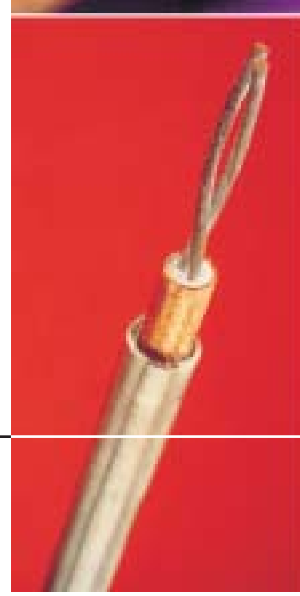
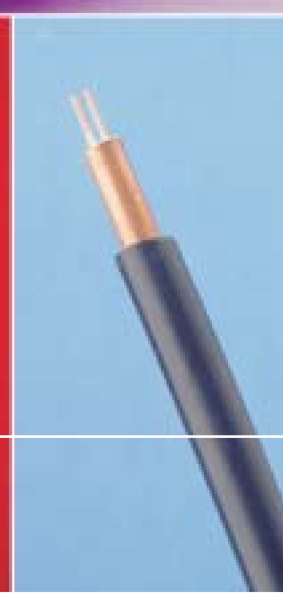
Pyrotenax Mineral Insulated Metal Sheathed "Type MI" Wiring Cable

ENGINEERING DATA MANUAL





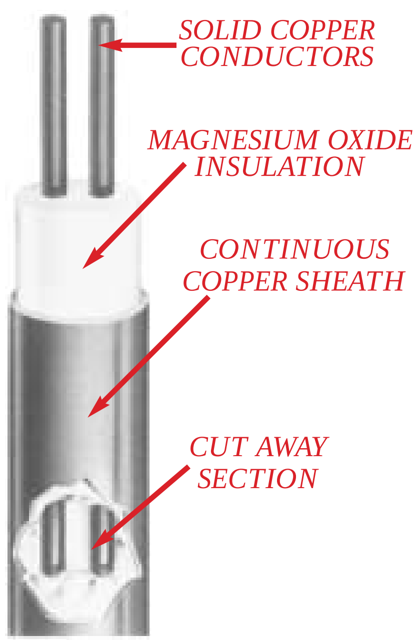
Contents

NOTE

The contents of this publication are based on the latest information available and the materials being used at the time of printing.

CABLE DESCRIPTION & CONSTRUCTION

The cable consists of solid copper conductors insulated by magnesium oxide and enclosed in a continuous copper sheath. The conductors sizes range from 18 AWG to 500 kcmil with 1, 2, 3, 4 or 7 conductors in one cable.



1/18-150D 18 AWG	2/18-230D 18 AWG	3/18-246D 18 AWG	4/18-309L 18 AWG	7/18-355L 18 AWG
1/500-1000 500 kcmil	2/2-865 2 AWG	3/3-834 3 AWG	4/6-730 6 AWG	7/8-710 8 AWG

The drawings show the smallest and largest cable in each conductor configuration. (Not To Scale)

CERTIFICATION

Pyrotenax cable is manufactured to ISO 9002 Quality Program. 600 volt cables are UL and C.S.A. certified under the designation "Type MI" They are permitted in hazardous (classified) areas as follows, with termination fittings and seals appropriate for the location:

300 volt cables and LWMI (light-weight) cables are also CSA and/or UL certified.

- Class I, Divisions 1 and 2, Groups B, C,&D
- Class II, Divisions 1 and 2, Groups E, F & G
- Class III, Divisions 1 and 2

System 1850 (2hour fire rated) includes cables from 600 volt and 300 volt classes; however, System 500 lightweight cables are not fire rated.

CABLE RANGE DIMENSIONAL DATA

TABLE NO. 1 • NOMINAL CABLE OUTSIDE DIAMETER, SYSTEM 1850

AWG	SINGLE CONDUCTOR		2 CONDUCTOR				3 CONDUCTOR				4 CONDUCTOR				7 CONDUCTOR			
	600 VOLT		300 VOLT		600VOLT		300 VOLT		600VOLT		300 VOLT		600VOLT		300 VOLT		600VOLT	
	in	mm	in	mm	in	mm	in	mm	in	mm	in	mm	in	mm	in	mm	in	mm
16	0.215	5.46			0.340	8.64			0.355	9.02			0.387	9.83	0.344	8.74	0.449	11.40
14	0.230	5.84	0.277	7.04	0.371	9.42	0.309	7.85	0.387	9.83			0.465	11.81	0.387	9.83	0.496	12.6
12	0.246	6.25	0.298	7.57	0.402	10.21			0.480	12.19	0.371	9.42	0.465	11.81	0.449	11.40	0.543	13.79
10	0.277	7.04	0.340	8.64	0.449	11.40	0.387	9.83	0.480	12.19			0.590	14.99			0.621	15.77
8	0.298	7.57			0.512	13.00			0.590	14.99			0.590	14.99				
6	0.340	8.64			0.590	14.99			0.621	15.77			0.730	18.54				
4	0.402	10.21			0.684	17.37			0.746	18.95								
3	0.449	11.40																
2	0.449	11.40																
1	0.496	12.60																
1/0	0.512	13.00																
2/0	0.580	14.73																
3/0	0.621	15.77																
4/0	0.684	17.37																
250 kcmil	0.746	18.95																
350 kcmil	0.834	21.18																
500 kcmil	1.000	25.40																

CABLE REFERENCE SYSTEM:

	#Conductors	/	AWG	-	Diameter*
Eg.	3	/	8	-	590

* = H or V, Jacketing; L = System 500; D = 300V

System 2200 and System 2000: refinery "flash fire" rated cable
System 1850: 2-hour fire rated cable UL, ULC.
System 500: non-fire rated cable.

NOTE

The diameters shown in Table 1 correspond to System 1850 sizes. System 500, System 2200 and System 2000 cable diameters are different from System 1850 in some cases. For System 500, System 2200 and System 2000 cable sizes, see the "cable range" cut sheets for those products.

TABLE NO. 2 • NOMINAL CONDUCTOR DIMENSIONS

AWG kcmil	18	16	14	12	10	8	6	4	3	2	1	1/0	2/0	3/0	4/0	250	350	500
Dia.(inch)	.040	.051	.064	.081	.102	.128	.162	.204	.229	.258	.289	.325	.365	.410	.460	.500	0.590	0.710
Dia. (mm)	1.02	1.30	1.63	2.06	2.59	3.25	4.11	5.18	5.82	6.55	7.34	8.26	9.27	10.41	11.68	12.70	14.99	18.03
AREA (cm)	1.62	2.58	4.11	6.53	10.82	16.51	26.25	41.74	52.63	66.37	83.69	105.50	133.10	167.80	211.60	250	350	500
AREA (sq.mm)	.82	1.31	2.08	3.331	5.48	8.37	13.30	21.15	26.67	33.63	42.41	53.46	67.44	85.03	107.2	126.7	177.4	253.4

TABLE NO. 3 • MINIMUM SHEATH THICKNESS (SYSTEM 1850)

AWG	SINGLE CONDUCTOR		2 CONDUCTOR				3 CONDUCTOR				4 CONDUCTOR				7 CONDUCTOR			
	600 VOLT		300 VOLT		600VOLT		300 VOLT		600VOLT		300 VOLT		600VOLT		300 VOLT		600VOLT	
	in	mm	in	mm	in	mm	in	mm	in	mm	in	mm	in	mm	in	mm	in	mm
18			.015	.38			.015	.38							.018	.48		
16	.016	.41	.016	.41	.023	.58			.023	.58	.018	.48	.024	.61	.023	.58	.030	.76
14	.017	.43	.016	.41	.026	.66	.016	.41	.026	.66			.026	.66	.023	.58	.028	.71
12	.018	.46	.018	.48	.026	.66			.027	.69	.022	.56	.027	.69	.026	.66	.028	.71
10	.019	.48	.018	.48	.027	.69	.018	.48	.028	.71			.028	.71			.031	.79
8	.022	.56			.027	.69			.028	.71			.030	.76				
6	.022	.56			.030	.76			.031	.79			.034	.86				
4	.024	.61			.034	.86			.036	.91								
3	.026	.66																
2	.027	.69																
1	.028	.71																
1/0	.028	.71																
2/0	.030	.76																
3/0	.032	.81																
4/0	.035	.89																
250	.037	.94																
350	.039	.99																
500	.041	1.04																

INSULATION THICKNESS

This thickness is both between conductors and between conductors and sheath.

Two conductor 300 volt cables	.025 inch (.64 mm) nominal
Three conductor 300 volt cables	.030 inch (.76 mm) nominal
Four and seven conductor 600 volt LTWT cables	.040 inch (1.02 mm) nominal
600 volt cables	.060 inch (1.52 mm) nominal

NOTE

18 AWG configurations have .040 inch (1.02 mm) nominal.

MECHANICAL CHARACTERISTICS

TABLE NO. 4 • CABLE TENSILE STRENGTH

AWG	SINGLE CONDUCTOR		2 CONDUCTOR				3 CONDUCTOR				4 CONDUCTOR				7 CONDUCTOR			
	600 VOLT		300 VOLT		600VOLT		300 VOLT		600VOLT		300 VOLT		600VOLT		300 VOLT		600VOLT	
	lb	kg	lb	kg	lb	kg	lb	kg	lb	kg	lb	kg	lb	kg	lb	kg	lb	kg
18			347	157			425	193			495	225			710	322		
16	320	145	381	173	670	304	486	220	740	336	650	295	865	392	935	424	1180	535
14	376	171	492	223	815	370	662	300	920	417	850	386	1010	458	1295	587	1495	678
12	460	209	677	307	970	440	886	402	1170	531	1150	522	1340	608	1790	812	1880	853
10	595	270	928	421	1260	572	1221	554	1480	671	1670	757	1790	812	2580	1170	2660	1207
8	773	351			1600	726			1950	885			2420	1097				
6	1047	475			2200	998			2800	1270			3540	1606				
4	1480	671			3130	1420			4050	1873								
3	1775	805																
2	2105	955																
1	2520	1143																
1/0	3075	1395																
2/0	3760	1705																
3/0	4560	2068																
4/0	5620	2549																
250	6560	2975																
350	8800	3990																
500	12,000	5440																

NOTE

Maximum pulling load should not exceed 35% of these values.

