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Study for Relation of Pressure and Aging Degradation during LOCA Test

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1. Introduction

For environmental qualification of electric equipment in containment building of nuclear power plant, LOCA test should be applied. During the LOCA test, temperature and pressure of LOCA chamber shall be controlled to meet a requirement of plant specific LOCA profile.

It is general to keep LOCA test temperature and pressure above the plant specific LOCA profile. If the test temperature is lower than required profile in some time zone while it is higher in other time zone, calculation of total cumulated test temperature is required to compare with that of plant profile. Arrhenius equation can be applied for calculation of total temperature accumulation.

If there is a deviation of pressure between test profile and plant specific profile, can we still use the same rule of temperature? Since the Arrhenius equation can't be applied to pressure, analysis of pressure effect to aging degradation is not easy.

Study for relation of pressure and aging degradation during LOCA condition is described herein.

2. Methods and Results

2.1 Relation between pressure and aging degradation

2.1.1 Effect of oxygen partial pressure during LOCA

Partial pressure is a pressure of each gas when several gases are combined in air. Partial pressure of oxygen in the air can be assumed as 159.1mmHg when composition rate of oxygen in the air is 20.93%.

Pressure in the LOCA chamber is mostly affected by pressure of steam supply. Since air is not introduced into LOCA test, the air existed before LOCA test will be remained during LOCA test. It can be described that quantity of oxygen in the LOCA chamber is constant during LOCA test. Accordingly, partial pressure of oxygen is equal even the chamber pressure change according to the steam supply and condensation.

2.1.2 Literature search for pressure effect during LOCA

According to NUGEQ report 6.2.1, it was concluded that degradation mechanisms from pressure related or moisture related was not significant during the post-transient period[1].

According to EPRI TR-1021067, it is described that oxygen during accident simulations is not a risk significant qualification issue[2].

2.2 Theory between pressure and aging degradation

If material A and B have chemical reaction, equation (1) can be formulated. According to equation (1), it can be described that reactivity speed increase when concentration increase because high particle concentration induce high opportunity of particle collision.

$$v = k(T)\cdot\alpha^m\cdot\beta^n \tag{1}$$

v is reactivity speed where k(T)is constant of reactivity speed, α & β are concentration of material A & B and m & n are reactivity degree.

Reactivity speed constant *k(T)* can be described as equation (2) by applying Arrhenius equation.

$$k(T) = Z\exp\left(-\frac{E_a}{KT}\right) \tag{2}$$

K(T) is reactivity speed where Z is material constant, E_a *is activation energy, K is Boltzmann constant and T is absolute temperature.*

Since primary reaction of cable aging is oxidation and temperature, new equation can be induced by combining equation (1) and (2). By replacing the parameter of oxygen concentration to pressure, equation (3) can be induced as functional equation of temperature and pressure.

$$v = D\exp\left(-\frac{E_a}{KT(t)}\right)\cdot P(t) \tag{3}$$

v is reactivity speed where D is constant, p(t) & T(t) are time related function of pressure and temperature.

By integrating equation (3), reaction amount R can be induced from equation (4)

$$R = D\int \exp\left(-\frac{E_a}{KT(t)}\right)\cdot P(t)dt \qquad (4)$$

2.3 Evaluation of pressure effect during LOCA test

To evaluate LOCA pressure effect of cable aging degradation, LOCA tests were performed for 3 unaged CSPE/EPR cables. One test was performed according to general LOCA profile which has proportional temperature and pressure. Temperature and pressure followed the curve of saturation steam. The other test was performed according to unordinary LOCA profile which has relatively low pressure while the temperature is similar to that of general LOCA profile. Table 1 shows test condition of LOCA profiles. Fig. 1 and Fig.2 show test result of general and unordinary LOCA. Tests were implemented during 24 hours.

To compare aging degradation of cable between general LOCA profile and low pressure LOCA profile, IRs were measured every 2 hrs interval as shown on Fig. 3. It was found that IR of low pressure significantly decreased compare with that of high pressure.

