LIA23866

LEAD INDUSTRIES ASSOCIATION, INC.

202 MADISON AVENUE

NEW YORK 17, N.Y.

October 10, 1963

SUBJECT: BROCHURE ON LEAD SHEATHING FOR POWER CABLE.

To Members of the Lead Industries Association, Inc.:

We are pleased to enclose a copy of our just published brochure entitled "Lead Sheathing for Power Cable." It describes the uses and advantages of lead sheathing and provides a sheathing guide for an engineer or administrator concerned with the installation of power cable systems.

The brochure will be mailed to 16,000 engineers and supervisors in the power transmission and equipment fields, and college engineering libraries. Approximately 150 copies are being distributed to the electrical power and engineering press.

Additional copies are available free of charge in quantities up to 25 and at our cost of $15 per hundred for larger quantities.

Sincerely yours,

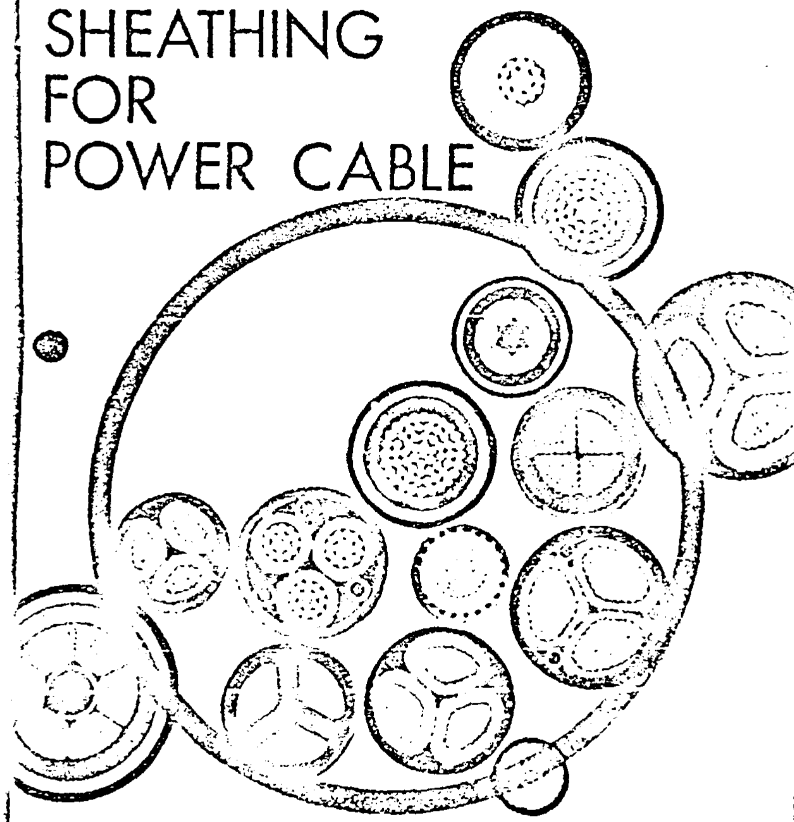
Robert B. Travis

Robert B. Travis

RBT/S
Enc:

Look Ahead with Lead

LEAD SHEATHING FOR POWER CABLE



Lead Industries Association, Inc.
292 Madison Avenue, New York, N. Y. 10017

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LEAD SHEATHING FOR POWER CABLE

