Evaluation of Empirical Methodology used in SNL for The Calculation of Activation Energy

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1. Introduction

To pre-age the cables before simulating an accident exposure and to make long-term predictions about aging of their insulation and jacket materials exposed to the temperature and radiation environments of nuclear power plants, experiments must be conducted under accelerated thermal and radiation conditions. The elevated temperatures typically are chosen based on the arrhenius method. Historic arrhenius approach have been used to calculate the activation energy even it has a problem of using processed data point. Empirical methodology for the calculation of activation is suggested by Sandia National Laboratory. We have tried to find any problem in application of the empirical methodology. Problems we met during the test are described herein, and representative results are presented.

2. Methods and Results

In this section comparison of activation energy for historic arrhehius methodology and improved methodology are described. Break-elongation test data for neoprene cable jacket are used for the calculation of activation energy.

2.1 Arrhenuis Model

Arrhenius equation is generally used as a physical model for making predictions on the lifetime in accelerated thermal aging. Heating for accelerated aging has to follow the monitoring result of plant environment to prove that accelerated aging equals natural aging. It is assumed that the rate of the thermal aging decrease in an inverse manner to the temperature, such that the rate constant "k" can be described as follows.

$$(\ln k = \ln A - Ea/RT)$$

where "A" is a constant for the material being tested, "Ea" is the activation energy for the process, "R" is the gas constant, "k" is the boltzman constant and "T(°K)" is the absolute temperature. A graph of the reaction rate on a log scale against "1/T" should show a straight line whose slope is determined by the activation energy "Ea". Activation energy controls the sensitivity of the degradation rate.[1]

2.2 Break-elongation test result

Accelerated aging at the temperature of 90℃, 100℃, 110℃ is performed during the time of 234 ~ 1490hour. We can see a decline in the elongation rate in Figure 1. Elongation rate reached a limit value of 50% at the 1,273 hour in 90℃, 485hour in 100℃, 278 hour in 110℃[2]

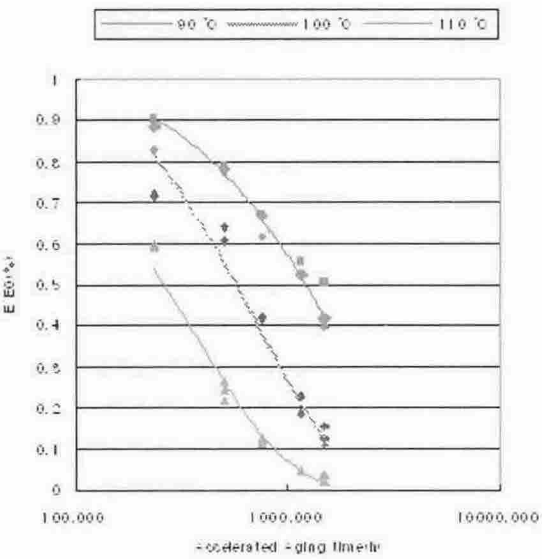

Figure 1. Break -elongation test result

2.3 Activation Energy by the Historic method

Activation energy was calculated by using the historic method as shown in Figure 2. We had a linear curve of straight rate 99%. Activation Energy is calculated as 0.912ev, which is very similar to data in the material library.[3]

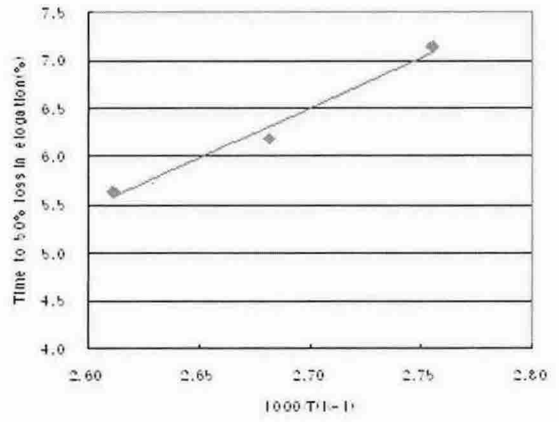

Figure 2. Activation energy curve by using historic method

2.4 Calculation of Activation Energy by Empirical method

In the empirical method for calculation of activation energy, it does not use the 50% failure point. Instead of failure point, we chose a reference T and find empirical α_t that gives optimum superposition at each T. Example of arrhenius equation for empirical α_t s is described below.[4]

$$a_T = \exp \frac{E_a}{R}\left[\frac{1}{T_{ref}} - \frac{1}{T}\right]$$

Data after superposition is shown in Figure3. Reference T is 90℃. Empirical α_t are 1 at 90 ℃, 2.02 for 100℃ and 4.45 for 110 ℃.

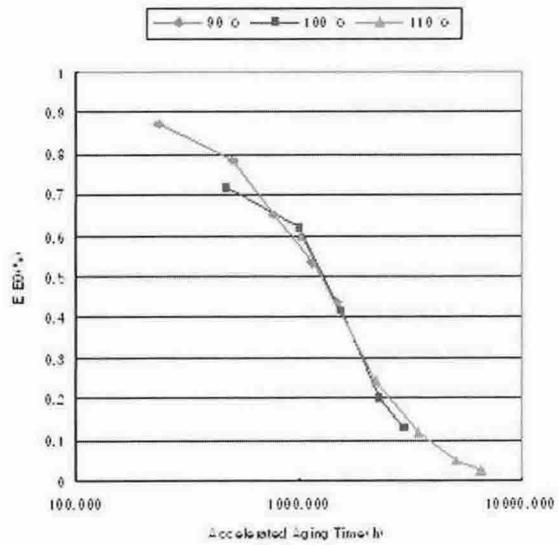

Figure 3. Break-elongation data after superposition

Based on the Empirical α_t and heating temperature in Figure 3, activation energy is calculated as 2.05ev which is inconsistent with historic method. Slope in Figure 4 almost double the slope of Figure2.

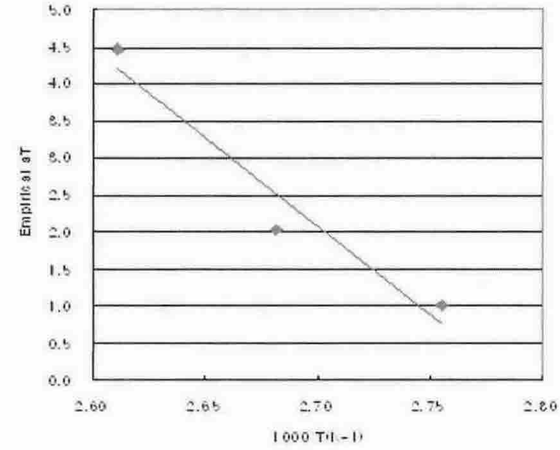

Figure 4. Activation energy curve by empirical method