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Thermal condition monitoring methods applied to degraded cable insulations and jackets

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Selection of condition monitoring (CM) method is an important aspect of cable ageing management for Nuclear Power Plants (NPP). The current status of cables might be inter alia assess by various thermal methods based either on Differential Scanning Calorimetry (DSC) or on Thermogravimetric (TG) analysis. The techniques might be used to determine the extent of cable damage caused either by degrading stressors occurring in a hot spot of NPP or by accelerated thermal and/or radiation aging performed in the laboratory. Using DSC apparatus Oxidation Induction Time (OIT) and Oxidation Induction Temperature (OITp) measurements might be carried out and the data obtained dependents on the remaining upon degradation content of antioxidants and the extent of oxidation. On the other hand, TG dynamic tests which theoretically might follow the changes in chemical structure of polymeric matrix are usually insufficiently sensitive to monitor progress of cable aging. Thus, finding other opportunities for such applications is currently a challenge.
Our TG studies confirmed that for the cable insulations/jackets made of some polymers (EPR, EVA) tests conducted via an isothermal mode seem to be promising manner allowing for the diagnosis of gradual radiation aging. Variations in the TG thermograms for polymers degraded to different extents are substantial only if the experiments are performed in the aerobic atmosphere, whereas under nitrogen the changes are insignificant and can not be used for the evaluation of cable aging. During the first stage of tests the specimens were fast heated to 400 oC, i.e. to the temperature throughout which the thermal decay of hydrocarbon macromolecules starts. In the second step the samples were kept at 400 oC until the thermal decomposition of polymer. Functions of mass loss versus time for specimens irradiated to various doses were analyzed and compared. Surprisingly, the data confirmed that the more degraded insulations the higher thermal stability of the polymeric matrix measured as the time required to achieve assumed mass loss. The thermo-oxidation effects detected by the isothermal TG analysis are the consequences of chemical and physical changes occurring during radiation aging in the aerobic environment, such as oxidative degradation, formation of double bonds in the main chains improving thermal resistance, saturation of oxygen sensitive sites, barrier effects caused by flame retardant transformations, etc. It was also found that initial crosslinking of the polymers influences their thermo-oxidative stability. The effect was attributed to the raise of the rate of oxidation due to chain branching and increasing population of the labile bonds between third order carbon and hydrogen atoms.
The method may not be considered as a condition indicator or an acceptance criterion but can provide information about the state of cable. Contrary to OIT and OITp measurements, the isothermal characteristic is not associated with the antioxidant content but rather with the extent of polymeric matrix degradation. The time necessary for achieving the selected ratio of mass loss might be confronted with other data characterizing progress of insulation/jacket aging, e.g. elongation at break, degree of swelling or density.

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