Look Ahead with Lead

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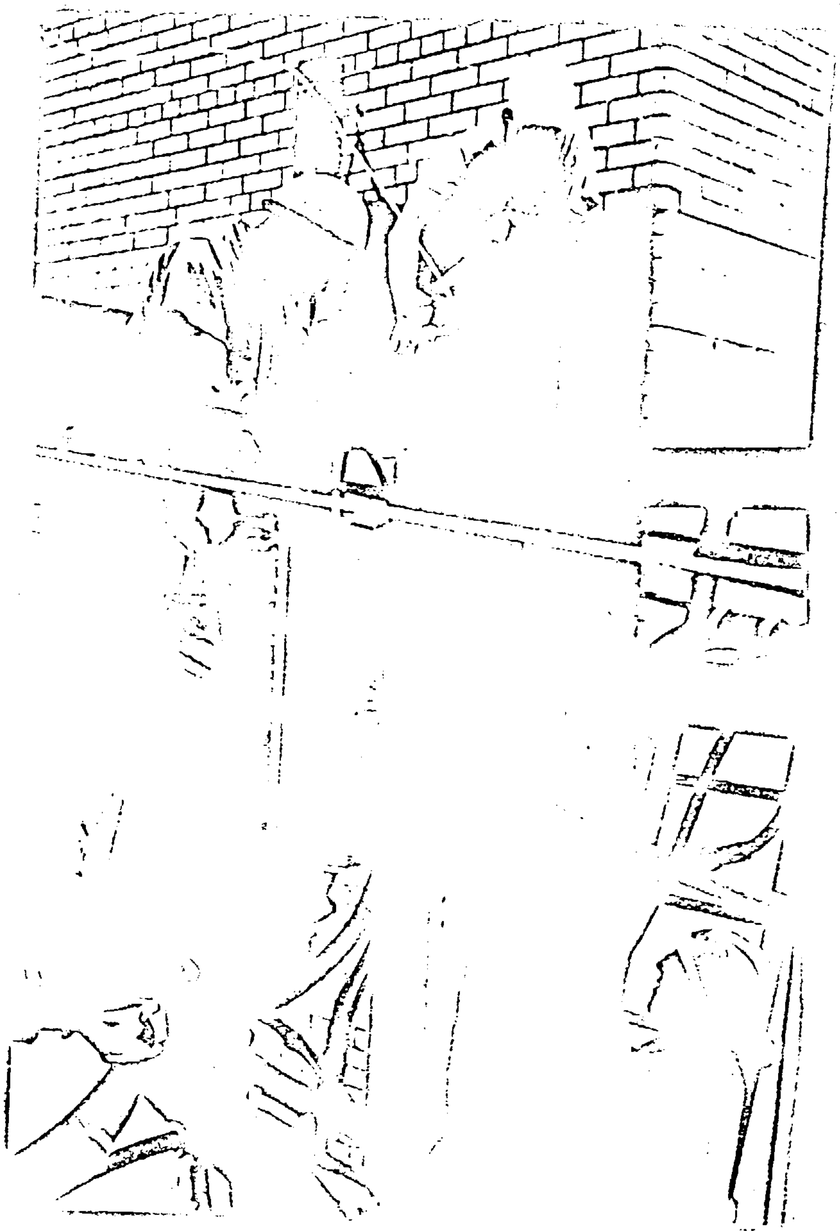

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INTRODUCTION

Lead sheathing for electric power cable offers the optimum protection for power cables that operate in all common voltage ranges and in every type of installation whether submarine, conduit, aerial, or buried directly in the ground. Lead provides the essential properties for durable cable sheathing: flexibility, moisture impermeability, corrosion resistance, chemical stability, availability in very long lengths, an efficient return path for fault currents and a return for the neutral leg of the circuit. Lead sheathing is economical and has the added advantage of high scrap value.

This booklet is intended as a general guide for prospective cable purchasers to enable them to have a broad idea of their sheathing requirements in terms of the operating requirements of their electrical installation. As cable design and installation is a highly complex field, the specific examples and data given here are only typical and not meant to be considered definitive.

Inherent moisture and fatigue resistance suits lead sheathed cables to aerial power installations.

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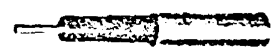
Series lighting cable, single solid conductor, non-shielded



LEAD SHEATHING PRINCIPLES

Designing and specifying cable for electrical power systems is a complex and specialized job with many inter-related problems. One of the most important of these is selecting the material for the cable sheath. The sheath must protect the cable wiring against mechanical and chemical damage while containing it both physically and electrically.

Where cables are employed in power systems, the sheath must withstand almost every conceivable environment, ranging from harbor bottoms to deserts. And almost all installations impose many hazards on the sheath at the same time; consequently, a good sheathing material must have a broad combination of properties to be generally useful.

Lead uniquely combines the properties most desirable in a cable sheathing material. It provides mechanical protection during installation and operations; it is moisture-proof, resistant to sunlight and weather and to many corrosive elements that attack other sheathing materials. The sheath contains both the conductors and the insulation. In addition to providing highly effective protection against the environment, lead sheaths also play an active role in the electrical system itself by providing electrical shielding and a ground return path. When used as a ground return, the lead sheath eliminates the need for the neutral conductors in the cable.

Economically, lead offers other advantages as well. It is extremely durable and can, under proper conditions, serve for hundreds of years. On the other hand, its value as scrap metal significantly reduces the cost of replacing obsolete cable networks.

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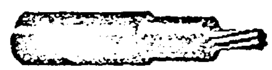
Paper insulated cable, single concentric stranded conductor.



POWER CABLE DESIGN

An almost infinite variety of types and sizes of cable are available commercially, so it will be possible in this brief report to discuss them only in general terms. Essentially, any power cable consists of one or more groups of wires, individually insulated and covered with a containing and protective sheath.

The number, size and arrangement of the conductors is dictated by the electrical and operating requirements of each installation. There are a number of types of insulation used for covering conductors, the most important of which are oil-impregnated paper, varnished cloth, rubber and rubber-like synthetics and plastics. Selection depends principally on the system's operating voltage and installation conditions.

Certain cables are mechanically protected with round wires or flat armor tapes applied helically over a bedding on the outside of the sheath. Such constructions are used in submarine and direct earth burial runs where extra mechanical protection and strength is needed.

