Injection Transition Analysis of PLGS MP/LP ECC System

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Abstract

To analyze the transition from MP ECC to LP ECC injection, a RELAP5 model has been developed for the Point Lepreau Generating Station (PLGS) MP/LP ECC system. By using this model, some transition analyses have been performed with emphasis on stroke times of the dousing tank suction test isolating valves and the recovery sump isolating valves. The results indicate that if either in-line valve pair of the dousing tank isolation valves fails to close, air could be ingested by the ECC pumps shortly after the dousing tank is empty.

1. Introduction

Some important factors, such as dousing tank volume, valve stroke time, annunciation delays, pump head curve and dousing tank level instrumentation uncertainty, can affect the transition from MP ECC (Medium Pressure Emergency Core Cooling) to LP (Low Pressure) ECC. Also, there are some potential transition operational concerns from MP to LP ECC. For example, if either in-line valve pair of the dousing tank isolation valves (i.e. 3432-PV10/PV11 and 3432-PV162/PV163 in PLGS MP/LP ECC system) fails to close, will the elevation head of the reactor building sump be adequate to prevent air ingress to the ECC pumps if the dousing tank is empty, hence to prevent damage to the pump? To analyze the transition from MP to LP ECC, a RELAP5 MOD 3.3 model has been developed for the PLGS MP/LP ECC system and some preliminary transition analyses were performed.

RELAP5, a one-dimensional non-equilibrium two-phase thermal hydraulic best estimate system code issued by USNRC, has been successfully applied to PWR, BWR and some CANDU safety analyses. The RELAP5 code was developed principally to calculate fluid behavioral characteristics during operational and LOCA transients. It is judged that RELAP5 is capable of modeling the MP/LP ECC systems.

The piping characteristics of PLGS MP/LPECC system are reflected in a detailed RELAP5 model that has been developed in a manner based on the previous experience and consistent with RELAP5 MOD3.3 documents [1, 2, 3].

Presented in this paper are a brief PLGS MP/LPECC system description, the associated RELAP5 model introduction and a preliminary MP/LP ECC injection transition analysis.

2. MP/LP System Description and RELAP5 Model

2.1 System Description

The function of the ECC system is to provide cool light water to the Primary Heat Transport (PHT) system for fuel cooling and inventory makeup. It is composed of three stages: High Pressure (HP ECC), Medium Pressure (MP ECC), and Low Pressure (LP ECC) or Recovery Stage. The MP to LP transition of the ECC system is the subject of this modeling effort using the RELAP5 code

As described in the PLGS safety analysis report, the transition from the HP ECC stage to the MP ECC stage is automatic, initiating 90 seconds after the ECC injection signal. A timer generates a signal to open the MP ECC injection valves (MV31 & MV50) at the outlet of the recovery pumps.

The transition from the MP ECC stage to the Recovery stage is automatic. The signal to initiate recovery is 2 out of 3 dousing tank low level indicators. To ensure reliable measurement and indication, three level transmitters (LT8K, LT8L & LT8M) are installed. As the dousing tank nears depletion a transition signal is generated to initiate the logic for MP ECC to LP ECC transition. This logic closes the dousing tank isolation valves (PV10 & PV11) and the dousing tank test isolating valves (PV162 & PV163) and opens the recovery sump isolation valves (PV1 & PV2).

2.2 RELAP5 Model

According to the above description of the MP/LP ECC system operation, the MP/LP ECC piping arrangement is modeled as a nodal network shown in Figure 1 for input file of RELAP5 code with the following main assumptions:

(1) The PLGS HP ECC piping system is not modeled in the current model, since ECC transition from MP to LP occurs after the HP ECC process ends.

(2) Resistance orifices 3432-RO10 and RO3 are modeled as junctions in the model.

(3) Since RELAP5 is limited to the use of one liquid fluid throughout a simulated system, H_2O is used instead of D_2O inside the piping system from rupture discs RD1/RD2 to reactor headers.

(4) Pumps 3432-P1 and P2 are modeled for liquid-only phase flow due to lack of two-phase pump data. Moreover, it is assumed that the pump maintains constant velocity after start-up.

