An analysis of a Steam Generator Tube Rupture for the SMART-P

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1. Introduction

The purpose of this study is for the safety analysis of a SGTR(Steam Generator Tube Rupture) for the SMART-P(System-integrated Modular Advanced ReacTor for a Pilot). The assessment of a SGTR for the LCO(Limiting Conditions for Operation) is also performed. The TASS/SMR (Transient And Setpoint Simulation/Small and Medium Reactor) code is used for the calculation. It can calculate the core power, pressure, flow, temperature and other values of the primary and secondary system according to the various initiating conditions. The point of this study is not the minimum CHFR(Critical Heat Flux Ratio) but the maximum leakage amount from the primary to secondary sides at the steam generator. Therefore the break area causing the maximum accumulated break flow is researched for this reason.

2. Methods and Results

The definition of a SGTR in SMART-P means one helical tube rupture of a steam generator in the reactor vessel. The penetration parts of the reactor vessel are the subsection pipes of the feed lines and the main steam lines. They consist of 12 pipes respectively and one pipe has 6 module pipes. These 6 module pipes have 96 helical tubes with a 7 mm diameter in a steam generator.[1] The helical tubes in a reactor vessel act as a protective barrier for any radioactivity propagation from the primary to the secondary system. If a SGTR occurs, there is a complex thermal hydraulic effect as well as a leakage of the break flow to the secondary system.

2.1 The general behavior of SGTR

One helical tube rupture at a steam generator is the initiating event. The fluid in the secondary system is mixed with that of the primary system which included radioactivity. Mixed fluid is sent to the turbine successively until a ceasing of the turbine. This radioactivity can be released to the environment by the air ejector at condenser after sending it to the condenser. The air ejector is used for the release of the noncondensible gas to the air. Actually before long the reactor trip signal will be set by the radioactivity detectors on the steam lines. This signal indicates a high level leakage of radioactivity from the secondary system. After signaling a reactor trip the steam generators are isolated by the feedwater and main steam isolation valves. And the steam generators are connected to the PRHRS(Passive Residual Heat Removal System). The PRHRS removes the decay heat by a natural circulation. The concerned parameters of this study are the integrated break flow from the primary to the secondary and the fuel integrity.In view of the break flow a smaller break area creates an integrated larger amount through the main steam lines. Because the small break area brings about a delay of the reactor trip time. For a conservation of the result, a reactor trip signal by an operator is used after skipping a signal of a high level radioactivity at the secondary system in the beginning. The system is tripped after 30 minutes from the initiating event by the operator trip signal.

2.2 The Analysis method and Assumption

The mathematical models are implemented in TASS/SMR. Basically TASS/SMR can model SMART-P with nodes and paths. It can calculate the core power, heat flux, fluid temperature, pressure, flow change and CHFR[2, 3]. ABAQUS code is used for the calculation of the fuel temperature. One stuck CEDM(Control Element Drive Mechanism) having the largest reactivity is assumed. The LOOP(Loss Of Offsite Power) is not considered for the increase of the integrated break flow. As a result the MCP(Main Coolant Pump) supplies coolant to the primary system continuously. SGTR is classified as one of the limiting condition accidents in the Safety Related Design Based Events for the SMART-P. The limiting criteria are;

- The minimum CHFR must be greater than 1.3.
- The primary system pressure must be less than 110% of design value

The ANS-73 curve is used for the calculation of the decay heat.

2.3 Results

The sensitivity study for the break size is done by searching for the maximum integrated break flow. The study for the various initial conditions with the same break size is performed. The longest time case until a reactor trip signaling gives the maximum integrated leakage amount. As a result, the determined initial conditions are a high primary flow, high core power and high coolant temperature at the core entrance. It is also identified that the leakage amount would increase in a flash of the initiation if a guillotine break occurs. In that case, the integrated break flow is rather small. Because the reactor trip signal by the low primary system pressure does occur early. The smaller break size creates a greater integrated break flow by the delay of reactor trip signal. The used reactivity coefficients are the least negative for the moderator density coefficient and the most negative for the fuel temperature coefficient.

