8. INSTALLATION AND TESTING

CONTENTS

ANIXTER

8. INSTALLATION AND TESTING (CONT)

CONTENTS

ANIXTER

This section is intended as a guide for the installer's use in the field. The information has been obtained from many sources and covers some of the major considerations when installing and testing power, control, instrumentation, fiber and communication cable.

8.1 Receiving, Handling and Storage

The following guidelines are recommended to prevent possible deterioration or damage of cable during handling or storage prior to installation:

8.1.1 Receiving

Before accepting any shipment, all reels should be visually inspected for both hidden and obvious damage. Be especially alert if:

- A reel is lying flat on its side.
- Reels are poorly stacked.
- Cable covering is removed or damaged.
- Cable end seals are removed or damaged.
- Reel flanges are broken.
- A reel has been dropped.
- Cable ties are loose.

8.1.2 Handling

Cable reels should always be rolled in the direction of the "roll this way" stenciled on the flanges. This prevents loosening of the cable turns which may cause problems during installation. If the roll direction is not indicated, roll the reel in the same direction it was turned when the cable was wound *onto* the reel.

Cable reels should only be lifted by forklift trucks from the sides and only if forks are long enough to cradle both flanges.

Steel lifting bars of a suitable diameter and length should be used when lifting cable reels by crane or other overhead lifting devices. With heavy reels or reels that may be unbalanced the use of a lifting yoke is recommended to prevent reels from slipping or tipping during lifting.

8.1.3 Storage

Where possible, reels should be stored indoors on a hard, dry surface. If reels must be stored outside they should be supported off the ground and covered with a suitable weatherproof material.

- Align reels flange to flange.
- Each reel should be chocked.
- Reels should be stored to allow easy access for lifting and moving.

When cable lengths are cut from a master cable reel, all exposed cable ends should be resealed with plastic weatherproof caps or tape to prevent the entrance of moisture.

8. INSTALLATION AND TESTING

8.2 Conduit Fill

Below is a table of the maximum number of conductors that can be installed in electrical metallic tubing (EMT). The table is based on Table1, Chapter 9 of the National Electrical Code. For installation in other types of conduits or for installation of compact stranded conductors, refer to Tables C1 through C12 in Appendix C of the 1996 NEC.

Table 8.1–Maximum number of conductors in electrical metallic tubing

Conduit or Tubing Trade Size (inches)		½	¾	1	1¼	1½	2	2½	3	3½	4
Type Letters	**Conductor Size AWG/kcmil**										
RH	14	6	10	16	28	39	64	112	169	221	282
	12	4	8	13	23	31	51	90	136	177	227
RHH, RHW, RHW-2	14	4	7	11	20	27	46	80	120	157	201
	12	3	6	9	17	23	38	66	100	131	167
RH, RHH, RHW, RHW-2	10	2	5	8	13	18	30	53	81	105	135
	8	1	2	4	7	9	16	28	42	55	70
	6	1	1	3	5	8	13	22	34	44	56
	4	1	1	2	4	6	10	17	26	34	44
	3	1	1	1	4	5	9	15	23	30	38
	2	1	1	1	3	4	7	13	20	26	33
	1	0	1	1	1	3	5	9	13	17	22
	1/0	0	1	1	1	2	4	7	11	15	19
	2/0	0	1	1	1	2	4	6	10	13	17
	3/0	0	0	1	1	1	3	5	8	11	14
	4/0	0	0	1	1	1	3	5	7	9	12
	250	0	0	0	1	1	1	3	5	7	9
	300	0	0	0	1	1	1	3	5	6	8
	350	0	0	0	1	1	1	3	4	6	7
	400	0	0	0	1	1	1	2	4	5	7
	500	0	0	0	0	1	1	2	3	4	6
	600	0	0	0	0	1	1	1	3	4	5
	700	0	0	0	0	0	1	1	2	3	4
	750	0	0	0	0	0	1	1	2	3	4
	800	0	0	0	0	0	1	1	2	3	4
	900	0	0	0	0	0	1	1	1	3	3
	1,000	0	0	0	0	0	1	1	1	2	3
THHW, THW, THW-2*	14	6	10	16	28	39	64	112	169	221	282

* This row is also valid for single layer insulated RHH, RHW, and RHW-2

Continued

Table 8.1–Maximum number of conductors in electrical metallic tubing

Continued

Conduit or Tubing Trade Size (inches)		½	¾	1	1¼	1½	2	2½	3	3½	4
Type Letters	**Conductor Size AWG/kcmil**										
THHW, THW THW-2*	12	4	8	13	23	31	51	90	136	177	227
	10	3	6	10	18	24	40	70	106	138	177
THHW, THW, THW-2*	8	1	4	6	10	14	24	42	63	83	106
TW, THW, THHW, THW-2*	6	1	3	4	8	11	18	32	48	63	81
	4	1	1	3	6	8	13	24	36	47	60
	3	1	1	3	5	7	12	20	31	40	52
	2	1	1	2	4	6	10	17	26	34	44
	1	1	1	1	3	4	7	12	18	24	31
	1/0	0	1	1	2	3	6	10	16	20	26
	2/0	0	1	1	1	3	5	9	13	17	22
	3/0	0	1	1	1	2	4	7	11	15	19
	4/0	0	0	1	1	1	3	6	9	12	16
	250	0	0	1	1	1	3	5	7	10	13
	300	0	0	1	1	1	2	4	6	8	11
	350	0	0	0	1	1	1	4	6	7	10
	400	0	0	0	1	1	1	3	5	7	9
	500	0	0	0	1	1	1	3	4	6	7
	600	0	0	0	1	1	1	2	3	4	6
	700	0	0	0	0	1	1	1	3	4	5
	750	0	0	0	0	1	1	1	3	4	5
	800	0	0	0	0	1	1	1	3	3	5
	900	0	0	0	0	0	1	1	2	3	4
	1,000	0	0	0	0	0	1	1	2	3	4
THHN, THWN, THWN-2	14	12	22	35	61	84	138	241	364	476	608
	12	9	16	26	45	61	101	176	266	347	443
	10	5	10	16	28	38	63	111	167	219	279
	8	3	6	9	16	22	36	64	96	126	161
	6	2	4	7	12	16	26	46	69	91	116
	4	1	2	4	7	10	16	28	43	56	71
	3	1	1	3	6	8	13	24	36	47	60
	2	1	1	3	5	7	11	20	30	40	51
	1	1	1	1	4	5	8	15	22	29	37
	1/0	1	1	1	3	4	7	12	19	25	32
	2/0	0	1	1	2	3	6	10	16	20	26
	3/0	0	1	1	1	3	5	8	13	17	22

