to fusing.
2. To find the fusing current for a particular time, divide the time by 4.93 and enter the chart with this figure to find the fusing current.

Short Circuit Curvers for Copper Conductors
For Aluminum Multiply Time Scale by 0.45



Time vs. Fault Current for Safe Operation
5 mil Copper Tape



Charging Current

When magnitude of charging current (where IC represents the current in each cable of the three phase circuit) in a cable is needed, the following formula can be used:

$$I_C = \frac{L \times C \times E_N}{2{,}650 \times 10^6}$$

I_C = Charging current in milliamps (milliamps/circuit length)
L = Circuit length (in feet)
C = Cable capacitance (picofarads/ft)
E_N = Voltage to Neutral (volts)

This equation is specific to a 60 hertz frequency. The capacitance (C) values needed in the calculation can be obtained using the following table.

Conductor Size (AWG/kcmil)	5kV	15kV		25kV		35kV	
	Insulation Thickness						
	115 Mil	175 Mil	220 Mil	260 Mil	220 Mil	345 Mil	420 Mil
6	66	–	–	–	–	–	–
4	76	–	–	–	–	–	–
2	89	66	57	–	57	–	–
1	97	72	62	55	62	–	–
1/0	105	77	66	59	66	–	–
2/0	114	84	71	63	71	45	40
4/0	136	98	83	74	83	51	45
250	146	105	89	79	89	55	48
350	167	120	101	88	101	61	53
500	193	137	115	101	115	69	60
750	232	164	137	119	137	81	70
1000	262	184	153	133	153	90	77
1250	244	199	168	146	168	98	84
1500	264	216	181	157	181	105	90
1750	263	234	193	167	193	112	95
2000	300	254	204	176	204	118	100

	46kV	69kV	115kV	138kV
	Insulation Thickness			
	445 Mil Insulation	650 Mil Insulation	800 Mil Insulation	850 Mil Insulation
4/0	58	36	–	–
250	61	38	–	–
350	69	42	–	–
500	78	47	41	40
750	91	54	47	45
1000	101	59	52	50
1250	111	64	56	53
1500	119	69	59	57
1750	127	73	62	60
2000	133	76	65	63

Sheath Losses

The common practice of multipoint grounding of cable shields in three phase systems at multiple locations results in induced voltages and circulating currents, depending on the load currents and shield impedance.

With individually jacketed cables these currents can be eliminated by interrupting the shield and grounding each section at only one point. When using single point grounding, it is recommended that the voltage rise at the opposite end from ground of each section be limited to approximately 120 volts, under normal operating conditions. Circulating sheath currents can also be reduced by cross bonding the sheaths to cancel out the induced voltages that generate these currents (for more information on sheath currents and cross bonding, refer to IEEE Standard 575).

Voltage Rise in Open Sheaths

Eliminating the problem of circulating sheath currents with grounding at one end results in a voltage being induced in the sheath. This voltage rise is proportional to the distance from the ground point. This voltage rise should be limited to approximately 120 volts under normal operating conditions.

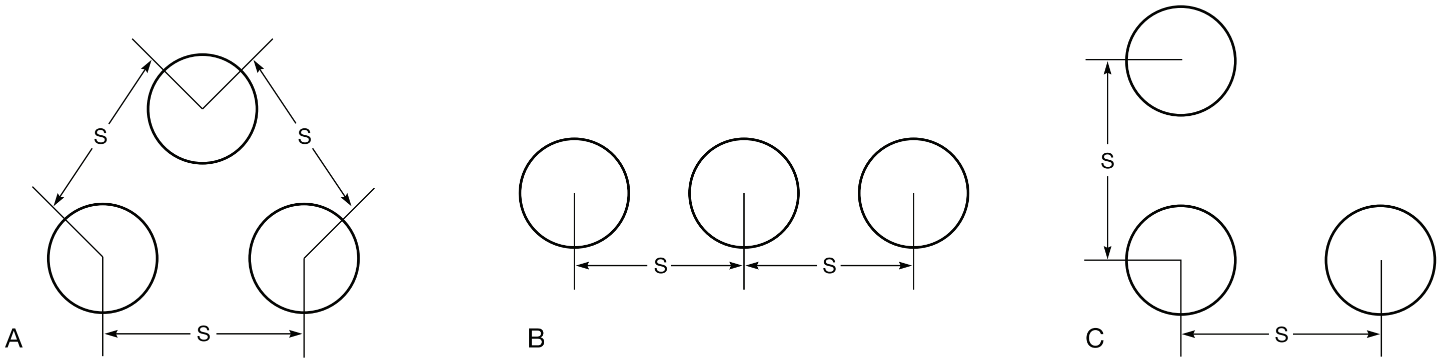
The following equation may be used for approximating (±10%) the voltage rise on an open circuited sheath.

$$V_S = 0.053 \times \log\left(\frac{2 \times D_M}{D_S}\right) \times I_C$$

V_S = Voltage rise in an open sheath (volts/kilofoot)
D_M = Geometric mean distance between cables (inches)
D_S = Diameter of the tape shield (inches)
I_C = Current in the phase conductors (amperes)

To obtain the value of D_M use the following table by matching the configuration (1/C = one cable and 3-1/C = 3 cables paralleled or twisted) and the installation setup (A, B or C).

	Cable Configuration	
	1/C	3-1/C
A	DM = S	DM = Cable O.D.
B	DM = 1.26 x S	
C	DM = 1.12 x S	



Sequence Impedance

Three phase non-symmetrical faults involve positive, negative and zero sequence impedances. The positive and negative sequence impedances of a transformer are identical. The zero sequence impedance is dependent upon the path available for the flow of zero sequence current and the balancing ampere turns available within the transformer. The following table can be used for obtaining such impedance for single conductor cables horizontally spaced 8" on center.

