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EXPLORING THE WATER TREEING INHIBITION EFFECT OF ANTIOXIDANTS FOR XLPE INSULATION

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ABSTRACT

A review of commercial water tree retardant XLPE insulations reveals that water tree resistance is generally obtained by the use of either WTR additives, or polymer modification, or both.
Some of these formulations are now proven and their up and down sides are well known.
This communication presents exploratory work conducted to identify antioxidants that have the dual effect of providing long term thermal stability ***and*** *enhancing the water treeing resistance of XLPE.*
This line of research is thought to be of interest, for its simplicity of implementation (substitution of antioxidants), its cost effectiveness (no other additive or polymer modification required) and its compatibility with all cable manufacturing technologies (ready-to-use XLPE, self compounding, peroxide injection).

KEYWORDS

XLPE, water treeing, water tree resistance, liquid antioxidants.

INTRODUCTION

A review of publications reveals that water tree retardant XLPE insulation in now widely accepted and that the benefits provided by the new compounds is becoming increasingly quantified [1] [2].
We, however, noted that the approach to provide water treeing resistance is not uniform [3] [4] [5] and can consist of using polar polymer blends (Homopolymer-copolymer), non polar polymer blends (Homopolymer – non polar polymer), water treeing retardant additives, or even a combination of the above. This is summarized in figure 1.

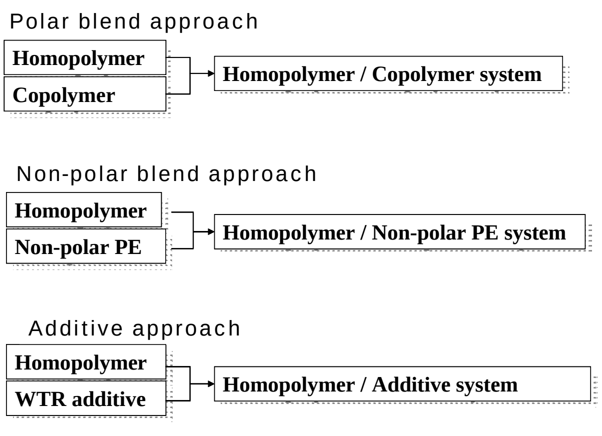


Figure 1: Approaches to water tree inhibition

However, the various approaches have advantages and limitations. The well known downsides for the various technologies can be summarized as follows:

Polar blend:
- o Restricted to fully bonded insulation shields
- o Higher dielectric losses

Non polar blend:
- o Cleanliness of second phase polymer
- o Gels in the second phase polymer

Additives:
- o Permanence of effect
- o Higher dielectric losses
- o Exudation of additive

The composition of a water tree retardant XLPE insulation is relatively simple (in terms of components):

Composition of WTR XLPE:
- o Polymer (single or blend)
- o Peroxide for crosslinking
- o Ao for thermal stability
- o Water treeing inhibitor

The concept of an antioxidant with water treeing inhibition characteristics looks appealing, on paper, because it could replace totally or partially a component (the water treeing inhibitor itself) that may have the drawbacks of permanence, sweat out, dielectric losses and/or cost.

FOCUS OF THE STUDY

We focussed our study on antioxidants susceptible to be compatible with the XLPE technology and requirements, namely:
- o Ageing
- o Crosslinking
- o Reduced sweat out
- o Reduced water treeing growth
- o High cleanliness, implying that it had to be liquid to allow fine filtration

Among the antioxidants initially screened, two appeared particularly promising (AO-L1 and AO-L2) and, therefore, were fully evaluated in an XLPE formulation and compared to the classical solid antioxidants (AO-S1) currently used in XLPE compounds.

<u>Ageing</u>

At this point in time, no optimization of the antioxidant content was attempted, it was established first that 0.2% of the liquid antioxidants were sufficient to pass the 10 days at

150°C ageing specification. A specimen without antioxidant was included for reference.
The results shown in figures 2 and 3 highlight the comparable ageing protection provided by all antioxidant systems evaluated, whilst the specimen without antioxidant naturally degrades immediately.