COMPARATIVE CRUSHING FORCE TO HALF DIAMETER

3/14 AWG	lb.	kg	3/14 AWG	lb.	kg
Armored Cable (BX)..........	800	363	Rigid Conduit....................	7500	3400
Thin wall Conduit (EMT)	2500	1134	Type M.I (600 volt copper)	5400	2450

TERMINATION PERFORMANCE

The watertight gland will withstand hydrostatic pressure up to 9000 lbs./sq. in. (6.37 kg/sq. mm)
Pull-off force for watertight glands...270 lbs. appox. (122 kg)

CURRENT RATINGS

TABLE NO. 5 • CURRENT RATING (90˚C RATING)

AWG	SINGLE CONDUCTOR			2 CONDUCTOR			3 CONDUCTOR			4 CONDUCTOR			7 CONDUCTOR		
	C.E.C.	N.E.C.	Gland	C.E.C.	N.E.C.	Gland	C.E.C.	N.E.C.	Gland	C.E.C.	N.E.C.	Gland	C.E.C.	N.E.C.	Gland
16	-	24	1/2”	-	18	1/2”	-	18	1/2”	-	18/14	1/2”	-	14/13	3/4”
14	20	35	1/2”	15	25	1/2”	15	25	1/2”	15/12	25/20	3/4”	12/10	20/18	3/4”
12	25	40	1/2”	20	30	1/2”	20	30	1/2”	20/16	35/24	3/4”	16/14	24/21	3/4”
10	40	55	1/2”	30	40	3/4”	30	40	3/4”	30/24	40/32	3/4”	24/21	32/28	1”
8	70	80	1/2”	45	55	3/4”	45	55	3/4”	45/36	55/44	3/4”			
6	100	105	1/2”	65	75	3/4”	65	75	3/4”	65/52	75/60	1”			
4	135	140	1/2”	85	95	1”	85	95	1”						
3	155	165	1/2”												
2	180	190	3/4”												
1	210	220	3/4”												
1/0	245	260	3/4”												
2/0	285	300	3/4”												
3/0	330	350	3/4”												
4/0	385	405	1”												
250	425	455	1”												
350	530	570	1 1/4”												
500	660	700	1 1/4”												

NOTE

1. *Current ratings are for 90˚C rated cable.*
2. *Current ratings are based on 30˚C ambient. For ambients in excess of 30˚C, refer to the code for the de-rating factors.*
3. *In the case of four and seven conductor cables, current ratings are based on one conductor being a neutral. Where a system neutral is not used the smaller capacity applies.*

TABLE NO. 5A • CURRENT RATING (75˚C RATING)

AWG	SINGLE CONDUCTOR			2 CONDUCTOR			3 CONDUCTOR			4 CONDUCTOR			7 CONDUCTOR		
	C.E.C.	N.E.C.	Gland	C.E.C.	N.E.C.	Gland	C.E.C.	N.E.C.	Gland	C.E.C.	N.E.C.	Gland	C.E.C.	N.E.C.	Gland
16			1/2”			1/2”			1/2”			1/2”			3/4”
14	20	30	1/2”	15	20	1/2”	15	20	1/2”	15/12	20/16	3/4”	15/10.5	16/14	3/4”
12	25	35	1/2”	20	25	1/2”	20	25	1/2”	20/16	25/20	3/4”	20/14	20/18	3/4”
10	40	50	1/2”	30	35	3/4”	30	35	3/4”	30/24	35/28	3/4”	30/21	28/21	1”
8	65	70	1/2”	45	50	3/4”	45	50	3/4”	45/36	50/40	3/4”			
6	95	95	1/2”	65	65	3/4”	65	65	3/4”	65/52	65/52	1”			
4	125	125	1/2”	85	85	1”	85	85	1”						
3	145	145	1/2”												
2	170	170	3/4”												
1	195	195	3/4”												
1/0	230	230	3/4”												
2/0	265	265	3/4”												
3/0	310	310	3/4”												
4/0	360	360	1”												
250	405	405	1”												
350	505	505	1 1/4”												
500	620	620	1 1/4”												

NOTE

1. *Current ratings are for 75˚C rated cable.*
2. *Current ratings are based on 30˚C ambient. For ambients in excess of 30˚C, refer to the code for the de-rating factors.*
3. *In the case of four and seven conductor cables, current ratings are based on one conductor being a neutral. Where a system neutral is not used the smaller capacity applies.*

ELECTRICAL CHARACTERISTICS

TABLE NO. 6 • CONDUCTOR RESISTANCE (OHMS/1000FT) AT 25˚C

AWG kcmil	18	16	14	12	10	8	6	4	3	2	1	1/0	2/0	3/0	4/0	250	350	500
Nominal DC Resistance	6.51	4.094	2.58	1.62	1.02	0.641	0.403	0.253	0.201	0.159	0.126	0.100	0.0795	0.0630	0.0500	0.0420	.0303	.0210
Maximum DC Resistance	7.05	4.25	2.73	1.72	1.08	0.680	0.426	0.269	0.213	0.169	0.134	0.106	0.0844	0.0668	0.0524	0.0444	.0321	.0223

TEMPERATURE CO-EFFICIENT OF RESISTANCE

The resistance of copper conductors will increase with temperature in accordance with the following formula:

R_T = R [1+.0039 (T-25)]

R_T = resistance at new temperature

R = resistance at 25˚C

T = new temperature (˚C)

TABLE NO. 7 • CAPACITANCE AND INDUCTANCE

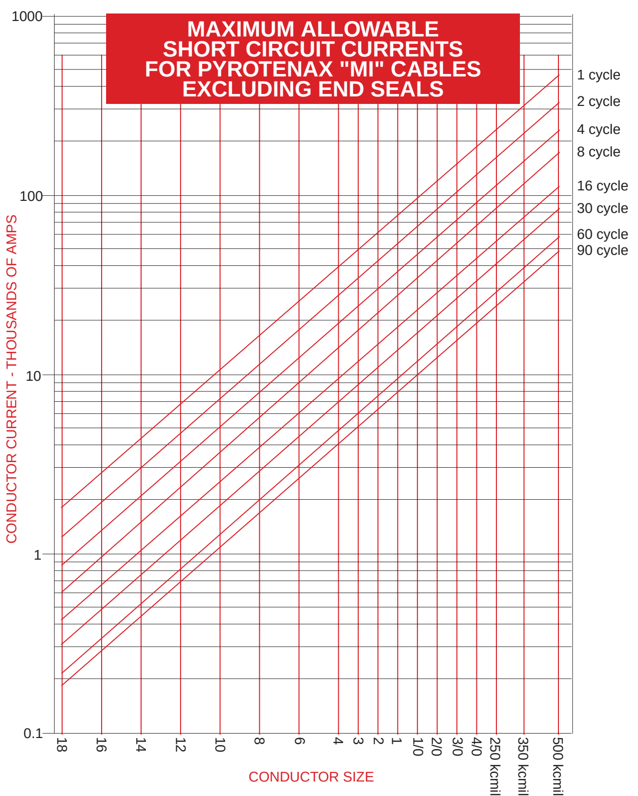
	CAPACITANCE UF/1000FT			INDUCTANCE UH/1000 FT		
AWG	SINGLE CONDUCTOR	MULTI-CONDUCTOR		SINGLE CONDUCTOR	MULTI-CONDUCTOR	
	600	300	600	600	300	600
18		.048			100	
16	.055	.090	.043	90	83	103
14	.063	.106	.049	81	79	99
12	.074	.127	.058	70	75	91
10	.084	.154	.067	66	72	86
8	.095		.079	59		81
6	.118		.095	51		77
4	.129		.113	47		73
3	.139			45		
2	.153			42		
1	.170			40		
1/0	.179			39		
2/0	.194			37		
3/0	.215			35		
4/0	.232			33		
250 kcmil	.243			32		
350 kcmil	.256			30		
500 kcmil	.270			27		

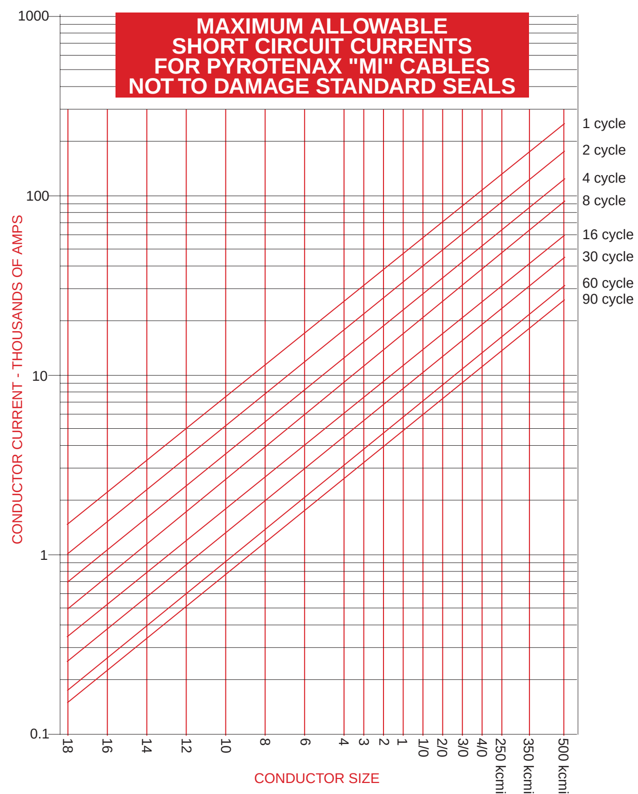
INSULATION RESISTANCE

The insulation resistance of both 300 volt and 600 volt cables is a minimum of 15000 MegOhm•Ft at 25˚C.