The sheath that covers the cable core provides the physical and chemical protection of the cable during transporting, installing and operating. Lead combines more of the mechanical and physical properties than any other material required to meet the users' requirements.

Long runs of lead sheathed cable armored with steel wire dependably withstand submarine conditions for many decades

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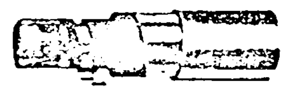
LIA23874

Paper insulated cable, shielded, compact segmented conductor.



CABLE MANUFACTURE

The first lead covered cables were made by drawing the cable core, consisting of one or more insulated conductors, through a *cylindrical pipe*. A method was soon developed for extruding the sheath directly around the core. In this process, molten lead is fed into the chamber of a large hydraulic press where it is cooled under pressure to the extrusion temperature. The cable core is centered within the circular die that forms the outer surface of the sheath. When hydraulic pressure forces lead through the die, it carries the core along with it. Very long cable runs can be covered in this way; *the limiting factors are the supply* of lead in the press reservoir, which can be replenished, and the length of the cable core. In a typical press, the pressure on the lead is about 54,000 psi.

The extrusion process forms a defect-free, homogeneous sheath with uniform wall thickness and practically unlimited length. Lead's low temperature during extrusion, about 400-450°F does not injure the conductor *insulating materials*. Cable is *coiled* or wound on reels as it comes from the extrusion press. Lead provides the flexibility for the addition of armoring or other protective coatings and other manufacturing steps.

A recently developed method of making lead cable sheathing is by continuous extrusion. In this method, *molten lead or alloy* is introduced at one end of the machine which has a screw type feeder. Under controlled cooling conditions the metal is conveyed by the screw through the machine and emerges solid around the cable core through a die at the other end. This machine can now be used with commercially pure or alloyed lead.

Paradoxically, the heavy metal lead, because of its unusual pliability,

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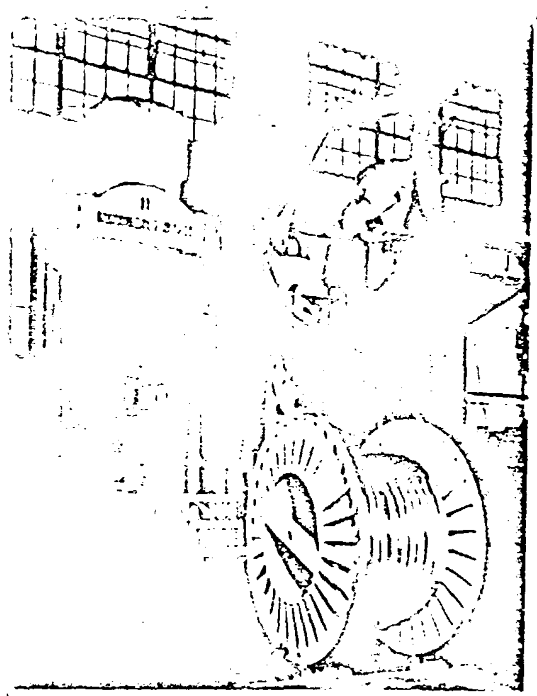

Very long lengths of cable are sheathed by the press (left) with lead from the melting kettle (right)

enables the designer to minimize sheath thickness and weight while meeting the operating requirements of the installation and without risking buckling or kinking when the cable is bent.

Cable Shipment

When finished power cable is shipped from the manufacturer to the installation site it is wound on large reels and the cable ends are firmly secured.

It is important that the reel be rolled in the right direction to insure that the cable does not unwind or slacken. If the latter should happen, the cable sheath must either have sufficient tensile strength to carry the load or have sufficient ductility to stretch and relieve the stress. Manufacturers guard against this slackening by showing the wind direction of the cable and the direction in which the reel should be rolled. The lead sheathing on a properly designed power cable has sufficient tensile strength and elasticity to withstand vibrations or other stresses that may occur during shipment, installation or service.

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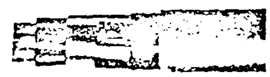
Rubber insulated cable, three stranded conductors.



MECHANICAL STRESS AND CREEP

When a cable is installed and in use, all sheathing is subjected to some combination of the following mechanical stresses:

Continuous tensile hoop stress from steady internal pressure.

Continuous compressive hoop stress from external pressure.