(5) Rupture discs RD1/RD2 are modeled with components “VALVE” defined in RELAP5 code since its burst process is similar to opening of a valve with very short stroke time.

(6) Elbows along the piping systems are modeled as separate control volume, and their flow resistances are accounted for in the model.

(7) Since the fluid temperature does not have significant effects on the MP/LP transition analysis, the heat exchanger 3432-HX1 is modeled as a simple flow resistance component, that is, heat transfer is not considered in the current model.

(8) Other small vent, drain and instrument sensing lines are not contained in the model because it is expected that these components do not affect the analysis results significantly.

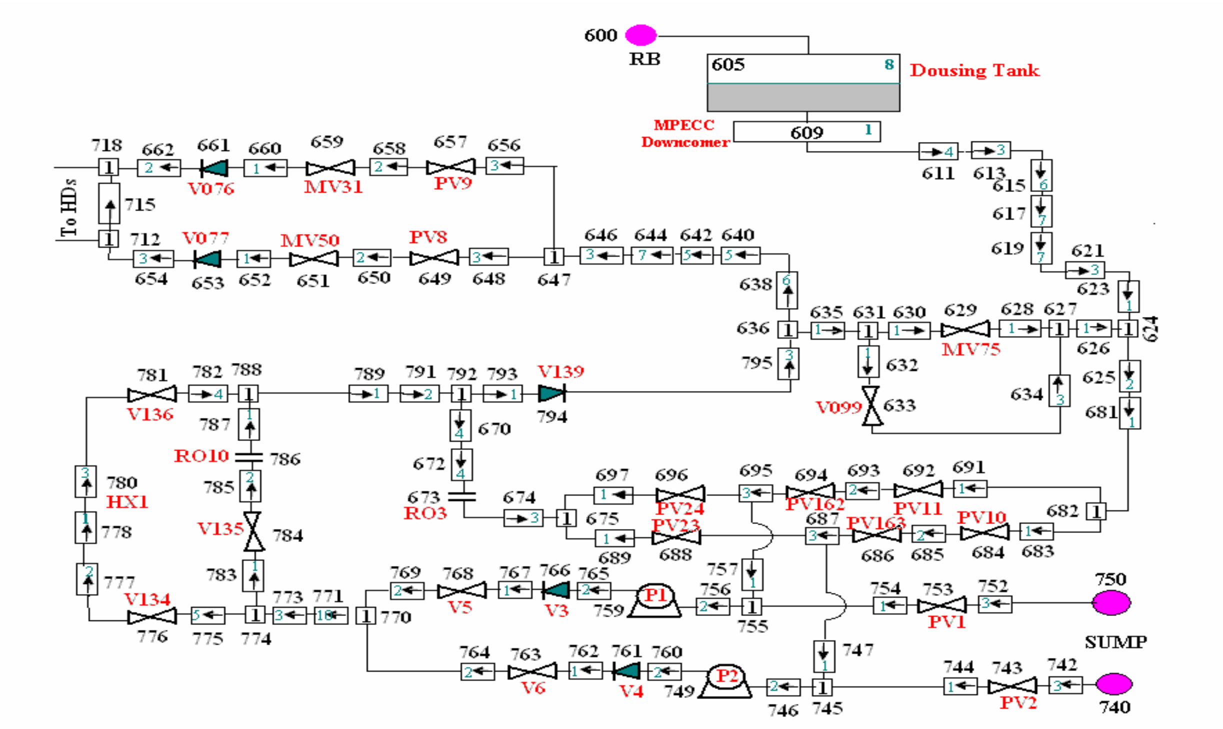

Figure 1 Schematic of nodalization of PLGS MP/LP ECC system RELAP5 model

This model can describe the hydraulic behavior inside the MP/LP ECC piping system in detail. The parameters available from the model output results that are important to the MP/LP transition analysis are:

a) Dousing tank inventory and level
b) Valve opening and mass flow
c) Piping component void fraction

The analysis range of the model is from dousing tank and sump to reactor headers, (see Figure 1), while the reactor building pressure and the reactor header pressure are used as the pressure boundary conditions of the model. The valves modeled are check valves, trip valves and motor valves with their control systems, which can be used to define the actions of the valves.