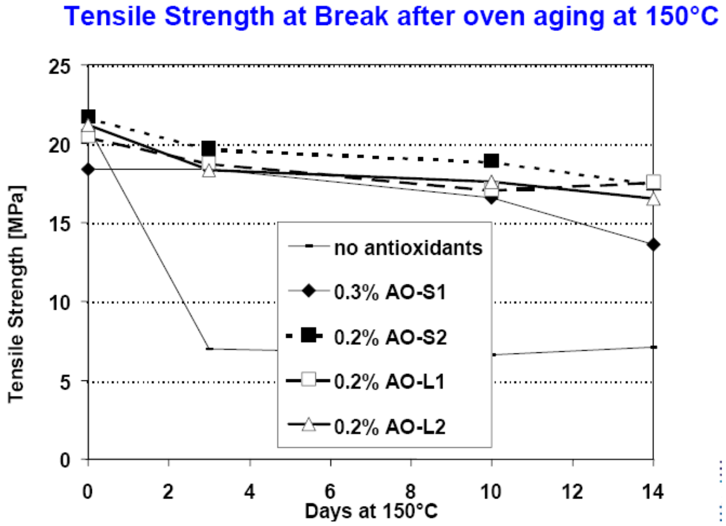


Figure 2: Tensile strength after ageing

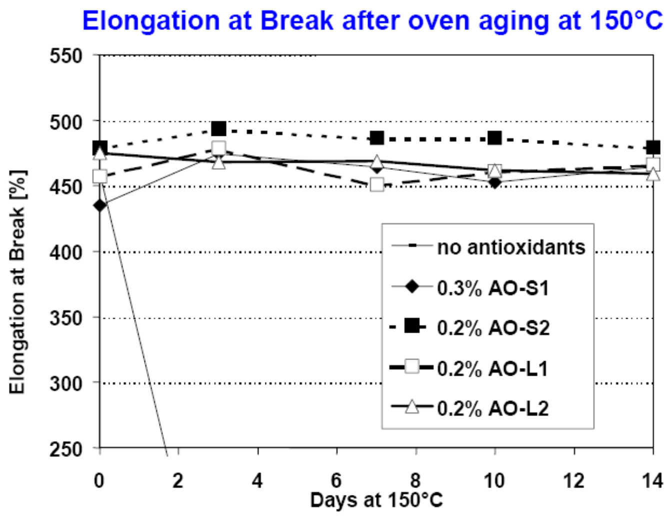


Figure 3: Elongation after ageing.

Crosslinking

The XLPE compounds were fully crosslinked and their gel content was measured by the decaline extraction method. As shown in figure 4, the degree of crosslinking is the same for all products.

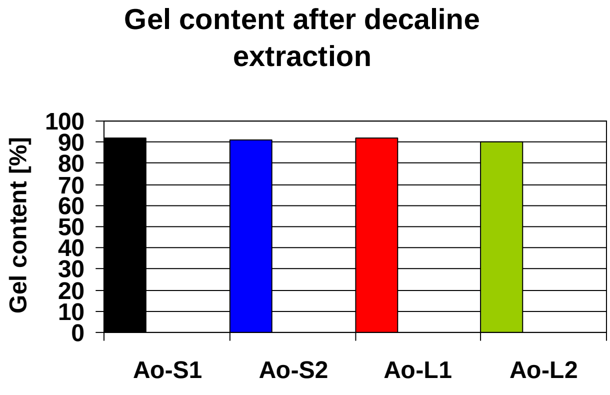
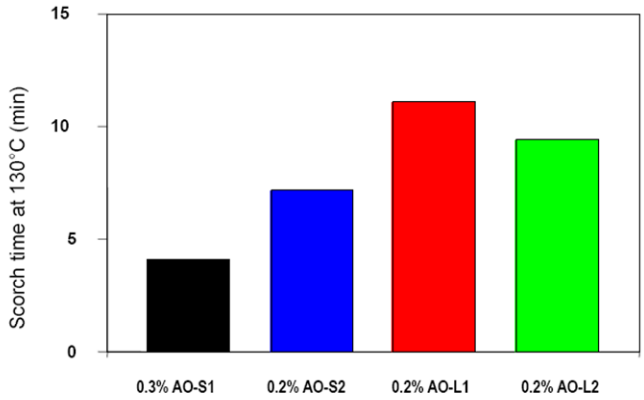


Figure 4: degree of crosslinking

Scorch resistance

The resistance to scorch (premature crosslinking in the extruder) was determined by means of a Brabender Plasticorder at 130°C under a load of 2 kg and 30 rpm. The time to scorch is defined as the time required to increase one torque (from the minimum torque); obviously the longer the scorch time, the better. It can be observed that the liquid antioxidants provided longer resistance to scorch (at comparable concentrations). This is summarized in figure 5.



Measured on Lab Kneader (Brabender Plasticorder 814 300), 30 rpm, 2.0 kg load at 130°C. Time from minimum torque to 1Nm torque increase.

Figure 5: Resistance to scorch

Sweat out

Users of XLPE know that some antioxidants have a tendency to sweat out at critical temperatures (in general between 50 and 60°C). The various samples were conditioned at 55°C for a period of 4 months and the corresponding sweat out was determined by washing a specified amount of pellets in methanol. In this case the liquid antioxidants showed the lowest sweat out, as shown in figure 6.

