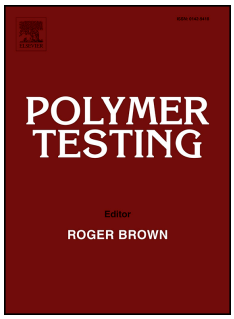

Comparative study on different methods for determination of activation energies of nuclear cable materials

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PII: S0142-9418(18)30453-7

DOI: 10.1016/j.polymertesting.2018.06.029

Reference: POTE 5526

To appear in: *Polymer Testing*

Received Date: 20 March 2018

Revised Date: 10 June 2018

Accepted Date: 24 June 2018

Please cite this article as: Y. Gong, J. Tang, B.-N. Sun, Z.-G. Yang, X.-Q. Shi, X.-Q. Liu, Y.-C. Xie, X.-L. Xu, Comparative study on different methods for determination of activation energies of nuclear cable materials, *Polymer Testing* (2018), doi: 10.1016/j.polymertesting.2018.06.029.

Comparative study on different methods for determination of activation energies of nuclear cable materials

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Abstract: During the design stage of a nuclear power plant, the qualification testing is obliged to be conducted on the electrical equipment like cables to ensure the reliability and to predict the service lifetime of them under the operational conditions. Thereinto, thermal and oxidative degradation of the cable insulations and sheaths that are made of polymeric materials is the priority concern, and the renowned Arrhenius model is always referred to, which consequently calls for determination of the imperative kinetic constant - the activation energy. Actually, diverse methods for activation energies have been established by the scientists and applied by the engineers, but consensuses still have not been reached for such a method that is both convenient and conservative, and for such value ranges that are both reasonable and representative. Hence, in this paper, totally five different testing and data processing methods including thermal ageing test, differential scanning calorimetry and thermogravimetry analysis were utilized to determine the activation energies of three domestic polymeric materials that are intended for nuclear cables of the advanced pressurized water reactors in China. The results were then collected and the reasons for the differences among them were discussed, based on which the advantages and disadvantages of these methods were compared, and finally a compromising approach was proposed.

Key words: activation energy; Arrhenius model; thermal ageing; differential scanning calorimetry; thermogravimetry analysis; nuclear cables.

1. Introduction

The compromise between increasing energy demand and pressing environmental challenge has seen the gradual renaissance of nuclear power since the beginning of this century [1], especially in China who now owns the largest quantity of nuclear power plants under construction in the world. Certainly, on account of the Fukushima Daiichi nuclear disaster, higher requirement of safety has been put forward, which essentially relies on the reliability of the structures, systems and components (SSCs) and is generally guaranteed by equipment qualification [2], ageing management [3] and failure analysis [4-11]. Nuclear cables, whose total length is about 1000 kilometers per reactor [12], is one of the principal categories of polymers used in nuclear power plants besides pipes, coatings, sealants, gaskets etc., and its reliability is always credited by qualification testing during design and by condition monitoring during operation against the degradation factors including thermal oxidation, gamma and beta irradiation, moisture, stresses, chemicals and so on.

Among them, thermal oxidation - the synergism from both heat/temperature and oxygen/air is the priority concern [13, 14], and the accelerated ageing testing is usually implemented to assess its ageing effect on and to predict the service lifetime of the nuclear cables under the actual operational conditions. Thereinto, the concept of the renowned Arrhenius model is always referred to, and the tests grounded on conventional high-temperature ageing in ovens, and on convenient thermal analysis like differential scanning calorimetry (DSC) and thermogravimetry analysis (TGA) are usually utilized to obtain the indispensable parameter of it - the activation energy (E_a) [15-17]. Certainly, it should be noted that, from the thermal ageing point of view, the activation energy in this case just reflects the difficulty of the thermal-oxidative degradation to occur on nuclear cables, rather than its original meaning as the minimum energy required to initiate a chemical reaction, thereby it is also called the apparent activation energy.

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