Engineering Evaluation of Unanticipated Operating Event in ShinKori 1 NPP

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1. Introduction

Reactors must operate within specified pressure-temperature limits to maintain adequate safety margins against pressure vessel failure during normal operation. When reactors have occurred beyond the limits of the plant technical specification, an engineering evaluation shall be performed to determine the effects of the out-of-limit condition on the structural integrity of the reactor coolant system (RCS). The ASME B&PV Section XI provides procedures and criteria to evaluate these unanticipated operating events.

ShinKori 1 NPP exceeded the pressure temperature limits of the plant technical specification during the trial run. The engineering evaluation for the unanticipated operating event was performed by Korea Hydro & Nuclear Power-Central Research Institute (KHNP-CRI).

This paper gives an overview of the procedures and results for the engineering evaluation of the unanticipated operating event in ShinKori 1 NPP.

2. Evaluation of Unanticipated Operating Events

Operation within specific pressure temperature (P-T) limits is considered essential for maintaining adequate margins against failure of reactor pressure vessels during normal operation. An exceeding of any the P-T curve limit requires a restoration of the temperature and/or pressure below the limits within 30 minutes, an engineering evaluation to determine the effects of the out-of-limit condition on the structural integrity of the reactor coolant system, and a determination that the system remains acceptable for continued operation or be in hot standby within 6 hours.

2.1 Technical Specification of P-T Curve Limits

The technical specification of ShinKori 1 NPP requires periodically monitoring for the P-T curve limits every 30 minutes when RCS pressure and temperature conditions are undergoing planned changes. All components of the RCS are designed to withstand effects of cyclic loads due to system pressure and temperature changes. These loads are introduced by heatup and cooldown operations, power transients, and reactor trips. The use of the curves is operational guidance during heatup or cooldown maneuvering, when pressure and temperature indications are monitored and compared to the applicable curve to determine that operation is within the allowable region.

The P-T curves are prescribed during normal operation to avoid encountering pressure, temperature, and temperature rate of change conditions that might cause undetected flaws to propagate and cause nonductile failure of the reactor coolant pressure boundary (RCPB).

The two elements of limiting condition for operation (LCO) are the limit curves for heatup, cooldown, and inservice leak and hydrostatic testing and limits on the rate of change of temperature. The LCO limits apply to all components of the RCS, except the pressurizer [1].

Exceeding the LCO limits places the reactor outside of the bounds of the stress analyses and can increase stresses in other RCPB components. Operation outside the P-T limits during mode 1, 2, 3, or 4 must be corrected so that the RCPB is returned to a condition which has been verified by stress analyses.

The 30 minute completion time reflects the urgency of restricting the parameters to within the analyzed range. The evaluation must verity the RCPB integrity remains acceptable and must be completed before continuing operation. ASME B&PV Section XI, Appendix E [2] may be used to support the evaluation. If a required action and associated completion time of condition are not met, the plant must be placed in a lower mode. The example of the P-T limit curves is shown in the following Fig. 1.

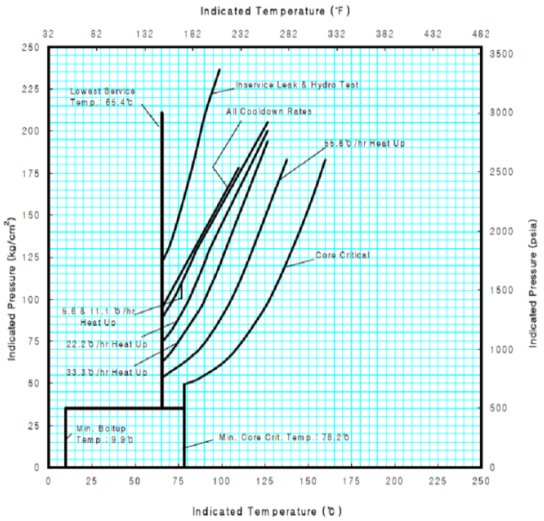

Fig. 1. P-T Limit Curves

2.2 Acceptance Criteria and Guidance for the Evaluation

ASME B&PV Section XI, Appendix E provides acceptance criteria and guidance for performing an engineering evaluation of the effects of an out-of-limit condition on the structural integrity of the reactor vessel beltline region. The flow chart for the evaluation of unanticipated events is shown in the following Fig. 2.