* This row is also valid for single layer insulated RHH, RHW, and RHW-2

Continued

Table 8.1–Maximum number of conductors in electrical metallic tubing

Continued

Conduit or Tubing Trade Size (inches)		½	¾	1	1¼	1½	2	2½	3	3½	4
Type Letters	**Conductor Size AWG/kcmil**										
THHN, THWN, THWN-2	4/0	0	1	1	1	2	4	7	11	14	18
	250	0	0	1	1	1	3	6	9	11	15
	300	0	0	1	1	1	3	5	7	10	13
	350	0	0	1	1	1	2	4	6	9	11
	400	0	0	0	1	1	1	4	6	8	10
	500	0	0	0	1	1	1	3	5	6	8
	600	0	0	0	1	1	1	2	4	5	7
	700	0	0	0	1	1	1	2	3	4	6
	750	0	0	0	0	1	1	1	3	4	5
	800	0	0	0	0	1	1	1	3	4	5
	900	0	0	0	0	1	1	1	3	3	4
	1,000	0	0	0	0	1	1	1	2	3	4
XHH, XHHW, XHHW-2	14	8	15	25	43	58	96	168	254	332	424
	12	6	11	19	33	45	74	129	195	255	326
	10	5	8	14	24	33	55	96	145	190	243
	8	2	5	8	13	18	30	53	81	105	135
	6	1	3	6	10	14	22	39	60	78	100
	4	1	2	4	7	10	16	28	43	56	72
	3	1	1	3	6	8	14	24	36	48	61
	2	1	1	3	5	7	11	20	31	40	51
XHH, XHHW, XHHW-2	1	1	1	1	4	5	8	15	23	30	38
	1/0	1	1	1	3	4	7	13	19	25	32
	2/0	0	1	1	2	3	6	10	16	21	27
	3/0	0	1	1	1	3	5	9	13	17	22
	4/0	0	1	1	1	2	4	7	11	14	18
	250	0	0	1	1	1	3	6	9	12	15
	300	0	0	1	1	1	3	5	8	10	13
	350	0	0	1	1	1	2	4	7	9	11
	400	0	0	0	1	1	1	4	6	8	10
	500	0	0	0	1	1	1	3	5	6	8
	600	0	0	0	1	1	1	2	4	5	6
	700	0	0	0	0	1	1	2	3	4	6
	750	0	0	0	0	1	1	1	3	4	5
	800	0	0	0	0	1	1	1	3	4	5
	900	0	0	0	0	1	1	1	3	3	4
	1,000	0	0	0	0	0	1	1	2	3	4

Continued

Table 8.1–Maximum number of conductors in electrical metallic tubing

Continued

Conduit or Tubing Trade Size (inches)		½	¾	1	1¼	1½	2	2½	3	3½	4
Type Letters	**Conductor Size AWG/kcmil**										
TFN, TFFN	18 16	22 17	38 29	63 48	108 83	148 113	244 186				

Source: 1996 NEC, Appendix C1

Table 8.2–Maximum cable diameters for permissible conduit fill

No. of Wires or Cables	Nominal Conduit Size (in.)									
	½	¾	1	1¼	1½	2	2½	3	3½	4
	Actual ID of Conduit (in.)									
	0.622	0.824	1.05	1.38	1.61	2.07	2.47	3.07	3.55	4.03
	Max. Diam. of Wires or Cables in Conduit (in.)									
1	0.462	0.610	0.778	1.02	1.19	1.53	1.83	2.27	2.63	3.00
2	0.249	0.380	0.420	0.552	0.644	0.828	0.988	1.23	1.42	1.61
3	0.231	0.305	0.390	0.511	0.596	0.767	0.914	1.14	1.31	1.49
4	0.201	0.266	0.339	0.445	0.519	0.668	0.796	0.999	1.14	1.30
5	0.178	0.235	0.300	0.395	0.460	0.591	0.706	0.876	1.01	1.15
6	0.164	0.216	0.276	0.364	0.424	0.545	0.650	0.807	0.935	1.06
7	0.152	0.201	0.256	0.337	0.392	0.505	0.603	0.749	0.868	0.984
8	0.141	0.187	0.239	0.314	0.366	0.470	0.562	0.698	0.806	0.916
9	0.133	0.175	0.224	0.294	0.342	0.441	0.525	0.653	0.755	0.858
10	0.125	0.165	0.210	0.276	0.322	0.414	0.494	0.614	0.710	0.807
11	0.119	0.157	0.200	0.263	0.307	0.394	0.471	0.584	0.676	0.768
12	0.114	0.151	0.193	0.254	0.296	0.380	0.453	0.563	0.651	0.740
13	0.109	0.144	0.184	0.242	0.283	0.363	0.435	0.538	0.623	0.707
14	0.106	0.139	0.178	0.234	0.273	0.351	0.418	0.520	0.601	0.683
15	0.102	0.135	0.172	0.226	0.264	0.339	0.405	0.503	0.583	0.661

Source: Based on NEC Table 1, Chapter 9

Table 8.3 – Dimensions and maximum allowable percent fill of electrical metallic tubing (EMT)

Trade Size	Internal Diameter	Total Area	Allowable Fill—Square In.		
			1 Cond. 53% Fill	2 Cond. 31% Fill	Over 2 Cond. 40% Fill
In.	In.	Sq. In.			
½	0.622	0.30	0.16	0.09	0.12
¾	0.824	0.53	0.28	0.16	0.21
1	1.049	0.86	0.46	0.27	0.34
1¼	1.380	1.50	0.80	0.47	0.60
1½	1.610	2.04	1.08	0.63	0.82
2	2.067	3.36	1.78	1.04	1.34
2½	2.469	4.79	2.54	1.48	1.92
3	3.068	7.38	3.91	2.26	2.95
4	4.026	12.72	6.74	3.94	5.09
5	5.047	20.00	10.60	6.20	8.00
6	6.065	28.89	15.31	8.96	11.56

Source: National Electrical Code, Chapter 9, Table 4

For other conduit types, please refer to Table 4 in Chapter 9 of the NEC.

Area In Square Inches $= \dfrac{\pi \times OD^2}{4} \times n$

Example: Pulling (3) 2/0 15 kV cables, each cable has an overall diameter of 1.20 inches. Using the formula, solve as follows: $\dfrac{3.14 \times 1.2^2}{4} \times 3 = 3.39$ square inches. Referring to the table, minimum conduit size would be 4 inches.

8.3 Pulling

8.3.1 Methods of Gripping Cables

In general, insulated cables may be gripped either directly by the conductors or by a **basket-weave pulling grip** applied over the cables. The method used depends on the anticipated maximum **pulling tension** in each case. When pulls are relatively light a basket-weave grip is often used. Heavier pulls usually require connecting directly to the conductor either by means of **pulling eyes** or by forming a loop with the conductor itself. In some instances it is desirable to use a grip over the outer covering in addition to the conductor connection to prevent any slippage of one with respect to the other.

Nonmetallic Sheathed Cables

The smaller sizes of nonmetallic sheathed cables are usually gripped directly by the conductors by forming them into a loop to which the pull wire or rope can be attached. The insulation on each conductor is removed before the loop is formed. Larger sizes are more easily handled by applying a **pulling grip** over the cable or cables provided the pull is not too severe. If more than one cable is involved the ends should be bound together with electrical tape before applying the grip overall. Long, hard pulls will necessitate the use of pulling eyes.

Lead-Sheathed Cables

Pulling eyes for lead-sheathed cables can be applied either at the factory or in the field. They often must be wiped to the lead sheath to prevent the entrance of moisture. For shorter pulls a basket-weave grip may be applied over the lead sheath or over the jacket if one is present over the lead sheath.

