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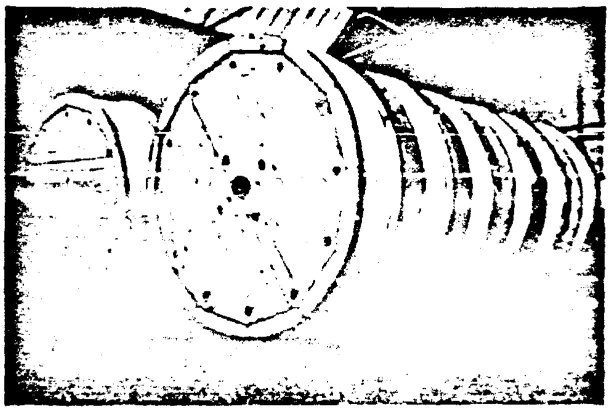
A Report on the Sheathing of Cables With Aluminum

BY KENNETH S. WYATT



Reels of 3½-inch diameter aluminum-sheathed coaxial cables awaiting shipment for Las Vegas, Nevada

PHELPS DODGE COPPER PRODUCTS CORPORATION
40 WALL STREET, NEW YORK 5, N. Y.

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Phelps Dodge Copper Products is in production on communication cables and limited quantities of power cables sheathed with aluminum by the "draw-down" method. Production of larger quantities will be by direct extrusion when the demand warrants.

Will Aluminum Displace Lead As A Cable Sheathing Material?

By KENNETH S. WYATT
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The threat of aluminum to the lead cable sheathing industry is today more than a small black cloud on the horizon. Already the British have made more than 3,000 miles, the Germans perhaps 500 miles, while in North America there is about 100 miles. Abroad and at home new methods and machines are being developed for the application of aluminum cable sheathing. The subject is frequently referred to in current technical journals. The question is: How far will this revolution go and how fast will it take place?

Historical

The earliest use of aluminum sheathing known to the writer was for 5,000 feet of telephone cable for the dirigible "Akron" and 5,000 feet for the "Macon" in 1932. Both were produced by Alcoa by the tube reducing method, i.e., the cable is threaded into an aluminum tube which is then rolled down to fit the cable snugly. Later, in 1938-44, the Oberspree Cable Works in Germany manufactured test lengths of aluminum-sheathed power cables from one to 30 kv. Siemens and other German manufacturers are known to have also produced aluminum-sheathed communication and power cables commercially in small amounts before the war.

Large scale manufacture, however, did not take place until 1946 when the shortage and high price of lead and to some extent of labor, led Johnson & Phillips in England to introduce the "draw-down" method. In this the cable core is threaded into a seamless aluminum tube of 10% greater diameter, the core and tube being then drawn through a die which "sinks" the aluminum tube closely onto the cable. To date over 3,000 miles of cable, both paper and rubber-insulated, have been sheated by this process, and this cable is in service in many parts of the British Empire. Particular success was met with in industrial cables where normally iron-conduit would be used, into which cable would be later pulled and jointed; here the great saving of labor was the impetus and not the scarcity and high price of lead. The phenomenal success of Johnson & Phillips is leading other British cable makers to get activity into aluminum cable sheathing, either by the "draw-down" method or by hot extrusion.

Both before, during, and after the war the Germans had been developing presses and techniques for hot-extruding aluminum sheath continuously onto cables, but the difficulties were almost insurmountable. In 1949 Felten and Guilleaume adopted a form of the Johnson & Phillips "draw-down" method. The aluminum tube is laid out straight in a gallery several thousand feet long originally used for pre-stretching steel wire rope, the cable core is pulled in, and then a die travels along the cable making on the sheath. Whereas Johnson & Phillips had confined themselves chiefly to small cable diameters, usually 1 to 1½ inches, and to relatively short lengths (300 to 500 feet), F & G made lengths of 1,000 feet, and in one inch sizes, of 1,800 feet; and diameters as great as 6½ inches. In this way they sheathed over 300 installations of coaxial Styroflex Cable, and many telephone cables over the Rhine bridges where vibration difficulties made aluminum especially desirable. F & G had mastered the technique of joining billet to billet without mechanical weakness at the junction. Both very pure aluminum (99.99%) and commercial grades (99.4%) were used, depending on the application. The drawn-down method is looked on purely as an interim method to take care of production until an 5,000 ton extrusion press is shortly installed.