The piping model for MP/LP ECC injection to flow into the reactor headers is the same as that in reference [4]. Development of the PLGS MP/LP ECC RELAP5 model follows the methodology presented in reference [4] for PLGS HPECC system modeling.

3. MP/LP ECC Transition Analysis

By using the developed RELAP5 model, preliminary MP/LP ECC transition analyses have been performed with emphasis on stroke times of the dousing tank suction test isolating valves (PV162/PV163) and the recovery sump isolating valves (PV1 and PV2).

Refer to nine cases listed in Table 1, where closing time of the dousing tank suction valves (PV10/PV11) is assumed to be constant. The valve timing comes from the Safety Operating Envelope (SOE) document of the PLGS ECC system.

The associated case characteristics are presented in Table 2. In-line partial failure means the valves PV163 and PV10, which are in line with the running pump P2, fail to close on low dousing tank level. Partial failure means the valves PV162 and PV11, which are in line with the stand-by pump P1, fail to close on low dousing tank level. Full failure refers to all four of these valves failing to close.

Table 1 Analysis cases for MP/LP ECC transition

	Closing Time (sec)				Opening Time (sec)	
Cases	**PV162**	**PV163**	**PV10**	**PV11**	**PV1**	**PV2**
Case-0	25	25	45	45	15	15
Case-1	45	45	45	45	35	35
Case-2	25	25	45	45	35	35
Case-3	45	45	45	45	15	15
Case-4	25	Fail to close	Fail to close	45	15	15
Case-5	25	Fail to close	Fail to close	45	35	35
Case-6	Fail to close	25	45	Fail to close	15	15
Case-7	Fail to close	25	45	Fail to close	35	35
Case-8	Fail to close	Fail to close	Fail to close	Fail to close	15	15
Case-9	Fail to close	Fail to close	Fail to close	Fail to close	35	35

Table 2 Characteristics for MP/LP ECC transition analysis cases

Cases	Case Characteristics	Stop MP ECC	Start LP ECC
Case-0	Fastest-Fastest	Fastest	Fastest
Case-1	Slowest-Slowest	Slowest	Slowest
Case-2	Fastest-Slowest	Fastest	Slowest
Case-3	Slowest-Fastest	Slowest	Fastest
Case-4	In-Line Partial Failure-Fastest	PV163/PV10 fail to close	Fastest
Case-5	In-Line Partial Failure-Slowest	PV163/PV10 fail to close	Slowest
Case-6	Partial Failure-Fastest	PV162/PV11 fail to close	Fastest
Case-7	Partial Failure-Slowest	PV162/PV11 fail to close	Slowest
Case-8	Full Failure-Fastest	PV162/PV163, PV10/PV11 fail to close	Fastest
Case-9	Full Failure-Slowest	PV162/PV163, PV10/PV11 fail to close	Slowest

Shown in Figures 2 to 3 are the dousing tank levels and MP/LP ECC flows under the condition of both the valves PV10/PV11 and PV162/PV163 closing on low dousing tank level. It can be seen that the closing time of valves PV162 and PV163 has significant effects on the dousing tank level. The steady level difference between the fastest closing (25 seconds stroke time) and the slowest closing (45 seconds stroke time) is about 0.04 m. Opening time of the valves PV1 and PV2 has obvious effects on the MP/LP ECC flow. The faster that valves PV1/PV2 open, the earlier the ECC flow decreases. The corresponding time difference between the fastest PV1/PV2 opening (15 seconds stroke time) and the slowest PV1/PV2 opening (35 seconds stroke time) is about 7 seconds.