SHORT CIRCUIT CURRENTS

The following curves give the maximum allowable short circuit currents for Type M.I. cables. The first is based on the cable only. In other words, the cable would be intact if the short circuit currents shown are not exceeded, however, the terminations would be destroyed. The second curve provides the maximum short circuit current to not damage standard seals. In other words, the cable system could tolerate short circuit currents up to this magnitude and survive completely undamaged.





BREAKDOWN STRENGTH

300 volt cables..2500 volts RMS
600 volt cables..5000 volts RMS

NOTE

Breakdown strength remains relatively constant up to 1000˚C, beyond this point it declines rapidly.

FACTORY TEST VOLTAGE

300 volt cables..1600 volts RMS
600 volt cables..2200 volts RMS
250 -500 kcmil cables ....2500 volts RMS

VOLTAGE DROP CALCULATIONS

VOLTAGE DROP

To calculate voltage drop on a single phase circuit, the following formula should be used with the appropriate factor "A" from Table 8. These calculations are simplified for ease-of-use, and give approximate results which are generally conservative.

$$\text{VOLTAGE DROP} = \frac{\text{(RUN LENGTH) X (CIRCUIT CURRENT) X (TEMP. CONST) X (FACTOR “A”)}}{1000}$$

$$\text{PERCENTAGE VOLTAGE DROP} = \frac{\text{VOLTAGE DROP X 100\%}}{\text{CIRCUIT VOLTAGE}}$$

These calculations are reasonably accurate when single phase circuits and three phase circuits using single conductor cables are configured as recommended by Pyrotenax.

TEMPERATURE CONSTANT		
	Cable at full rated current	1.00
	Cable at 3/4 rated current	0.95
	Cable at 1/2 rated current	0.91
	Cable at 1/4 rated current	0.88

NOTE

Use the appropriate voltage & line current for 3-phase applications. The relationships between single phase and 3-phase voltage drop in the line is given by:
3-phase, line to line voltage basis: single phase voltage drop X 1/√2
3-phase, line to neutral voltage basis: single phase voltage drop X √3/√2

TABLE NO. 8 • FACTOR "A" FOR VOLTAGE DROP CALCULATIONS

AWG	SINGLE CONDUCTOR	2 CONDUCTOR	3 CONDUCTOR	4 CONDUCTOR	7 CONDUCTOR
18		15.06	15.57	15.16	15.60
16	9.2	9.40	9.48	9.63	9.63
14	5.7	5.46	5.67	5.50	5.86
12	3.46	3.43	3.49	3.49	3.62
10	2.24	2.20	2.24	2.20	2.32
8	1.492	1.470	1.512	1.480	
6	.954	.928	.968	.944	
4	.602	.580	.608		
3	.478				
2	.406†				
1	.314†				
1/0	.254†				
2/0	.202†				
3/0	.1626†				
4/0	.1296†				
250	.1112†				
350	.090†				
500	.076†				

† An allowance for the effect of sheath loss is included in these figures (assuming the cables are run close together).

NOTE

These factors are generally very conservative. For more precise calculations, contact Pyrotenax Engineering.

EXAMPLE:
1/0 cable, 3 Phase 600 V, 100A Load, 85% PF, 500'

$$\frac{500 \text{ x } 100 \text{ x } 0.91 \text{ x } 0.254}{1000} = 11.6\text{V or } 1.9\% \quad \text{single phase}$$

or

$$11.6 \text{ X } \frac{\sqrt{3}}{2} = 10.0\text{V or } 1.7\% \quad \text{3 phase line-to-line}$$

SINGLE CONDUCTOR CABLES

Single conductor cables offer a significant advantage over multi-conductor cable assemblies when large amounts of electrical energy must be delivered, as single conductor cables have a higher current rating (free air rating); multi-conductor cable is subject to de-rating factors covering assemblies of not more than three conductors. Using free air ratings rather than the de-rated values, it is possible to employ substantially less copper in a given application. In addition, the handling of large multi-conductor cable can be difficult, especially compared to the relative ease of handling of several smaller conductors. Mineral insulated single conductor cable is particularly well-suited to installations requiring large current carrying capacity in a very compact, easy to install assembly, as the solid conductor construction results in a minimum overall cable diameter. When using single conductor cable, these are specific steps that must be taken because of the magnetic fields associated with single conductors. While the magnetic field will be the same for MI or other cable types, the unique properties of MI allow the fields to be neutralized, and sheath currents to be minimized, as explained in the following section.

SHEATH CURRENTS

PRINCIPLE

When an isolated single conductor cable carries alternating current, an alternating magnetic field is generated around it. If the cable has a metallic sheath, the sheath will be in the field, and a voltage will be induced in it. This voltage will tend to drive a current along the sheath in a direction so as to induce a field opposing the original field. If the metal sheath is grounded at more than one point, a closed circuit is available and the induced sheath voltage causes an electric current to circulate in the sheath and grounding system. If the metal sheath is not grounded at more than one point, no current can flow, although a voltage exists on the sheath.

Diagram No. 1

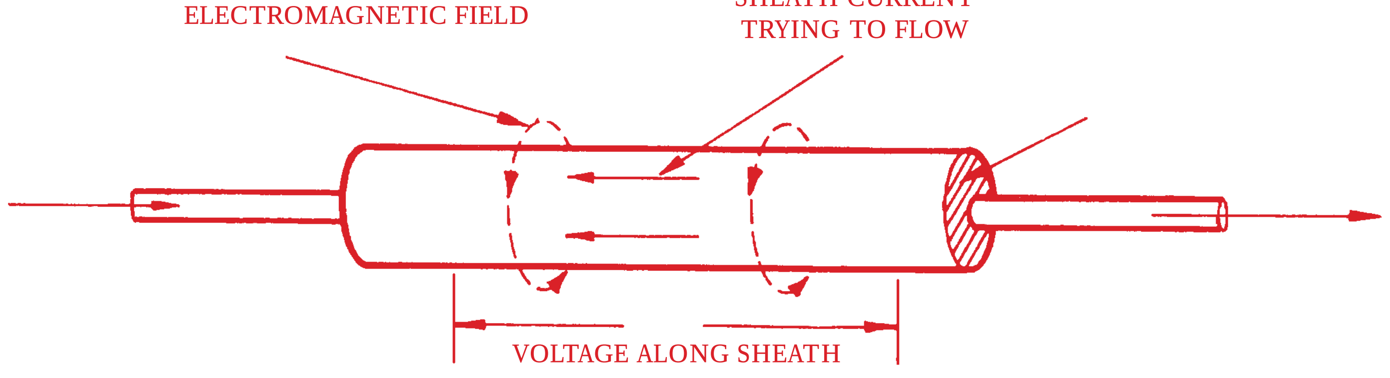


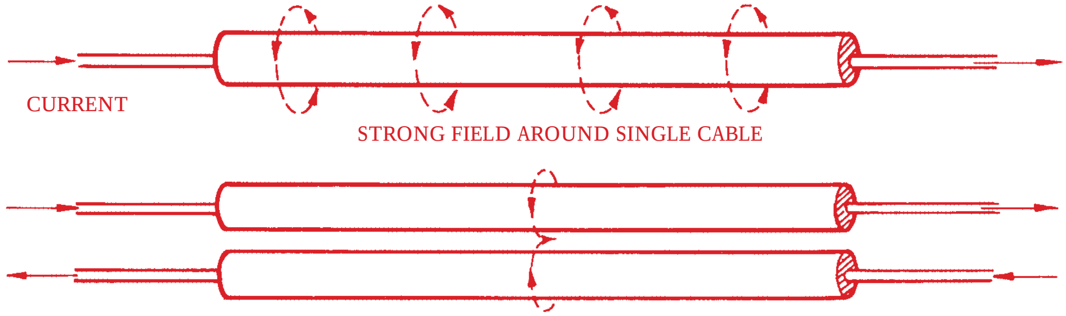
Diagram No. 2

EFFECTS:

The magnitude of the induced voltage depends on the current flowing in the conductor, the length of the cable and the thickness of the insulation between the conductor and sheath. The magnitude of the sheath current in turn depends on the induced voltage, and the resistance of the sheath current path. (Note that increased cable length results in both higher induced voltage and higher sheath resistance (in proportion) and therefore sheath current is independent of cable length.) Sheath voltages can reach significant values, usually in the order of a few to tens of volts which, while low, can be sufficient to cause sparking under certain circumstances that at the very least is unnerving to maintenance personnel, as well as potentially dangerous in explosive atmospheres, and should be avoided. Multipoint grounding of the sheath will allow sheath currents to flow, thereby minimizing induced sheath voltage and preventing occurrences of sparking.

In turn however, the sheath currents result in both heating of the sheath itself, and increased voltage drop on the circuit supplied by the cables, as a result of the energy loss in heating the sheath. The heating of the sheath can be a serious issue, particularly with polymer jacket or polymer insulated cable; de-rating is required above certain current levels if sheath current flow is allowed.

