Calculation for Top and Bottom Break of RPV with PECCS in ATLAS

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1. Introduction

Considering an importance of a passive safety features and related accident mitigation measures during SBLOCA scenario, top and bottom simultaneous break of RPV along with a passive emergency core cooling system (PECCS) was selected as the main topic of C2.1 experiment of OECD-ATLAS3 project. In this paper, preliminary calculation results using MARS-KS (Multi-dimensional Analysis of Reactor Safety-KS) and a resultant sequence of event table along with related set-points for the trigger of corresponding devices will be presented.

2. Descriptions on the Preliminary Calculation and the C2.1 Test

Two major functions of the PECCS are automatic depressurization of the primary system pressure through automatic depressurization valves (ADVs) and passive safety injection using HPSITs and SITs. For these designated design functions, the PECCS consists of four major subsystems such as four automatic depressurization valves (4 ADVs) for an automatic depressurization of the primary loop, two high-pressure safety injection tanks (2 HPSITs), two safety injection tanks (2 SITs), and finally low-pressure long term cooling injection from IRWST.

2.1 Preliminary Calculation

In the pre-calculation for the C2.1 test, four safety functions of the PECCS has been adequately simulated. Fig. 1 shows the node diagram for the present calculation.

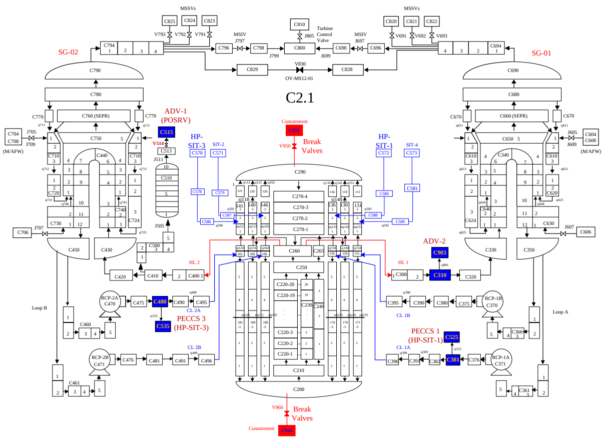

Fig. 1. Node diagram for the pre-calculation of the C2.1

2.2 C2.1 Test

As can be seen in Fig. 1, RPV breaks are occurred at a top and a bottom head nozzle. ADV-1 and ADV-2 valves were connected to the top head of the pressurizer and hot leg-1 (HL-2), respectively. Top head of the HPSIT-1 and HPSIT-3 were connected to cold leg-1A (CL-1A) and cold leg-2A (CL-2A), respectively, by pressure balance lines (PBLs) for the pressure equalizing flow from the primary system to the HPSITs. Fig. 2 and Table I show a schematic diagram of test configuration and a sequence of events, respectively.