The core power has a maximum at the initiating event time[Fig. 1]. The maximum integrated break flow is found at 14.2% of the full break size during 30 minutes. This case is the most critical one from the view of an integrated break flow. The integrated steam flow in the broken section is 11,740kg[Fig. 2]. The primary system pressure is decreased continuously by a leakage of the coolant to the secondary system during the transient. The initial pressure, 15.52 Mpa, is the maximum primary system pressure and the minimum CHFR is 1.81[Fig. 3]. The hottest temperature of the fuel rod is 542 **°C** below the limitation value.

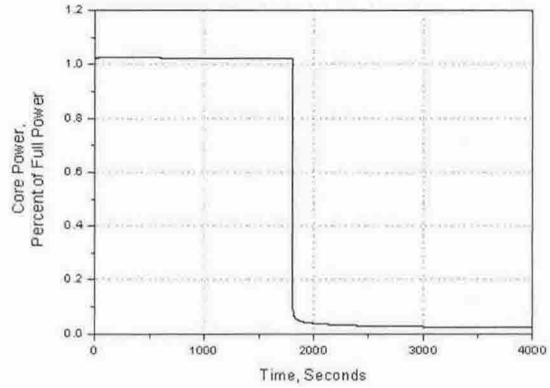

Figure 1. The behavior of core power

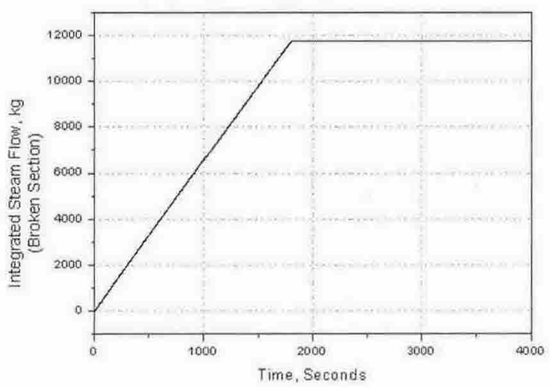

Figure 2. The change of integrated steam flow

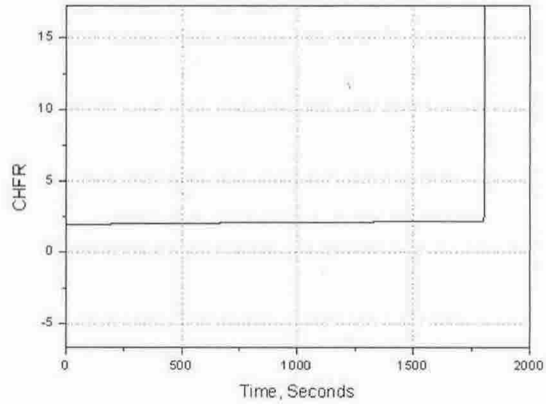

Figure 3. The behavior of CHFR

3. Conclusion

In the case of a SGTR without LOOP for the SMART-P, the minimum CHFR is maintained at over 1.3 and the hottest fuel rod temperature is below 606°C during the transient. It means that the integrity of the fuel rod is guaranteed. The primary system pressure is maintained below 18.7 Mpa. The total integrated break flow is 11, 740 kg in the worst case scenario. The radioactivity analysis will be performed with the integrated break flow later.

ACKNOWLEDGEMENT

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REFERENCES

[1] S.H. Kim, et al., "Design verification program of SMART", Proc. of GENES4/ANP2003, Kyoto, Japan, Sep. 15-19, 2003
[2] H. Y. Yoon, et al., "Thermal Hydraulic Model Description of TASS/SMR", KAERI/TR-1835/2001, 2001
[3] S. K. Sim, et al., "TASS Code Topical Report", KAERI/TR-845/97, 1996