Interlocked Armor Cables

When pulling interlocked armor cable it is necessary to grip both the armor and the conductors. This can be accomplished in a number of ways. One method requires that a portion of the armor be removed. Electrical tape is then applied over the armor and down over the conductors and a long basket-weave grip is applied such that it grips both the armor and the conductors. Another method requires that two holes be drilled through the cable (armor and conductors) at right angles to each other and a loop formed by passing steel wires through the holes and out over the end of the cable. A third approach is to use a pulling eye and a grip together, the grip being applied over the armor to prevent it from slipping back. This latter approach provides the greatest strength.

Preassembled Aerial Cable

This type of cable should always be gripped by the messenger which is usually attached to a **pulling swivel.** In addition, a basket grip should be applied over the conductors to prevent any slippage and to facilitate guiding the conductors through the pulleys.

8.3.2 Tension Limitations

When the pulling force is applied directly to the conductor (i.e., when pulling eyes are used or when the conductor is formed into a loop) it should be limited to 0.008 lb per circular mil area of cross-section for copper and 0.006 lb per circular mil for aluminum.

When a grip is applied over nonmetallic sheathed cables, the pulling force should be limited to 1,000 pounds provided this is not in excess of the force calculated above using the 0.008 or 0.006 factors.

8. INSTALLATION AND TESTING

To limit the **sidewall pressure** to a safe value at **bends in duct and conduit runs,** the pulling force in pounds should not exceed 300 times the radius of the bend in feet.

The above limits are maximum values which should not be exceeded. However, it is possible to damage cables while applying lower tensions if, for example, there are sharp projections in a poorly constructed duct bank, or if an interlocked armor cable is pulled around too small a **sheave.** Every installation detail cannot be covered here but staying within the above tension limits will help assure a successful installation.

8.3.3 Helpful Hints

The following suggestions—though not all-inclusive—will give greater assurance of success.

(**1**) Be sure there is adequate clearance between conduit and cable. Clearance refers to the distance between the uppermost cable in the conduit and the inner top of the conduit. Clearance should be 1/4 inch at minimum and up to one inch for large cable installations or installations involving numerous bends. It is calculated as follows:

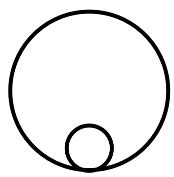
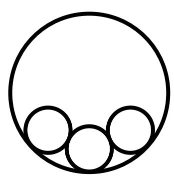
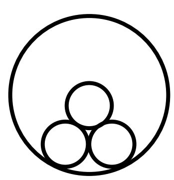
# of Conductors/Cables	Configuration	Formula
1		$D - d$
3	 CRADLED	$\frac{D}{2} - 1.366d + \frac{D-d}{2}\sqrt{1-\left(\frac{d}{(D-d)}\right)^2}$
3	 TRIPLEXED	$\frac{D}{2} - \frac{d}{2} + \frac{D-d}{2}\sqrt{1-\left(\frac{d}{2(D-d)}\right)^2}$

Figure 8.1–How to calculate clearance

Where “D” is the inner diameter of the conduit and “d” is the outer diameter of the cable. When calculating **clearance,** ensure all cable diameters are equal. Use the triplexed configuration formula if you are in doubt. The cables may be of single or multiple conductor construction. Do not exceed recommended “percent fill” requirements.

(**2**) **Jamming** is the wedging of three cables lying side by side in a conduit. This usually occurs when cables are being pulled around bends or when cables twist.

Jam Ratio is calculated by slightly modifying the ratio D/d. A value of 1.05D is used for the inner diameter of the conduit because bending a cylinder creates an oval cross-section in the bend.

- If 1.05D/d is larger than 3.0, jamming is impossible.
- If 1.05D/d is between 2.8 and 3.0, serious jamming is probable.
- If 1.05D/d is less than 2.5, jamming is impossible but clearance should be checked.

Since there are manufacturing tolerances on cable, the actual overall diameter should be measured prior to computing jam ratio.

(**3**) Use adequate **lubrication** of the proper type to reduce friction in conduit and duct pulls. The grease and oil type lubricants used on lead sheathed cables should not be used on nonmetallic sheathed cables. There are a number of commercially available **wire pulling compounds** (many of which are UL Listed) that are suitable for use with polymer jacketed cables. They usually consist of soap, talc, mica or the like, and are designed to have no deleterious effect on the cable. Graphite and other electrically conducting lubricants should not be used on nonshielded cables rated 2kV and above. These materials can lead to tracking of the cable jacket.

(**4**) Avoid sharp bending of the cable at the first pulley in overhead installations by locating the pay-off reel far enough away from the first pulley that the lead-in angle is kept relatively flat.

(**5**) After installation check that **end seals** are still intact and have not been damaged to the point where water could enter. Apply plastic or rubber tape to help protect against invisible damage if the cable will be subjected to immersion or rain. This is particularly important if there will be a delay of some time between the pulling operation and splicing and terminating.

(**6**) When installing interlocked armor cables in cable tray, use sufficient rollers to prevent the cable from dragging on the tray which might result in excessive tension. Avoid sharp bends in the cable by using one 3-sheave pulley at 45-degree bends and two **3-sheave pulleys** at 90-degree bends.

(**7**) Keep adequate tension on the messenger in aerial cable installations to prevent sharp bends at pulleys. Do not release the tension on the messenger until it is secured to poles on both ends.

8.3.4 Pulling Tension Calculations

The following recommendations are based on a study sponsored by ICEA. These recommendations may be modified if experience and more exact information so indicate.

(**1**) **Maximum Pulling Tension**
a. With pulling eye attached to copper conductors, the maximum pulling tension in pounds should not exceed 0.008 times the circular mil area.

b. With pulling eye attached to aluminum conductors, the maximum pulling tension in pounds should not exceed 0.006 times the circular mil area.

Example: For copper

$T_M = 0.008 \times n \times CM$

where

T_M = maximum tension, lb.

n = number of conductors

CM = circular mil area of each conductor

(**2**) **Maximum Permissible Pulling Length:**

$$L_M = \frac{T_M}{C \times W}$$

where

L_M = maximum pulling length, feet (valid only for straight sections)

T_M = maximum tension, lb.

W = weight of cable per foot, lb.

C = coefficient of friction (typically 0.5 but can vary from 0.2 to 1.0 depending on condition of the duct and the amount of lubricant used)

(**3**) **Bend Multipliers**
For a curved section, the multipliers given below are applied to the tension calculated for the straight section preceding the bend.

Table 8.4 – Bend multipliers for pulling tension calculations

Bend Angle		Bend Angle	
Degrees	**Multiplier**	**Degrees**	**Multiplier**
15	1.14	75	1.94
30	1.30	90	2.20
45	1.48	105	2.50
60	1.70	120	2.86

Note: These multipliers are based on a coefficient of friction of 0.5. If the coefficient of friction were 1.0 instead of 0.5 the multipliers would have to be squared. If the coefficient of friction were 0.75, the multipliers would be raised to the one and one-half power.

8.3.5 Pulling Lubricants

Many commercial lubricants are available and may be employed to reduce pulling tensions provided they do not affect electrical or mechanical characteristics of the cable.

