Reliability Verification of DBE Environment Simulation Test Facility by using Statistics Method

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1. Introduction

In the nuclear power plant, all the safety-related equipment including cables under the harsh environment should perform the equipment qualification (EQ) according to the IEEE std 323 [1]. There are three types of qualification methods including type testing, operating experience and analysis. In order to environmentally qualify the safety-related equipment using type testing method, not analysis or operation experience method, the representative sample of equipment, including interfaces, should be subjected to a series of tests. Among these tests, Design Basis Events (DBE) environment simulating test is the most important test. DBE simulation test is performed in DBE simulation test chamber according to the postulated DBE conditions including specified high-energy line break (HELB), loss of coolant accident (LOCA), main steam line break (MSLB) and etc, after thermal and radiation aging [2]. Because most DBE conditions have 100% humidity condition, in order to trace temperature and pressure of DBE condition, high temperature steam should be used. During DBE simulation test, if high temperature steam under high pressure inject to the DBE test chamber, the temperature and pressure in test chamber rapidly increase over the target temperature. Therefore, the temperature and pressure in test chamber continue fluctuating during the DBE simulation test to meet target temperature and pressure. We should ensure fairness and accuracy of test result by confirming the performance of DBE environment simulation test facility. In this paper, in order to verify reliability of DBE environment simulation test facility, statistics method is used.

2. Methods and Results

2.1 DBE Environment Simulation Test Facility

KEPCO Research Institute has DBE simulation test facility for cables and small equipment. The facility is consisted in DBE test chamber, boiler that provide saturated steam, accumulator that provide saturated water, super heater that provide superheated steam, chemical tank that contain chemical water, air tank that compensate pressure and controller that control many valves and equipments. At the start of DBE environment simulation test, the steam generated in boiler and super heater and saturated water generated in accumulator are injected to the DBE chamber to raise the temperature and pressure exponentially. In order to trace temperature and pressure profile, the controller which is composed of PLC (Programmable Logic Controller) and parameter monitoring PC controls steam injection valves and pressure control valves automatically.

Fig. 1. DBE simulation test facility

2.2 Method for Reliability Verification of DBE Environment Simulation Test

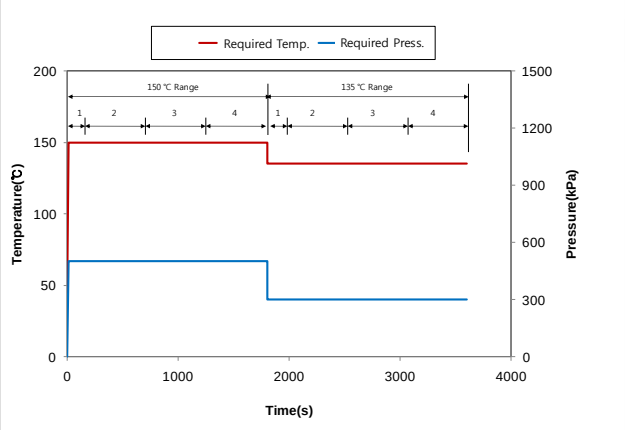
In order to confirm the performance of DBE environment simulation test facility, some test was performed. For the test, power cable test specimen was installed in DBE test chamber. The saturated water of accumulator was used to increase temperature and pressure rapidly at start of test and saturated steam of boiler was used to trace temperature profile. Air tank was used to trace pressure profile. During the test, temperature and pressure data was acquired in every 0.2 ms continuously from DAQ equipment. Tested temperature and pressure profile is shown in Table I.

Table I: Tested temperature and pressure profile

Time(s)	Temperature(℃)	Pressure(kPa)
0	45	0
10	150	500
1800	150	500
1800	135	300
3600	135	300

In order to analyze the acquired data statistically, over 3 times DBE environment simulation test is needed.

We focused on isothermal and isopressure ranges after 60 seconds at the start of each range, because temperature and pressure control from rapid target value variation would be stable after about 60 seconds. At the isothermal range, we divided into 3 ranges (2, 3, 4 in Fig. 3) again as shown in Fig 3. There are 2 isothermal ranges which are 150 ℃ and 135 ℃ in case of temperature, and there are 3 ranges at each isothermal range. So there are 6 ranges at isothermal and isopressure range. We would perform analysis of variance about temperature and pressure of each range.



2.3 Test Results

We performed 5 times DBE environment simulation test continuously according to the profile of temperature and pressure shown in Fig. 2. The mean values of acquired result data from DBE environment simulation test at each range are shown in Table II.

Table II: The mean values of acquired result data

Repeated No.	Range	Mean of Temp.(℃)		Mean of Press.(℃)	
		150 ℃ range	135 ℃ range	500 kPa range	300 kPa range
1	2	151.489	136.134	501.664	306.595
	3	150.909	135.817	502.106	305.439
	4	150.761	135.762	501.071	306.234
2	2	151.075	135.881	500.774	304.607
	3	151.089	136.016	500.682	305.407
	4	151.044	135.905	502.133	305.195
3	2	150.868	135.902	498.376	306.394
	3	150.929	135.996	502.072	303.368
	4	150.847	135.862	500.813	303.283
4	2	151.047	136.137	500.001	304.12
	3	151.072	136.099	501.182	305.015
	4	151.021	136.033	498.497	304.501
5	2	151.036	136.048	501.295	305.351
	3	151.098	136.142	499.378	302.439
	4	151.17	135.998	502.639	304.923

Analysis of variance about acquired temperature and pressure data was performed at each range. For the analysis of variance, Minitab program was used. Null hypothesis is that the mean values of each range are all same. Otherwise, alternative hypothesis is that the mean values of each range are not same. The result of analysis of variance is shown in Table III. If p-value which is significance level is over 0.05, null hypothesis is correct.

Table III: The result of analysis of variance

	Mean of Temp.(℃)		Mean of Press.(℃)	
	150 ℃ range	135 ℃ range	500 kPa range	300 kPa range
P-value	0.480	0.308	0.701	0.397

At all ranges, p-value is over 0.05, in other words, the mean values of each range are all same. It means that the DBE environment simulation test facility maintains a constant temperature and pressure at the isothermal and isopressure ranges.

3. Conclusions

In order to verify reliability of DBE environment simulation test facility, we performed repetitive test according to the certain temperature and pressure profile. We focused on isothermal and isopressure range. Isothermal and isopressure ranges are divided into 3 ranges again. In each range, the mean values of temperature and pressure were obtained. As a result of analysis of variation from obtained mean values, it was found that the DBE environment simulation test facility maintains a constant temperature and pressure at the isothermal and isopressure ranges. There is no standard for DBE environment simulation test facility yet. The proposed reliability verification method will make the result of DBE environment simulation test to be more accurate and trustable.

REFERENCES

[1] IEEE std 323-2003, IEEE Standard for Qualifying Class 1E Equipment for Nuclear Power Generating Stations, IEEE Power Engineering Society , 2003.
[2] ERPI, Nuclear Power Plant Equipment Qualification Reference Manual, 1992.