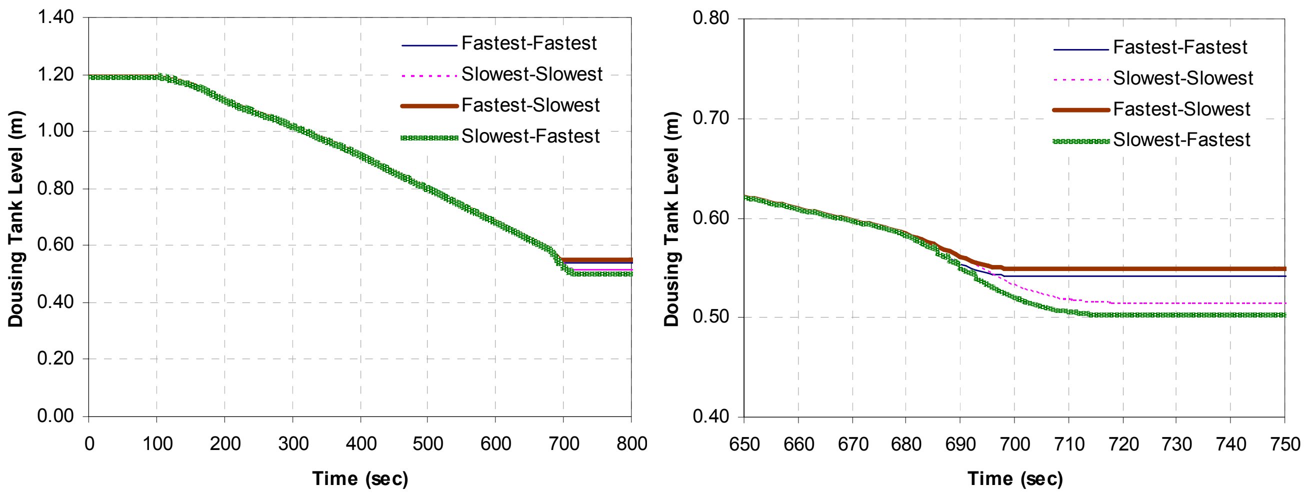

Figure 2 Dousing tank level for dousing tank suction valves closing on low level signal

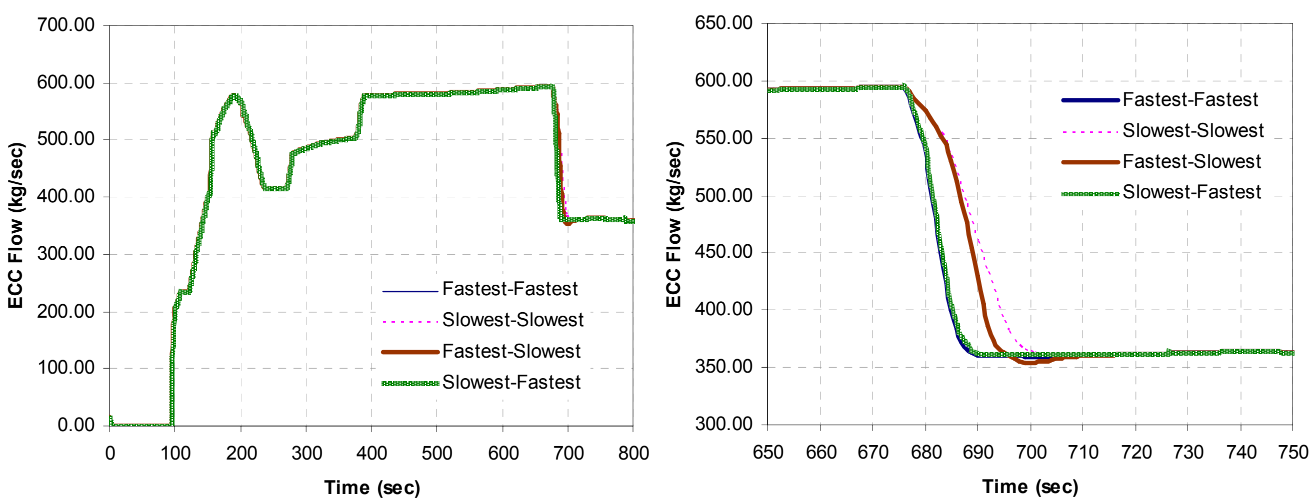

Figure 3 MP/LP ECC flow for dousing tank suction valves closing on low level signal

