Development of Thermal Stress Test Profile for Class 1E Equipment in Main Control Room of a Research Reactor

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1. Introduction

The primary objective of an equipment qualification (EQ) is to demonstrate with reasonable assurance that Class 1E equipment for which a qualified life or condition has been established can perform its safety function without experiencing common-cause failures before, during, and after applicable design basis events (DBEs) [1].

The thermal stress test is one of the tests for the EQ program described in [1,2]. For the environmental test of Class 1E equipment installed in the main control room (MCR) of a research reactor, the thermal stress test profile should be developed based on normal and abnormal environmental conditions of the MCR.

2. Conditions for Thermal Stress Test

For the development of an environmental test profile, the abnormal environmental conditions anticipated during the design life should be considered. Since the MCR of the research reactor considered in this study is classified as the mild environment conditions of which are not affected directly by DBEs, the abnormal condition in the MCR is assumed to be driven by a failure of the ventilation system for the MCR.

The MCR of the research reactor considered in this study is assumed to be equipped mainly with following equipment.

- Large Display Panel
- Operator Workstations
- Reactor Protection System Cabinets
- Post-Accident Monitoring System Cabinets
- Automatic Seismic Trip System Cabinet
- Radiation Monitoring Computer
- Fire Alarm Receiving & Control Panel

2.1 Temperature Condition

The comfortable environmental conditions for equipment and operators in the MCR defined in the system design requirements are maintained by the Heating, Ventilation, and Air Conditioning (HVAC) system. If the HVAC system fails to ventilate the MCR, the temperature in the MCR will be increased mainly due to the heat generated from powered equipment, as heat sources, installed inside the MCR.

Figure 1 shows the time-temperature curve for the MCR after the HVAC system is shut down, assuming that all the equipment in the MCR is continuously operating. This curve is derived using the heat transfer equation provided in [3]. As the MCR is assumed to be insulated, the temperature inside the MCR is not affected by the external temperature variations.

It is assumed that the ventilating capability of the HVAC is recovered within a maximum of 8 hours after an unplanned shutdown. As shown in Fig. 1, the temperature inside the MCR climbs to about 42°C at 8 hours after a shutdown of the HVAC. Therefore, the maximum temperature for the environmental test is set to 50°C including a margin of +8°C recommended in IEEE Std. 323 [1]. In consideration of the minimum ambient temperature specified in the design specifications for the Class 1E equipment located in the MCR, the minimum temperature for the environmental test is set in a conservative manner to 2°C including a margin.

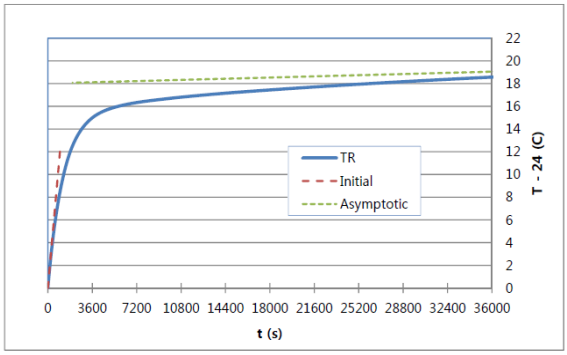

Fig. 1. Temperature change inside the MCR after a shutdown of the HVAC system.

2.2 Test Duration

The environmental test duration under an abnormal condition should be determined in light of the time for recovering the ventilation capability after an unplanned shutdown of the HVAC system.

IEEE Std. 650 [2] and the reference used for Ulchin nuclear power plant units 5, 6 [4] recommend an 8 hour period for the test duration under maximum/minimum ambient temperature conditions. The 8 hour period was selected on the basis of the engineered judgment as a reasonably conservative period for plant operators to 1) recognize that actual conditions in the non-harsh environments have exceeded their normal values, and

2) restore those environments to within normal limits [4].

On the assumption that the recovery of the failed HVAC system or an electrical outage in the reactor does not take more than 8 hours, the 8 hour period is used for the test duration under each abnormal temperature condition.

2.3 Number of Test Cycles

The frequency that the HVAC system loses the capability to ventilate the MCR can be estimated using failure rates of sub-components of the HVAC system and the electrical supply system and electrical outage frequency of the reactor. The failure frequency is calculated as 0.117/year using the fault tree analysis with generic reliability data of research reactors [7]. This result means that the Class 1E equipment inside the MCR is expected to undergo the abnormal environmental conditions about 4.7 times during the life time of 40 years due to a loss of ventilating capability inside the MCR. Therefore, the environmental test imposes 5 cycles of abnormal environmental conditions on the Class 1E equipment.

3. Development of Thermal Test Profile

Based on the conditions made in Section 2, the thermal stress test profile for qualifying the Class 1E equipment inside the MCR is provided as shown in Fig. 2. The test profile is developed based on normal and abnormal environmental conditions. The Class 1E equipment is tested under the simultaneously high temperature and high humidity conditions for 8 hours.

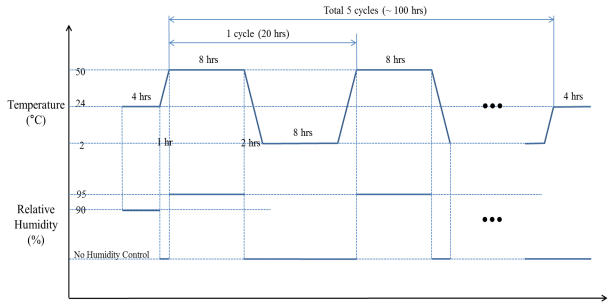

Fig. 2. Proposed thermal stress test profile for Class 1E equipment inside the MCR.

4. Conclusion

A thermal stress test profile for Class 1E equipment located in the MCR of a research reactor is developed based on an engineering justification. A set of thermal stress test conditions including temperature, test duration, and number of test cycles is defined considering the specific characteristics of the targeted research reactor. The method used in this study can be applied to develop a thermal stress test profile used for the EQ test to qualify Class 1E equipment installed in the MCR of various research reactors.

REFERENCES

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