In the United States little or no progress was made until 1952, despite the early start with the "Akron" cables in 1932. Five thousand feet of 11 pair No. 19 telephone cables sheathed by the tube reducer method were installed by Alcoa in their Point Comfort plant in 1950, but this was ½ to ¾ inch in diameter and in lengths of 100 feet or less. The Bell Telephone Laboratories had installed perhaps one quarter mile of aerial telephone cable with aluminum sheath at Chester, N. J., for experimental purposes. Then in December 1951, Phelps Dodge Copper Products Corporation decided to go into the manufacture of aluminum-sheathed high frequency coaxial cable and power cables under license from Felten and Guilleaume of Cologne, Germany, the decision being announced in the press January 15, 1952. (Two days later, January 17, 1952, British-Insulated Callender's Cables and Loewy's Engineering Company, Ltd., of England, announced the formation of Alsheath, Ltd., to develop the extrusion process.) Phelps Dodge at this time took an order from the Atomic Energy Commission, through their sub-contractors, the Naval Research Laboratory, for 200,000 feet of 3⅛ inch and 100,000 feet of ⅞ inch aluminum-sheathed coaxial cable. In this cable the sheath is also the outer conductor, and only a metal of high electrical conductivity could be used, hence there was in this instance no displacing of lead by aluminum. Since six months was required to get into production here, the cable was made by Felten and Guilleaume in Cologne and shipped to the USA in 1,000 foot lengths. The first deliveries of this unusually long-length, large diameter cable arrived here in early February 1952. This is the date when intense activity in aluminum cable sheathing commenced in the United States. The installation of this cable at Las Vegas demonstrated beyond doubt that large diameter aluminum sheath cables could be reeled and unreeled and handled satisfactorily in the field, that billet to billet junctions did not introduce weakness, and indeed that long lengths of such large diameter aluminum sheath cable could be manufactured uniformly. Since then several hundred thousand feet of Styroflex Cables have been supplied, much of it manufactured by Phelps Dodge at their Yonkers, N. Y., plant.

Phelps Dodge is also manufacturing aluminum-sheathed power cables, 4,000 feet—3-conductor—15 kv. aerial cable for Boston Edison, 200 feet—3-conductor—13.2 kv. cable for Commonwealth Edison of Chicago, and 15,000 feet of 1-conductor — 27 kv. duct cable for Consolidated Edison Company of N. Y. All three cables will have a polyethylene jacket over the aluminum as corrosion protection.

The Canada Wire & Cable Company of Toronto, under license from Johnson & Phillips, are making alu-

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minum-sheathed power cables. One installation for the Quebec Hydro Commission at Montreal, consisting of 15,000 feet of 1-conductor—120 kv. Pirelli-type oil-filled cable in ducts has been in operation for eight months. Another installation by the British Columbia Electric Railway Company of Vancouver consists of 54,000 feet of 69 kv. single conductor cable, three cables being pulled into one duct. They are also manufacturing 4,500 feet of 300 kv. oil-filled cable with aluminum sheath for the Aluminum Company of Canada at Kittimat. In all cases the aluminum sheath is protected by a "rubber sandwich" jacket. In the extension to their Leaside plant, Canada Wire & Cable used aluminum-sheathed — 3-conductor—12 kv. cable for supplying power. The cable was suspended on racks. Although the spacing of the latter was rather great, the cable did not show undue sag.

From this brief resume it will be seen that aluminum sheathing for cables is already well established and growing rapidly in Great Britain, on the Continent it is less well established, and in North America it is making a successful beginning.

The Relative Merits Of Lead Vs. Aluminum For Cable Sheathing

A glance at the table of properties of the two metals makes it obvious that aluminum is not just a substitute for lead.

Table I

		Lead	Aluminum
Specific weight	g/cm³	11.4	2.7
Electrical conductivity	m/ohm.mm²	4.7	*
Vibration factor	.10⁶	1.5-2	†
Hardness	kg/mm²	3.5-4	25-30
Tensile strength ...	kg/mm²	1.7	8-10
Elongation ..	%	40-33	25-15

* Greater than 33.

† Greater than 50.

Aluminum is much lighter than lead (less than ¼) making it easier to handle and cheaper to ship, with very great advantage for telephone or power aerial cable. It is much stronger (six times) and harder (seven times), making it ideal for cables with internal pressure since no reinforcement is necessary; this applies also to buried cables where the steel tape reinforcement required with lead may be omitted. Its higher resistance to vibration fatigue (25 times) makes it very desirable for bridge cables and for aerial cables. Its greater electrical conductivity (seven times that of lead) makes it excellent for coaxial cable sheathing.

Lead, on the other hand, is easy to join, patch or repair, aluminum more difficult. (If the aluminum is first "tinned" with an alloy of 60% cadmium—40% zinc, it can be wiped to a lead or copper sleeve in the usual manner; the Johnson & Phillips use of 90% tin—10% zinc is not recommended because of corrosion at the interface.) Lead is not as susceptible to corrosion as aluminum, although both should be protected with a jacket for bad electrolytic or other conditions. However, aluminum of ordinary EC grade has been widely used throughout the United States for transmission lines for more than 30 years without any corrosion trouble whatever, excepting near the sea, hence it should be suitable for aerial cable sheathing. Lead is far easier to form around the cable than aluminum. Lead bends and reels more easily than aluminum.