If one set of the dousing tank suction valves (either PV163/PV10 or PV162/PV11) fails to close on low dousing tank level, the dousing tank will be empty within about 150 seconds after the low dousing tank level signal, see Figures 4 and 6. If two sets of the valves (both PV163/PV10 and PV162/PV11) fail to close, the dousing tank empty time will shortened by about 12 seconds, as shown in Figures 6 and 7. Air will be ingested by the ECC pumps very quickly after the dousing tank is empty, hence the pump could be damaged. Compared with results in Figure 3, the MP/LP ECC flow does not change significantly before the dousing tank is emptied, no matter two sets of dousing tank suction valves fail to close or one set of them fails, see Figures 5, 6 and 7. It is expected that the MP/LP ECC flow will change significantly when the air is ingested by the ECC pump.

Initial calculations and analyses have also been done for the effects of dousing tank volume, annunciation delays and dousing tank level instrumentation uncertainty on the MP/LP ECC transition, which are documented in the technical report of ANSL (Atlantic Nuclear Services Ltd.).

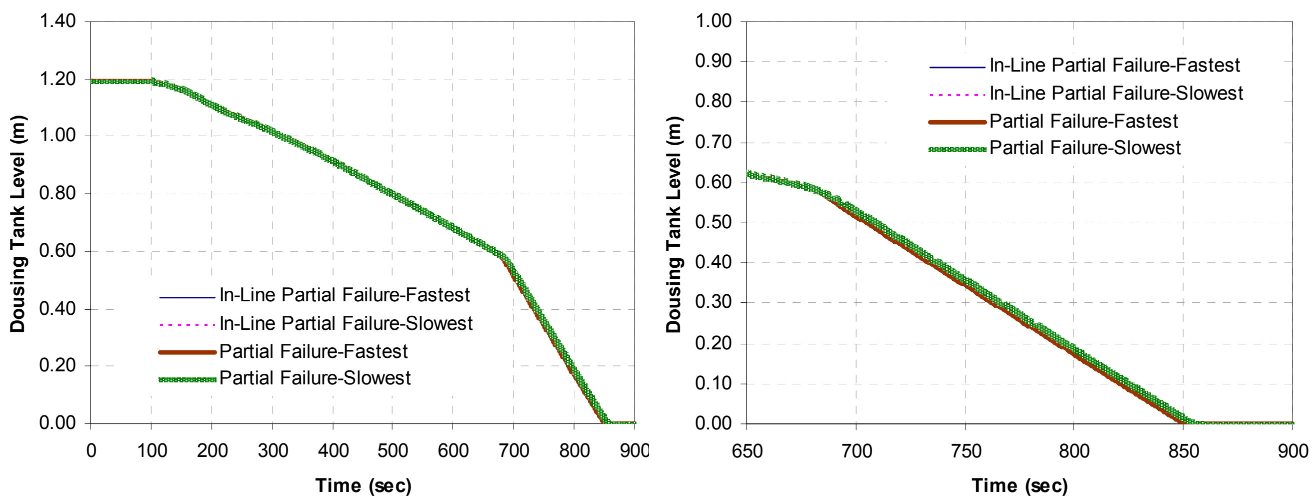

Figure 4 Dousing tank level for one set of dousing tank suction valves failing to close