The primary function of a pulling lubricant is to reduce the tension on the cable as it is installed in a duct. This is accomplished by reducing the friction (technically the **"coefficient of friction"**) between the cable and the inside surface of the conduit, i.e., it makes the cable more "slippery."

Cable pulling lubricants should be formulated for the conditions of the pull, be safe for the environment, not degrade the cable jacket, and be easy to work with.

The quantity of lubricant required depends on various factors: The pull length, the condition and size of the conduit, and the difficulty of the pull. The recommended average quantity of lubricant per pull is equal to:

$$\mathbf{Q = 0.0015 \times L \times D}$$

Where Q is the quantity of lubricant needed in gallons, L is the length of the pull in feet, and D is the inner diameter (ID) of the conduit in inches.

The appropriate quantity to use can vary by ± 50% from the average depending on installation conditions. Follow the manufacturer's instructions for the conditions affecting each pull.

8.3.6 Sidewall Pressure (SWP)

To prevent damage to a cable from pressure which develops when a cable is pulled around a bend under tension, the pressure must be kept as low as possible and should not exceed the following values. Sidewall pressure = Tension out of the bend divided by bend radius.

Note: Many cable manufacturers recommend a maximum SWP of 500 pounds/foot.

Table 8.5 – Maximum sidewall pressure (SWP) for power cables

Cable Type	Maximum SWP (lbs/ft) ①
XLPE Insulation/Jacket – 600V Cable	1,200
EPR, Neoprene – 600V Cable	1,000
PE & XLPE insulation, concentric wire shield:	
without jacket	1,200 ②
with encapsulating jacket	2,000
PE & XLPE insulation, LC shield LDPE jacket	1,500
PE, XLPE, EPR insulation, concentric wire or tape shield, LDPE & PVC sleeved jackets	2,000 ③
Lead sheathed cable, with & without jackets:	
XLPE insulation	2,000
EPR insulation	
XLPE insulation, copper ribbon shield, MDPE sleeved jacket	2,000

Continued

Table 8.5 – Maximum sidewall pressure (SWP) for power cables

Continued

NOTES

① When considering the use of the above sidewall pressures the stress on the cable conductor should not exceed the following values:

16,000 psi for copper conductor (annealed)
14,000 psi for stranded aluminum conductors (1/2 thru Full Hard)
10,000 psi for solid aluminum conductors (3/4 & Full Hard)

For three conductor cables in parallel configuration, the allowable conductor stress should be based on two cables sharing the load.

② For a three cable pull, a maximum SWP limit of 750 lb/ft is recommended.

③ The recommended SWP limit should be reduced to 1500 lb/ft when the jacket is not applied tightly to the cable core.

Source: EPRI Report EL-3333-CCM, Volume 2

8.3.7 Minimum Bending Radii

Power Cables without Metallic Shielding
The minimum bending radii for both single and multiple-conductor cable without metallic shielding are as follows:

Table 8.6 – Minimum bending radii for cables without metallic shielding

Thickness of Conductor Insulation in Mils	Minimum Bending Radius as a Multiple of Cable Diameter		
	Overall Diameter of Cable in Inches		
	1.00 and less	1.01 to 2.00	2.01 and Over
155 and Less	4	5	6
170 – 310	5	6	7
325 and over	–	7	8

Example:
If minimum bending radius is 6 times cable O.D. and cable O.D. is 2.0 inches, the minimum bending radius is 12 inches (minimum bending diameter is 24 inches).

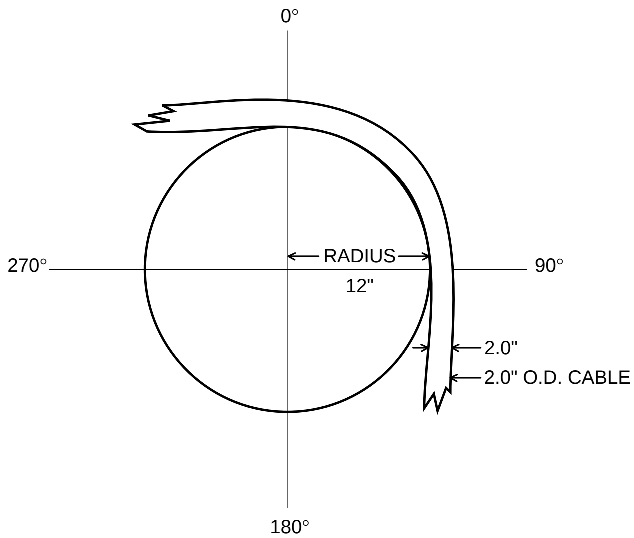


Figure 8.2 – Calculating minimum bending radius

Power Cables with Metallic Shielding
The minimum bending radius for all cables with metallic shielding is twelve times the overall diameter of the cable.

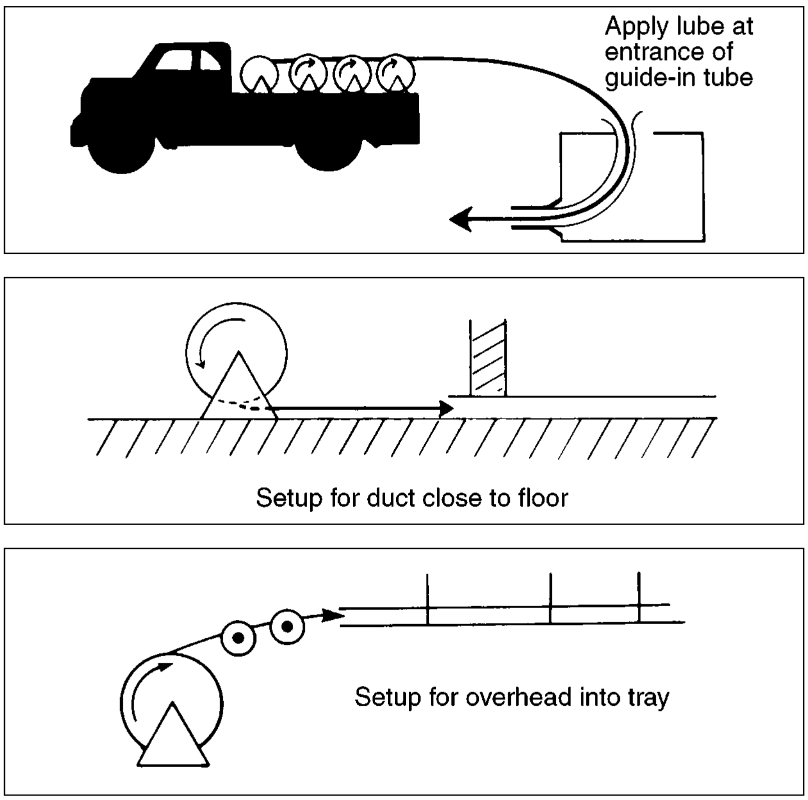
Portable Cables
The minimum bending radius for portable cables during installation and handling in service is six times the cable diameter for cables rated 5000 volts and less. For cables rated over 5000 volts use eight times the cable diameter. For flat twin cables, the minor diameter is used to determine the bending radius.