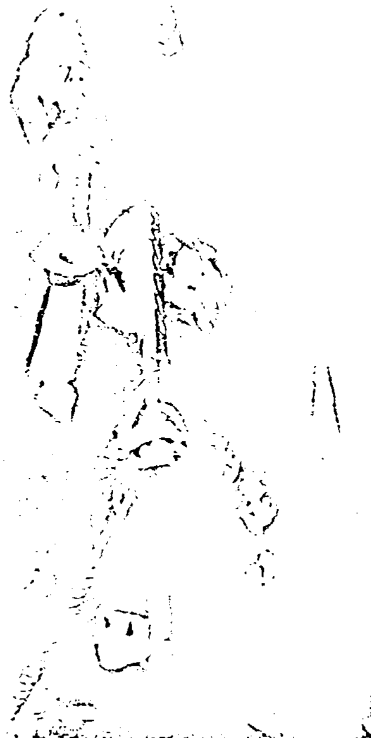
Longitudinal tensile stress

Slow bending in one direction that creates longitudinal tensile and compressive stresses.

Alternating tensile and compressive stresses which may be irregular and unpredictable and cause the lead to fatigue.

Lead sheathing offers sufficient resistance to tensile and compressive stress and fatigue for most cable applications. In addition, alloying lead with arsenic or other metals and armoring the cable exterior with steel wire or tape enables the lead sheath to meet more severe operating conditions.

Weatherproof lead sheathed cables are suited to suspension in wooded areas where threats of outages in wet weather are minimized



Lead sheathed cables lend themselves readily to joint- ing. A lead sleeve joints have proved most reliable.

It should be pointed out that any reference to the "tensile strength" of lead requires amplification. Time is a far more important factor in determining the tensile properties of lead than it is with the hard metals. For example, a lead specimen in a tensile test could be weighted so that it would stretch and break in a specified time; the maximum load before failure would be one value of tensile strength. However, because lead creeps, a smaller weight could break the specimen in a longer time with a consequent change in nominal tensile strength.

Fluid filled types (oil or gas) of lead covered cable commonly operate at 15 psi pressure.

On oil filled types, however, higher internal pressures may develop at the low point of the run when the cable is laid on a slope or at the bottom of a vertical riser. Reinforced, double walled sheaths may be used in these situations.

The most prevalent forces acting on a lead sheathed cable are:

Changes in electrical load on cables during the day's operation cause them to heat and expand and cool and contract.

Movement of the entire cable caused by mechanical forces in the environment. Jacketing with neoprene or polyethylene provides additional protection against the deleterious effects of such vibration.

Creep Resistance

The sheaths of most conventional solid type power cables are not normally subjected to conditions that cause creep; consequently lead with strengthening alloying elements is not selected except for special installation requirements.

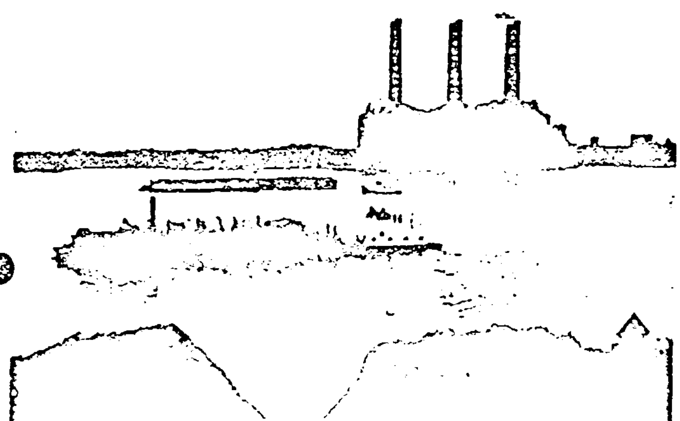
The sheaths of oil-filled cables and cables that operate at elevated temperatures are, however, subject to significant internal pressures during service and creep can occur in their sheaths. Alloy lead or metal tape reinforced sheath may be employed when creep is a factor. In this type of installation it is not the lead's resistance to creep that matters, but is rather the sheath's ductility that permits slow expansion to the limits of the tape without rupturing.

The desirable ability to deform uniformly and to a considerable extent without rupturing depends largely on the lead's composition and cleanliness, that is its freedom from oxygen and sulphur films or inclusions. Oxides and sulphides form grain boundary films that are brittle and reduce ductility and fatigue resistance. These films between grains also make a sheath sensitive to stress-cracking when subjected to sustained loads at relatively low stresses with only slight elongation (creep).

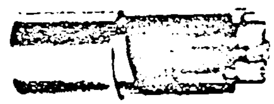
The presence or absence of certain trace elements in lead can decrease the tendency for dross formation, thus adding to its cleanliness. In addition, uniformity of grain structure is very important in aiding ductility. Clean, well crystallized welds with uniform grain size are also highly desirable.

Considerable research is being conducted on the effect of grain structure on properties and also on the effect of extrusion conditions in varying the grain of sheathing lead.

Laying steel armored lead sheathed cable that will carry 35 kv service across the Mississippi River. Cable is unreeled from shore to shore from the barge



Shielded three-conductor paper insulated cable.