Cond. Size (AWG/kcmil)	Positive/ Negative	Zero Sequence	Positive/ Negative	Zero Sequence	Positive/ Negative	Zero Sequence
	5kV		15kV		25kV	
6	0.519 + j 0.115	0.803 + j 0.501	–	–	–	–
4	0.329 + j 0.110	0.619 + j 0.479	–	–	–	–
2	0.209 + j 0.104	0.506 + j 0.453	0.210 + j 0.104	0.518 + j 0.399	–	–
1	0.167 + j 0.100	0.466 + j 0.437	0.168 + j 0.100	0.477 + j 0.384	0.168 + j 0.100	0.478 + j 0.360
1/0	0.134 + j 0.096	0.436 + j 0.421	0.134 + j 0.097	0.444 + j 0.370	0.134 + j 0.097	0.444 + j 0.347
2/0	0.108 + j 0.095	0.414 + j 0.404	0.108 + j 0.095	0.418 + j 0.355	0.108 + j 0.095	0.417 + j 0.333
4/0	0.070 + j 0.090	0.380 + j 0.337	0.071 + j 0.089	0.379 + j 0.323	0.071 + j 0.089	0.376 + j 0.296
250	0.061 + j 0.067	0.371 + j 0.349	0.061 + j 0.067	0.367 + j 0.302	0.061 + j 0.067	0.363 + j 0.284
350	0.046 + j 0.063	0.354 + j 0.319	0.046 + j 0.063	0.347 + j 0.277	0.046 + j 0.063	0.343 + j 0.280
500	0.034 + j 0.079	0.338 + j 0.281	0.034 + j 0.079	0.329 + j 0.248	0.035 + j 0.079	0.323 + j 0.234
750	0.026 + j 0.074	0.319 + j 0.240	0.026 + j 0.074	0.308 + j 0.213	0.026 + j 0.074	0.300 + j 0.196
1000	0.022 + j 0.071	0.305 + j 0.213	0.022 + j 0.071	0.291 + j 0.187	0.022 + j 0.071	0.285 + j 0.177
1250	0.019 + j 0.070	0.290 + j 0.189	0.019 + j 0.070	0.279 + j 0.171	0.019 + j 0.070	0.273 + j 0.162
1500	0.018 + j 0.066	0.281 + j 0.171	0.018 + j 0.066	0.269 + j 0.155	0.018 + j 0.066	0.263 + j 0.148
1750	0.017 + j 0.064	0.272 + j 0.159	0.017 + j 0.064	0.260 + j 0.144	0.017 + j 0.064	0.255 + j 0.137
2000	0.016 + j 0.063	0.284 + j 0.148	0.016 + j 0.062	0.253 + j 0.135	0.016 + j 0.062	0.247 + j 0.129
	35kV		46kV		69kV	
1/0	0.135 + j 0.097	0.438 + j 0.298	–	–	–	–
2/0	0.109 + j 0.095	0.400 + j 0.286	–	–	–	–
4/0	0.071 + j 0.089	0.366 + j 0.261	0.071 + j 0.089	0.357 + j 0.237	0.071 + j 0.089	0.337 + j 0.199
250	0.061 + j 0.067	0.353 + j 0.248	0.061 + j 0.067	0.344 + j 0.226	0.062 + j 0.067	0.324 + j 0.191
350	0.046 + j 0.063	0.331 + j 0.229	0.046 + j 0.063	0.321 + j 0.209	0.046 + j 0.063	0.301 + j 0.177
500	0.035 + j 0.079	0.309 + j 0.203	0.035 + j 0.079	0.301 + j 0.189	0.035 + j 0.079	0.281 + j 0.181
750	0.026 + j 0.074	0.286 + j 0.175	0.026 + j 0.074	0.278 + j 0.164	0.026 + j 0.074	0.259 + j 0.141
1000	0.022 + j 0.071	0.271 + j 0.157	0.022 + j 0.071	0.263 + j 0.148	0.022 + j 0.070	0.245 + j 0.129
1250	0.019 + j 0.070	0.259 + j 0.145	0.020 + j 0.070	0.251 + j 0.137	0.020 + j 0.070	0.234 + j 0.121
1500	0.018 + j 0.066	0.250 + j 0.133	0.018 + j 0.066	0.243 + j 0.125	0.018 + j 0.066	0.226 + j 0.111
1750	0.017 + j 0.064	0.242 + j 0.124	0.017 + j 0.064	0.235 + j 0.117	0.017 + j 0.064	0.219 + j 0.104
2000	0.016 + j 0.062	0.235 + j 0.117	0.016 + j 0.062	0.228 + j 0.111	0.016 + j 0.062	0.213 + j 0.099
	115kV		138kV			
500	0.035 + j 0.079	0.248 + j 0.127	0.035 + j 0.078	0.231 + j 0.114		
750	0.026 + j 0.074	0.228 + j 0.113	0.026 + j 0.074	0.212 + j 0.102		
1000	0.022 + j 0.070	0.216 + j 0.105	0.022 + j 0.070	0.201 + j 0.095		
1250	0.019 + j 0.070	0.206 + j 0.100	0.019 + j 0.070	0.192 + j 0.091		
1500	0.018 + j 0.066	0.199 + j 0.092	0.018 + j 0.066	0.186 + j 0.084		
1750	0.017 + j 0.063	0.192 + j 0.087	0.016 + j 0.064	0.181 + j 0.079		
2000	0.016 + j 0.060	0.186 + j 0.082	0.015 + j 0.060	0.178 + j 0.075		

SECTION TWO – CABLE INSTALLATION

Conduit and Duct Sizes

It is recommended that conduit sizes be governed by the National Electrical Code. Unless strict adherence to NEC is specified, larger conduit sizes may be used with a minimum 1/2" clearance between the conduit inside diameter and the circumscribing diameter of the installed cable(s).