Fiber Optic Cables
Minimum bending radius for fiber optic cable is ten times the cable diameter for multimode and 20 times the cable diameter for single mode.

Interlocked Armor or Corrugated Sheath (Type MC) Cables
The minimum bending radius for Type MC cable is seven times the external diameter of the metallic sheath.

Sources: NEC Articles 300-34, 334-11(b), and 336-16
ICEA S-66-524 (NEMA WC7) and
S-68-516 (NEMA WC8), Appendix H

8.4 Installation Methods



The feed-in setup should unreel the cable with the natural curvature (a) as opposed to a reverse “S” curvature (b).

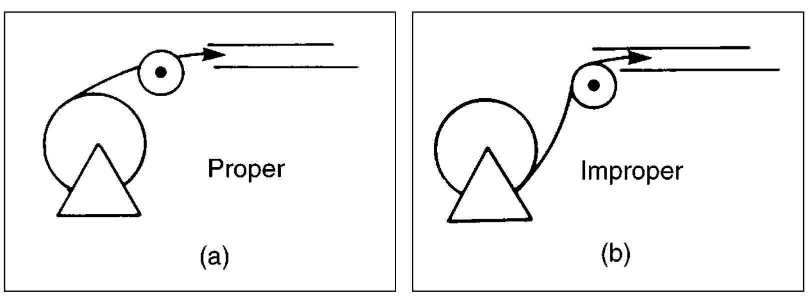


Figure 8.3 –Cable feed-in setups

Continued

Continued

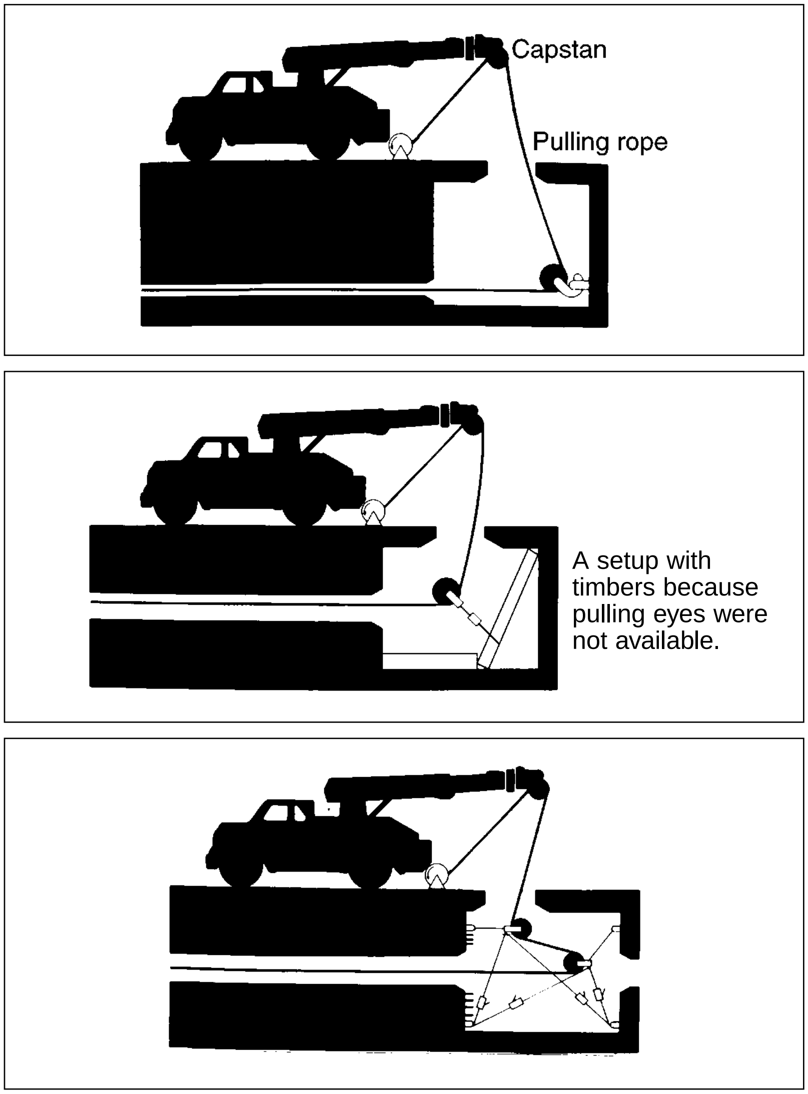
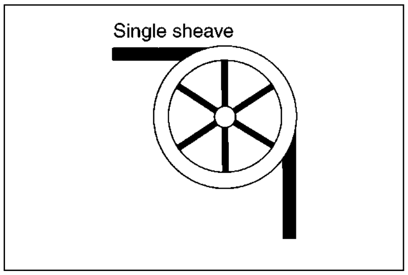


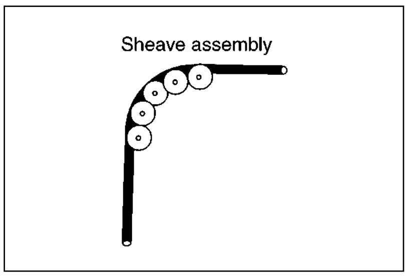
Figure 8.3–Cable feed-in setups

Continued

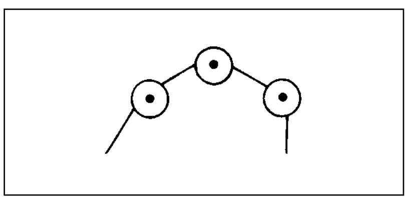
Continued



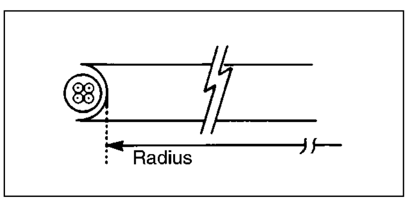
Single sheaves should be used only for *guiding* cables. Arrange multiple blocks if necessary to maintain minimum bending radii whenever cable is deflected.



For pulling around bends, use conveyor sheave assemblies of the appropriate radius.



The pulleys must be positioned to ensure that the effective curvature is smooth and deflected evenly at each pulley. Never allow a polygon curvature to occur as shown.



The fit of the pulley around the cable is also important when the pulling tension is high (for example, pulleys at the top of a vertical drop). Remember to use the radius of the surface over which the cable is bent, not the outside flange diameter of the pulley.
A “10 inch” cable sheave typically has an inside (bending) radius of 3 inches!

Figure 8.3 –Cable feed-in setups

8.5 Overhead Messengers

Table 8.7–Messenger breaking strength in lbs.