Diagram No. 3



If the two single conductor cables of a single phase circuit are placed close to each other, their fields have a cancelling effect reducing the overall field, and therefore reducing the sheath current. The closer together they are, the less the sheath current. Similarly a multi conductor cable will have very little field and very little sheath current. In the case of a three phase circuit the fields of the three cables interact with one another in a similar manner to produce a reduction or increase in the effect of induced sheath voltages as the cables are brought closer together or farther apart. For example, if the cables of a balanced three phase system are placed together as in diagram 4, their field will tend to cancel, leave a weak overall field which will cause very little induced voltage and, therefore, very little sheath currents. The cables on the outside will have slightly higher induced voltages than the centre one since the distances from each other are not equal. If the cables are placed as in diagram 5, they will have better ventilation but will have less field cancelling effect and, therefore, higher sheath voltages and currents.

RECOMMENDED METHODS OF INSTALLATION

Diagram No. 4

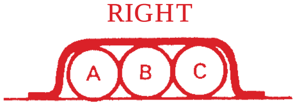


Diagram No. 5

In three phase applications which utilize single conductor cables, sheath voltages and currents tend to decrease with decreased spacing between the conductors. This results from field cancellation, as illustrated. The closer together they are, the less is the sheath current, with maximum cancellation occurring when the cable sheaths are in actual contact (similarly, a multi-conductor cable will have very little field and very little sheath current.) Being close together minimizes magnetic field and sheath current, but it is counter-indicated for polymer insulated cables because of mutual heating effects among the conductors being potentially or actually damaging to the insulation.

It is recommended that MI cable be run close together, ensuring that sheath voltages are kept to a minimum. While cables will run slightly hotter as a result of being close together and providing less ventilation, this increase of temperature is only small and has no effect on the insulation of MI cable.

The alternative to this recommendation is to run cable spaced from one another, which adds to installation difficulties and costs, takes up additional space, and increases the cable voltage drop due to impedance which increases as the space between cables increases. To run cables spaced apart and prevent sheath currents, it is necessary to insulate the cable sheaths from one other, and from ground, throughout the run lengths, by utilizing an over jacket. It is necessary also at one end of the run to have the cable glands isolated from one another where they enter the cabinet. Since the cable sheath normally acts as a bonding conductor, isolating one end will require separate bonding conductors be run.

PARALLELING OF SINGLE CONDUCTOR CABLES

It is often necessary to use more than one conductor per phase when dealing with very large current loads for reasons of conductor size, ease of installation, and cost. it is important to ensure that each of the conductors in a phase group carries a proportionate share of the total load so as not to overload the other conductors in the group.

Balancing out inductive reactance is generally more difficult, and differences in load-sharing can occur as a result of cable spacing, relative position, and number of conductors per phase. The recommended configuration for MI single conductor cables is as follows.

Electrical codes generally limit paralleling to cable sizes 1/0 and larger, and address the balancing resistance by stipulating:

1. Each conductor must be the same length
2. All conductors must be the same size and temperature rating.
3. All conductors must have the same type of insulation.

SINGLE CONDUCTOR MI CABLES - RECOMMENDED INSTALLATION

MI single conductor cables should be run in groups having one cable from each phase, with the cables fastened tightly together, and with the cable sheath effectively grounded by connecting the gland connector at each end of the cable run to the metal enclosure. This will reduce sheath voltages and sheath currents to a minimum.

RECOMMENDED CONFIGURATIONS

	SINGLE PHASE	3 PHASE • 3 WIRE	3 PHASE • 4 WIRE
Single Circuit Preferred	N / A B	A / B C	A N / B C
Single Circuit Alternative	A B N	A B C	A B C N
Two Cables In Parallel Per Phase Preferred	N / A B — S — N / B A	A / B C — S — A / B C	A N / B C — S — A N / B C
Two Cables In Parallel Per Phase Alternative	A B N N B A	A B C — S — A B C	A B C N N C B A
Three Or More Cables In Parallel Per Phase Preferred	N / A B — S — N / A B — S — N / A B	A / B C — S — A / B C — S — A / B C	A N / B C — S — A N / B C — S — A N / B C
Three Or More Cables In Parallel Per Phase Alternative	A B N — S — A B N — S — A B N	A B C — S — A B C — S — A B C	A B C N — S — A B C N — S — A B C N

NOTE
(1) Spacing (S) between groups of phase cables (not counting neutral) should be at least two cable diameters.
(2) Neutral may be located as shown, or outside groups in most convenient location.

BOX ENTRY

When single conductor cables, carrying more than 200 amps, enter through a ferrous box or plate, precautions must be taken to prevent heat by induction in the steel. This may be done in dry locations where one cable per phase is used, by hacksaw cuts between knockouts. Where more than one cable per phase is used, or for wet locations, a section of the box should be removed and a non-ferrous metal plate installed.

PHASING OUT

Note that the neutral conductor may be located within or outside the cable group, and that the spacing between groups of phase cables should be at least two cable diameters. Most importantly, note that each group of cables must contain one conductor from each phase so as to minimize the resulting magnetic field in each grouping. Current balance should be checked immediately after the cables begin to carry load. Load imbalances between conductors of up to 10% are tolerable and expected. Greater imbalances are of concern and should be investigated.

For ungrounded systems it is good practice to install secondary arrestors on services supplied from overhead lines. Other than where corrosive conditions exist, protective jackets are not required for these cables.

TEMPERATURE CHARACTERISTICS

COPPER SHEATH CABLES

Because the magnesium oxide insulation is stable and unaffected by temperature up to its melting point of 2800˚C, the only temperature limit in short-time exposures is the melting point of copper itself, 1083˚C.

Short of that point MI cable is completely non-flammable; not only will it not burn, but it will not develop flammable or toxic gases.

The temperature limit of the cable for continuous operation is determined only by the progressive oxidation temperature of the copper sheath. Investigations show this to be about 250˚C (482˚F) in normal atmospheres.

TABLE NO. 9 • DECREASE IN COPPER SHEATH THICKNESS AS A FUNCTION OF TIME AT VARIOUS TEMPERATURES

Decrease in Sheath Thickness, Mils*	250 ˚C, Years	400 ˚C, Years	800 ˚C, Hours
1	2.57	0.0583	0.259
2	10.3	0.233	1.04
5	64.3	1.46	6.48
8	257	5.83	25.9

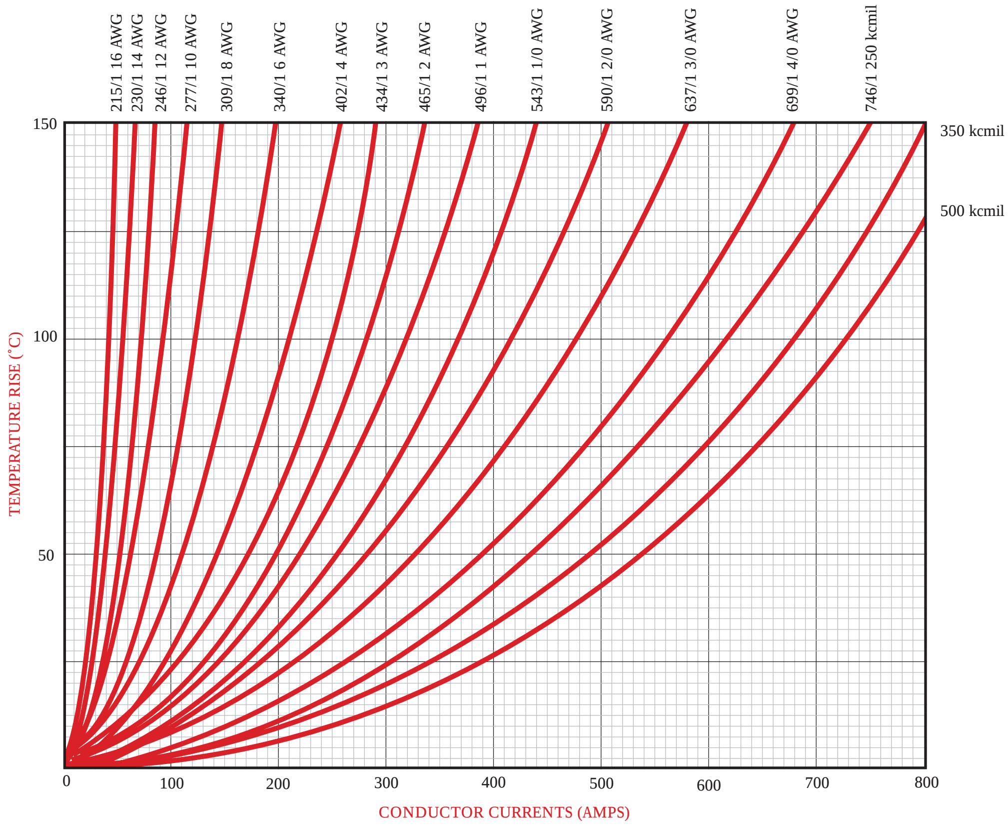
*1 mil = 0.001 inch.

For special high temperature applications, the cable may be exposed to temperatures above 250˚C. However, limited sheath life should be anticipated as shown in table No. 9.

