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A Study on Analytical Evaluation of Environmental Qualification Class 1E Cable for Yonggwang Unit 1&2

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1. Introduction

The equipment and cables used for nuclear power plants shall be maintained following the guidance of USNRC Regulatory Guide 1.89 [1]. In particular, strict management is required for the maintenance of cables. For the replacement of previously installed cables without qualification documentations, thorough review is required considering cost and the intent of environmental qualification (EQ). In this study, we are to acquire the specimens of EQ cables for Yonggwang Unit 1&2, analyze them to identify their similarity, and make use of them as the reference material substituting qualification documentation.

2. Methods and Results

Polymer materials of EQ cables for Yonggwang Unit 1&2 were analyzed using FT-IR (Fourier Transform Infrared Spectroscopy), TGA (Thermo-Gravimetric Analysis), and DSC (Differential Scanning Calorimetry) to qualify the similarity with the cables having qualification documentations. Four types of cables were analyzed as shown in Table 1. The similarity of materials was analyzed through FT-IR and the activation energies of the cables were analyzed through TGA and DSC equipment to compare them with the cables having qualification documentations.

Table 1. List of Four Types of Cables whose samples were Collected and Analyzed

No.	System	Code	Cable No.
1	BB	EP61	A7EBBHBCAXP(Insu.)
			A7EBBHBCAXP(Jack.)
2	GN	IE6	N7EGNHBC1XM(Insu.)
			N7EGNHBC1XM(Jack.)
3	BB	L151	A7ESEHAC1XE(Insu.)
			A7ESEHAC1XE(Jack.)
4	BM	C935	N7EBMHAC5SD(Insu.)
			N7EBMHAC5SD(Jack.)

2.1 Arrhenius equation

Arrhenius equation is a common equation which can get activation energy from rate constant and temperature.

$$k = A\exp(-\frac{E_a}{RT})$$

Which is k: rate constant, A: pre-exponential factor, E_a: Activation energy, R: gas constant, T: temperature we can convert rate constant as the time[2]. That is

$$\ln\frac{t}{t_o} = \frac{E_a}{R}(\frac{1}{T} - \frac{1}{T_0})$$

2.2 FT-IR Analysis

For FT-IR, Travel IR tester manufactured by Smiths was used to identify the composition of cables through material analysis of cable insulation and jacket. The spectrum for the insulation and jacket of representative cable, EP61, is shown as Figure 1, 2.

After comparing them with the cables having qualification documentation, it was concluded having the similarity of 98%

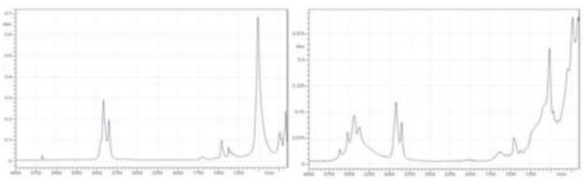

Figure 1. EP61 – Insulation & Jacket Spectrum

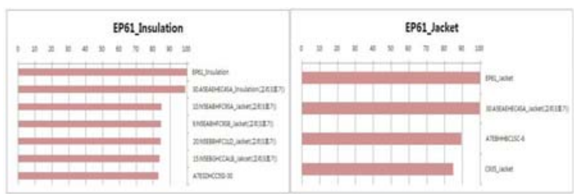

Figure 2. EP61 – Result of Similarity Analysis for Insulation & Jacket

It is to analyze polymer materials of cables using FT-IR, TGA, and DSC equipment to qualify the similarity with cables having qualification documentation through analytical method described in IEEE 323-1974[3].

2.3 TGA Analysis

For TGA analysis, Q-5000 tester manufactured by TA was used to derive the activation energy of cables. The test method was based on the requirements of ASTM E1641 (07) and ASTM E 1131 (08) Code.

Activation energy is measured with heating rate β and temperature T when it is reached on weight loss 5% of thermal degradation curve as shown in Figure 3 using Ozawa method which is integral method [4] for measuring activation energy of TGA [5].

$$Ea \approx -4.35 \frac{d \log \beta}{dT^{-1}} \quad (1)$$

E_a: activation energy [eV], β: Heating rate [^{o}C/min], T: temperature [K]

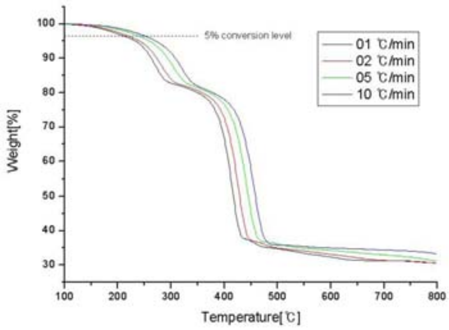

Figure 3. Thermal degradation curve of EP61

2.4 DSC Analysis

For DSC analysis, Diamond DSC tester manufactured by PE was used to derive activation energy of cables. The test method including the derivation of OIT (Oxidation Induction Time) was based on the requirements of ASTM E 2070 [6].

Through isothermal method, as one of the method for the derivation of activation energy, the relationship between time and isothermal temperature can be achieved when exothermic reaction is occurred where the temperature of sample of specific material is maintained at isothermal temperature and its result is derived as Table 2. Plotting *ln* (Δt) and 1000/*T* with this result can result in the calculation of activation energy.

$$K(T) = Ze^{-\frac{E}{RT}} \quad (2)$$

Z: eigen constant of material, E: activation energy [eV], R: gas constant

Table 2. OIT according to isothermal temperature of EP61

T(^{o}C)	OIT(t,min)	T(K)	1000/*T*	*ln* (Δt)
190	166.753	461.3	2.168	5.122
195	107.722	466.3	2.145	4.680
200	67.546	471.3	2.122	4.213
205	42.756	476.3	2.100	3.756
210	28.978	481.3	2.078	3.367

2.4 Result

Examining the activation energies derived, it is possible to have different values based on the thermal characteristics according to cable materials and field condition of plants. The mean values measured were described in Table 3.

Table 3. Cable code & Material Result

Cable code & Material		Activation energy	
		TGA	DSC
EP61	Insulation	1.23 eV	1.70 eV
	Jacket	1.32 eV	0.93 eV
IE6	Insulation	1.36 eV	1.82 eV
	Jacket	1.08 eV	1.18 eV
L151	Insulation	1.39 eV	1.38 eV
	Jacket	1.18 eV	1.15 eV
C935	Insulation	1.91 eV	1.30 eV
	Jacket	1.34 eV	1.26 eV

3. Conclusion

For four cables of Yonggwang Unit 1&2 without qualification documentation, FR-IR, TGA, and DSC analysis were performed and their results were compared with the data in EQDB to derive the findings as below.

1. The criteria for the similarity is assumed to be 98% for FT-IR analysis of cable insulation and jacket.
2. Comparing the result of the cables collected from Yonggwang Unit 1&2 with EQDB (EQ Data base), jacket showed conformance while insulation showed slight nonconformance.
3. Comparing the activation energy values measured from TGA and DSC analysis with those of EQDB, their values fell within the range of ± 3%, which shows the similarity with the cables having qualification documentations.

REFERENCES

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