LEAD CABLE SHEATHING

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INTRODUCTION

Lead is the most versatile sheathing material employed in the electric cable industry.

Being metallic, it is capable of functions unique to metals, but, in addition, its physical characteristics enable lead and its alloys to perform equally well functions specific to flexible non-metallic jacketing materials. For example, it may be readily hand-formed into position and furthermore with no spring-back. Nor does it shrink-back at cuts, as do some plastics. Splicing by wiping is straight-forward. Significantly, lead sheathing is readily adapted to economical reclaiming and reworking, being the only cable component acceptable to AEIC after stripping and reapplying.

Nevertheless, as a result of the necessary sustained effort to achieve lower costs, a number of alternative cable constructions have come into being which provide service at lesser expense than their lead sheathed counterparts.

Voltage-wise, lead is still the predominant sheathing material in the U.S. at 12 to 15 Kv. and above up to 69 Kv. However, at 69 Kv. and higher, alternatives dominate, and like trends are appearing in other world areas.

Even so, the rate of growth of cable usage in the voltage ranges where lead predominates has held demand high.

Moreover, the successful development of the continuous lead press has been particularly advantageous to the manufacture of long lengths of submarine cable.

FUNCTIONS OF METALLIC SHEATHS

The metallic sheaths of electric cables must with few exceptions be non-magnetic and sufficiently flexible to permit the winding and unwinding necessary to factory processing and field handling.

They must be capable of one or more of the following operating functions:

1.- Preclude ingress of moisture, and protect against other deleterious environmental factors.

   a.- The dielectric properties of high voltage cable with oil-impregnated paper tape insulation are directly dependent upon freedom from moisture.

   b.- Likewise, the transmission efficiency of communications cable is adversely affected by moisture, whether plastic or paper insulated.

2.- Provide electrostatic and electromagnetic shielding.

   a.- A.C. capacitance charging current must be drained to preclude excessive surface voltages and corona discharge, otherwise radio interference

occurs as well as rapid degradation of cable insulations, culminating in faults. This is a prime operating factor at 3 to 5 Kv. and above.

b.- Protection from lightning requires a low resistance grounded shield, one ohm or less.

c.- Likewise, a low ground loop-resistance is essential to preclude critical voltage build-up and short-circuit on communication lines, generated by electromagnetic fields radiating either from nuclear disturbances or from power transmission systems (particular under power fault conditions).

3.- Afford an effective (low-impedance, coaxial) neutral return, so as to assure efficient relay operation and switching.

4.- Mechanical protection, during handling and throughout service life.

a.- The metallic covering must withstand, without fatigue, manhole bend or like motion derived from length-wise cable expansion resulting from temperature rise under current loading. Service life is 20 to 40 years, with operating temperatures in the U.S. ranging from a low of minus 40°C to a high of the order of 110°C.

b.- Normal winding and handling radii usually involve strains beyond the elastic limit; likewise, periodically in service.

In order to assure maintenance of operating function capability, metallic coverings have to be reasonably corrosion resistant, otherwise corrosion protective jacketing is required (vulcanized neoprene jacket, or extruded polyethylene).

Lead sheathing meets all these required functions. However, a number of factors (winter salting of streets, demise of streetcars, and very heavy fault current duty with the growth of large grounded systems leading to vulnerability to indiscriminant arcing and sheath damage) have made jacketing of lead sheathed cable mandatory in many of the major cities.

ALTERNATIVES TO LEAD

The alternatives to lead are outlined in the following paragraphs, more or less chronologically as they came into being.

Initially, lead sheathing was needed for all insulations over the complete voltage range, because early rubber insulations, like paper, also were affected deleteriously by exposure to moisture.

A.- RUBBER AND PLASTIC CABLES

Research led first to the development of moisture resisting rubber compounds, then to plastic formulations even more resistant, thereby eliminating the necessity of moisture-proof sheathing for these classes of dielectric materials.

Next, non-metallic jackets, resistant to all manner of environmental conditions, came into being, so that a ground wire sufficed for neutral return at voltages below levels where corona discharge becomes a factor, namely 3 to 5 Kv.

Then, thin metal tapes (0.005"), wound helically over the cable insulation, were demonstrated to provide ample electrostatic shielding.

These developments have brought rubber and plastic cables into general use up to 15 Kv. with growing usage at 34.5 Kv., plus some pioneering work with plastics at 69 and 138 Kv.

Interestingly, lead sheathing is being considered at these higher voltages applications of plastics for a variety of reasons, such as the possible deleterious effects of moisture absorption on service life, to avoid structural and chemical problems (shrink-back, plasticiser migration) associated with plastic jackets, and to afford a more secure ground return.

B.- PAPER CABLE

While paper cable is vulnerable to moisture contamination, it is exceedingly resistant to critical degradation by voltage stress.

However, an order of degradation which is of no consequence at 15 Kv., becomes considerably more significant as the operating voltage becomes higher, increasing more or less as the square of the voltage.

As a result, ionizable voids can be tolerated at the lower voltages, but at 69 Kv. and above they cannot, making void-free or pressurized systems necessary.

