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Design Change Effect of Automatic PHT Pump Trip on Small Break LOCA for Wolsong Unit 1

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1. Introduction

In Wolsong Unit 2,3,4 design, the primary heat transport (PHT) pumps are automatically tripped on low reactor outlet header pressure (less than 2.5 MPa(a)) to prevent the pumps from cavitation. Low pressure in the PHT pump casing would allow cavitation and cause vibration. Then, the excessive vibration could damage the PHT pump or piping.

However, there is no automatic PHT pump trip logic in Wolsong Unit 1 protection system and these pumps can be tripped only by the operators. If these PHT pumps are not tripped properly, they could be damaged by the excessive vibration. Thus, the automatic pump trip logic is adopted as one of design change items for Wolsong Unit 1 refurbishment program. This design change is the addition of a PHT pump trip parameter. The new parameter trips all four PHT pumps on sustained low reactor outlet header pressure.

In this paper, the design change effect of the automatic PHT pump trip for Wolsong Unit 1 small break LOCA is presented.

2. Analysis Scope and Methodology

A 2.5% RIH small break LOCA with all available safety systems is scoped to evaluate the design change effect as a typical case in this work because this is pre-assessment stage of Wolsong Unit 1 refurbishment program.

The same analysis methodology and assumptions are used as Wolsong Unit 2,3,4 safety analysis. CATHENA computer code is also used, and the design change logic is added to the safety analysis model for Wolsong Unit 1.

3. Analysis Results

For a 2.5% RIH break, a break in the reactor inlet header (IHD8) causes an initial mass discharge rate of about 447 kg/sec. The break discharge depressurizes the broken loop. At 63 sec, the low PHTS pressure trip setpoint on both shutdown systems is reached. Following reactor trip, reactor power drops rapidly and then quickly approaches a decay power level within a few seconds. After reactor trip, PHTS pressure decreases rapidly by coolant shrinkage due to core heat reduction (Figure 1).

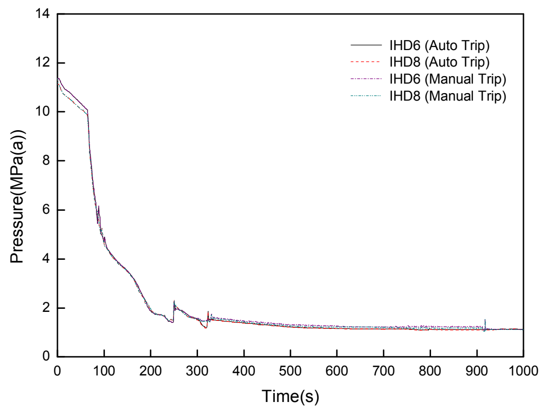

Figure 1. PHTS Pressure.

As the PHTS pressure continues to decrease, the two ECCS rupture discs burst. However, since the primary circuit pressure is still above the ECC injection pressure, ECC water injection is delayed for a while. As soon as the PHTS pressure falls below the assumed ECC injection pressure lower than design value, emergency coolant is injected to the broken loop at 172 sec (Figure 2).

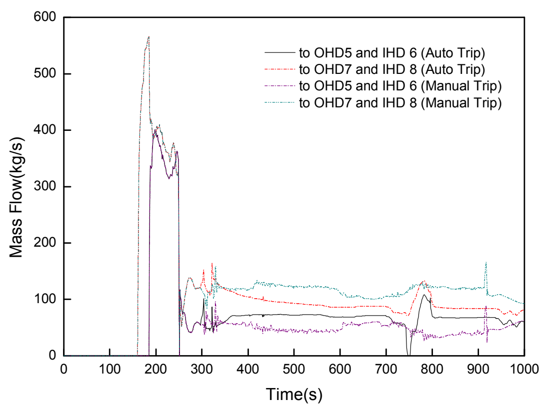

Figure 2. ECC Injection Flow

When pressures in the broken loop outlet headers drop below 2.5 MPa(a) at 177 sec, the automatic PHT pump trip signal is initiated with a delay of two minutes. However, in the case of no automatic PHT pump trip the PHT pumps are tripped manually at 912 sec. Following PHT pump trip at 297 sec, both core passes in the broken loop settle into steady and single-phase forward flow (Figure 3&4).

