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EPR insulation cuts treeing and cable failures

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There is considerable difference of opinion among utilities as to the relative merits of polyethylene and ethylene-propylene rubber as cable insulation. EPR is admittedly more expensive, but some utilities feel that it's worth it. Others disagree. Here is the case for EPR, presented by one of its manufacturers.

When polyethylene cable insulation was introduced some 30 years ago, it seemed to be the answer to a maiden's prayer, because traditional paper/lead cables were far too costly for URD installations. At the time, there was every reason to expect the traditional 40-year life span for this new insulation.

But within five years, it was apparent that, for many installations, the lifetime would be far less than 40 years. A recent study covering some 25% of all installed PE cables indicates that cables insulated with high-molecular-weight polyethylene are failing at a rate of 14.4 failures per 100 miles of cable installed. Worse yet, this already-unacceptable rate is clearly increasing (EW, November 1980, p 98). Although the rate is much lower for cross-linked polyethylene (XLPE) cables—1.89 failures per 100 miles—this rate is also increasing, which points toward an unacceptable rate of failure soon (EW, January 1981, p 100).

What has changed

The more-costly ethylene-propylene-rubber (EPR) cable insulation has been around for a long time. It has demonstrated superior insulation strength, but has higher losses than PE insulations. Recent changes have improved its loss properties, but EPR is still more expensive initially, and total life-cycle costs must be considered if EPR cables are to compete on an equal basis.

For Northeast Utilities, a company that has been using EPR for 10 years, it now seems clear that the added cost of EPR was a good investment—one that is lowering the lifecycle costs of cable systems and increasing customer reliability.

Both EPR and PE are hydrocarbons. Each has power factors and dielectric qualities (Table I) that are superior to the industry standard—paper/lead insulation. Now that EPR is being manufactured with reduced clay filler and without oil, its insulation performance has been improved. In the past, both clay and oil were included, to improve desired physical qualities and to aid in its manufacture. But to reduce these losses, the fillers had to be reduced.

The newer elastomers of EPR can be formulated with much less clay and no oil. As a result, the superior insulation qualities of EPR are now further improved. Specifically, losses are lowered, and an oil-migration problem has been eliminated.

What are the differences?

Below 90°C—the crystalline melting point—PE has a higher dielectric strength. But most distribution cables are exposed to at least occasional thermal overloads. During these periods, EPR retains dielectric strength, both 60-Hz and impulse, whereas strength of PE and XLPE decreases to levels below those of EPR. This can be important in minimizing progressive degradation of the insulation.

It is in this area of thermal overloads that EPR has demonstrated its superior physical (Table II) and dielectric properties. A second key advantage is the higher modulus of elasticity; the resultant reduced deformation of the insulation at elevated temperatures makes for increased insulation strength. Also, at ambient temperatures EPR cables can be more easily bent, resulting in better splicing and greater ease of installation.

EPR thermal conductivity is up to 30% higher that that of PE (Table III) and allows greater current carrying capacity for a given cable conductor.

Table III: Thermal conductivity

Watts/m° C	XLPE	EPR (low-clay)	EPR (high-clay)
at 90° C	.226	.268	.272
at 130° C	.205	.264	.268

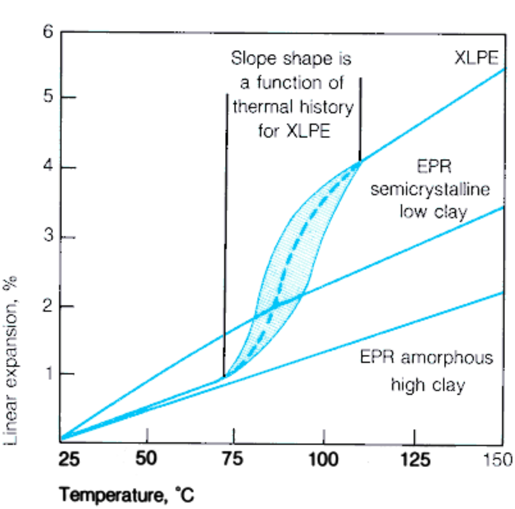
EPR also has reduced thermal expansion (Fig 1). Excessive thermal expansion of insulation can result in severe stresses at the boundary between the shield and the insulation, or at terminations. When