Formulas for computing the minimum conduit inside diameter (D in inches) using an individual cable outer diameter (d in inches) based on the above rules are shown below.

Number of Cables Per Conduit	National Electric Code		Standard Utility Method for Conduits 2'+
	Max Percent Occupancy	Calculation Formula	Calculation Formula
One	53%	D = 1.374 x d	D = 0.5 + d
Two	31%	D = 2.540 x d	D = 0.5 + (d x 2)
Three	40%	D = 2.739 x d	D = 0.5 + (d x 2.155)

The approximate maximum allowable diameters cable diameters for standard conduit and duct sizes are in the table below.

Conduit Trade Size	Internal Diameter (Inches)	Conduit Area (Inches^2)	Per NEC		Per ½" Clearance		3 in Parallel (AVOID)
			Number of Conductors				
			1	3	1	3	
In Steel or PVC Conduit							
½"	0.602	0.29	0.44	0.22	–	–	0.19-0.22
¾"	0.804	0.51	0.59	0.29	–	–	0.26-0.29
1"	1.029	0.83	0.75	0.38	–	–	0.33-0.37
1¼"	1.360	1.45	0.99	0.50	–	–	0.44-0.49
1½"	1.590	1.99	1.16	0.58	–	–	0.51-0.57
2"	2.047	3.29	1.49	0.75	1.55	0.72	0.61-0.73
2½"	2.445	4.70	1.75	0.89	1.95	0.90	0.79-0.87
3"	3.042	7.27	2.21	1.11	2.54	1.18	0.98-1.09
3½"	3.521	9.74	2.56	1.29	3.02	1.40	1.14-1.26
4"	3.998	12.55	2.91	1.46	3.50	1.62	1.29-1.43
5"	5.016	19.76	3.65	1.83	4.52	2.10	1.62-1.79
6"	6.031	25.57	4.39	2.20	5.53	2.57	1.95-2.15
In Cement Conduit or Duct							
2"	1.9	2.84	1.36	0.89	1.40	0.65	0.61-0.68
3"	2.9	6.61	2.11	1.06	2.40	1s.11	0.94-1.04
3½"	3.4	9.08	2.48	1.24	2.90	1.35	1.10-1.21
4"	3.9	11.95	2.84	1.42	3.40	1.58	1.26-1.39
4½"	4.4	15.21	3.20	1.61	3.90	1.81	1.42-1.57
5"	4.9	18.86	3.57	1.79	4.40	2.04	1.58-1.75
6"	5.9	27.34	4.30	2.15	5.40	2.51	1.90-2.11

When installing three parallel cables in the same conduit jamming can occur. To minimize potential jamming the ratio of conduit inner diameter to one cable outer diameter should not be in the range of 2.8 to 3.1. Jamming does not apply to twisted assemblies in normal installations, but should be considered when multiple bends occur in the same conduit or long, difficult pulls are anticipated.

Pulling Tensions

This information is a guide to installing cables in ducts or conduits and is based in part on industry studies. Where experience has justified it, we have included our own figures.

Two tension calculations are required for each cable installation. First must be calculated the MAXIMUM ALLOWABLE TENSION for the particular cable that is to be installed. This value is dependent upon the method of attaching to the cable, the allowable sidewall bearing pressure and the construction of the cable.

Second, knowing the weight of the cable and the details of the conduit run, the ESTIMATED PULLING TENSION that can occur during installation is calculated and compared with the MAXIMUM ALLOWABLE TENSION.

Maximum Allowable Tension

The actual tension will be governed by the lowest of the following calculated tensions, where applicable.

1. Based on pull by conductor (for both annealed copper and hard drawn aluminum conductors):

$$T_M = 0.008 \times n \times CM$$

T_M = Maximum allowable tension (pounds)
n = Number of conductors in cable
CM = Circular mil area of each conductor

2. Based on pull by Kellems grip applied over shielded, jacketed cable: 1,000 pounds
3. Based on pull by Kellems grip applied on the insulation after removing the shielding: 3,000 pounds
4. Based on maximum allowable side bearing pressure when pulling around a conduit bend for the diameter (D in inches) of an individual cable and radius (R in feet) of the bend is given by:

1/C	3-1/C Twisted	3-1/C Paralleled
$T_M = 450 \times D \times R$	$T_M = 225 \times D \times R$	$T_M = 675 \times D \times R$

Estimated Pulling Tension

Pulling tensions anticipated for an installation can be calculated using cable size, weight, number, length of run and angle of bends. Usually only approximations can be made, based on following simple assumptions providing safe guideline limits. The following two equations will provide the expected tension for straight and bending pulls.

1. Straight horizontal run:

$$T = W \times L \times n \times CF$$

T = Tension (pounds)
W = Cable weight (pounds/feet)
L = Length of run (feet)
n = Number of cables
CF = Coefficient of friction

The coefficient of friction will vary between 0.3 for well lubricated cables pulled into new, smooth wall conduits to 0.5 for lubricated cables pulled into rough or dirty conduits or ducts.