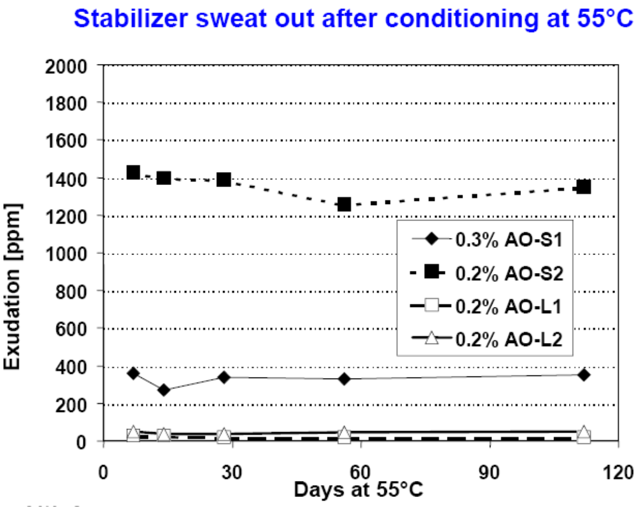


Figure 6: Sweat out

Cleanliness

An essential aspect of the research was to ascertain the purity of the liquid antioxidants. For this purpose, 10 g of each antioxidant were dissolved in 100 ml of solvent (toluene) and passed through a filter. The particles larger than 50 microns present in the filtrated residue on the filter were recorded by a computer controlled microscope. Figure 7 highlights the quasi absence of particles on the residue for the liquid antioxidants.

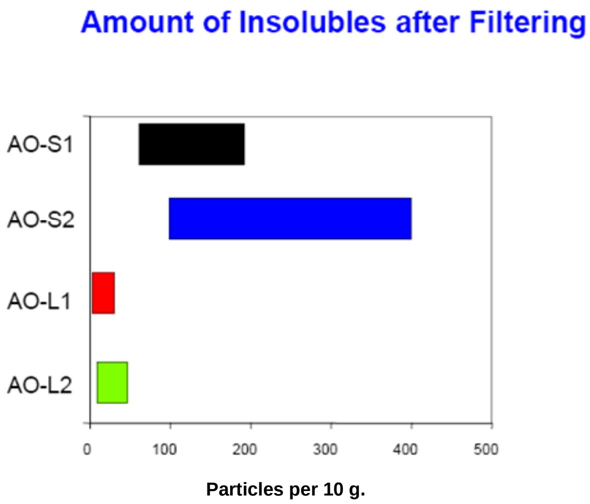


Figure 7: Particle count after filtering

First conclusions

After this first assessment, it could be concluded that the liquid antioxidants met all the requirements for XLPE insulation, particularly AO-L1 which appeared to be superior in all respects to the other antioxidants evaluated.

It was then decided to proceed with the water treeing evaluation.

WATER TREEING

The method used for the initial evaluation was the modified ASTM D 6097-00, where a standard defect is moulded in order to generate a highly divergent electric field. The measured length of the observed water trees allows the calculation of the speed of propagation of the water tree (growth rate) [6] [7] [8].

The test configuration is shown in figure 8.

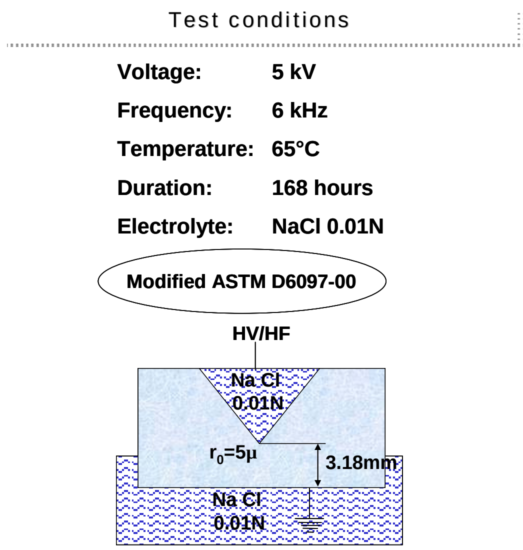


Figure 8: Test configuration

After the test, the specimens are boiled in a methylene blue solution (in order to render visible the water trees), microtomized and he water tree growth rate is calculated as per the above calculation method.

The results are reported relatively to a standard XLPE in per cent; thus a water tree growth rate of 50% would mean that, in the particular specimen, the water tree has propagated at half the speed of the water tree propagation in the reference sample.