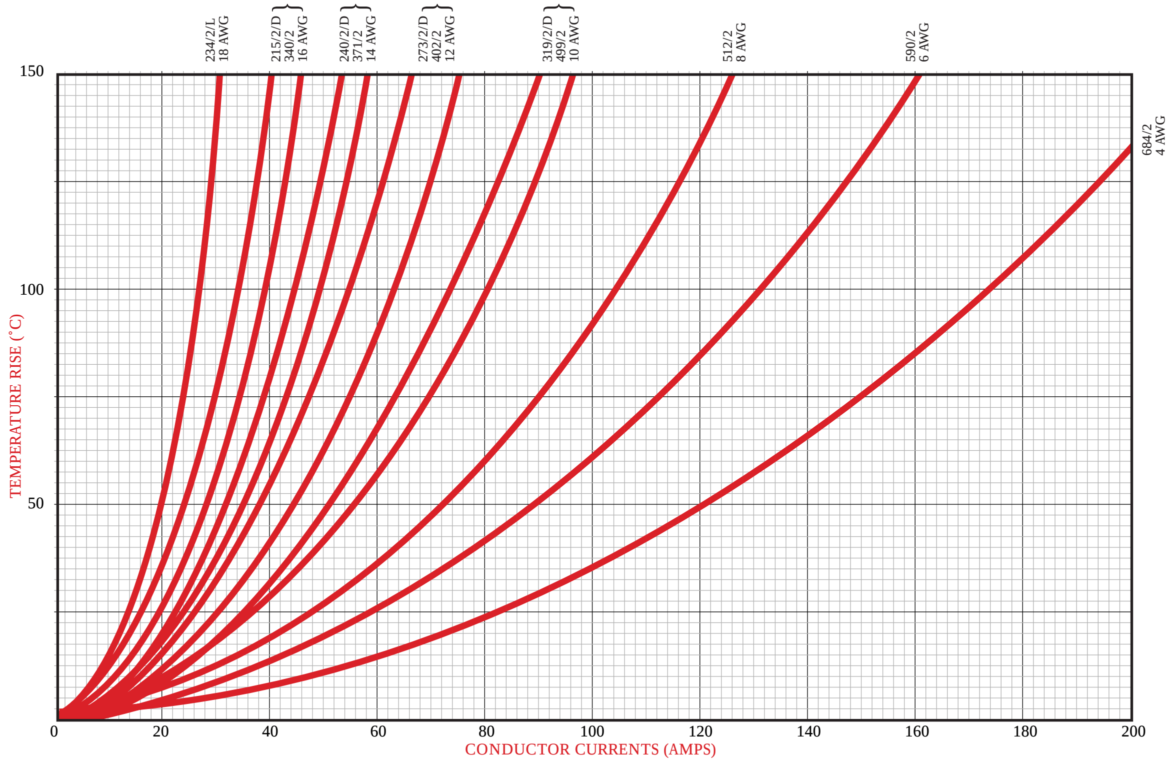
CABLE OPERATING TEMPERATURE

The following graphs give the approximate cable sheath temperatures likely to occur at different current densities. It must be appreciated that the curves are based on the cable being in free air at 25˚C and sheath temperatures will be lower if the cables are embedded in a medium which has a quenching or cooling effect, or conversely, if the cables are surrounded by a medium which acts as a heat insulator, the sheath temperatures would be higher for a given current.

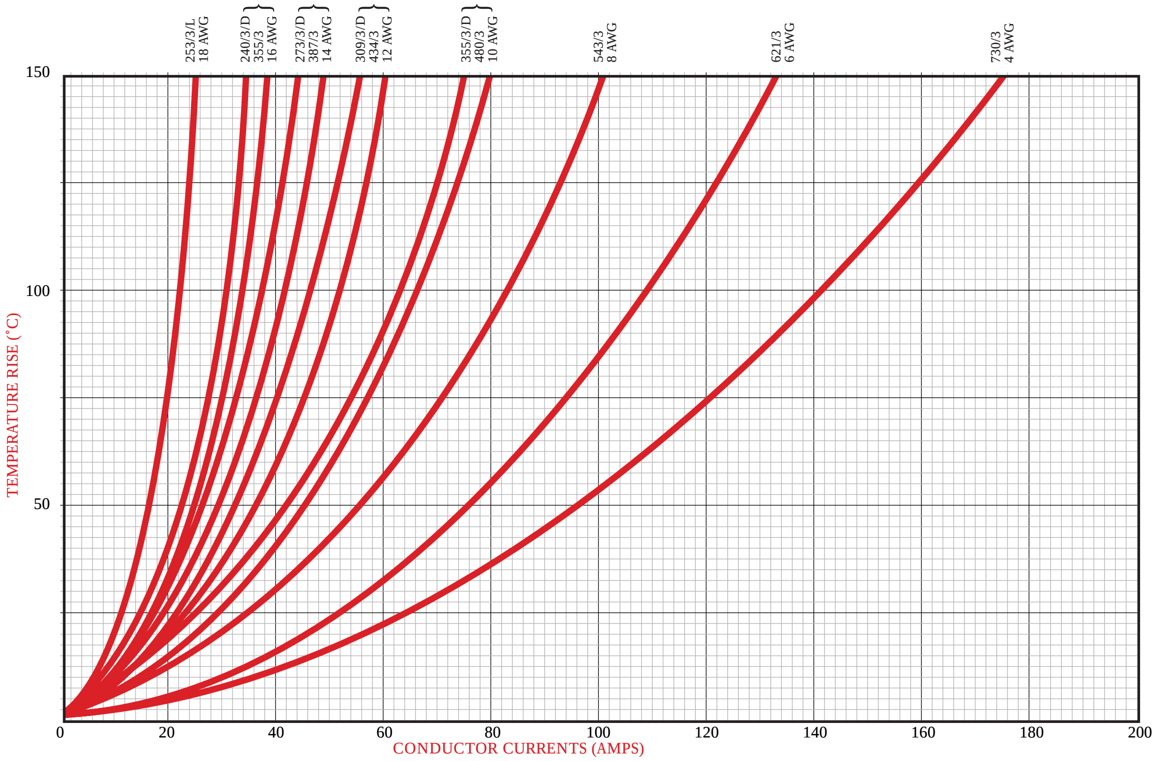
SHEATH TEMPERATURE RISE TYPE MI SINGLE CONDUCTOR 600 VOLT FREE AIR CONDITIONS



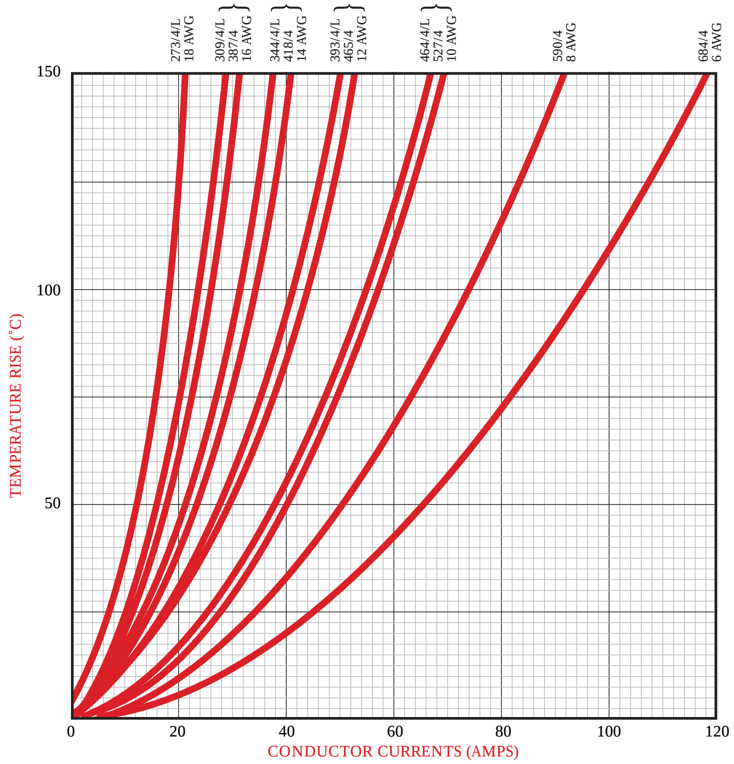
SHEATH TEMPERATURE RISE TYPE MI TWO CONDUCTOR CABLES FREE AIR CONDITIONS



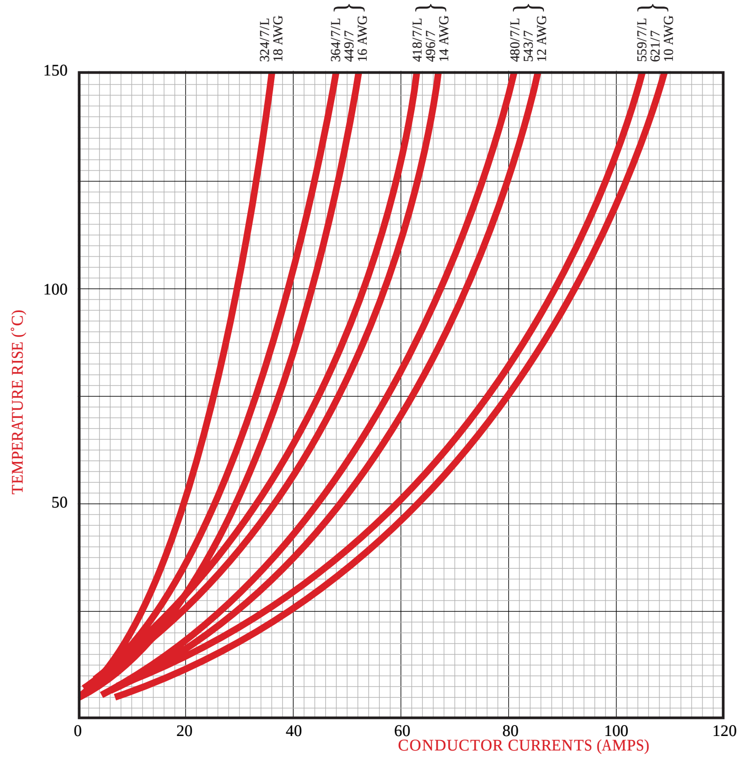
SHEATH TEMPERATURE RISE TYPE MI THREE CONDUCTOR CABLES FREE AIR CONDITIONS



SHEATH TEMPERATURE RISE TYPE MI FOUR CONDUCTOR 600 VOLT CABLES FREE AIR CONDITIONS



SHEATH TEMPERATURE RISE TYPE MI SEVEN CONDUCTOR 600 VOLT CABLES FREE AIR CONDITIONS



SEAL TEMPERATURE LIMITS

There are several terminations available for sealing and terminating our MI cables. The temperature limit for these terminations are dependent on the sealing material and sleeving used.