While the writer has never been able to see any particularly good reason for aluminum conductors in insulated power cable, except wartime shortages or national necessity, the use of aluminum for cable sheathing has always appeared a "natural." The question then arises as to why aluminum was not used for sheathing before. The answer of course lies in the extreme difficulty of extruding aluminum around a cable, both because the high temperature necessary (530 C) causes the cable insulation to melt or charr, and causes troubles with the steel of the press, and because it is difficult to unite billet to billet as is necessary in a continuous operation, and because pressures are high, and porosity of the sheath difficult to avoid. These difficulties have now been overcome.

Of all these difficulties with aluminum there are only two of consequence, corrosion and joining. There is now over 10 years experience with plastic strip protection of aluminum sheath in Germany and Dorfel (27) states that such cables are no more prone to corrosion than lead. The fact remains that all aluminum-sheathed cables for use underground must be given corrosion protection; lead for buried service is also protected, but for ducts is usually left unprotected. Joining is more difficult with aluminum but is no longer a problem.

Methods Of Applying Aluminum Sheath

Aluminum sheath may be formed on the cable in three ways: the "draw-down" method, hot-extrusion, or the strip process. The "draw-down method consists in sinking an oversize aluminum tube snugly onto the cable. Either the tube and core are drawn through a die, or the die is drawn along the tube containing the core. This method is the only one used to any extent so far in the sheathing of cables. It was worked out by the British and is an achievement. It is a discontinuous method; since most cable makers purchase their aluminum tubing outside, it frequently leaves them without full control. The writer believes the "draw-down" method is purely an interim method which will be replaced eventually by the hot-extrusion and strip methods.

The hot-extrusion of aluminum sheathing directly onto the cable continuously has been for long years the ultimate goal of German engineers, but the high temperature (530° C.) necessary for the aluminum affected both the steel of the press and the insulation of the cable core. After a number of small presses had been built and tried out in Germany and in England, several large presses employing different principles have been constructed and are now being installed. These should prove successful. The largest is that of Felten and Guilleaume with 8,000 metric tons capacity. Such a press, installed, would cost in this country over one million dollars, and overhead would require that it constantly be fed with large quantities of cables. Cable manufacturers in England and Germany having such machines will thus be forced to actively develop markets for aluminum-sheathed cables throughout the world. The F&G press can extrude a ten mil wall uniformly and without porosity onto a low-melting point polyethylene core and the latter may be left in the press for half an hour without damage. It would not of course be economical to use such a large press for very small cables. The press can be used also for extruding aluminum wire bars, four or more at a time, and it is said it will be cheaper than rolling.

The strip method consists in forming a strip of aluminum around the cable with forming rolls, and then welding the longitudinal seam by high-frequency induction under argon atmosphere. Subsequent to the welding, the sheath is reduced slightly by finishing rolls to tightly fit the cable. The best method appears to be that of the Yoder Roller Company of Cleveland. Their cable machine is not yet ready for commercial production, although their machine for making aluminum piping is. Cable sheathing is applied at rates up to 120 feet a minute. The weld is at least as strong as the rest of the sheath. A ridge is left inside which, however, would be harmful in high voltage cables. While the method is satisfactory for tubes because the latter can be subsequently tested for porosity. It is less satisfactory for cables because of the impossibility of testing. For some types of cables, e.g., rubber-insulated cables, occasional porosity at the seam in the aluminum sheath would not be of consequence.

A recent variation in the strip method is to give the aluminum strip a zinc dip and a thin copper plating on both sides. Then the standard Yoder machine which solders the longitudinal seam may be used, and the bugbear of seam porosity is eliminated.

A similar method has been developed in England by Pirelli-General of Southampton. Its speed of five feet per minute is relatively slow.

The cost of aluminum billets for the extrusion machine is 21 cents per pound, of aluminum strip 23 cents per pound, and of aluminum tubing 48 cents per pound.

When the Yoder strip process is perfected the machine, because of its low capital cost and high output, might be useful in supplementing a heavy press in sheathing small rubber or plastic cables, leaving the press for heavy work.

Economics

Since aluminum is less than ¼ the weight of lead, it follows that the price of lead must be about ¼ the price of aluminum if the same thickness is used, or ⅛ the price of aluminum if ½ thickness is used as in telephone cable, if the two metals are to be economically equivalent, disregarding the cost of application. For telephone cables, to match aluminum at 20 cents per pound, lead would have to sell for 2.50c per pound. In power cables the thickness employed for aluminum sheathing are only 75% to 85% lead, hence at 75% thickness lead would have to sell for four cents per pound to be economically equivalent.