An XLPE formulation (homopolymer) modified with AO-1 was compared to commercially available XLPE formulations, both homopolymer and copolymer.

The results shown in figure 9 clearly indicate that AO-L1 has a strong water tree inhibition effect.

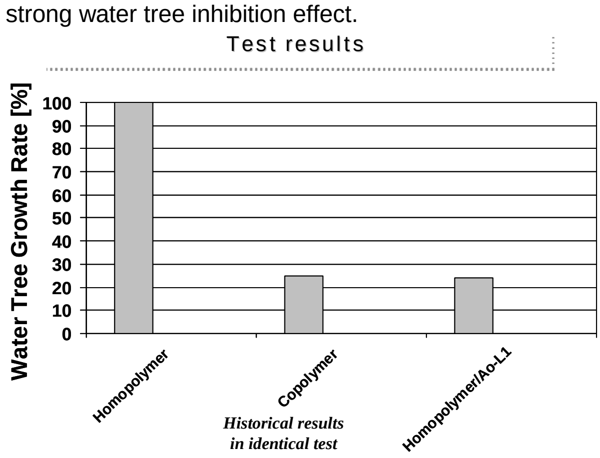


Figure 9: Water treeing test results

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Furthermore

Having observed a marked water treeing inhibition effect on a homopolymer XLPE formulation. We thought of interest to verify the effect of AO-L1 on a water tree retardant formulation. For this purpose, 0.2% of AO-L1 was added to a water tree retardant XLPE compound.
The results displayed in figure 10, show that as expected the water tree retardant formulation had a reduced water tree growth rate of only 10% (by definition, the reference standard XLPE has a growth rate of 100%). However, when AO-L1 was added to the formulation, a significant further reduction could be observed.

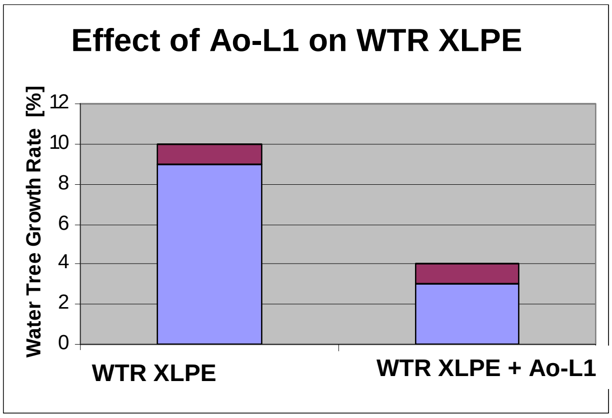

Figure 10: Effect of AO-L1 on WTR XLPE

CONCLUSIONS

We have verified at **laboratory stage** that is possible to reach a high level of water treeing resistance by the use of a dual purpose antioxidant (AO-L1).
This antioxidant meets all the requirements to be used in an XLPE formulation, such as long term thermal protection, compatibility and scorch resistance
A further guaranty of cleanliness lays in the fact that, being a liquid, it can be filtered down to 1µ if necessary.
The water treeing inhibition effect is incremental in formulations containing other water treeing inhibitors
This line of research appears particularly interesting if considered in the perspective of an insulation thickness reduction trend and is compatible with all XLPE manufacturing technologies

Acknowledgments

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REFERENCES

[1] H. Schädlich
"Comparative Long-Term Testing on 20 kV XLPE Cables"
Jicable 95, Versailles, June 1995, pp. 357-360 R.

[2] Eichhorn et al
"Long Life Cables by Use of Water Tree Retardant Insulation and Supersmooth Shields"
Jicable 91, Versailles, June 1991, pp 145-149

[3] J.J. De Bellet et al.
"Some aspects of the relationship between Water Treeing, Morphology and Microstructure of Polymers"
IEEE Transactions on Electrical Insulation, April 1987, EI-22, pp. 211-217

[4] Matey et al
"WTR XLPE insulation – Laboratory and Field Experience"
Jicable 91, Versailles, June 1991, pp. 154-160

[5] A. Campus et al
"20 years of experience with copolymer power cable insulation"
Jicable 03, Versailles June, 2003, pp 350-356

[6] A.C. Ashcraft
"Water Treeing in Polymeric Dielectrics"
World Electrical Congress, Moscow, June 22nd 1997

[7] G. Matey et al
"The Development of a WTR XLPE Insulation"
ETG-CIGRE Conference, Berlin, Sep 9-11 1985, pp 170-173

[8] J.O. Bostrom et al
"Assessment of cable performance as measured by a variety of accelerated ageing tests"
Jicable 03, Versailles, June 2003, pp 536-542