ANACONDA

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BY POWER CABLE ENGINEERING AND RESEARCH

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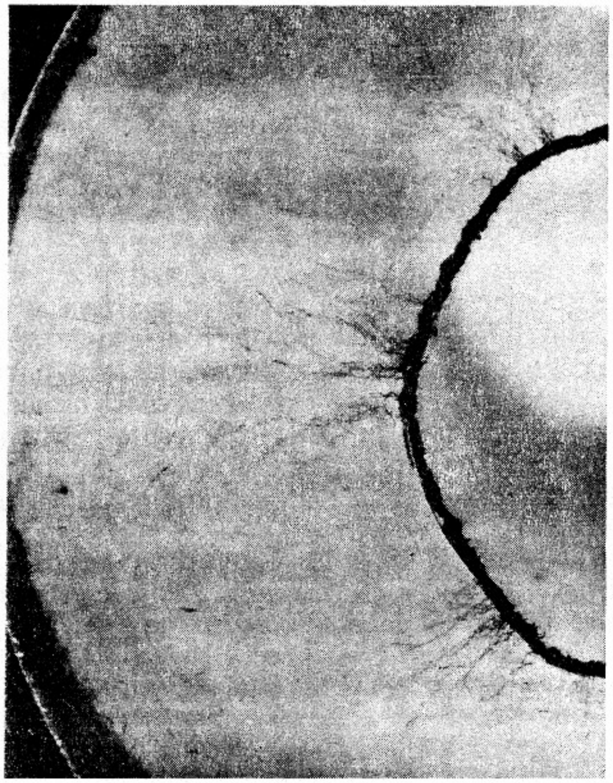
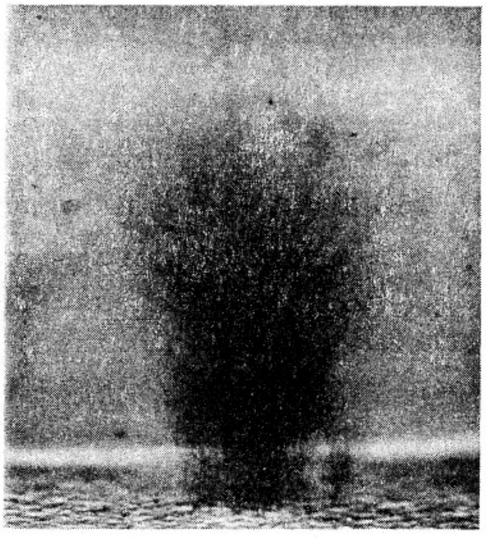
WHAT ARE "WATER TREES"?

During the last few years, a large amount of interest in "water treeing" has been shown by insulation compound suppliers, power cable manufacturers and electric utility companies. This interest was started several years ago, by reports from the West Coast of the United States that "water trees" were being found in a high percentage of polyethylene extruded dielectric cables examined after 1 to 10 years in service. "Water trees" have since been found in cables from Illinois, Connecticut, Japan, Sweden, and many other places. The term "water treeing" is used to make it clear the problem is not due to "electrical trees" like those generated in the laboratory by needle inserting techniques developed in the last twenty - thirty years.

NOMENCLATURE

Under electrical stress, a series of tiny (usually less than 0.025 mm - 0.001 inches in diameter) hollow channels can develop within an insulation exposed to water. Since the resulting pattern looks like a poplar tree without leaves (see figure 1), the name "water tree" is used to identify the pattern.





The base of the tree is located at the point where the tree originated and its extremities tend to grow in a direction parallel to the direction of the electrical field. Thus, a tree originating at the stress-relieving layer at the conductor (conductor shield) of a cable grows radially until the cable fails.

The "water trees" are usually filled with water or materials carried in by water at an earlier time in the cable's history. Should sulfur be dissolved (usually as sulfide) in the water to which copper conductor cable is exposed, the copper sulfide produced at the conductor can move out through the insulation to cause cable failure by "sulfide trees". Voids or contaminants sometimes initiate a tree on both sides - one which grows toward the conductor, the other toward the outer shield system. Their resemblance to "bowties" gives them that name.

GROWTH MECHANISM

"Water trees" begin to form when a cable is exposed to water and normal operating voltage over an extended period of time. Electrical forces acting on water molecules (electrophoresis) at a microscopic point within the insulation increases the separation between polymer units. These minute water droplets become oriented into a chain-like channel that is conducting. The result is a sharp electrode, producing highly localized stresses. Once treeing is initiated, an electrical stress exists from the base of the tree channel or trunk to its other extremity. Tree growth continues, often branching out from the main trunk or channel. The appearance of the resulting water tree is similar to the electrical trees produced by inserted needles. Growth can continue in the presence of an electrical field and water until the total insulation wall thickness is bridged. When this occurs, there is a high probability of cable failure.

CAUSE OF IN-SERVICE TREEING

Long term exposure of an energized cable to environmental water is the primary cause of "water trees" observed in in-service cables. "Electrical trees" can also develop in a cable, in the absence of water, but more rarely, when very high electrical stresses are involved, either from very high overvoltages (i.e. switching surges or lightning strokes) or from localized stresses due to major defects.

CONCLUSION

The traditional method of evaluating an insulation's resistance to treeing has been to use sharp needles to obtain high localized electrical stresses and tree growth. Times to failure or rate of extension of the tree channels have been used as the evaluation criteria. With the recent knowledge that water is an important factor in causing failures of in-service cables, it now becomes evident that water must be an ingredient of any laboratory test for resistance to treeing, if the test is to be meaningful. Our EMA test is a life test conducted in water at elevated temperatures with electrical stress applied. It provides a meaningful measure of a cable's overall in-service resistance to treeing.

The relative performance of EP and XLPE insulation in EMA tests will be discussed generally in the next Cable Lore, No. 42, and more specifically in Cable Lore No. 46.

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