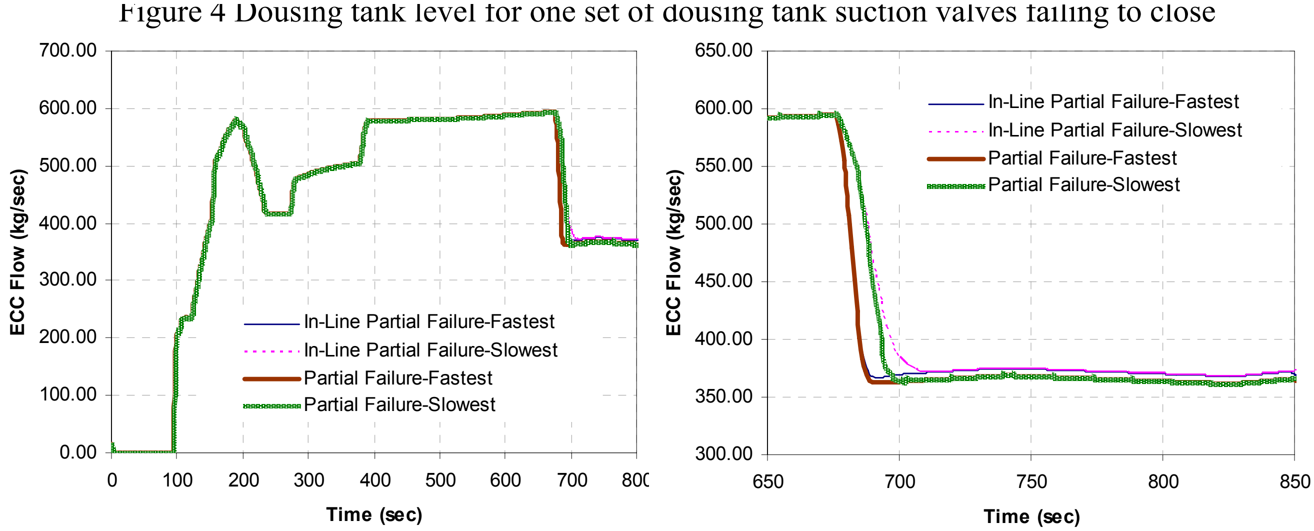

Figure 5 MP/LP ECC flow for one set of dousing tank suction valves failing to close