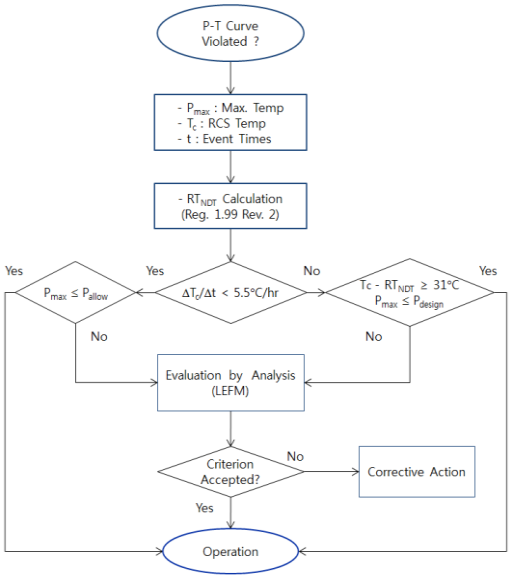

Fig. 2. Flow Chart for Evaluation of Unanticipated Operation Events

2.2.1 Acceptance Criteria

Adequate structural integrity of the reactor vessel beltline region is assured if the following applicable criterion is satisfied throughout the event.

- For isothermal pressure transients $(\Delta T_c / \Delta t < 5.5^{\circ}C/hr)$, the maximum pressure does not exceed the allowable pressure.
- For pressurized thermal transients $(\Delta T_c / \Delta t \ge 5.5^{\circ}C/hr)$, the maximum pressure does not exceed the design pressure and RCS temperature minus RT_{NDT} is not less than 31°C.

If compliance with the criteria is not shown, adequate structural integrity can be assured by evaluation.

2.2.2 Engineering Evaluation by Analysis

Adequate structural integrity of the reactor vessel beltline region is assumed if the following criterion is met throughout the event.

$$1.4(K_{Im} + K_{It}) + K_{Ir} \le K_{Ic} \qquad (1)$$

Where

K_{Im} = stress intensity factor due to member stress

K_{It} = stress intensity factor due to thermal stress

K_{Ir} = stress intensity factor due to residual stress

K_{Ic} = fracture toughness

If compliance with the above criteria is shown, the acceptable margins of safety will be maintained during subsequent operation.

2.3 Evaluation of Unanticipated Event in ShinKori 1

The RCS cooldown rate of RCS temperature in the technical specification LCO is limited to a maximum of 55.6°C in any 1-hour period. ShinKori 1 NPP exceeded the limits that the maximum cooldown rate was 114°C/hr [3]. The cooldown rate of ShinKori 1 NPP is shown in the following Fig. 3.

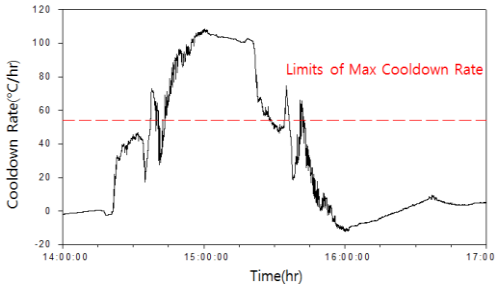

Fig. 3. Unanticipated Event in ShinKori 1 NPP

Engineering evaluation was performed based on ASME Section XI, App. E procedure. During the unanticipated event of ShinKori 1, the pressure transients are pressurized thermal and the maximum pressure (35.6 kg/cm^2) is not exceed the design pressure (175.44 6 kg/cm^2). RCS temperature minus RT_{NDT} (50 °C) is not less than 31°C.

The result shows that the time period of the unanticipated operating event in terms of P-T limit is satisfied the acceptance criteria of the structural integrity of reactor vessel beltline region.

3. Conclusions

Reactors must operate within specified pressure-temperature limit to maintain adequate safety margins against pressure vessel failure during normal operation.

ShinKori 1 NPP exceeded the limits of the maximum cooldown temperature rate in the plant technical specification during the trial run. The engineering evaluation for the unanticipated operating event was performed. The result shows that the unanticipated operating event is satisfied with the acceptance criteria of the structural integrity of reactor vessel beltline region based on ASME Section XI, App. E.

REFERENCES

[1] EPRI NP - 5151, "Evaluation of Reactor Vessel Beltline Integrity Following Unanticipated Operation Events", April 1987.

[2] ASME Section XI, App. E, "Evaluation of Unanticipated Operating Events", 2007.

[3] KEPRI Report, "Technical Support for the Establishment of the Engineering Evaluation Procedure for an Unanticipated Operation Events ", January 2010.