CORROSION RESISTANCE

There are two principal types of corrosion that attack power cable sheaths: The first is natural corrosion in which the electrical current causing the damage is created by the interaction between the sheath metal and chemicals in the immediate environment. This includes both direct chemical attack (such as salt used in highway snow removal) on the sheath and the formation of a galvanic cell and another metal.

The second is stray current corrosion from buried or submerged power lines (d.c. railroad, subway power or pipe lines that use one of the rails for the return leg of the system). As stray current corrosion problems depend on the geometry of each specific installation there is little reason for a detailed discussion here. In general, direct currents are far more destructive than alternating. Under some conditions stray current corrosion can severely damage lead sheaths unless they are protected by non-conducting jackets. However, it should be pointed out that any metal cable sheath, and lead sheaths in particular, afford the conductors an extra measure of protection by providing an excellent, low resistance return path for stray currents in the soil or fault currents arising from some breakdown in the power system itself. There are also a number of ways of designing the cable system that eliminate, or at least minimize, stray current damage.

The most prevalent and expensive form of corrosion is not due to stray currents but is natural corrosion caused by the electrochemical interaction of the cable surface and the chemical it is exposed to in soils, in waters, or in the air.

Corrosion In Soils — Lead cable sheathing resists the corrosive action of soils because of the presence of

TABLE 15

LOSS OF WEIGHT AND MAXIMUM PENETRATION OF LEAD PIPE EXPOSED TWO AND FOUR YEARS*

Soil		Chemical Lead (a)				Tellurium Lead (b)				Antimonial Lead (c)			
No.	Type	Loss of Weight		Maximum Penetration		Loss of Weight		Maximum Penetration		Loss of Weight		Maximum Penetration	
		2 years	4 years	2 years	4 years	2 years	4 years	2 years	4 years	2 years	4 years	2 years	4 years
		mdd	mdd	mils	mils	mdd	mdd	mils	mils	mdd	mdd	mils	mils
53	Cecil clay loam	0.92	0.44	18	12	1.04	0.65	12	20	1.04	0.46	10	10
55	Hagerstown loam	1.33	0.42	24	26	1.42	0.59	26	26	0.80	0.31	26	18
56	Lake Charles clay	0.88	0.94	38	37	1.59	1.71	30	48	1.30	1.04	39	52
58	Muck	6.51	5.03	34	28	7.03	5.85	55	56	6.06	4.43	50	58
60	Rifle Peat	0.75	0.59	18	15	0.63	0.42	29	10	0.42	0.46	6	P
61	Sharkey clay	4.10	4.62	35	39	5.06	3.64	33	30	3.93	3.64	31	42
62	Susquehanna clay	1.26	1.94	32	29	1.51	1.34	19	31	1.13	2.16	12	30
63	Tidal marsh	0.23	0.031	14	18	0.23	0.031?	10	12?	0.16	0.03	P	16
64	Docas clay	0.84	0.40	24	16	1.34	0.38	21	13	0.50	0.40	12	12
65	Chino silt loam	0.59	0.27	40	24	0.71	0.33	22	16	0.71	0.44	6	15
66	Mohave fine gravelly loam	0.42	0.21	44	34	1.04	0.25	23	41	0.27	0.25	12	15
67	Cinders	15.35	25.5	79	104	14.0	27.6	71	94	13.3	6.80	56	90
69	Houghton muck	1.51	1.49	21	15	0.96	2.26	8	12	0.84	2.18	9	7
70	Merced silt loam	0.14	0.25	48	14	0.40	0.31	16	27	0.42	0.29	11	12

* Kirk H. Logan and Melvin Romanoff, "Soil Corrosion Studies, 1941," J. Research Natl. Bur. Standards, 33, 145 (1944). R.P. 1602. See asterisk footnote Table 6.

(a) Cu, 0.056%; Bi, 0.002%; Sb, 0.0011%.

(b) Cu, 0.082%; Te, 0.043%; Sb, 0.0011%.

(c) Cu, 0.036%, Bi, 0.016%; Sb, 5.31%.

P indicates definite pitting but no pits greater than 6 mils.

(?) Data for one specimen only.

† Corrosion Handbook, H. H. Uhlig, John Wiley & Sons, Inc., New York; pp 459.

substances such as silicates, sulfates and carbonates that form protective films on the surface of the lead. Silicates form highly protective coatings; sulfates are less pronounced as lead sulfate is soluble and forms a somewhat porous film, and although carbonates are generally protective they are soluble in high concentrations of carbon dioxide—not a common condition. Protective films may also be formed by cataphoretic action in which postively charged colloidal particles of silt, clay or organic matter migrate to cathodic areas on the sheath, discharge and deposit on the metal. Other factors of importance are the concentration of oxygen, nitrates, organic acids and alkalis.

In general, the corrosion of lead in soils is not a single, clearly defined process, but is rather the ratio of the rate of formation of reactive substances versus the rate of formation of soluble protective films.