2. Pulls around bends:

Multiplying factors, shown below, must be used to estimate the increase in tension due to pulling around bends. The tension at the point just ahead of the bend is multiplied by the appropriate factor from the table below, the product being the tension that exists immediately past the bend. This factor must be applied in the calculation of the estimated pulling tension at each point where the cable encounters a bend as it is pulled through the duct or conduit run.

Coefficient of Friction	Angle of Bend					
	15°	30°	45°	60°	75°	90°
0.30	1.06	1.17	1.27	1.37	1.48	1.60
0.40	1.11	1.23	1.37	1.52	1.69	1.67
0.50	1.14	1.30	1.48	1.69	1.92	2.19

Pulling Lubricants

There are literally dozens of pulling compounds on the market which meet the criterion of lubricity. However, many of these contain chemicals which, with time and at operating temperatures, will attack many of the commonly used jacket and insulation materials. The effect of the attack may be the degradation of either physical or electrical properties, or both. Physically, the attacked material may become swollen, embrittled or suffer reduction in tensile strength, elongation and thermal-environmental stress-crack resistance. Electrically, the insulation resistance may fall to unacceptable levels, or the dielectric losses may increase to prohibitive levels. Consult pulling compound manufacturer before use to address such concerns.

Selection of a pulling compound is based on the following three factors.

1. The basic function of the lubricant is to reduce the coefficient of friction between the cable and duct surfaces, with different quality levels of lubricant giving better coefficients and allowing higher pulling tensions. Thus, selection should be appropriate for expected pulling tensions.
2. The temperature rating of the lubricant must be selected appropriately depending on the installation conditions.
3. A lubricant with an appropriate viscosity should be chosen for the application.

The following ready–to–use pulling compounds may be used with all Kerite cables.

Manufacturer	Product		
	Name	Grade	Min Temperature
Polywater Corp.	A (Clear Liquid)	Summer	20°F (-5°C)
Polywater Corp.	G (Clear Gel)	Summer	40°F (5°C)
Polywater Corp.	J (High Performance)	Summer	20°F (-5°C)
Polywater Corp.	WJ (High Performance/Winter)	Winter	-20°F (-30°C)
Polywater Corp.	DynaBlue (Heavy Duty)	Summer	20°F (-5°C)
Plymouth Rubber Co.	No. 45 Cable Pulling Lubricant	Summer	32°F (0°C)
Mac Products, Inc.	MacLube No. CA-51	Winter	0°F (-18°C)
Minerallac Electric Co.	Minerallac H-2B	Summer	32°F (0°C)
Generam Machine Products Co.	No. 7437-PC	Winter	0°F (-18°C)
Cable Associates, Inc	Gel-Lube 7/5	Winter	0°F (-18°C)
American Cable Colloid Co.	Slip X-300	Winter	0°F (-18°C)
Ideal Industries, Inc.	Aqua-Gel II	Summer	32°F (0°C)
Ideal Industries, Inc.	CW	Winter	-25°F (-32°C)

The Kerite Company has no control over the manufacture or use of these compounds. It assumes no liability for their use.

Minimum Bending Radius

The minimum bending radius for training or positioning of installed cable should not be less than 12 times the outer diameter of the cable. Due to limitation of side bearing pressure, which significantly increases pulling tensions, it is recommended that larger radius bends be used.

Continuous Support of Cables (Vertical)

For installed cables, certain mechanical and physical restrictions must be taken into consideration. Formulas for calculating the maximum weights (W_{MAX} in pounds) under various installation conditions follow.

Support by Conductor

The maximum weight to be supported by the cable conductor is:

$$W_{MAX} = K \times CM$$

K = 0.004 for soft copper
K = 0.003 for aluminum (1350 H19)
CM = Circular mil area of cable involved

The above is based on limiting the working load of soft copper to about 5,000 pounds/inch^2 and the aluminum to about 4,000 pounds/inch^2, for a safety factor of about seven.

Support by Bend (at Top or Bottom)

The maximum weight to be supported by a cable on a bend is related to the radius of the bend (R in inches), the conductor O.D. (D in inches) and its configuration as follows:

1. For a 1/C cable in a conduit of diameter no greater than 2 times the cable O.D.
   $W_{MAX} = 25 \times R \times D$
2. For 3 1/C cables in parallel (with 2 cables on bend surface and third above)
   $W_{MAX} = 37.5 \times R \times D$
3. For 3 1/C cables twisted
   $W_{MAX} = 10 \times R \times D$

(Note: Support by conductor maximums may be more limiting).

Support by Tray or Other Flat Surface Bends

Use one-half of the values for the appropriate conduit bends, except for 3 1/C cables in parallel. For 3 1/C cables in parallel use one-half the value of a single conductor cable in a conduit. This assures that all 3 1/C cables are lying on bend surface, not stacked on other cables.

Care must be taken that the cable is secured in the horizontal portion immediately before the supporting bend to prevent ratcheting and build-up of tensions in the cable on load cycling.

The above formulas are based on limiting pressure on the cable surface to 50 pounds/inch^2, assuming contact width of $^1/_2$ cable diameter when in conduit and $^1/_4$ cable diameter when on flat bend. Assumed factor of 0.4 to account for intermittent contact on three conductor twisted cables. The pressure in pounds/inch^2 on a single conductor cable is:

$$P = \frac{Tension}{R \times W}$$

P = Pressure on single conductor cable (pounds/inch^2)
R = Radius of bend (inches)
W = Contact width (inches)

Support by Cable in Grips

Continuous support by grips requires transfer of lifting to the load bearing components of the cable (conductors, concentric wires or armor wires) without physical damage to the insulation, shielding tapes, outer jacket, etc. Adequate force transfer is dependent on many variables, the most important of which is a sufficiently high coefficient of friction at all interfaces between the grip mesh and the load bearing components of the cable. If any such interface has a coefficient of friction less than 0.25, the weight of the cable supported by a conventional Kellems grip alone shall be limited to 50 pounds. If the cable support is partially horizontal (as in a cable tray at the upper end of a vertical run), the limit is determined by the use of equations under “Support by Bend (Top or Bottom)”, plus the 50 pounds limit for intervals between grips. Typical slippery interfaces include:

1. Metal tapes and conducting fabric tape.
2. Metal tapes and bedding tapes.
3. Any interface involving a polyester tape.