C.- LOW-PRESSURE OIL-FILLED PAPER CABLE

Low-Pressure Oil-Filled Cable is designed to operate void-free at a maximum pressure of 15 to 20 psig., pressure being maintained by a system of reservoirs feeding the oil demand of the cable under load cycle via an oil channel in the conductor.

These pressures are compatible with the use of unreinforced lead and over a thousand miles of this class of cable has been put into service in the U.S. at voltages from 69 to 230 Kv.

However, the low pressure limited the length of operating sections, necessitating periodic use of costly stop-joints.

This class of cable has been largely superseded in the past decade by the Pipe Cable.

D.- PIPE TYPE CABLE

Pipe type cable operates at 200 psig. While it was developed about the same time as low-pressure oil-filled cable, it did not come into general use until about 15 years ago.

Whereas lead sheathed cables are fabricated completely in the factory, so are designated "self-contained", pipe cables are only partially completed in the factory, the metallic sheath or covering being constructed in the field. That is, the "pipe" is welded from double random lengths and laid directly in the ground. Next, three single-conductor factory-made cables are pulled into the pipe, which then is filled with oil or nitrogen gas and maintained at the 200 psig.

Special precautions, such a sealing of the reel against atmospheric moisture, make it feasible to ship this class of cable without the benefit of a protective lead sheath.

Without sheath, the cable is lighter, so longer lengths can be shipped and pulled, reducing the number of costly manholes and joints.

The high pressure makes it possible to feed long lines from a relatively inexpensive pumping plant and without recourse to stop-joints.

Furthermore, there is sufficient clearance in the pipe to permit oil circulation, thereby eliminating hot-spots along the line and increasing load rating.

The end result is a most economical H.V. and E.H.V. system, approaching 2000 circuit miles in the U.S., at voltages including 345 Kv.

E.- EXTRUDED (TUBULAR) ALUMINUM SHEATH

Extruded aluminum sheath has become available over the past decade, finding use in the U.S. primarily in aerial paper cable where the weight saving is important.

Two methods of manufacture are in use, direct extrusion from the press onto a cable core, or separate extrusion with the tube laid out on a runway to permit drawing in of the cable core, similar to pipe cable practice.

Comparatively extensive direct buried applications of high voltage pressurised (75 to 100 psig.) corrugated aluminum sheath cable are being made in Europe. These depend upon the absolute integrity of the corrosion protective coverings, otherwise, the aluminum very rapidly corrodes through by a localised pitting action.

Corrugation permits employment of thinner gage metal, so implements cable training and handling. On the other hand, it increases the overall diameter, so limits applications where space is a factor, such as in conduit and duct.

F.- SEAM-WELDED METAL SHEATH

The latest development in the metal sheathing field is seam-welding. A metal tape is precision formed about a cable core, then butt-welded electrically, followed by either a sizing or a corrugating operation.

This process may be adapted to a variety of metals including copper as well as aluminum and steel.

FUTURE CONSIDERATIONS

We referred in the introduction to the successful development of the Hansson-Robertson continuous lead press as a day-in day-out production tool. This has been particularly significant, in that it has helped to reduce production costs, as applied to plain lead and copper-bearing lead, but not to higher alloys. The problem with the latter is a tendency toward zonal refinement and plating out on the screw. This causes slippage and raises the possibility of pieces of segregated material becoming embedded in cable sheath.

Ram presses suffer similar contamination but only at the die, which is removed

and polished with each change of cable size.

Fortunately, copper bearing lead is a most satisfactory material, in the minds of many experts the best for cable sheathing, whether aerial, underground or submarine, so no really practical limitations have arisen.

However, with the increasing use of a variety of scrap supplies in refining lead, there is a measure of concern lest some unspecified element be retained and have a deleterious effect on production procedures.

This is a most important consideration in view of the growing tendency to undertake long submarine A.C. and D.C. interconnections to allow pooling of reserve capacity; armored, self-contained (lead sheathed) cable design is virtually dictated to the exclusion of other types.

Electro-negative gases, such as sulfurhexafluoride, are receiving more and more attention by cable research and design engineers, because of the enhancement of dielectric strength which may be achieved without resort to high pressures.

Lead should benefit from this work, not only because expensive sheath reinforcement will be avoided, but also because of the ease and certainty with which dependable, leak-free wiped seals can be made on lead sheath compared to closures on most alternate constructions.

CONCLUSIONS

Generally speaking, overall costs are a function of cubic content. Except for the lower voltages, lead sheathed paper cable provides the minimum dimensions for a given conductor size, so minimum duct size, and so forth. Accordingly, lead cable should continue to dominate the underground power cable market in the voltage ranges from 10 to 60 Kv.

Likewise, as to submarine applications, including 138 Kv. and higher A.C. voltages, plus H.V. D.C.

Both of these areas are experiencing stimulation due to the emphasis on underground and the increasing attention to savings through interconnection.

Aerially, the space factor or volume content is a less dominant factor. Rather, weight rules, and several alternatives other than lead no doubt will remain in control of this market.