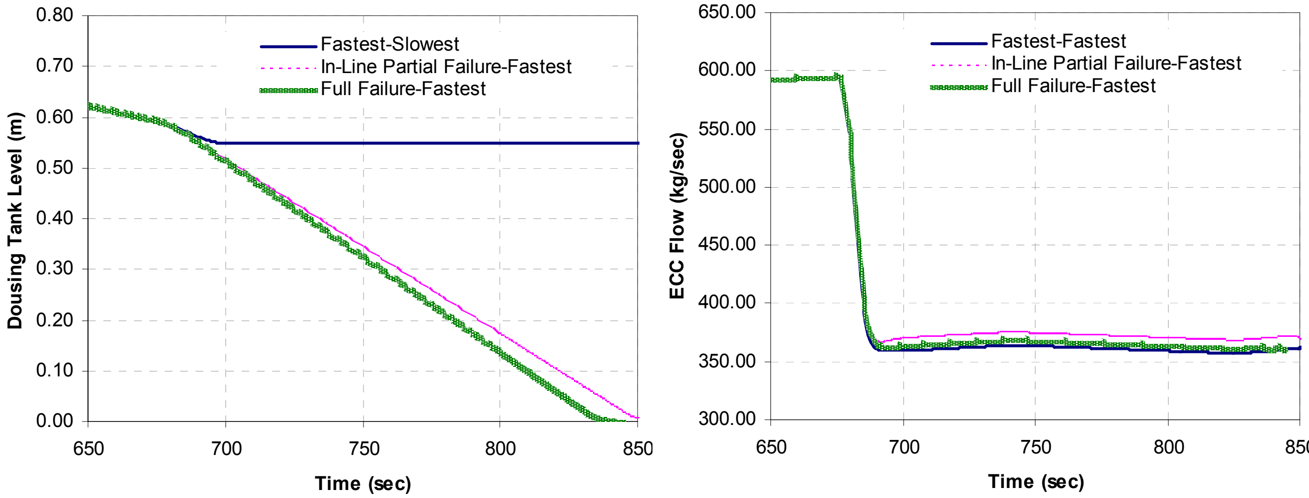

Figure 6 Comparison of dousing tank levels and ECC flows for different cases

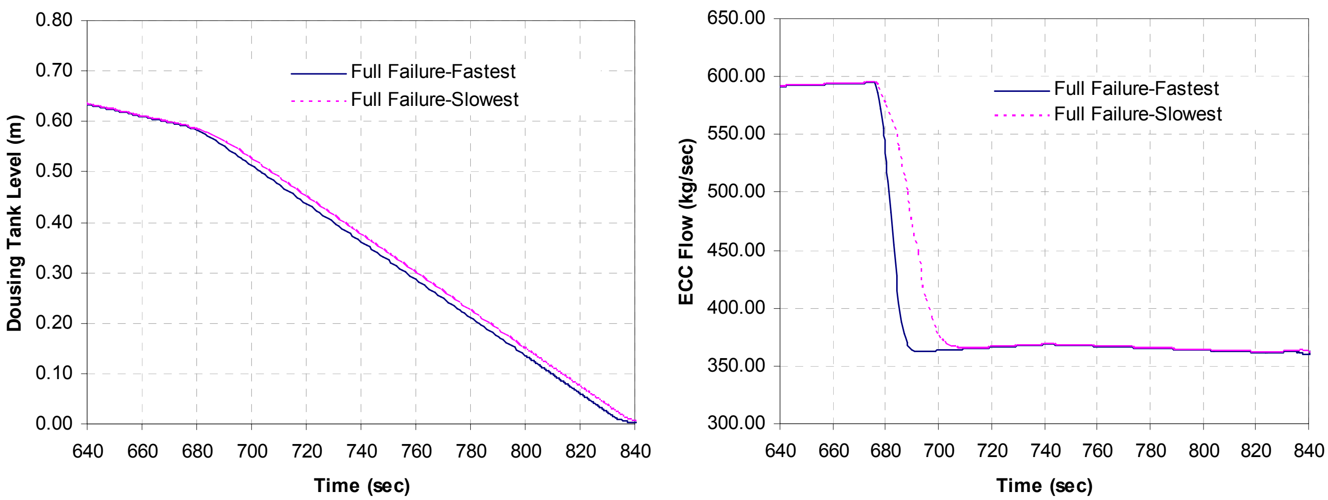

Figure 7 Dousing tank level and MP/LP ECC flow
for two set of dousing tank suction valves failing to closing

Except for application to the MP/LP ECC transition analysis, the developed RELAP5 model can be applied to address water hammer concerns and SOE issues regarding the MP/LP ECC system. For example, the results from the model indicate that the leak flow back to the dousing tank through valve V099 during LP ECC is about 0.5 kg/sec for 20% Reactor Inlet Header (RIH) break event, which is too small (about 0.1% of the ECC flow) to materially impair the efficiency of the ECC System.

4. Conclusions

Preliminary MP/LP ECC injection transition analyses were performed for PLGS ECC system by developing the associated RELAP5 model. The analysis results presented in this paper indicate that valve stroke time can have significant effects on the transition. In particular, failing to close either in-line valve pair of the dousing tank isolation valves could cause air to be ingested by the ECC pumps, hence to damage the pump. Further investigation for this issue is necessary.

5. References

References un-published publically are not listed here.

[1] The RELAP5 Development Team, "RELAP5/MOD3.3 Code Manual Volume I: Code Structure, System Models, and Solution Methods", NUREG/CR-5535/Rev – Vol. I. December 2001.

[2] The RELAP5 Development Team, "RELAP5/MOD3.3 Code Manual Volume II: User's Guide and Input Requirements", NUREG/CR-5535/Rev – Vol. II. December 2001.

[3] The RELAP5 Development Team, "RELAP5/MOD3.3 Code Manual Volume V: User's Guidelines", NUREG/CR-5535/Rev – Vol. V. December 2001.

[4] Z. Cui, M. McIntyre and R. Prime, "Applying RELAP5 Code to Water Hammer Analysis of the Point Lepreau HPECC Piping System", Proceedings of the 28th Annual Conference of the Canadian Nuclear Society, Saint John, New Brunswick, Canada, 2007 Jun 3-6.