For cables with acceptable coefficients of friction, the allowable loading per grip must be less than the maximum load based on the strength of the conductors or other load bearing components, and also less than the maximum load based on the ability of the cable to resist compressive forces developed by the grip.

When more than one grip is used in a vertical support arrangement, it is imperative that each grip carry only its own share of the load. The next higher grip is then applied, the cable lowered into it, and so on until the uppermost grip is applied last of all.

Maximum Load Based on Ability to Resist Compressive Forces

Compressive forces caused by the grip result in pressure under the grip wires which tend to make them penetrate into the cable. The magnitude of this pressure is related to many variables including the load on the grip, size, and geometry of the wires. The effects of "bridging" of the grip over the concentrics must also be considered. The following formulas allow a solution for W_{MAX}:

$$W_{MAX} = \frac{140 \times d \times D \times P_{MAX}}{D_{LIST}}$$

If the Cable has an outer finish of concentric wires and $\frac{\pi \times D}{n} \leq 0.75^{*}$ then:

$$W_{MAX} = \frac{P_{MAX} \times 6.4 \times n \times d \times \sqrt{(L_{LAY})^2 + (\pi \times D)^2}}{D_{LIST} = L_{LAY}}$$

In the above formulas:

d = Diameter of concentric wires or width of flat concentrics (inches)
D = The diameter of one cable (inches)
D_{LIST} = The smallest rated cable diameter for which the grip is designed (inches)
L_{LAY} = Lay length of concentric wires (inches)
n = Number of concentric wires on one cable
P_{MAX} = The maximum pressure under the grip wires or concentric wires
(= 200 pounds/inch^2 for most finishes excluding those previously referenced)
W_{MAX} = Maximum allowable total weight per grip (pounds)

* If > 0.75, then treat as a cable without concentric wires

Support by Cable in Block Clamps

Maximum support to be expected per block clamp is 50 pounds. Bearing surface must equal or be greater than the cable diameter but not less than 1 1/2".

Support by Messenger

We do not recommend that self-supporting cables be hung vertically by the messenger. However, there are messenger grip assemblies available which may be used. Spacing of grips is to be governed by the previous paragraph, "Support by Cables in Grips".

Continuous Support of Cables (Horizontal)

Support by Cable on Porcelain or Block Cup Supports

The maximum distance between supports (L in feet) is given by the following:

$$L = \frac{12.5 \times S \times D}{W}$$

S = Length of support (inches)
D = Diameter of cable (inches)
W = Weight of cable (pounds/foot)

The above is based on limiting the cable pressure to 25 pounds/inch^2 (to account for the cable resting on the edges of the support) and assuming a contact width of $^1/_2$ the cable diameter. More frequent supports may be desirable, depending on the installation from an appearance viewpoint.

Support by Cables in Trays

The maximum weight (per foot of cable tray) that can be installed on top of a bottom cable resting against cable tray rungs is calculated as follows:

1. For a 12" rung spacing: $W_{MAX} = 25 \times R \times D$
2. For a 9" rung spacing: $W_{MAX} = 37.5 \times R \times D$
3. For a solid bottom tray: $W_{MAX} = 10 \times R \times D$

Where: R = Radius of bend (inches)
D = Conductor O.D. (inches)

The above is based on limiting the cable pressure to 50 pounds/inch^2 and assuming a contact width of $^1/_4$ cable diameter.

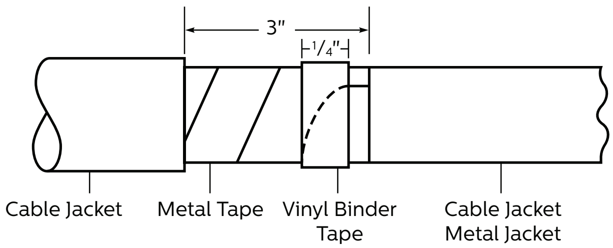
Terminating & Splicing

Commercially available pre-molded, cold or heat-shrink splices and terminations may be used on Kerite cables. Our evaluation of many devices show, when they are installed per the manufacturer's instructions, they do not affect the cable's performance. However, Kerite has no control over the design, manufacture or use of these splices and terminations. We cannot assume any liability for their performance.

Methods for Stripping of Jackets:

1. All jackets should be stripped using the "tear-strip" technique. This consists of making two parallel scoring cuts between $^1/_4$" and 1" apart followed by ripping out the strip of jacket between, and then removing the remainder. The depth of the cut necessary is approximately half-way through the jacket.
2. The preferred method of making the scoring cuts with any kind of knife is to hold the knife straight in toward the cable, contrary to the method used in stripping braids and tapes.
3. Similar scoring and ripping may also be used circumferentially at the terminus of the stripped portion.
4. The circumferential cutting of thin plastic layers either over tapes or the Kerite insulation can be neatly accomplished by using a narrow strip of abrasive cloth or any heavy string or twine as a wrap-around abrading tool. The heat generated by a see-saw motion of the string will cut a neat furrow in the plastic without loosening its ends or risk of cutting the underlying material.
5. For the stripping of braid, it is recommended that a light score be made on the braid followed by subsequent light strokes with the knife held flat to the cable surface.