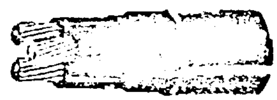
The National Bureau of Standards has intensively studied the corrosion resistance of lead in soils. Typical findings, Table I, indicate that lead sheathing is able to withstand soil corrosion, except cinders, for many years without failure.

Corrosion In Water — Lead is generally impervious to non potable water. Soft water, distilled water, and some acid water found in mines generally attack lead so that it would be necessary to protect the lead if it is exposed to them—again, an unusual circumstance. For example, tap water from metropolitan New York contains about 40 parts per million of dissolved chemicals and is not corrosive, where distilled water, lacking film-forming substances, corrodes lead with comparative rapidity

Lead and lead alloys are universally used on submarine cable and other power lines exposed to salt water because lead shows only slight corrosion (4-5 mils per year when exposed to 1 N sodium chloride solution and practically no corrosion when exposed to salt spray). In a typical test, lead bars were exposed to the salt water of the Bristol Channel off England. The corrosion rate for soft lead and 1.6 percent antimonial lead were less than 0.3 mils per year. No localized pitting was found on bars submerged for 93 percent of the test period.

Corrosion in Air — Lead is extremely durable in air, even in polluted city and industrial environments. Virtually nothing happens to lead sheaths exposed to dry air, whereas, moist air containing carbon dioxide covers the lead surface with a protective film of lead carbonate. Sulfides tend to blacken or discolor lead but the sulfide coating is not particularly corrosion resistant. Years of experience have shown lead cable sheaths to be resistant to atmospheric corrosives in installations ranging from the arctic to the equator.

Belted type, three conductor, varnished cambric cable.



LEAD AS A SHEATHING MATERIAL

Lead is particularly suited to use with rubber, varnished-cambric and paper insulated cables because it is the most effective protection against moisture, oxidation and weathering. It has the additional advantage of flexibility that permits the cable to be bent during handling and installation, and of availability in long lengths essential for submarine and similar systems.

Cables sheathed with lead can be installed aerially or in underground duct systems as well as directly buried or in submarine installations; any of these environments may be subject to varying degrees of corrosion. Lead sheathing can be protected against extremely severe corrosive elements or electrolysis caused by stray electric currents by applying a suitable thermosetting or thermoplastic jacket over the lead sheath of neoprene, polyethylene or polyvinylchloride.

Lead sheaths are useful for oil or gas-filled cables operating at pressures about 15 psi. The sheaths of cables operating up to 50 psi are usually reinforced with two 0.005-in. thick hard copper or bronze tapes.

Table III gives the thickness of lead sheaths for rubber or varnished cambric; Table IV for solid type impregnated paper-insulated cables; Table V for single and double sheaths for low-pressure oil-filled paper insulated cables; and Table VI for low-pressure gas-filled paper insulated cables.

Lead Sheathing Alloys

Alloying lead with certain other metals provides the stability and mechanical properties essential for cable sheathing. The foremost alloys are the following:

substances such as silicates, sulfates and carbonates that form protective films on the surface of the lead. Silicates form highly protective coatings; sulfates are less pronounced as lead sulfate is soluble and forms a somewhat porous film, and although carbonates are generally protective they are soluble in high concentrations of carbon dioxide—not a common condition. Protective films may also be formed by cataphoretic action in which postively charged colloidal particles of silt, clay or organic matter migrate to cathodic areas on the sheath, discharge and deposit on the metal. Other factors of importance are the concentration of oxygen, nitrates, organic acids and alkalis.

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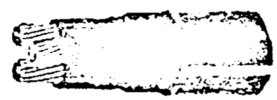

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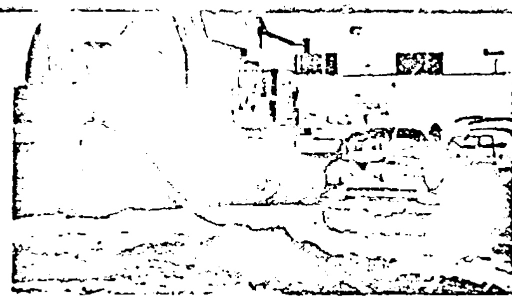

Jacketing and lead sheathing will protect this buried cable from moisture and corrosive elements in the soil

1) Copper bearing lead—stable, universally used commercial lead, usually considered not an alloy.
2) Arsenical lead—for underground and aerial use where fatigue resistance and low creep rates are necessary for durability.
   Contains small amounts of antimony, tin, bismuth or copper
3) Antimony lead—not now generally used on power cables because heat cycles induce age hardening that reduces cable flexibility

The chemical classifications of lead grades suitable for shielding are given in ASTM B 29 as shown in Table II

The alloy selected for the particular cable design and operating conditions must be assessed in terms of some of or a combination of the following characteristics:

1) Structural stability, particularly avoiding the formation of coarse grained, weak crystals.
2) Resistance to cyclic stresses or strains at frequencies as low as one cycle per day.
3) The rate of age hardening.
4) Creep resistance of unreinforced sheaths on pressurized cables.
5) Creep ductility under very slow straining rates (determines sheath expansion in pressurized systems).

