LOCA Test of Class 1E Cables Using Modified LOCA Profile

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1. Introduction

A LOCA (Loss of Coolant Accident) test has been performed for EQ(Equipment Qualification) for class 1E cable of nuclear facilities[1]. We have constructed the test facilities which can simulate large LOCA conditions (temperature, pressure, chemical spray) of domestic nuclear power plants. Class 1E Cables are consisted of various polymer, we choose CSP (ChloroSulfonated Polyethylene rubber) and CR (Chloroprene Rubber) placed at the part of cable sheath as specimen. UTM (Universal Testing Machine) and TGA (Thermo-Gravimetric Analyzer) have been used for analyzing specimens before and after the test to investigate elongation and activation energy, respectively.

2. Experiment

It is difficult to do qualification test because LOCA test of DBE (Design Basis Event) takes long time, usually 6 months. Though testing time may not be changed due to radioactive irradiation, it is possible to shorten the testing time, considering activation energy of specimens which are tested in LOCA without radiation and similar environmental conditions of aging test.

We could define hardening of CR and CSP after the test through the strain and stress graph obtained from tensile test of UTM analyzer[2,3] and could get activation energy of specimen before and after the test from TGA[4].

2.1 Test Conditions

LOCA profiles for temperature and pressure are shown in Figure 1 which is applied to Young-gwang 3& 4 Nuclear Power Plant. Overall testing time is 182 day, but it can be shortened by concept of thermal aging considering the environmental condition and material of cables. Arrhenius Equation (1) gives such quantitative information for shortened period of LOCA test when knowing activation energy.

$$t_1 = t_2 e^{[(E_a/k)(1/T_1 - 1/T_2)]} \qquad (1)$$

k: Boltzman constant [0.8617×10^{-3}, eV/K], E_a: activation energy [eV], t: time [sec], T: temperature [K]

Activation energy was acquired from UTM analysis beforehand and we confirmed that it almost corresponds to Wyle Lab. database as shown in Table 1. The modified LOCA profiles for temperature and pressure are considered margin with IEEE-323 [2] and are shown in Figure 1. Temperature and pressure of tail range on the modified profile were increased so that overall testing time is shortened. These profiles may not be applied to all the nuclear equipment. In case of valves and pumps, for example, testing time may not be shortened through this method considering an assigned basic role and function under specific environmental conditions.

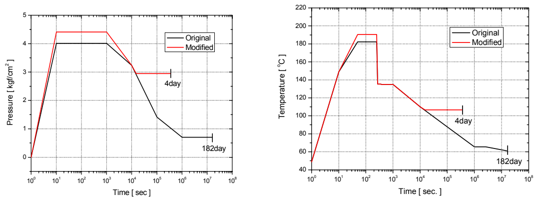

Figure 1. LOCA profile for pressure and temperature

Testing cables are rolled around the mandrel which is placed at the center of the test chamber (diameter 80 cm × length 200 cm). Temperature and pressure in the chamber are controlled according to the modified LOCA profile by Auto-Control System, and chemicals consisted of boron 3,000 ppm and sodium hydroxide 0.28 molar are sprayed out over specimen.

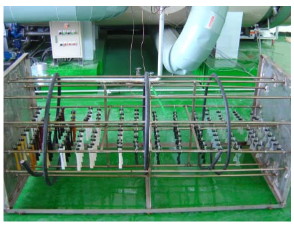

Figure 2. Specimen setup around mandrel

2.2 Analysis

UTM is used to investigate degradation for hardening of cables and TGA to acquire activation energy of material. Activation energy is calculated with heating rate β and temperature T using Ozawa method (2) which is integral method [6] for measuring activation energy of TGA [7] when weight loss of 5% is reached on thermal degradation curve as shown in Figure 3

$$E_a \approx -4.35 \frac{d \log \beta}{dT^{-1}} \qquad (2)$$

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

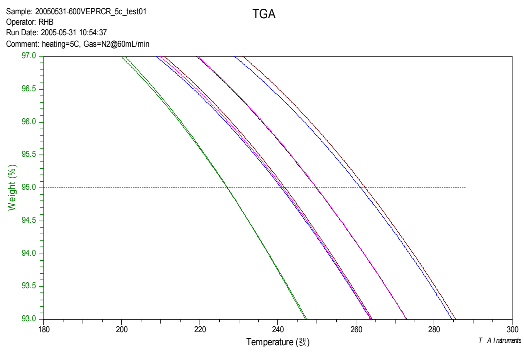

Figure 3. Thermal degradation curve of CR

3. Results

Cables after the test are deteriorated judging from the fact of reduced strain at breaking point as shown in Figure 4. The strains are decreased to about 40% for CR and 20% for CSP, respectively. This result could be easily expected considering conditions of high temperature and pressure in LOCA environment.

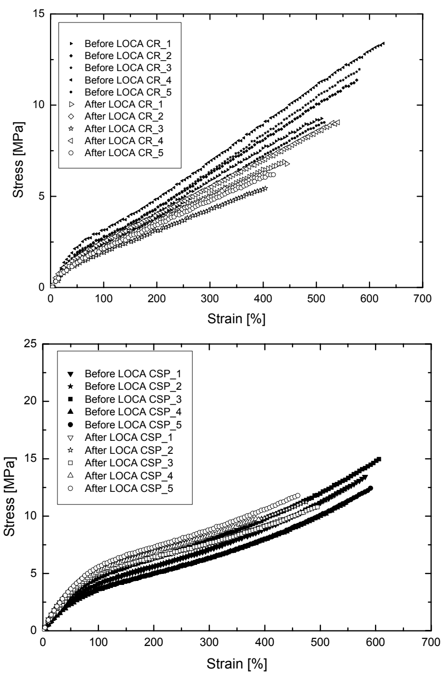

Figure 4. Stress and strain curve CR(Top) and CSP(Bottom)

Activation energy obtained from TGA is also decreased after the test as shown in Table 1, indicating shortened life of the cables. Activation energy of cables obtained from this experiment is indispensable to expect the life of cables.

	Before		After
	KIMM	Wyle Lab.	
CR [eV]	0.77	0.65	0.135
CSP [eV]	1.184	1.07	1.10

Table 1. Activation energy of CR and CSP before and after LOCA test

4. Conclusion

LOCA test of cables was successfully performed with LOCA test facilities in KIMM. This research implies many possibilities that LOCA test of EQ can be applied to other equipment related to primary facilities of nuclear power plant as well as cables. Furthermore, MSLB(Main Steam Line Break) and HELB(High Energy Line Break) as well as LOCA are possible if test conditions are modified to all DBE. Therefore, we expect that LOCA facilities in KIMM will play an active role in EQ of domestic nuclear facilities.

Acknowledgement

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