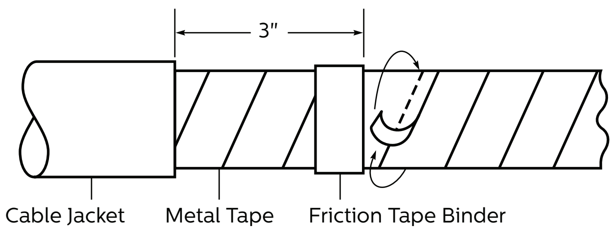
Methods for Stripping of Metal Tapes



1. Scissors Technique at Overlapped Tape End

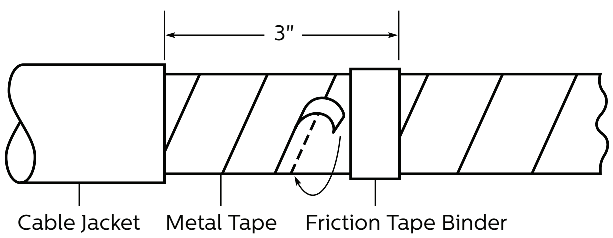
Circumferentially mark the intended end point of the metal tape. Unwrap from the cable ends one to two turns beyond the mark. Hold the tape out from cable and cut along mark with scissors. Round off sharp point. Rewrap and hold in place with a turn of vinyl tape set $^{1}/_{4}$" back from edge.

Note: The scissors-cut technique is the preferred method of stripping metal tape at the overlapped end (the tape will unwrap from the end of the cable).



2. Knife Technique at Underlapped Tape End

At the end with underlapped tape, apply friction tape binder at the intended end point of the metal tape as shown in sketch. Score through outer layer of metal tape along edge of friction binder only in that area where metal tape is lapped to prevent cutting into underlying insulation. Lift corner tab and tear around circumference guided by friction binder, remove binder and tamp down the tape edge to lay flat. To prevent metal tape from accidentally loosening over a long length of cable having no outer covering apply a friction tape binder 3" beyond end point of metal tape before starting stripping procedures. This method is recommended at the underlapped metal tape end or if no scissors are available.



3. Knife Technique at Overlapped Tape End

At end with overlapped tape, apply binder so edge of friction tape is at the intended end point of the metal tape as shown in sketch. Cut at lap as above. Lift tab and tear metal tape around the circumference along edge of binder. Fold or cut off sharp point of tape and rewrap onto cable. Hold in place with a turn of vinyl tape set $^{1}/_{4}$" back from end. Remove friction binder and unwanted metal tape, then tamp torn edge to lay flat.

Connectors

It is recommended that compression connectors be used whenever possible in Kerite splices. They are simple to install, reliable, and reproducible (not subject to wide variation in technique).

Although solder joints have not shown evidence of electrical problems on any Kerite cables to date, it is conceivable that poor technique could overheat the cable at the joints. Consequently, because of the wide variation in soldering techniques possible in the field, we have recommended the use of compression type connectors.

In those situations where solder connections are used, the following procedure is recommended to insure a higher degree of confidence in the joints.

1. The insulation should not be tapered prior to the soldering operation.
2. A layer of cotton tape should be applied over the insulation binding it down firmly to the conductor approximately 5" back from the splice on either side of the connector. This will improve the heat transfer from the conductor to the insulation, and shorten the cooling time.
3. Heat resistant tape or cord should be applied between the connector edge and the insulation edge to prevent the molten solder from directly contacting the insulation.

Ground Methods and Materials

Tape Shields

Based upon field observation, and experience at our Proving Grounds, we have concluded that permanent grounds are best assured by tack soldering to the cable metal tape. Whether a clamp, strap, or flexible braid is used, it is best to tack solder to the metal tape in order to assure good connections since temperature cycling may loosen the mechanical grip and corrosion may reduce the contact surfaces of the metals.

If clamps are used, care is required that stiff materials or large forces do not cause pinching or other deformation of the cable insulation or disruption of the metal tape during normal expansion due to current loading. Clamps or heavy straps should be preformed around a scrap piece of cable before final application.

When using braid of light strap, tack solder the end to the metal tape, wrap 1 1/4" turns around the cable, tack solder again to the previous turn and the cable metal tape, then train the lead away from the cable. When attaching the ground in this manner, an accidental pull on the ground lead will not likely rip the metal tape.

Check the solderability on a length of scrap cable before starting. We recommend the use of rosin core solder or stearine flux. DO NOT USE prepared paste or acid core solder. Use a soldering iron. DO NOT USE A TORCH on any metal taped cable, as it may seriously damage the cable.

The ground leads should have short circuit ampacity equal to or greater than the cable metal tape. Heavy tinned copper wire braid or 1/2" x .030" tinned copper strap are most satisfactory. Tinsel or light copper wire braids do not have adequate ampacity and are subject to flexing fatigue and corrosion.

Where vibration is expected, special sleeves and heavy leads may be required; refer such problems to a Kerite representative for special recommendations.

Concentric Neutrals

Concentric neutral cables are easy to work with. The individual wires should simply be pulled back and twisted together.
The resulting wire can then be lugged to the ground conductor or point.