TABLE II* — CHEMICAL REQUIREMENTS

	Corroding Lead	Chemical Lead	Acid Copper Lead	Common Desilverized Lead
Silver, max, per cent	0.0015	0.020	0.002	0.002
Silver, min, per cent	—	0.002	—	—
Copper, max, per cent	0.0015	0.080	0.080	0.0025
Copper, min, per cent	—	0.040	0.040	—
Silver and copper together, max, per cent	0.0025	—	—	—
Arsenic, antimony, tin, max total, per cent	0.002	0.002	0.002	0.005
Zinc, max, per cent	0.001	0.001	0.001	0.002
Iron, max, per cent	0.002	0.002	0.002	0.002
Bismuth, max, per cent	0.050	0.005	0.025	0.150
Lead (by difference), min, per cent	99.94	99.90	99.90	99.85

* American Society for Testing and Materials "Standard Specification for Pig Lead, ASTM B 29-55."

TABLE III*

THICKNESS OF LEAD SHEATH FOR RUBBER OR VARNISHED-CAMBRIC INSULATED CABLE

Diameter of Core inch	Thickness of Sheath mils
0 to 0.425	47
0.426 to 0.700	63
0.701 to 1.050	78
1.051 to 1.500	94
1.501 to 2.000	109
2.001 to 3.000	125
3.001 and larger	141

The thickness of lead sheath for twin flat construction shall be that corresponding to the major core diameter.

In submarine cable the thickness of the sheath shall be in accordance with the above table except that the thickness for the first two core diameter classifications shall be 78 mils.

* Underground Systems Reference Book, Edison Electric Institute, 1957, New York City

TABLE IV*

THICKNESS OF LEAD SHEATH FOR *IMPREGNATED-PAPER INSULATED CABLE "SOLID TYPE"*

Diameter of Core inch	Thickness of Lead Sheath mils	Diameter of Core inch	Thickness of Lead Sheath mils
0 to 0.462	75	2.500 to 2.685	135
0.463 to 0.648	80	2.686 to 2.870	140
0.649 to 0.833	85	2.871 to 3.055	145
0.834 to 1.018	90	3.056 to 3.240	150
1.019 to 1.203	95	3.241 to 3.425	155
1.204 to 1.388	100	3.426 to 3.611	160
1.389 to 1.574	105	3.612 to 3.796	165
1.575 to 1.759	110	3.797 to 3.981	170
1.760 to 1.944	115	3.982 to 4.166	175
1.945 to 2.129	120	4.167 to 4.351	180
2.130 to 2.314	125		
2.315 to 2.499	130		

Underground Systems Reference Book, Edison Electric Institute, 1957, New York City

Except when an alloy lead sheath is used the lead used for the sheath shall be commercially pure lead meeting the requirements of ASTM B 29 for one of the following types: chemical lead, acid-copper lead, and common desilverized lead. If a copper bearing sheath is used the type shall be either chemical lead or acid-copper lead. If an alloy sheath is used, the lead used in preparing the alloy shall meet the requirements of ASTM B 29.

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TABLE V*

THICKNESS OF LEAD SHEATH FOR IMPREGNATED-PAPER INSULATED CABLE "LOW-PRESSURE OIL-FILLED TYPE"

Single Sheath		Double Sheath†	
Diameter of Core, inch	Thickness of Lead Sheath, mils	Diameter of Core, inch	Thickness of Lead Sheath, mils
0 to 1.462	110	0 to 1.617	95
1.463 to 1.648	115	1.618 to 1.911	100
1.649 to 1.833	120	1.912 to 2.205	105
1.834 to 2.018	125	2.206 to 2.499	110
2.019 to 2.203	130	2.500 to 2.794	115
2.204 to 2.388	135	2.795 to 3.088	120
2.389 to 2.574	140	3.089 to 3.382	125
2.575 to 2.759	145	3.383 to 3.676	130
2.760 to 2.944	150	3.677 to 3.970	135
2.945 to 3.129	155	3.971 to 4.264	140
3.130 to 3.314	160		
3.315 to 3.499	165		
3.500 to 3.685	170		
3.686 to 3.870	175		
3.871 to 4.055	180		

† For double sheath, the thickness given above applies to each of the two sheaths.

* Underground Systems Reference Book, Edison Electric Institute, 1957, New York City.

