

RAPID QUALIFICATION OF POWER CABLE MATERIALS

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ABSTRACT

We have applied a wide range of molecular spectroscopies including infrared, Raman and hyperspectral UV-VIS-NIR methods to measure and spatially resolve chemical composition and structure of cross-linked polyethylene insulated cables both before and after electrical and thermal stressing.

Changes in charge mobility, charge injection, potential of the polymer to oxidise, the concentration of luminescent species, photo and electroluminescence metrics can all be related to changes in the chemistry of the insulation as a result of cable stressing. In addition, concentrations of typical flame retardants and their effect on properties can be readily determined.

KEYWORDS

Non destructive testing, infrared spectroscopy, chemometrics, cable testing, flame retardants.

INTRODUCTION

The European Artemis program required the measurement of changes in the chemical and physical properties of the high-voltage XLPE cable insulation and of the fate and distribution of various additives and degradation products, especially as a function of the radial distance during ageing [1, 2]. Given the need to look at molecular species, spectroscopic techniques that observe the vibrational and electronic transitions in molecules were used, especially spatially resolved infrared and Raman spectroscopies.

Although these methods have often been used in failure investigations, there has been little work on examining whole cables, and correlating this with cable properties and behavior. Using a comprehensive cable set, the analysis method looked for correlations with the physical properties measured during the program. In many cases these materials were also studied as thermally conditioned materials having the volatile products removed.

The bulk polymer starts as low-density polyethylene (LDPE), containing dicumyl peroxide DCP [CAS 80-43-3] and Santanox type "R" antioxidant [CAS 96-69-5]. The semiconductor is an ethylene-butyl acrylate copolymer, containing 1,2-Dihydro-2,2,4-trimethylquinoline [CAS 147-47-7], Di (2-tert-butylperoxypropyl-(2))-benzene [CAS 2212-81-9] and carbon black.

The cable sheathing material Ethylene Vinyl Acetate [CAS 24937-78-8] was examined to determine the feasibility of determining the flame retardant concentration of both Gibbsite (aluminium trihydrate) and Boehmite (aluminium oxide hydroxide) with simultaneous prediction of limiting oxygen index (LOI).

SAMPLES

Sixteen cables were examined - conditioning ranged up to 15,000 hours of ageing, temperatures at 20 C or 90 C, and 0, 145, 225 and 325 kV voltages. Samples removed from service with lifetimes to 18 years were also examined.

For infrared spectral analysis, samples were examined as peels, corresponding to radial intervals of about 0.15 mm all the way from the inner conductor to the outer semi-conducting layer, using a Perkin-Elmer System 2000 FT-IR spectrometer over the spectral range 4,000 to 400 cm⁻¹. The base polymer was also examined.

Cable sheathing was examined using both wide-wavelength (350 to 2500 nm) and Raman transpec methods.

The DCP cross-linking agent has two primary degradation products, shown in Fig. 1.

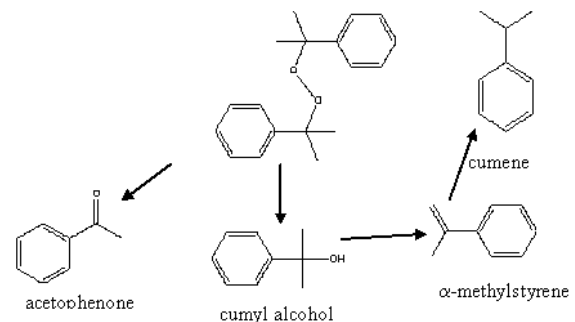


Fig. 1: Thermal decomposition of dicumyl peroxide

Typical results, illustrating the differences between the base polymer, two points on an unused standard, and a thermally-conditioned standard are shown in Fig. 2, and compared with acetophenone and cumyl alcohol.

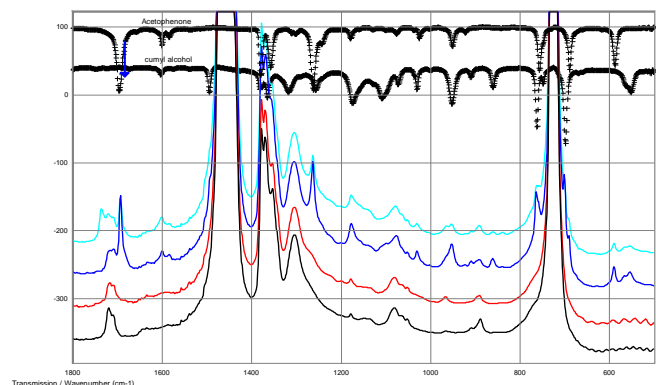


Fig. 2: From bottom, comparison of base polymer, thermally-conditioned unaged reference, unaged reference middle and unaged reference inner, with acetophenone and cumyl alcohol spectra shown in transmission at the top.