Sealing

For jacketed cables with shields grounded in outdoor or submersible locations, adequate seals should be made to prevent water entering under the jacket. Sealing putty formed around the ground leads with an over wrap of several layers of insulating tape makes an effective seal. When insulating tape is used over metal braid, the braid must be solder filled to effect a good seal. Outdoors, ground leads should be brought from the bottom side of horizontal cables and downward to form a drip loop on vertical cables. Friction tape binders to secure the lead to the cable help prevent disturbing the seal if the lead is pulled.

Grounding Practices

Grounds should be applied to cable sheaths at terminals, in accordance with the appropriate terminal instructions. Possible exceptions where only one ground is used include:

- Very short lengths.
- Locations (such as pole top) where exposed grounds are not allowed.
- Situations where a sheath interruption is recommended to avoid sheath circulating current.

Where cables fan out from conduit to terminals, and grounds are to be made to the conduit, the connections to cable sheaths may be made close to the terminals, and insulated or bare grounding leads brought down along the cable to the conduit in an open helix around the cable, or secured with rings of tape.

In long runs, cable may be grounded additionally between terminals according to the user’s normal practice. Where more than one ground is applied to a cable sheath, there may be sheath currents and consequent losses. Sometimes these losses are great enough to affect the rating of the cable, in which case sheath interrupting joints may be considered.

For more information on shield currents and cross bonding, refer to IEEE Standard 575.

Movement, Storage and Handling

Movement of Reels of Cable

When moving reels of cable they must not be dropped from any height, particularly from trucks or other transporting equipment. The movement of reels of cable by lifting and rolling can be done as follows:

1. Lifting Method #1: Crane or boom type equipment: insert shaft (heavy rod or pipe) through reel hubs and lift with slings on shaft, preferably utilizing spreader or yoke to reduce or avoid sling pressure against reel flange.
2. Lifting Method #2: Forklift type of equipment may be used to move smaller, narrower width reels. Fork lines should be placed so that lift pressure is on reel flange (not on cable) and must reach all the way across reels so lift is against both reel flanges.
3. Rolling Reels of Cable: Wood reels should be rolled in the direction indicated by arrows painted on reel flanges. Surfaces over which the reels are to be rolled should be firm, clear of debris, and also clear of protruding stones, humps, etc., which might damage the cable if the reel straddled them.

Storage of Reels of Cable

The following three points cover storage of the reels of cable. These include ensuring the cable ends are properly sealed, the cable is covered and the storage area is suitable.

1. Cable Seals: The cable ends are sealed prior to shipment. If factory seals are removed or damaged, new tape seals must be applied to prevent moisture entry into cable: strip cable finishes back 2", down to insulation and apply four layers of an insulating tape criss-cross over the cable end and carry back at least 4" onto cable outer finish. Then, add a containing cover of two layers of vinyl electrical tape completely over the end seal.
2. Cable Covering: Whenever possible, the factory applied lagging (protective cover) should be left in place. Additional covering such as tarpaulin, plastic sheeting, etc., may be used if cable is to be stored for long periods outdoors or in excessively dirty, dusty areas.
3. Storage Area: Store reels of cable on a firm surface, paved if possible, or on planking to prevent settling into soft ground. The storage area should have good drainage and the reels should be upright. Fencing or other barriers should also be used to protect cables and reels against damage by vehicles or other equipment moving about in the storage area.

Handling During Installation

1. Cable Temperature: Cold-induced stiffness, which can make the pulling-in of cable more difficult, must be considered along with radius and number of bends in the proposed installation run. Most cables can be safely handled without damage if not subjected to temperature lower than 10°F (25°F for PVC jacketed cables) in the 24 hour period proceeding pulling and bending. If it is anticipated that storage temperatures will be below this temperature, arrangements should be made to move the reel to a warmer area. If no indoor warming area is available a plastic sheeting-covered shelter may be constructed and heated. The reel should be at a temperature of at least 60°F (16°C) for 24 hours to ensure total warm-up. Apply pulling eyes or grips while cable is in the warming area prior to movement outdoors or uncovering.
2. Pulling Tension: Always determine the safe maximum pulling tension of the cable and compare this to the tension required for the particular run configuration being considered.
3. Cable Ducts: Always determine that ducts and conduits are clear of obstructions and properly sized. After swabbing or brushing, a sizing mandrel should be pulled through to ensure the cables will fit without jamming.
4. Pulling Grips/Eyes and Cable Seals: Attachment to the cable can be accomplished with any of the commercially available devices (Kellems grips, Greenlee wire grip, etc.) or by field or factory-made pulling eyes. The choice may depend on the tension requirements, especially when long runs or runs with several bends are to be made. The cable ends must be positively sealed to prevent moisture entry, and resealed after pulling (as seals may be disrupted during the pulling operations) if the cables are not going to be spliced or terminated shortly after. This is especially important for underground runs where cable ends may be left in manholes which are subject to flooding.
5. Directly Buried Backfill: For this installation a layer of approximately 3" to 4" of selected backfill (thermal sand or sand-clay-gravel mixture containing some small stones no greater in size than 1/4" to 1/2" across at their largest dimension) should be placed at the bottom of the open trench prior to installing cables and above the cable surface after installation. Care should be taken not to abrade or impact the cable surface(s) as it leaves the pay-off equipment and enters the trench, where it should be laid without twisting or kinking it. Over-bending the cable to a point less than the recommended minimum bending radius should also be avoided. Cables can become easily over-bent at guide points such as small sheaves or rollers located on the cable laying equipment.
6. Cable Plow: When installing cables in the earth using a cable plow, make sure the bottom of the plow blade has a large enough bore and radius of curvature to easily accommodate the cable(s). During the installation, the plow blade should never be raised suddenly nor the equipment operated in a reverse direction for any distance, as either of these actions can severely damage the cable.