Table I: Electrical properties

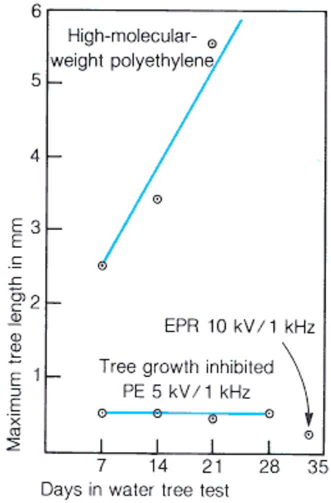
	Power factor, %	Dielectric constant
Butyl	1.50	3.4
Paper-lead	0.80	3.5
XLPE	0.05	2.3
EPR, 120 parts clay, 10 parts oil	0.60	3.0
EPR, 60 parts clay, no oil	0.25	2.5
EPR, no clay, no oil	0.06	2.4

Table II: EPR vs XLPE: Properties of 1.2-mm insulation on No. 12 AWG wire

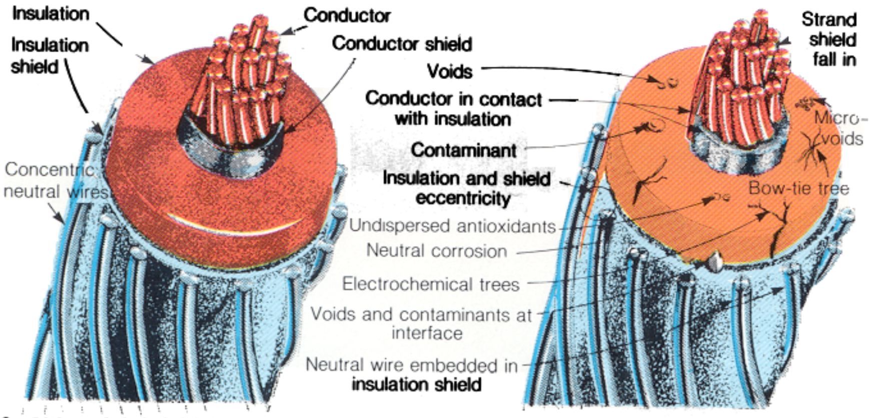
	EPR (60 phr clay)		
	Semicrystalline	Amorphous	XLPE
At 22°C:			
Tensile strength, MPa	12.4	8.6	16.7
Elongation at break, %	320	305	500
100% modulus, MPa	4.7	2.1	7.9
At 90°C:			
100% modulus, MPa	1.8	1.9	3.4
At 130°C;			
100% modulus, MPa	1.5	1.8	0.2
Heat distortion, (molded slab)	8	5	20
Tensile set, % at 22°C after 100% elongation	5	2	43



1. Thermal expansion and contraction is a prime cause of problems with joint seals. Therefore, reductions typically result in fewer cable faults at terminations. The XLPE curve of linear expansion changes, depending on past thermal history (shaded area)



2. Tree growth in XLPE is a linear function, ultimately resulting in cable failure. Growth-inhibiting compounds can arrest the growth, but not to the inherent level of low-clay-content hydrocarbon rubber (EPR)



3. Although it is initially more costly, EPR cable insulation eliminates many of the causes of insulation failures that are found in cable insulation made of high-molecular-weight polyethylene (HMPE) or crosslinked-polyethylene (XLPE)

these stresses are high enough, they can result in voids and structural separations that will consistently lead to insulation failures.

Another advantage of EPR insulation is that thermally induced stresses are not frozen into the insulation during the manufacturing process. In PE-insulated cables, these stresses cause shrinkage when the insulation is heated under load. Again, the result can be separations at terminations, leading to cable failure.

Both PE and EPR cables have a tendency to release dissolved gases within the insulation as it is cooled in the curing process. The higher modulus of elasticity of EPR resists most of the void formation, and those voids that do form are smaller (EW, Nov 15, 1978, p 97).

Trees, the cause of failure

When PE insulation is electrically stressed in the presence of water, electrochemical dendritic (tree-like) defects occur in the insulation. Even when water is not present, if the field is high enough (as it might be when a lightning or switching surge is present on an underground circuit), the defects known as electrical trees will form in the insulation. Once formed, either type of tree ultimately leads to cable failure.

Various laboratory tests that have consistently produced water (electrochemical) treeing in PE insulation do not produce trees in EPR insulation. In an attempt to generate water trees in EPR cables, engineers raised the electrical stress to the point where electrical trees (even harder to produce than electrochemical trees) would be created in PE. But after 28 days of accelerated testing, no trees of either type were generated in EPR.

Conclusions

EPR has performance characteristics that permit power cables to be used successfully under conditions of voltage, heat, and moisture that have produced high and increasing rates of failure in cables with other insulating polymers.

These characteristics of properly compounded EPR, combined with increased cable flexibility and ease of termination, are receiving more attention from electric utilities concerned with the failure rates experienced with high-density polyethylene and XLPE. ■