The following is a list of these terminations and their temperature limits:

(1) Standard Termination - 105˚C (221˚F)
(2) Medium Temperature Terminations - 150˚C (302˚F)
(3) High Temperature Terminations - 200˚C (392˚F)

NOTE

All three sets are available in field kit form. For Class 1 Div 1 hazardous locations, a heat cure is necessary.

INSULATION CHARACTERISTICS (MAGNESIUM OXIDE)

MOISTURE PENETRATION

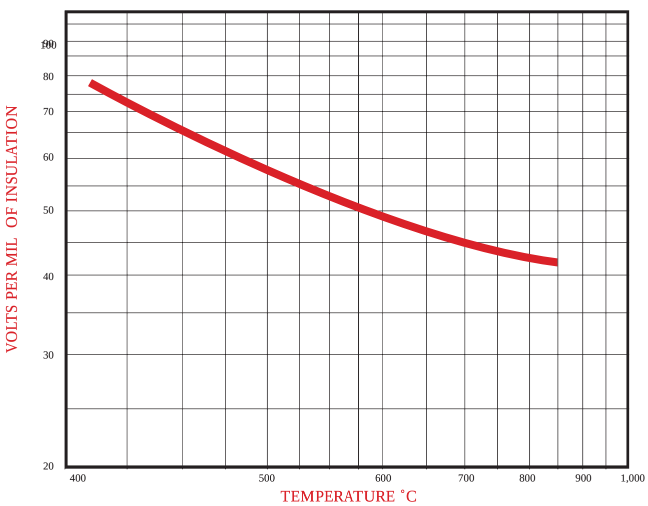
The magnesium oxide is hygroscopic and the presence of free moisture will penetrate for several inches reducing the insulation resistance of this section of cable. The moisture does not continue to penetrate for any distance and may be easily removed by applying heat to the cable in such a manner as to force the moisture back out the open end.

If this moisture is allowed to remain in contact with the insulation, for a prolonged period of time (approximately 1 year at 25˚C), it will combine with it to form magnesium hydroxide. Since magnesium hydroxide occupies a considerably greater volume than the oxide, it can result in swelling of the cable sheath.

Magnesium hydroxide can quickly be changed to magnesium oxide by the application of heat.

DIELECTRIC STRENGTH

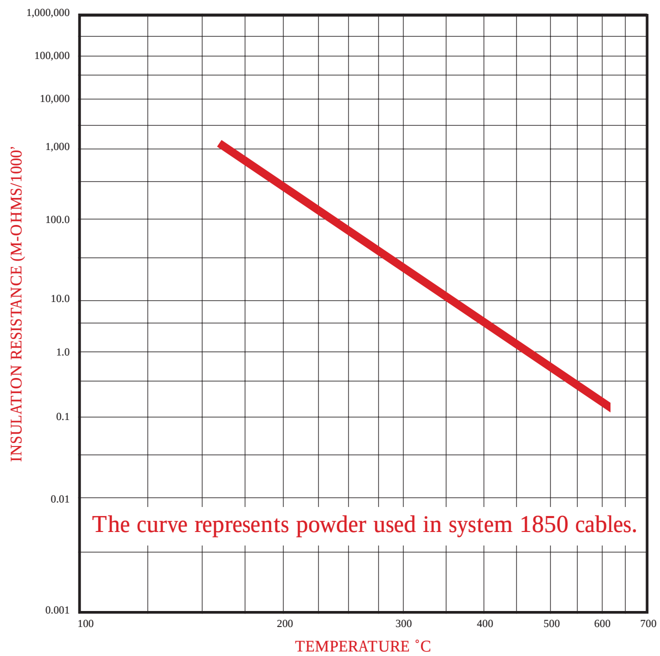
The dielectric strength of the insulation also decreases with temperature. However, this decrease is relatively unimportant at temperatures at which the cable normally operates.



DIELECTRIC STRENGTH OF MI CABLE AS A FUNCTION OF TEMPERATURE

INSULATION RESISTANCE

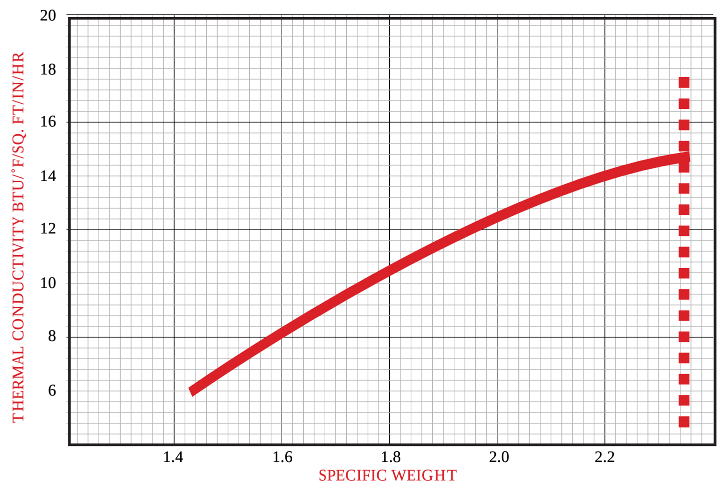
The insulation resistance decreases with increase in temperature as shown. It may be noted that this decrease in insulation resistance is relatively unimportant at temperatures below 250˚C.



INSULATION RESISTANCE OF MI CABLE AS A FUNCTION OF TEMPERATURE

THERMAL CONDUCTIVITY

Unlike most electrical insulations, magnesium oxide has a relatively high thermal conductivity. This enables the heat to be quickly conducted from the outside sheath and dissipated to the surrounding air. This conductivity increases when the magnesium oxide is compacted. The manufacturing process produces a specific weight approximately 2.2 and a thermal conductivity of 16.4 BTU/˚F/sq. ft./in./hr.



POWER FACTOR

The power factor of magnesium oxide is very low compared to that of most electrical cable insulation. When measured at room temperature, 60 cycles per second and 40 volts per mil., it is approximately 0.1%. This value increases with temperature to approximately 1.0% at 250˚C.

DIELECTRIC CONSTANT

The dielectric constant is approximately 4 over a range from 60 cycles per second to 400 megacycles per second and is relatively constant up to 300˚C.

EXPANSION AND VIBRATION

Although the electrical properties of mineral insulated cables are unaffected by vibration, on occasion it is necessary to provide for expansion of a cable operating under abnormal temperature conditions, or to prevent mechanical damage which may result from the relative movement of different items of equipment traversed by a cable.

Conditions encountered in industrial applications can be satisfied by providing between securing clips or other fixation methods, a right angle bend (Figure 1), two right angle bends (Figure 2), or one semi-circular bend and two right angle bends (Figure 3) in the cable, whichever is most appropriate for a particular installation.

In any case the bending radius should not be less than five times the cable diameter.

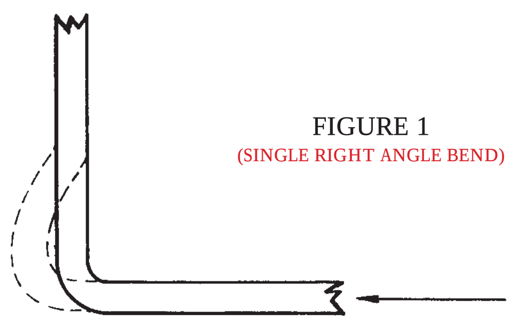


FIGURE 1
(SINGLE RIGHT ANGLE BEND)

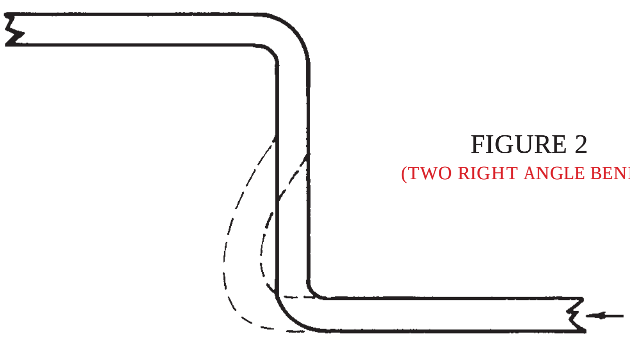


FIGURE 2
(TWO RIGHT ANGLE BENDS)

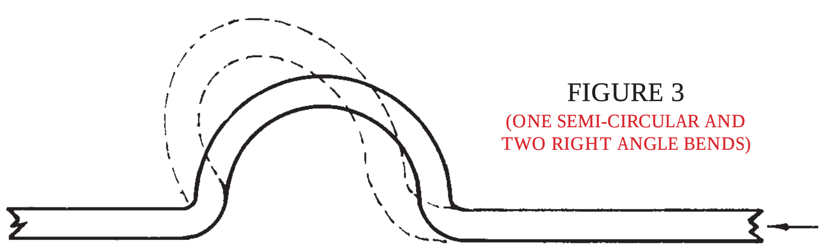


FIGURE 3
(ONE SEMI-CIRCULAR AND TWO RIGHT ANGLE BENDS)

METALLURGICAL AND CORROSION

The characteristics of MI cables result in their being often used in such arduous locations as chemical and refining plants, on towers, heavy construction sites, etc. Also they are required to operate at high temperatures, in many cases at temperatures near the limit of the metal involved.