These statements are an over-simplification but give a sound general picture. Some modification must be made for the cost of the corrosion protection on the aluminum but as it is fairly cheap, and as it would be an advantage to also use it with lead sheath, we have neglected it. Application costs for extruded aluminum sheaths should run higher than for lead. Lead has a slight disadvantage in freight and in labor of handling.

The comparison may be made in another way. The material cost for the sheath of one foot of one inch diameter telephone cable is, for lead at 1951 prices, 22 cents; for stalpeth, 12 cents; and for aluminum two cents.

For power cable, one foot long and two inches diameter, 18 cent lead would cost 81 cents a foot, 21 cent aluminum of 75% thickness would cost 14.50c.

For high pressure power cables the saving due to aluminum would be much greater because the re-enforcement can be omitted.

There seems little doubt of the economic advantage of aluminum for cable sheathing.

Availability Of Aluminum

Lead at the present time is in ample supply, and aluminum should also be in ample supply in the near future.

Primary aluminum production in the United States has been and is expected to be:

1951 — 1,680,000,000 lbs.
1952 — 1,870,000,000 lbs.
1953 — 2,700,000,000 lbs., estimated
1954 — 2,400,000,000 lbs., estimated

Total aluminum available for manufacture, including primary, imports and secondary:

1952 — 2,400,000,000 lbs.
1953 — 3,500,000,000 lbs., estimated

In the face of these figures and the obvious deductions therefrom, it is difficult to see any change in the differential that would be importantly favorable to lead in competition for cable sheathing.

Will Aluminum Cut Into The Consumption Of Lead For Cable Sheathing?

It has already been seen that technically and economically aluminum is in a favorable position. Let us attempt an analysis.

Telephone Cable.—If stalpeth had not been introduced, 125,000 tons of lead would have been used this year. As it is, 30,000 to 40,000 tons less of lead will be used because of the stalpeth sheath. When the aluminum sheath technique is worked out, it would appear that the 12 cent stalpeth sheath which nosed out the 22 cent lead sheath will itself be eliminated by the two cent aluminum sheath. It would not be surprising to see lead, commencing in about two years' time, gradually lose out completely to aluminum in this field. In the meantime, it is losing out to stalpeth.

Coaxial Cables.—Lead never has been generally used in this application. Aluminum sheathing is replacing copper piping, and should become almost universal in this field.
Power Cables.—For industrial cables, for example, wiring and control cables, aluminum-sheathed cables have been in great demand abroad and may in time replace other types fairly completely because of the saving of labor and the neat appearance. Since lead is little used in this application, the gain for aluminum will not be at the expense of lead.

In aerial cables aluminum may be expected gradually to replace lead almost completely because of its light weight, and high resistance to vibration fatigue.

In high pressure gas or oil cables which are used for the highest voltages, aluminum could replace lead fairly completely, since the strength of aluminum permits the re-enforcement to be omitted.

In duct cable (other than high pressure cables) which comprises the great bulk of lead-sheathed power cables in the United States, the use of aluminum sheath is problematical owing to its greater stiffness and the necessity for training the cable around manholes to take care of expansion. These and other problems have to be overcome. Already from dummy manhole tests it appears that aluminum sheath cable has a much higher flexing life than lead. The transition will be gradual at most because of the extreme conservatism of utility engineers.

Abroad, aluminum-sheathed cables will come in more quickly because most of the cables are directly buried in the ground, hence expansion problems are eliminated and at the same time there is a double saving, namely that on the metal sheath itself and that on the re-enforcement which the strength of the aluminum makes unnecessary. In addition, several large extrusion presses are being built in England and one of 8,000 tons in Germany. These machines can sheath tremendous quantities of cable and it is certain, because of the large investment they represent, that they will not be allowed to remain idle. These considerations appear to insure that a substantial percentage of power cable in Europe will, within the next two years, be sheathed with aluminum.

Conclusion

Lead has been in use for piping and sheathing for over 2,000 years. Its characteristics are well-known and particularly its resistance to corrosion. Yet the new-comer aluminum has sufficient technical and economic advantages to constitute a real threat to lead in the cable sheathing field. Despite its weakness to corrosion and the difficulty of joining or patching it, aluminum cable sheathing will come into wide use in Europe in the next few years. In America the change will come more slowly. Telephone cable will probably use aluminum sheath almost entirely within five years or less. In the power cable industry the transition will come more slowly owing to expansion problems in underground ducts and the conservatism of the utility industry.

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