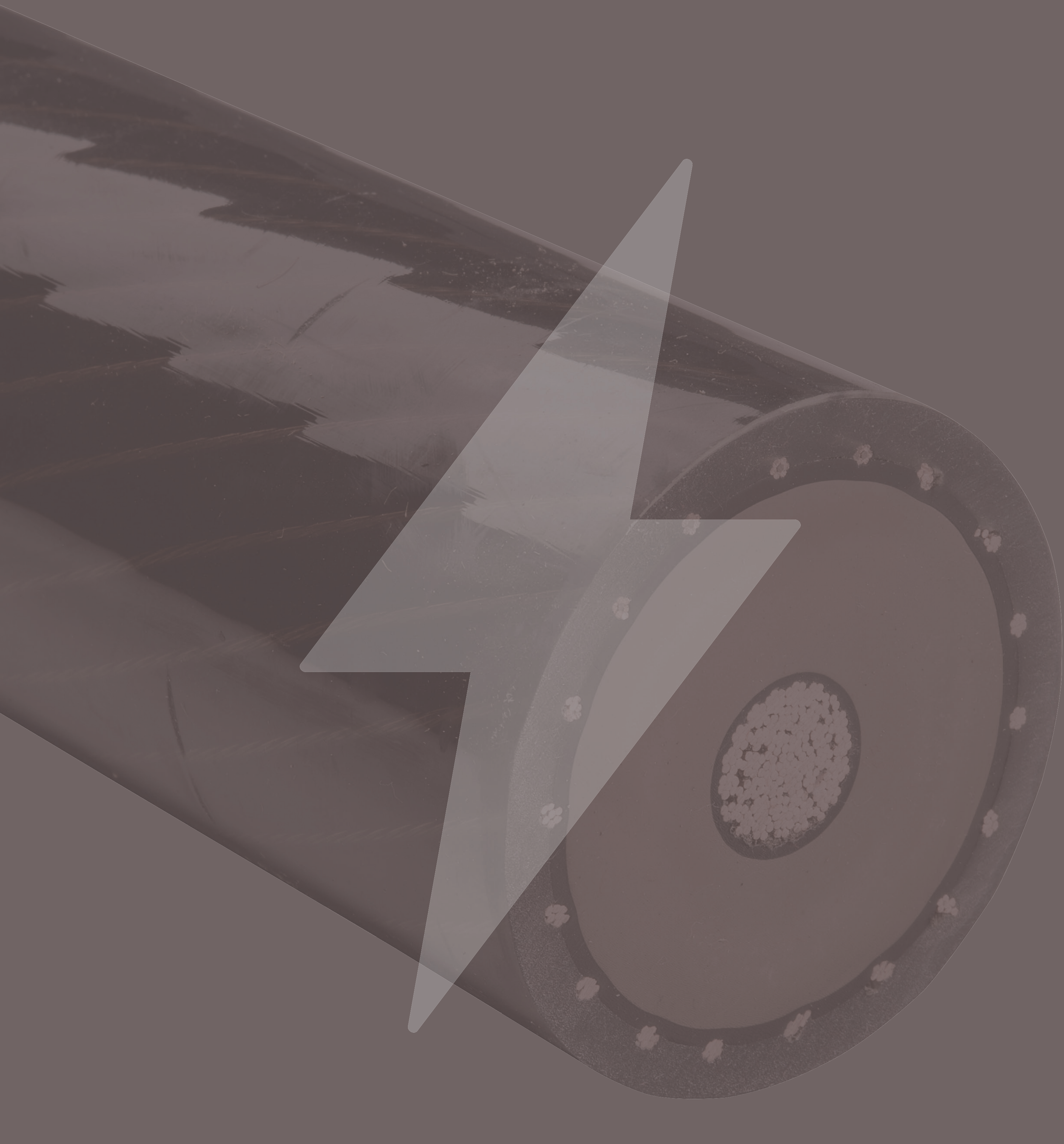
DC Field Testing

The table below has Kerite recommended DC field test voltages for our cables rated 5kV through 138kV. Test values are based on cable rated voltage and are provided for installations that are new, less than 5 years old and over 5 years old in dry environments. For cables over 5 years old in wet environments contact the factory for recommendations. For additional information on DC field testing voltages refer to IEEE Standard 400.

Rated Voltage kV RMS (phase-to-phase)	System BIL kV (peak)	DC Field Voltages (kV – Conductor to Ground) Maintenance Test Voltages			
		New Installations	First 5 Years After Installation	Installations More Than 5 Years Old	
		Any Location	Any Location	Above Grade Dry Location	Below Grade Or Wet Location
5	75	35	25	25	CONSULT FACTORY
15	110	55	40	40	
25	150	80	60	60	
35	200	100	75	75	
46	250	120	90	90	
69	350	170	125	125	
115	550	226	170	170	
138	650	240	180	180	

When DC field testing, it is critical that the ends of cables are clean, disconnected from any apparatus and positioned to minimize surface leakage current and corona. Care should be taken to prevent generation of very high stress by accidental flashovers at terminals or sudden grounding after the test. The voltage should be reduced to $1/4$ of full value by discharge through a resistor before solid grounding. Conductors should be grounded for a minimum duration equal to twice the test time.

Caution: Field testing is primarily a go, no-go test. The measured leakage current is very dependent on temperature, and unless terminals are properly prepared and/or guarded against surface leakage and corona the value recorded may have little relation to the true leakage through the insulation. Refer to IEEE Standard 400 for additional details.



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