Except when an alloy lead sheath is used, the lead used for the sheath shall be commercially pure lead meeting the requirements of ASTM B 29 for one of the following types: chemical lead or acid copper lead (copper content not less than 0.04%). If an alloy sheath is used, the lead used in preparing the alloy shall meet the requirements of ASTM B 29.

TABLE VI*

THICKNESS OF LEAD SHEATH FOR IMPREGNATED-PAPER INSULATED CABLE "LOW-PRESSURE GAS-FILLED TYPE"

Diameter of Core, inch	Thickness of Lead Sheath, mils	Diameter of Core, inch	Thickness of Lead Sheath, mils
0 to 2.343	110	3.490 to 3.593	170
2.344 to 2.447	115	3.594 to 3.697	175
2.448 to 2.552	120	3.698 to 3.802	180
2.553 to 2.636	125	3.803 to 3.906	185
2.637 to 2.760	130	3.907 to 4.010	190
2.761 to 2.864	135	4.011 to 4.114	195
2.865 to 2.968	140	4.115 to 4.218	200
2.969 to 3.072	145		
3.073 to 3.177	150		
3.178 to 3.281	155		
3.282 to 3.386	160		
3.387 to 3.489	165		

* Underground Systems Reference Book, Edison Electric Institute, 1957, New York City.

Except when an alloy is used, the lead used for the sheath shall meet the requirements of ASTM B 29 for either chemical lead or acid copper lead.

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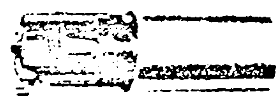
Low pressure gas-filled, three conductor cable.



TYPES OF CABLE

Service conditions and operating voltages largely determine which type of cable construction is best suited to the system. In general, the types of insulation employed are: plastics, rubber-like materials, varnished cloth and impregnated paper.

Rubber-Insulated Cable—Low voltage cables (120-600 v) jacketed in neoprene, polyethylene or vinyl are used for distribution at utilization voltage lines.

Lead sheaths are often used instead of nonmetallic sheaths because of their superior resistance to environmental factors.

Varnished-Cloth Insulated Cable — Varnished-cloth insulated cables are not recommended for use in underground installations subject to moisture attack without the protection of an impervious lead sheath.

Varnished-cloth insulated cables are suitable for voltages up to 28,000 v.

Lead clad cables are used in aerial runs, and for vertical risers, mine-shafts and boreholes where they may be provided with an armored covering for additional support.

Paper Insulated Power Cable — Oil-impregnated paper is the most widely used insulating material for power cables operating above 15 kv.

Solid Cable — consists of paper wrapped conductors enclosed in the sheath and impregnated with high grade oil. The design assumption is that the presence of ionizable gaseous voids within the cable is inevitable.

A crew easily installs lead sheathed cable in a conduit serving the Pentagon in Washington

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Therefore, the insulation must be of sufficient thickness to permit stable operation despite the aging effects of electric discharge in voids.

Adding an impermeable lead sheath prevents the penetration of air or moisture, precluding degradation by oxidation, and so enables the cable to operate dependably at the original design specifications. Solid type cable is available to 69 kv; however, its predominant use is at voltages below 35 kv.

Low Pressure Oil-Filled Cables — are used in 15-230 kv systems. This type of cable is filled with a high grade oil that flows both radially through the paper insulation and longitudinally in special channels made of strips of steel wound in an open helix. Three-conductor cables have a channel in each outer filler space; single conductor cables have one in the center of the stranded conductor. In manufacture of the cable the lead sheath is applied after which the cable is heat dried, gasses removed from the core by a vacuum pump, and the insulation impregnated.

Reinforced sheaths or double sheaths are used for higher oil pressures in the operating range. Higher pressures permit slopes or vertical risers to be successfully incorporated into the run.

Low Pressure Gas-Filled Cables — both single conductor and three conductor gas-filled cables are used in low pressure (15 psi) power cables that are lead sheathed.

Gas-filled cables have three advantages that are unusual:

Internal pressure provides a means of continuously checking the sheath for breaks (i.e. continuous sheath supervision). Low pressure alarms at cable terminals signal when any gas is escaping through a sheath break or the joints. Similarly, high pressure alarms warn of excessive pressure buildup.

Damage from any normal size leak can be prevented by maintaining internal gas pressure until the leak is repaired. This is an important safeguard against lost operating time.

Gas can be used safely in risers and on slopes without pressure buildups at the low points of the run.

Three conductor low pressure gas-filled cable is generally similar in appearance to oil-filled type except that one of the oil channels is replaced by a solid copper tube with no lateral openings to the insulation, but it is open at the cable joints. The other channels are open sided helixes carrying gas at about 15 psi. The solid wall tube provides the pressure between manhole sections at all times in the event that the helical channels become slugged due to oil drainage.

Single conductor cables do not have the gas tube at their axis but rather have flutes in the lead sheath to serve as gas channels.

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