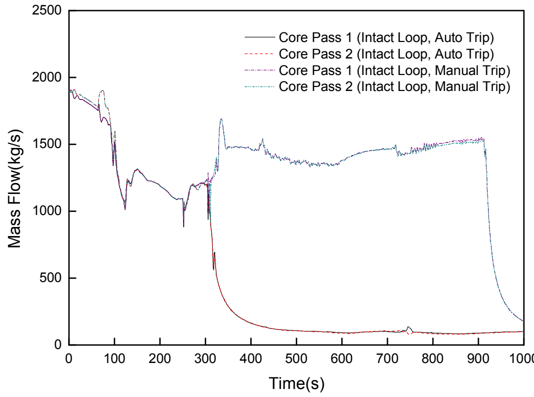

Figure 3. Core Flow in the Intact Loop

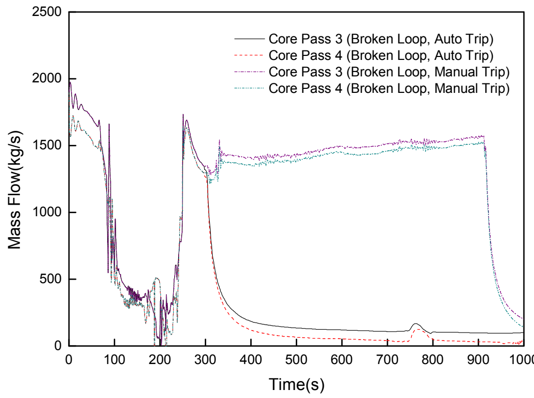

Figure 4. Core Flow in the Broken Loop

While emergency coolant is injected to the broken loop, the fuel channels experience a period of low two-phase flow. Under this condition, flow stratification may occur and eventually fuel heatup is expected to occur. However, since the duration of fuel heatup is short due to the ECC injection, fuel failure does not occur (Figure 5).

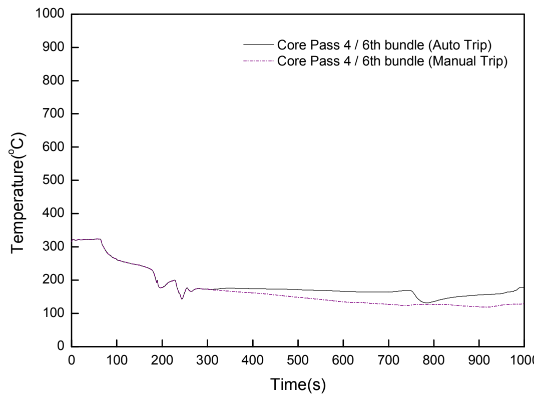

Figure 5. Fuel Temperature

As ECC water continues to be injected to the broken loop, loop void is collapsed and replaced by ECC water. The broken loop refill is accomplished at 250 sec (Figure 6). After refill, the pumps recover near-normal head, by providing also near-normal core flow.

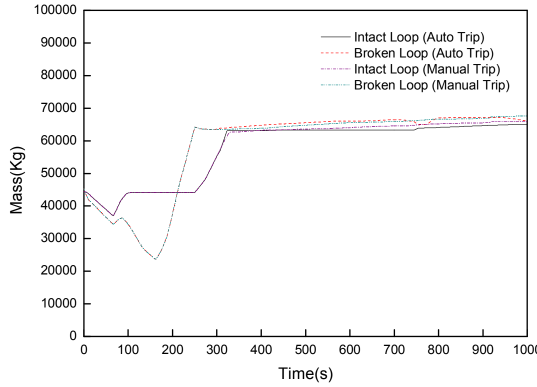

Figure 6. Inventory Mass in the PHTS

Consequently, the analysis results present that there are not much difference from the simulation without automatic PHT pump trip except for the mass flow rate through the core passes. It means that this design change is useful to prevent the possible damage on PHT pumps.

4. Conclusion

In this work, the CATHENA analysis model of automatic PHT pump trip logic was established to simulate the design basis accident for Wolsong Unit 1. The analysis results show that there is no severe effect on small break LOCA because the primary heat transport system parameters become stabilizing after the automatic PHT pump trip. Therefore, this design change is required to protect the PHT pumps from the risk of excessive vibration. Further analysis could be needed for more severe cases.

REFERENCES

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