Nominal Messenger Size	30% EHS* Copper-Clad Steel	Aluminum Clad Steel	EHS* Galvanized Steel	High-Strength Galvanized Steel	Type 316 Stainless Steel	Type 302 Stainless Steel
¼ inch (7×12 AWG)	6,282	6,301	6,650	4,750	7,650	8,500
5⁄16 inch (7×10 AWG)	9,196	10,020	11,200	8,000	11,900	13,200
⅜ inch (7×8 AWG)	13,890	15,930	15,400	10,800	16,200	18,000
7⁄16 inch (7×7 AWG)	16,890	19,060	20,800	14,500	23,400	26,000
½ inch (7×6 AWG)	20,460	22,730	26,900	18,800	30,300	33,700

* Extra-High Strength

Table 8.8 –Messenger weight in lbs./1000ft

Nominal Messenger Size	30% EHS Copper-Clad Steel	Aluminum Clad Steel	EHS Galvanized Steel	High-Strength Galvanized Steel	Type 316 Stainless Steel	Type 302 Stainless Steel
¼ inch	139	104	121	121	136	132
5⁄16 inch	204	165	205	205	208	208
⅜ inch	324	262	273	273	278	278
7⁄16 inch	408	330	399	399	405	405
½ inch	515	416	517	517	525	525

Table 8.9 –Maximum core weight in lbs./ft
(Based on final sag of 30 inches at 60°F in a 150ft span, 30% of ultimate strength)

Nominal Messenger Size	30% EHS Copper-Clad Steel	Aluminum Clad Steel	EHS Galvanized Steel	High-Strength Galvanized Steel	Type 316 Stainless Steel	Type 302 Stainless Steel
¼ inch	1.5	1.5	1.6	1.1	1.8	2.1
5⁄16 inch	2.2	2.4	2.7	1.9	2.9	3.3
⅜ inch	3.3	3.9	3.8	2.6	3.9	4.5
7⁄16 inch	4	4.7	5.1	3.4	5.8	6.5
½ inch	4.9	5.6	6.6	4.4	7.5	8.4

Table 8.10 – Galvanized steel strand/physical specifications

Nominal Messenger Size		Weight	Minimum Strength
inch	Grade	lbs. per 1000 ft	lbs.
3⁄16	Common	73	1,150
3⁄16	Utility 2.2M	73	2,400
1⁄4	Common	121	1,900
1⁄4	Siemens Martin	121	3,150
1⁄4	High Strength	121	4,750
1⁄4	Ex. High Strength	121	6,650
5⁄16	Common	205	3,200
5⁄16	Siemens Martin	205	5,350
5⁄16	Utilities Grade 6M	225	6,000
5⁄16	High Strength	205	8,000
5⁄16	Ex. High Strength	205	11,200
3⁄8	Common	273	4,250
3⁄8	Siemens Martin	273	6,950
3⁄8	Utility 10M	273	11,500
3⁄8	High Strength	273	10,800
3⁄8	Ex. High Strength	273	15,400
7⁄16	Siemens Martin	399	9,350
7⁄16	High Strength	399	14,500
7⁄16	Utility 16M	399	18,000
1⁄2	Siemens Martin	517	12,100
1⁄2	High Strength	517	18,800
1⁄2	Utility 25M	517	25,000

Class A: Minimum amount of zinc coating.
Class B: Twice the amount of zinc coating as “A.”
Class C: Three times the amount of zinc coating as “A.”

8.6 Vertical Suspension

8.6.1 Suspended By Clamping Around Cable

Table 8.11–Spacings for conductor supports

Maximum Support Spacing for Conductors in Vertical Raceways		
AWG or Circular Mil Size of Wire	**Aluminum or Copper-Clad Aluminum**	**Copper**
18 AWG through 8 AWG	100 feet	100 feet
6 AWG through 1/0 AWG	200 feet	100 feet
2/0 AWG through 4/0 AWG	180 feet	80 feet
over 4/0 AWG through 350 kcmil	135 feet	60 feet
over 350 kcmil through 500 kcmil	120 feet	50 feet
over 500 kcmil through 750 kcmil	95 feet	40 feet
over 750 kcmil	85 feet	35 feet

Source: NEC, Article 300-19

8.6.2 Suspended by Conductor

Source: NEMA WC3 (ICEA S-19-81) Section 7.2.2.1

$$F = \frac{A \times T}{W \times L}$$

Where
- A = conductor area in sq. in.
- T = conductor tensile strength in lbs./sq. in.
- W = cable weight in lbs./ft
- L = length in feet
- F = minimum safety factor (7 unless otherwise required by appropriate authority)

Example:

Suspend 470 ft of cable having three 4/0 AWG (211,600 circular mils each) soft-drawn copper conductors, total cable weight is 3,240 lbs./1,000ft or 1,080 lbs./1,000ft per conductor, *each* conductor is supported at the top with a full tension terminal:

$$F = \frac{[(211{,}600)\ (\pi/4)\ /1{,}000{,}000]\ 36{,}000}{(1{,}080/1{,}000)470} = 11.8 \text{ (OK)}$$

If the suspended cable is installed in a conduit elbow at the top, check sidewall loading.

8.7 Hipot Testing

Overview
This procedure is intended to provide general guidelines for high potential DC testing of power cables. For more details see IEEE Standard 400. All tests made after cable installation and during the guarantee period should be made in accordance with applicable specifications. **All safety precautions must be observed during testing at high voltage. Read and understand and follow the Operator's Manual for the particular test set being used!**

8.7.1 Test Equipment
Direct current test equipment is commercially available with a wide range of voltages. Accessory equipment is necessary to safely conduct high voltage tests such as safety barriers, rubber gloves and non-conducting hard hats. Consult appropriate safety officer.

8.7.2 Test Procedure
Refer to IEEE Standard 400. Acceptable procedures, although varying slightly in technique, have more or less been standardized as either a "withstand test" or a "time-leakage current test."

Before performing any DC overpotential tests:

- All equipment must be disconnected from the cable circuit, i.e., disconnect transformers, switch taps, motors, circuit breakers, surge arrestors, etc. This will preclude damage to such equipment and will prevent test interruptions due to flashovers and/or trip-outs resulting from excessive leakage current.
- Establish adequate clearance between the circuit test ends and any grounded object, and to other equipment not under test (about 2.5 feet).
- Ground all circuit conductors not under test and *all* cable shields as well as nearby equipment.
- Consult termination manufacturer for maximum test voltage recommendations and time limitations.

The **direct current test** may be applied either continuously or in predetermined steps to the maximum value in accordance with applicable specifications:

- *Continuous Method*—Apply test voltage at an approximate rise rate of 1 kV per second or 75% of the rated current input of the equipment, whichever is less. Some equipment will take longer to reach the maximum test voltage because of the amount of charging current.
- *Step Method*—Apply test voltage slowly in 5 to 7 increments of equal value, to the maximum specified. Allow sufficient time at each step for the leakage current to stabilize. Normally this requires only a few seconds unless cable circuits of high capacitance are involved. Record leakage current at each step.
- Maintain the test voltage at the prescribed value for the time designated in applicable specifications.
- At the end of the test period, set the test set voltage control to zero. Allow the residual voltage on the circuit to decay then ground the conductor just tested.
- *Caution*—It should be recognized that DC charges on cable can build up to potentially dangerous levels if grounds are removed too quickly. **Maintain solid grounds after the test on the cable for at least 4 times the duration of the test.** It is a good safety practice to maintain these grounds longer and while reconnecting circuit components.