For discussion this subject can be divided into mechanical abuse, oxidation, direct chemical attack, galvanic corrosion and stress corrosion. The method of manufacture makes it obvious that the cable will be able to stand considerable mechanical abuse such as crushing, twisting, bending, and stretching. However, it is vulnerable to shearing or cutting forces, especially since the metals are purposely annealed to a relatively soft condition for easier handling and installing.

As the cable is worked, either during installing or as a result of vibration in its installed condition, the metals will become harder. This hardening, makes the cable sheath more prone to cracking. However, provided the cable is not subject to drastic reformation and is handled with reasonable care this will normally present no problem.

The strength, elongation, and stress strain properties are similar to the same type of metal wire having the same cross sectional area as the combined sheath and conductor. This is as would be expected since the insulation has no strength in tension. The tensile strength of the cable range is given in table No. 4, Page No.4.

At temperatures below 250˚C copper develops a thin protective coating or patina, which almost completely retards further oxidation. Above this temperature the oxidation becomes progressive and the life of the cable sheath will be limited.

For example, it is estimated that at 500˚C the sheath may last several years, but at 800˚C the life would be limited to hours.

The sheath material, copper, in noted for its general resistance to chemical corrosion as compared to most other metals. However, as with all metals, there are certain environments which will be detrimental.

It is susceptible to oxidizing acids such as nitric, sulfurous, and concentrated sulfuric acid. Similarly, it is attacked by oxidizing salts. Ions that are susceptible of reduction are ferric, stannic, mercuric, and substitute ammonia. Although resistant to attack by most dry gas, it is susceptible to corrosion by wet fluorine, chlorine, bromine, iodine, and ammonia. Sulfur compounds have a strong tendency to attack it. For applications involving corrosion, contact Pyrotenax Engineering or consult a corrosion handbook.

When copper is in contact with a metal more active in electrochemical potential, through an electrolyte, corrosion of the metal may be stimulated. The common metals most likely to be affected are aluminum, magnesium, zinc, and, in some cases, galvanized steel. In actual practice the surface area of the cable or cathode is so small in comparison to the anodic metal that very little corrosion will take place. For example the cable is often used on aluminum and galvanized steel towers without any serious corrosion problem occurring. Again the surface area is small in comparison that, for most applications, this type of corrosion can be ignored.

Stress corrosion cracking is a combination of both stress and corrosion which causes metal embrittlement and cracking. Since the cables must be bent during installation they invariably contain sufficient surface stress so that when exposed to particular corrosive agents, cracking can occur. For this type of corrosion with copper the only known corrosive agent is ammonia, or ammonia bearing materials called amines. For ammonia to cause this type of cracking traces of moisture and carbon dioxide, as normally found in the atmospheres, are also required. This type of corrosion cracking has been encountered where urine has been in contact with the cable during installation. There is very little apparent surface corrosion, however, the cable sheath becomes brittle and may eventually crack with the slightest stress. In any case this particular type of corrosion has been relatively rare.

Where the copper sheath could be corroded, an extruded jacket can be supplied. The standard jacket is black PVC or HDPE.

JACKET MATERIAL AVAILABLE

JACKET MATERIAL	TYPICAL Inches	THICKNESS mm	FLAMMABILITY (A.S.T.M. D635)	SUGGESTED MAX. OPERATING TEMP
Polyethylene	.040	1.0	FT4	120˚C continuous
Polyvinyl chloride	.040	1.0	FT4	105˚C continuous

PVC becomes brittle at minus 22˚F (minus 30˚C).
High density polyethylene becomes brittle at minus 148˚F (minus 100˚C).
PVC releases toxic gases when exposed to flame.

CORROSION RESISTANCE RATINGS

CHEMICAL	Copper	Cupro Nickel	Alloy 825	304 Stainless	Inconel 600	Polyethylene	PVC
Acetic Acid	S	E	E	S	S	S	S
Acetic Anhydnde	S	S	E	S	S	N	N
Acetone	S	E	E	E	E	N	N
Acetylene	N	N	E	E	S	N	E
Alcohols	E	E	E	E	-	S	E
Alum	S	E	E	N	S	E	E
Alumina	E	E	E	N	N	-	E
Aluminum Chloride	S	S	E	N	-	E	E
Aluminum Hydroxide	E	E	E	E	-	S	E
Aluminum Sulfate	S	E	E	N	S	E	E
Ammonia, Absolutely dry	N	E	E	E	E	E	E
Ammonia, moist	N	S	E	E	E	N	N
Ammonium Hydroxide	N	S	E	E	E	E	E
Ammonium Chloride	S	S	E	N	S	E	E
Ammonium Nitrate	N	S	E	E	S	E	E
Ammonium Sulfate	S	S	E	S	S	E	E
Amyl Acetate	S	S	E	E	E	N	N
Amyl Alcohol	E	E	E	-	-	E	S
Aniline	N	N	E	E	E	S	N
Aniline Dyes	N	N	E	E	E	N	N
Asphalt	E	E	E	E	-	-	E
Atmosphere, Industrial	E	E	E	E	E	E	E
Atmosphere, Marine	S	E	E	N	S	E	E
Atmosphere, Rural	E	E	E	E	E	E	E
Barium Carbonate	E	E	E	E	E	E	E
Barium Chloride	S	S	E	S	S	E	E
Barium Hydroxide	N	E	E	S	E	E	E
Barium Sulfate	N	E	E	E	-	E	E
Barium Sulfide	N	S	E	E	-	E	S
Beer	S	E	E	E	E	E	E
Beet Sugar Syrups	E	E	E	E	-	-	E
Benzine	E	E	E	E	E	N	N
Benzoic Acid	E	E	E	S	-	E	E
Benzol	E	E	E	E	E	E	N
Black Liquor, Sulphate Process	S	S	E	S	N	-	E
Copper Sulfate	S	E	E	E	S	E	E
Corn Oil	E	E	E	E	E	E	E
Cottonseed Oil	E	E	E	E	E	E	E
Creosote	S	E	E	N	-	N	N
Crude Oil	E	E	E	E	-	-	-
Ethers	E	E	E	E	E	N	N
Ethyl Acetate	E	E	E	S	S	N	N
Ethyl Alcohol	E	E	E	E	-	E	E
Ethyl Chloride	S	S	E	E	E	N	N
Ethylene Glycol	E	E	E	E	-	E	S
Ferric Chloride	N	N	S	N	N	E	E
Ferric Sulfate	N	N	E	E	E	E	E
Ferrous Chloride	N	S	S	N	N	E	E
Ferrous Sulfate	S	S	E	S	-	E	E
Formaldehyde	S	E	E	S	E	E	S
Formic Acid	S	S	E	N	S	E	N
Freon	E	E	E	E	-	E	E
Fruit Juices	S	S	E	E	E	E	E

CHEMICAL	Copper	Cupro Nickel	Alloy 825	304 Stainless	Inconel 600	Polyethylene	PVC
Bleaching Powder, wet	S	S	S	N	N	-	N
Borax	S	E	E	E	E	E	E
Bordeaux Mixture	E	E	-	E	-	-	-
Boric Acid	S	E	E	S	E	E	E
Brines	S	E	E	-	S	E	E
Bromine, dry	E	E	E	N	-	N	N
Bromine, moist	S	S	S	N	E	N	N
Butane	E	E	E	E	E	-	E
Butyl Alcohol	S	S	E	-	-	E	S
Butyric Acid	S	S	E	E	S	N	N
Calcium Bisilite	S	S	E	S	N	S	E
Calcium Chloride	S	S	E	E	E	E	E
Calcium Hydroxide	S	E	E	S	E	E	E
Calcium Hypochorite	S	S	S	N	S	E	E
Cane Sugar Syrups	E	E	E	E	E	-	E
Carbolic Acid	S	S	E	S	E	E	E
Carbon Dioxide, dry	E	E	E	E	E	E	E
Carbon Dioxide, moist	S	E	E	S	E	E	E
Carbonated Water	S	E	E	E	-	E	-
Carbonated Beverages	S	E	E	E	E	E	E
Carbon Disulfide	N	-	E	E	-	N	N
Carbon Tetrachloride, dry	E	E	E	E	E	N	S
Carbon Tetrachloride, moist	S	E	E	S	E	N	N
Castor Oil	E	E	E	E	E	E	E
Chlorine, dry	S	E	E	S	-	S	N
Chlorine, moist	N	S	S	N	N	N	N
Chloracetic Acid	S	S	E	N	S	-	S
Chloroform, dry	E	E	E	E	E	N	N
Chromic Acid	N	N	E	N	N	S	S
Cider	S	S	E	S	-	E	E
Citric Acid	S	E	E	S	-	E	E
Coffee	E	E	E	E	-	-	-
Copper Chloride	N	N	E	S	N	E	E
Copper Nitrate	N	N	E	E	N	E	E
Oxalic Acid	S	S	E	N	E	E	E
Oxygen	E	E	E	E	E	-	E
Palmitic Acid	S	S	E	N	-	S	E
Paraffin	E	E	E	E	-	-	-
Phosphoric Acid	S	S	E	N	S	S	E
Potassium Carbonate	E	E	E	E	E	E	E
Potassium Chloride	S	E	E	N	E	E	E
Potassium Chromate	E	E	E	S	E	E	E
Potassium Cyanide	N	N	E	E	E	E	E
Potassium Dichromate, Acid	N	N	E	E	S	E	E
Potassium Hydroxide	S	E	E	S	E	E	E
Potassium Sulfate	E	E	E	E	E	E	E
Propane	E	E	E	E	-	-	E
Rosin	S	E	E	E	-	-	-
Sea Water	S	E	E	N	S	E	E
Sewage	E	E	E	-	-	E	E
Silver Salts	N	N	E	E	-	E	E

