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Study for Improvement of Temperature and Pressure Traceability to the DBE Profile during the DBE Simulation Test

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1. Introduction

All the safety-related equipment including cables under the harsh environment should perform the equipment qualification (EQ) according to the IEEE std 323 [1]. In order to qualify the safety-related equipment using testing method, not analysis or operation experience method, the type testing included in many sequences should be performed. Among these sequences s of type testing, Design Basis Events (DBE) simulating test is the most important sequence. 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. 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. In this paper, in order to improve temperature and pressure traceability and lower the variance of temperature and pressure in isothermal and isopressure range during DBE simulation test, the six-sigma method is used.

2. Method and Result

2.1 DBE Simulation Test Facility

KEPCO Research Institute has DBE simulation test facility for cables and small equipment. The facility is consisted in 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. In the majority of cases, when starting DBE simulation test, much flux of steam is needed due to exponential increase of temperature and pressure. Pipe line for injected steam to the test chamber has 1 inch diameter and the flux of steam is controlled by air operated valve. Figure 1 shows the DBE simulation test facility.

Fig. 1. DBE simulation test facility

2.2 Measurement of Current Condition

To measure the current condition of DBE simulation test facility, simulated test that contain several isothermal and isopressure steps was performed for 4 hours. Temperature and pressure in test chamber was collected per 0.2 second by the data acquisition equipment. The result of normality test showed that the acquired data was not normal distribution and had no appropriate distribution (p-value < 0.5). The acquired data was assumed that had normality and then performed process capability analysis. Z-value of temperature and pressure variance was 1.76 and 1.67, respectively, as shown in Fig 2.

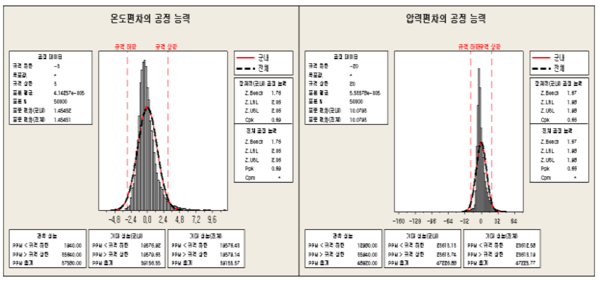

Fig. 2. Result of Process Capability Analysis

2.3 Analysis for the Problem

To improve the temperature and pressure traceability, problem of fluctuation should be found. We performed brainstorming among testers and manufacturers, and then extracted several vital fews that were flux of steam, state of steam and control algorithm.

First, in order to analyze influence of flux of steam, control valve opening instance of inlet pipe to test chamber compared with temperature and pressure of test chamber. As shown in Fig 3, when the control valve opened, the temperature and pressure of test chamber increased rapidly. Due to large size of the inlet steam pipe, the variance of temperature and pressure increased. Alternatively, when the temperature and pressure of test chamber was higher than target temperature, the temperature and pressure of test chamber decreased slowly.

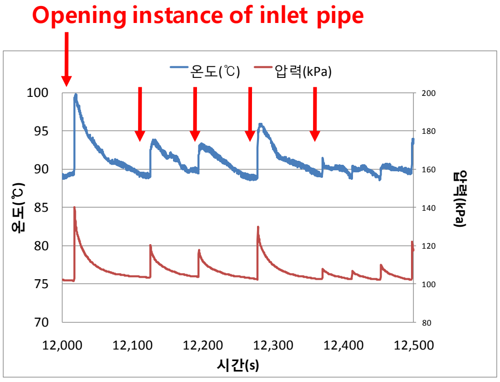

Fig. 3. Temperature and pressure according to the opening instance of inlet pipe

In order to analyze influence of state of steam, we performed simulated DBE test according to the pressure of inlet steam. We found that the variance of temperature and pressure of test chamber was changed, according to the pressure of inlet steam.

2.4 Improvement of Temperature /Pressure Traceability

When starting DBE simulation test, rapid increase of temperature and pressure is needed. So, large size inlet pipe is necessary during DBE simulation test. In order to improve the first vital few, flux of inlet steam, we installed the additional small size, 1/2 inch, inlet pipe, as shown in Fig. 4. In range of isothermal and isopressure, only small size inlet pipe and control valve would be used, in order to inject small flux of steam to the test chamber. And in order to decrease temperature and pressure rapidly when the temperature and pressure of test chamber is higher than target temperature, we installed small size outlet pipe in test chamber.

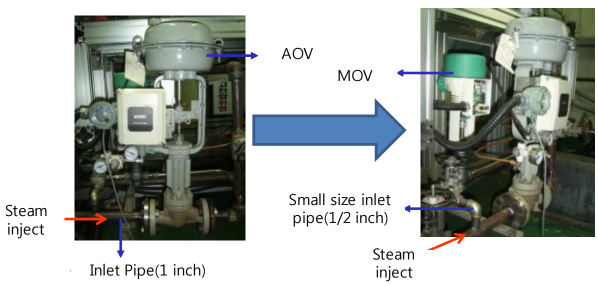

Fig. 4. Installed small size inlet pipe and control valve

In order to improve the second vital few, the state of steam, we perform DOE(Design Of Experiments) that have one factor and three levels. The one factor is the pressure of injected steam, and the levels are 13, 9, 6 kgf/cm^2. As the result of DOE, we selected 9 kgf/cm^2 for the appropriate pressure of steam.

Lastly, using modified DBE simulation test facility, we performed DBE simulation test with same profile of test performed to measure current condition. Temperature and pressure in test chamber was collected per 0.2 second by the data acquisition equipment. The result of normality test showed that the acquired data was not normal distribution and had no appropriate distribution (p-value < 0.5). The acquired data was assumed that had normality and then performed process capability analysis. Z-value of temperature and pressure variance was 3.33 and 6.33, respectively, as shown in Fig 5.

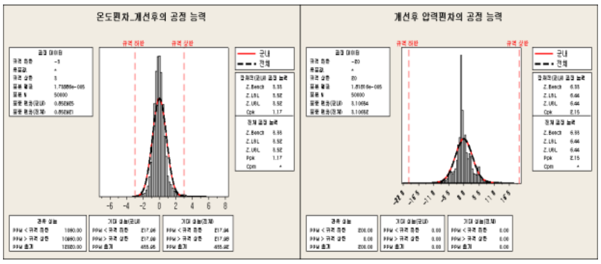

Fig. 5. Result of Process Capability Analysis after improve the DBE simulation test facility

3. Conclusions

To improve temperature and pressure traceability during DBE simulation test, the DBE simulation test facility was modified by using six-sigma method. As the result of the modification, the standard deviation of temperature decreased 41.4%, from 1.455 ℃ to 0.853 ℃ and the standard deviation of pressure decreased 69.2%, from 10.08 kPa to 3.11 kPa. This improvement of temperature and pressure traceability affects improvement of accuracy of DBE simulation test and minimizing test failure possibility due to reducing the conservatism.

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.