Table 1. Test condition of LOCA profile

LOCA Test Time	Test Condition			
	Temp. (℃)	High Pr. (kPa)	Low Pr. (kPa)	Chemical Spray
1	57.5	0	0	
10	148.9	455	455	
50	190.6	455	455	
250	190.6	455	455	Spray Start
270	143.7	455	50	
86,400	143.7	455	50	Spray end

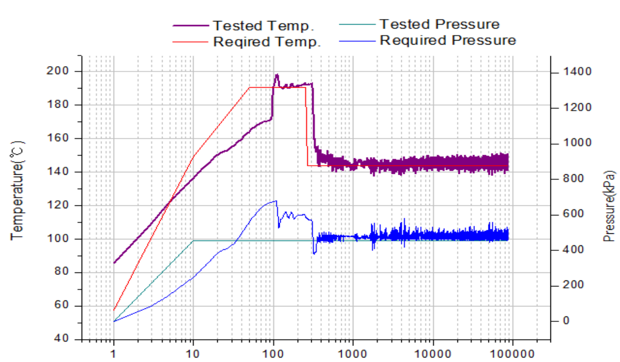

Fig. 1 General LOCA profile

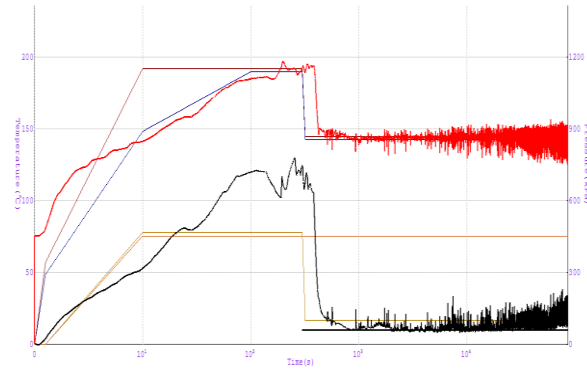

Fig. 2 Unordinary LOCA profile

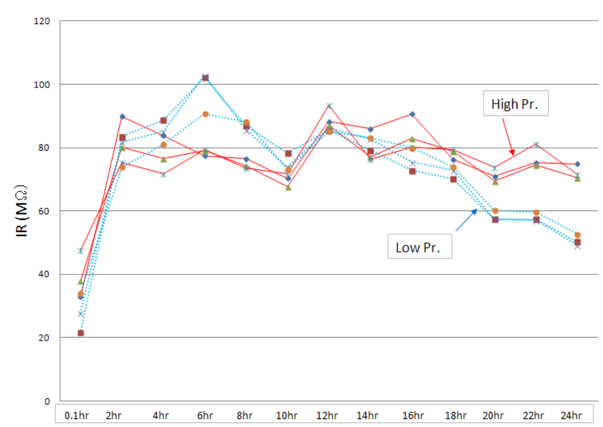

Fig. 3 Insulation resistances of cable during LOCA test

3. Conclusions

To Study an aging degradation effect of pressure during LOCA test, comparison of IR during high LOCA pressure and low LOCA pressure were implemented.

We expected low IR in high pressure because it contained a high concentration of oxygen which induces high aging degradation. Contrary to our expectation, IR of low pressure was lower than that of high pressure.

It is assumed that high vibration of temperature profile to maintain the low pressure at high temperature induced supply of high enthalpy steam into LOCA chamber.

As result of this test, it was found that low pressure effect in aging was not significant compared with that of temperature. If temperature profile in LOCA test can satisfy the plant LOCA profile, no further analysis of pressure profile for aging degradation is necessary.

REFERENCES

[1] NUGEQ, ‘Acceptability of arrhenius methodology to analyze LOCA and post-LOCA environment’, 1998

[2] EPRI, EPRI TR-1021067, ‘Nuclear power plant equipment qualification reference manual Rev.1’, 2010