CORROSION RESISTANCE RATINGS

CHEMICAL	Copper	Cupro Nickel	Alloy 825	304 Stainless	Inconel 600	Polyethylene	PVC
Fuel Oil	S	E	E	N	S	N	S
Furfural	E	E	E	E	S	N	N
Gasoline	E	E	E	E	E	N	N
Gelatine	E	E	E	E	E	-	E
Glucose	E	E	E	E	E	E	E
Glue	E	E	E	-	-	-	-
Glycerine	S	E	E	E	E	E	E
Hydrobromic Acid	N	N	S	N	N	E	E
Hydrocarbons, Pure	E	E	E	E	E	E	E
Hydrochloric Acid	N	N	S	N	N	E	E
Hydrocyanic Acid, dry	S	S	S	N	S	S	N
Hydrofluosilicic Acid	S	S	E	N	S	-	S
Hydrogen	E	E	E	E	-	E	E
Hydrogen Peroxide	N	N	E	S	E	S	E
Hydrogen Sulfide, dry	N	E	E	S	S	E	E
Hydrogen Sulfide, moist	N	N	E	S	S	E	E
Kerosene	E	E	E	E	E	N	E
Lacquers	E	E	E	S	-	-	-
Lacquer Solvents	E	E	E	-	-	-	-
Lactic Acid	S	E	E	S	S	E	S
Lime	S	E	E	S	-	-	E
Line-Sulfur	N	N	-	E	-	-	E
Linseed Oil	S	S	E	E	S	S	E
Magnesium Chloride	S	S	E	S	E	E	E
Magnesium Hydroxide	E	E	E	E	S	E	E
Magnesium Sulfate	S	E	E	E	E	E	E
Mercury	N	N	E	E	E	E	E
Mercury Salts	N	N	E	E	S	E	E
Methyl Alcohol	S	S	E	E	E	E	S
Methyl Chloride, dry	S	E	E	E	E	N	N
Milk	S	E	E	E	E	E	E
Mine Water	N	-	E	E	-	E	E
Natural Gas	E	E	E	E	E	-	-
Nitric Acid	N	N	E	S	N	S	N
Nitrogen	E	E	E	-	S	-	-
Oleic Acid	S	S	E	N	E	N	E
Tartaric Acid	S	E	E	S	S	S	E
Toluene	E	E	E	E	E	N	N
Trichloracetic Acid	S	S	E	E	-	-	-
Trichlorethylene, dry	E	E	E	S	S	N	N
Trichlorethylene, moist	S	E	E	S	S	N	N
Turpentine	E	E	E	S	E	N	E

CHEMICAL	Copper	Cupro Nickel	Alloy 825	304 Stainless	Inconel 600	Polyethylene	PVC
Soap Solutions	E	E	E	E	-	E	E
Sodium Barconrbonate	E	E	E	S	S	E	E
Sodium Bisulfate	S	E	E	S	S	E	E
Sodium Bisulfite	S	S	E	S	S	E	E
Sodium Carbonate	E	E	E	E	E	E	E
Sodium Chloride	S	E	E	N	E	E	E
Sodium Chromate	E	E	E	-	-	-	-
Sodium Cyanide	N	N	E	E	-	E	E
Sodium Dichromate, Acid	N	N	E	-	-	E	E
Sodium Hydroxide (Caustic Soda)	S	E	E	S	E	E	E
Sodium Hypochlorite	S	S	S	N	N	E	E
Sodium Nitrate	S	E	E	S	E	E	E
Sodium Peroxide	S	S	E	E	E	-	E
Sodium Phosphate	E	E	E	E	E	-	E
Sodium Silicate	S	E	E	E	E	-	-
Sodium Sulfate	E	E	E	E	S	E	E
Sodium Sulfide	N	N	E	N	S	E	E
Sodium Sulfite	S	S	E	E	S	E	E
Sodium Thiosulfate	N	N	E	E	E	E	E
Steam	E	E	E	E	-	E	-
Stearic Acid	S	E	E	S	E	E	E
Sugar Solutions	E	E	E	-	-	E	E
Sulfur, dry	S	E	E	S	S	E	E
Sulfur, molten	N	N	S	S	N	-	N
Sulfur Chloride, dry	E	E	E	S	-	-	E
Sulfur Dioxide, dry	E	E	E	E	E	S	E
Sulfur Dioxide, moist	S	N	E	S	N	S	N
Sulfur Trioxide, dry	E	E	E	-	-	E	E
Sulfuric Acid, 80-95%	N	S	E	N	N	N	S
Sulfuric Acid, 40-80%	N	N	E	N	N	N	E
Sulfuric Acid, 40%	N	S	E	N	S	E	E
Sulfurous Acid	S	N	E	N	N	E	E
Tannic Acid	S	E	E	E	-	E	E
Tar	E	E	E	-	-	-	-
Varnish	E	E	E	E	-	-	-
Vinegar	S	E	E	S	E	E	E
Water, Potable	S	E	E	E	-	E	E
Zinc Chloride	S	S	E	N	-	E	E
Zinc Sulfate	S	E	E	S	-	E	E

The table above lists various materials and their resistance to chemicals under average conditions.

However, it is intended only as a guide and does not imply a guarantee due to the number of variable conditions which may be encountered.

RATINGS

- E - The material should be suitable under most conditions.
- S - The material offers fair corrosion resistance. It may be considered in place of a material with an "E" rating when some property other than corrosion resistance governs its use.
- N - The material is not suitable.

FAULT LOCATING

1. EQUIPMENT AVAILABLE:
   a) 500 volt megger.
   b) Capacitance Bridge (battery operated) and Capacitance Meter (110 Volts AC).
   c) Tinsley Fault Locator (battery operated, also requires 6 volt storage battery).
   d) Search Coil Equipment which includes head phones (battery operated).
   e) Ohmmeter and Wheatstone Bridge (both battery operated).
   f) Time delay reflectometer (TDR).

2. TYPE OF FAULTS:
   a) Low resistance short between conductor or conductors and sheath (a few ohms) and conductor continuity.
   b) High resistance short between conductors or conductor and sheath and conductor continuity.
   c) Open circuit of conductor(s) with high resistance to sheath or other conductor and across open ends of conductor.
   d) Open circuit of conductor(s) with low resistance to sheath or other conductor and across open ends of conductor.

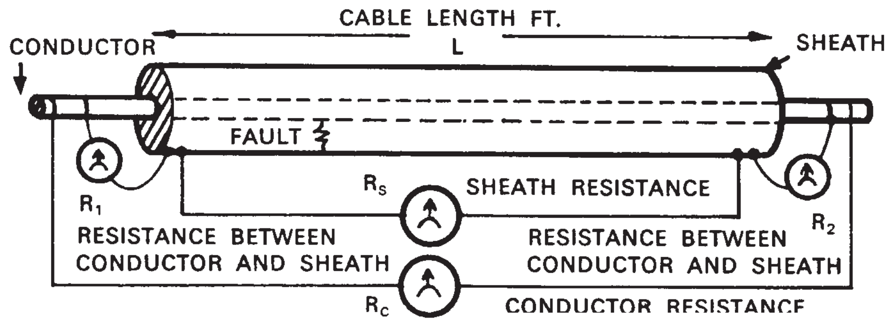
3. PROCEDURE:
   The first step is to disconnect the conductors from all equipment if possible, then using the 500 volt megger, take the insulation value between all conductors and between conductor(s) and sheath, from both ends of cable. Also the continuity of each conductor and of the sheath should be checked. From these tests the type of fault may be determined.

   a) Low Resistance Short
   The Tinsley Fault Locator may be used on this type of fault to find the percentage of the distance the fault is from one end.

   An ohmmeter or Wheatstone Bridge may also be used on this type of fault, although it will not give as accurate a result. The following formula may be used for this method:

$$D=\frac{(R_1-R_2+R_S)\ L/2}{(R_C+R_S)}$$

LOCATION OF CABLES AND CABLE FAULTS



R_1 = Resistance across shorted conductor and sheath from one end (ohms)

R_2 = Resistance across shorted conductors and sheath from the other end (ohms)

R_C = Resistance of conductor (ohms), measured across ends of cables.

R_S = Resistance sheaths (ohms), measured across ends of cables.

L = Total length of cable (feet)

D = Distance from first end of fault (feet)

   b) High Resistance Short
   The Tinsley Fault Locator is the only instrument available for finding this type of fault. A fault up to 200 megohms may be located with this instrument.

   c) Open Circuit With High Resistance Short
   The Capacitance Meter may be used if 110 volts AC is conveniently available and the resistance to sheath or other conductor is above one megohm.

   The Capacitance Bridge is a better and more convenient instrument to use for this type of fault. It may be used with a resistance to sheath or to other conductor down to 50,000 ohms, but not below.

   d) Open Circuit With Low Resistance Short Tektronix Model 1503 metallic cable TDR tester.

LOCATION OF CABLE:
The Search Coil equipment may be used to determine the location of cable but not to locate faults. The main difficulty of tracing a fault with this equipment is that there is no large reduction in sound when the coil passes the fault.

However, once the distance from the fault has been determined by one of the above methods, the search coil may be very useful in determining where the cable runs.

EQUIPMENT OPERATING INSTRUCTIONS:
Each piece of equipment has complete operating instructions with it. If these are lost, copies may be obtained from Trenton.

Order Desk Phone: 1-800-234-6501
Order Desk Fax: 1-800-410-8677

Order Desk Phone: 1-800-461-9583
Order Desk Fax: 1-800-272-7808

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