Acceptance Testing—After installation and before the cable is placed in regular service the specified test voltage is applied for **15 consecutive minutes.**

Proof Testing—At any time during the period of guarantee the cable circuit may be removed from service and tested at a reduced voltage (normally 65 percent of the original acceptance value) for **5 consecutive minutes.**

Record the **leakage current** at one minute intervals for the duration of the test. A constant or decreasing leakage current with respect to time at maximum test voltage is the usual acceptance criterion for DC hipot testing.

ADDITIONAL CONSIDERATIONS

High potential testing of medium voltage power cables is usually performed with negative polarity connected to the conductor.

High potential testing is a tool for determining insulation resistance at high voltages. Effective insulation resistance of the cable system may be calculated by means of Ohm's Law: $R = V/I$. Restated another way the relation is:

$$\text{Megohms} = \frac{\text{Kilovolts}}{\text{Microamperes}} \times 1000$$

Insulation resistance may also be measured with instruments which give a direct reading at 500 volts (or higher, depending on the model). IR in general has little or no direct relationship to breakdown strength.

The significance of conducting DC High Voltage tests on nonshielded, nonmetallic-sheathed cable is dependent upon the environment in which it is installed because the characteristics of the return circuits are unknown. The environment must be carefully considered or test results may not be significant. In fact these tests can result in damage to the cable insulation.

Humidity, condensation or actual precipitation on the surface of a cable termination can increase the leakage current by several orders of magnitude. Humidity also increases the termination leakage current, which is included in the total leakage current. Wind prevents the accumulation of space charges at all bare energized terminals. This results in an increase of corona. It is desirable to reduce or eliminate corona current at the bare metal extremities of cable or terminations. This may be accomplished by covering these areas with plastic envelopes, plastic or glass containers, plastic wrap (e.g., "Saran"® or "Handiwrap"®) or suitable electrical putty.

Routine periodic **DC maintenance testing** of cable for the evaluation of the insulation strength is not a common practice. Some power cable users have adopted a program of testing circuits during planned outages, preferring possible breakdowns during testing rather than experiencing a service outage. It is nearly impossible to recommend test voltage values for maintenance. An arbitrary test voltage level could break down a cable circuit that would otherwise render long trouble-free service at normal operating AC voltage.

One advantage of DC high voltage testing is that it can detect conducting particles left on the creepage surface during splicing or termination.

Test equipment should be supplied from a stable, constant voltage source. Do not use the same source which is supplying arc welders or other equipment causing line voltage fluctuations. The output voltage of the test set must be filtered and regulated. Consider using a portable motor driven alternator to energize the test set.

COMMON TESTING PROBLEMS

High leakage current can be caused by:

- Failure to guard against corona
- Failure to clean insulation surface
- Failure to keep cable ends dry (high relative humidity, dampness, dew, fog, wind, snow)
- Failure to provide adequate clearance to ground
- Improper shield termination

Erratic readings can be caused by:

- Fluctuating voltage to test set
- Improper test leads

8.7.3 Test Voltage

Table 8.12 – Maximum DC test voltages for shielded power cables

Rated Circuit Voltage Phase to Phase	Acceptance	
	100% (Grounded)	133% (Ungrounded)
Volts	kV	kV
2,001–5,000	25	25
5,001–8,000	35	35
8,001–15,000	55	65
15,001–25,000	80	100
25,001–28,000	85	–
28,001–35,000	100	–

Sources: IEEE Standard 400
NEMA WC-8 (ICEA S-68-516)
NEMA WC-7 (ICEA S-66-524)
NEMA WC-5 (ICEA S-61-402)

The acceptance test is to be made immediately after installation. A proof test can be made during the guarantee period. **Maintenance testing is not recommended.** However, if tests must be conducted use 40% of the above value for 5 minutes.

DC hipot test voltages are also specified by AEIC for tests conducted during and after installation as follows:

- At any time during installation, a DC proof test may be made at a voltage not exceeding the test voltage specified below, applied for 5 consecutive minutes.
- After the cable has been completely installed and placed in service, a DC proof test may be made at any time within the first 5 years at the test voltage specified below, applied for 5 consecutive minutes. After that time, DC testing is not recommended.

Table 8.13 – AEIC hipot test voltages

Rated Voltage Phase-to-Phase	Maximum DC Field Test Voltages in kV			
	During Installation		First 5 Years	
kV	100% (Grounded)	133% (Ungrounded)	100% (Grounded)	133% (Ungrounded)
5	28	36	9	11
8	36	44	11	14
15	56	64	18	20
25	80	96	25	30
28	84	100	26	31
35	100	124	31	39
46	132	172	41	54

Source: AEIC CS5 & CS6

8.8 Fault Locating

One of the many types of fault locating equipment is the **Time Domain Reflectometer** (**TDR**). These units are portable, commercially available devices which can be used in the field to locate some types of conductor breaks or shorts. Connected to the end of a cable, the device functions much like **radar**, sending out low voltage pulses which travel the length of the cable and echo back when an open, short, or tap is encountered. The device can usually locate faults within $\pm$ 2% of the cable length. However, TDRs are only capable of locating breaks or shorts having an impedance different than that of the cable. For most cables, this includes shorts having a resistance of less than a few ohms and opens having a resistance greater than several hundred ohms. Splices, taps, etc., sometimes distort the echo and can mask the fault. Nevertheless, the method is nondestructive and is used successfully on faults having characteristics within the capabilities of the method.

8.9 Megger Testing

If the DC voltage applied during an insulation resistance (IR) test on power cables is relatively low (0.6 to 2.5 kV) the test is often referred to as a “Megger” test. Low voltage **IR tests** are particularly useful in detecting shorts and indicating grossly deteriorated insulation on 600 volt rated cables.

An inherent limitation of low voltage IR tests is their interpretation. The readings obtained from such testing on nonshielded, nonmetallic-sheathed cable is very dependent upon the environment because the environment determines the characteristics of the return circuit. Low resistance readings may be caused by contaminated or moist cable ends, high humidity, etc. Failure to clean water based cable pulling lubricants from the cable test ends has caused erroneous rejection of good cable. Refer to the figures below for suggested hookup.

Reminders:

- **Safety—Follow the test equipment supplier’s instructions. Stay clear of energized cable. Operators must know the equipment. Be sure shields are grounded!** Remember that insulated conductors are capacitors.
- Voltages—Check cable and termination manufacturer’s guidelines.
- Records—Keep detailed records and provide a copy to the owner.

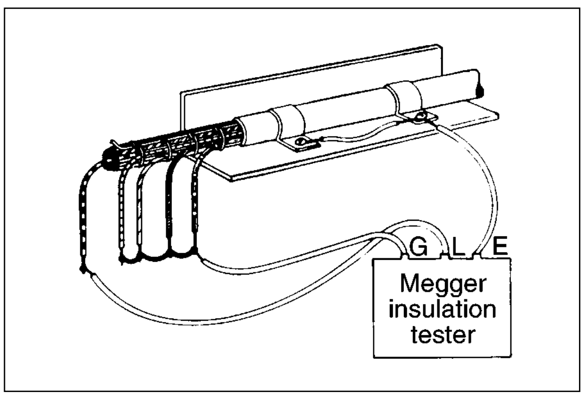


Figure 8.4 –Connections for testing insulation resistance between one wire and ground, without being affected by leakage to other wires. Note use of the Guard (G) connection

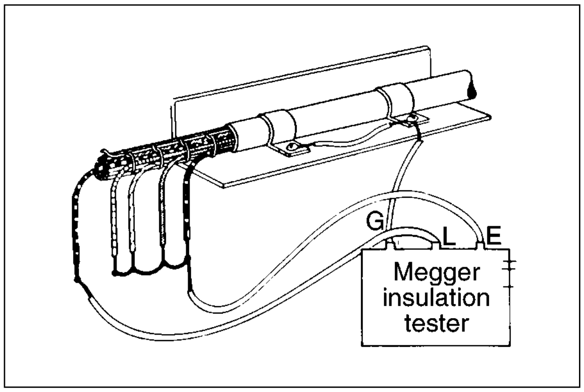


Figure 8.5 –Connections for testing insulation resistance between one wire and all other wires, without being affected by leakage to ground

8.10 Moisture Removal

8.10.1 Purging Water from Conductor Strand or Shield

All Cables: Purge the shield separately from the insulated strands; otherwise the nitrogen gas will only flow through the path offering the least resistance.

Cables Not Installed: Remove end seals. Position one cable end to its lowest possible elevation. At the cable end having the highest elevation apply two layers of half-lapped HV insulating tape to act as a sealing cushion. Connect the cable ends to a dry nitrogen or dry air supply using hoses, valves, fittings, and flow regulators as shown in Figure 8.6.

Attach a one-gallon plastic bag to the exhaust end of the cable. Secure the bag with tape or clamps. Make a small vent hole by clipping one bag corner.

As shown, several cables may be connected to the gas supply. Dry nitrogen is available from welding gas suppliers. Apply 15 – 25 psi (gauge). Maintain pressure for at least eight hours after all indications of moisture have stopped.

Water vapor may be readily detected by sprinkling one tablespoon of anhydrous cupric sulfate in the plastic bag, which turns blue instead of “off” white when wet. The sulfate is available from scientific laboratory supply houses. A hardware store humidity gauge may also be used.

Installed Cables: The splices and terminations must be removed if they interfere with the flow of air or nitrogen. The cable can then be purged as described above.

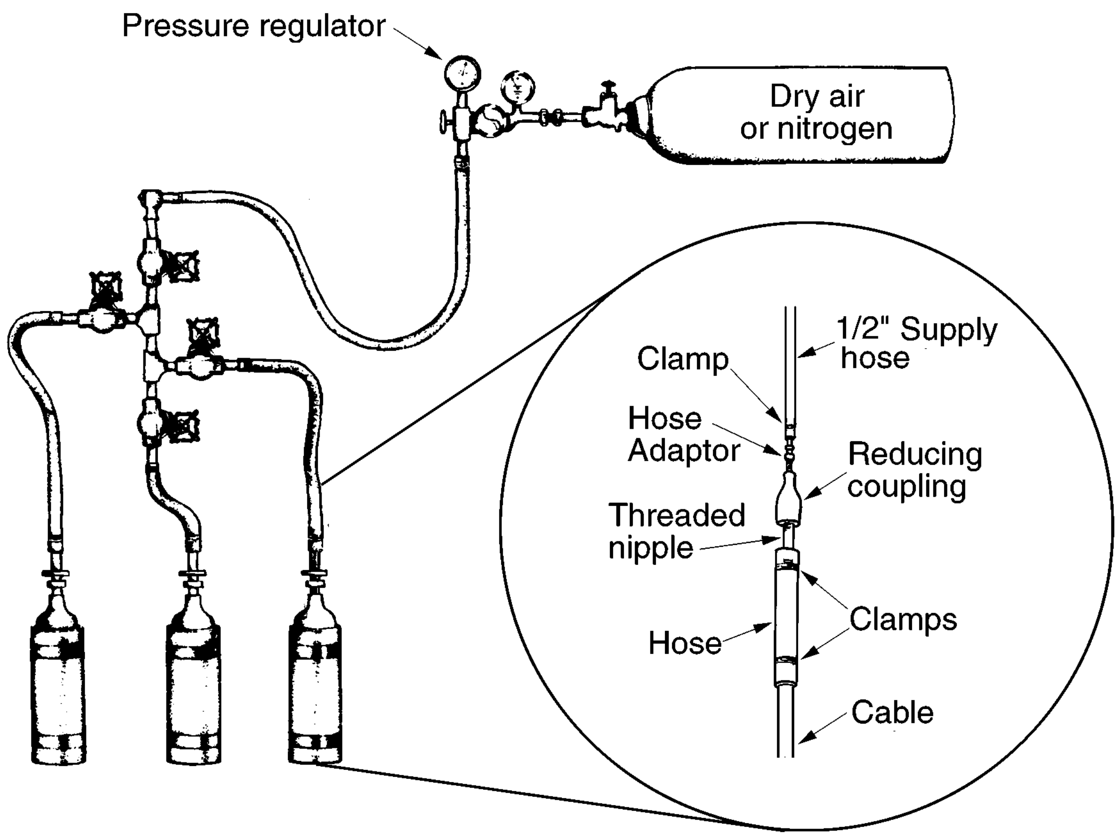


Figure 8.6 –Moisture removal equipment

8.11 Fiber Optic Testing

Testing a newly installed fiber optic system can increase the overall performance of a system, decrease the amount of downtime and reduce costs for the system owner. Attenuation is the parameter most frequently measured and includes the attenuation of the cable as well as that of attached connectors. Cable attenuation can be caused by **"microbending"** of the fiber, impurities in the fiber, excessive mechanical force on the cable or, of course, a **broken fiber.**

Handheld **optical power meters** and light sources (normally LED types for multimode and laser types for single mode fibers) are used to determine the total attenuation of the fiber and any splices or connectors. These devices can be considered the optical equivalent of the handheld "multimeters" used to troubleshoot electrical equipment.

Optical Time Domain Reflectometers (**OTDRs**) are used to **locate faults** and to measure attenuation of cables and connectors. A light pulse is sent down the fiber and as it encounters a fault, connector, splice, etc., a portion of the optical pulse is reflected back to the source. An OTDR is able to determine the distance to the reflection and the amount of signal loss at that point. OTDRs work on a radar-like principle.

Small optical microscopes are used to visually inspect the workmanship of installed fiber optic connectors.

8.12 LAN Cable Testing

As more and more users depend on data networks around the world, the ability to maintain proper system operation becomes increasingly important. There are several types of test equipment that are commonly used to evaluate LAN unshielded twisted pair (UTP) cabling.

Low cost handheld LAN cable testers are available that are used to certify the electrical performance, e.g., **Category III, IV or V,** of newly installed LAN cable. This characterizes the installed system with regard to **near-end crosstalk, attenuation** and **impedance.**

Time Domain Reflectometers (**TDRs**) are devices used to locate faults, determine length, and measure attenuation of the cable. The TDR sends a low voltage pulse along the cable and then "looks" for reflections that result from **impedance mismatches** that are caused by shorts, opens or severely deformed cable. TDRs analyze the reflections and report the amount of impedance mismatch and the location of faults.