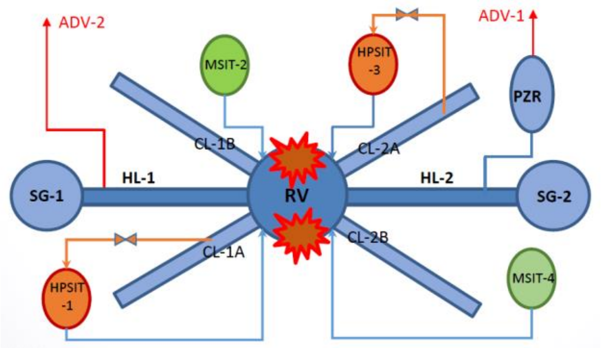

Fig. 2. Schematic diagram of test configuration

Table I: Sequence of Event Table

Phase	Event	Time (s)	Remark
1	SBLOCA at Top & Bottom of RPV	0	Top: 2 inch Break, Bottom: 2 inch Break
	LPP signal	298	1st-system trip, 2nd-system isolation
	Core Power Decay Start	310	12.0 s delay
	MSSV 1st Open	312	[MSSV Hysteresis] Open : 8.1 MPa /Close : 7.7 MPa
	HPSIT-1 & -3 Open	332	Primary Pressure (P_{Pzr}) < 10.0 MPa
	Primary Pressure Plateau & Secondary Inventory Decrease & 1st Clad Temperature Increase		
2	ADV #1 Open (from POSRV)	1691	T_{clad_max} > 380 °C
	ADV #2 Open (from Hot leg-1)	1716	T_{clad_max} > 410 °C (Test termination at T_{clad_max} > 520 oC)
	Initiation of 1st Loop Seal Clearing	1723	Occurred at all ILs
	Actual Injection of HPSITs and start of SITs with the Opening of ADV#1 and #2		
	SIT-2 & -4 Open	1739	P_{Pzr} < 4.2 MPa
	HPSITs Close	2015	WL of HPSITs < 0.43 m
	SITs Close	2060	WL of SITs < 0.43 m
	2nd Clad Temperature Increase and Long term safety Injection from IRWST		
	Clad temperature 2nd increase	2232	After the termination of SI from HPSITs and SITs
3	Long term Injection from IRWST	2327	P_{Pzr} < 0.35 MPa,
	End of Test	4500	No more clad temperature increase

3. Calculation Results

Pre-calculation was performed using the MARS-KS 1.4. Primary and secondary system pressures can be observed in Fig. 3. Primary system pressure decreases steeply with the start of the break at the RPV to the secondary pressure level and it shows an obvious pressure plateau period. Finally, the primary system pressure decreases again just after the open of the ADV valves.

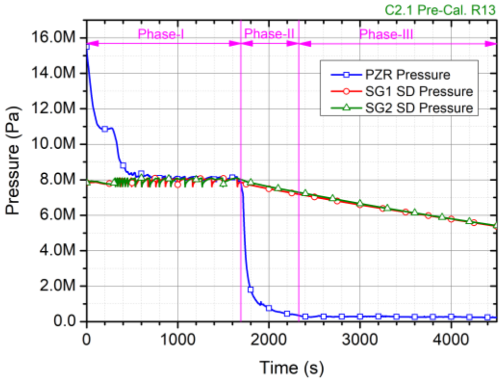

Fig. 3. Primary and secondary system pressure trends

Safety injection flow rate from the HPSITs and SITs is shown in Fig. 4, and low-pressure safety injection flow rate is presented in Fig. 5.

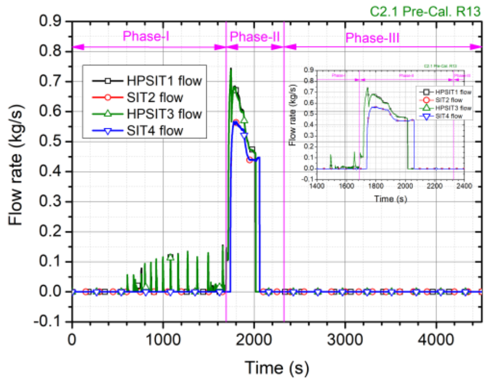

Fig. 4. Safety injection flow rates from HPSITs and SITs

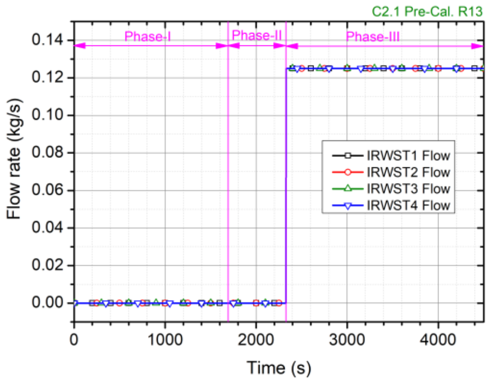

Fig. 5. Low-pressure injection flow rate from IRWST

Discharge flow rate from the ADV-1 and ADV-2 can be observed in Fig. 5. Even though safety injection valves of the HPSIT-1 and HPSIT-3 was open at 332 s as can be observed in Table I, the actual injection of HPSITs was initiated with the open of the ADVs as can be understood by comparing Fig. 4 and Fig. 6 which shows discharge flow rate from the ADVs. The maximum cladding temperature behavior is presented in Fig. 7.

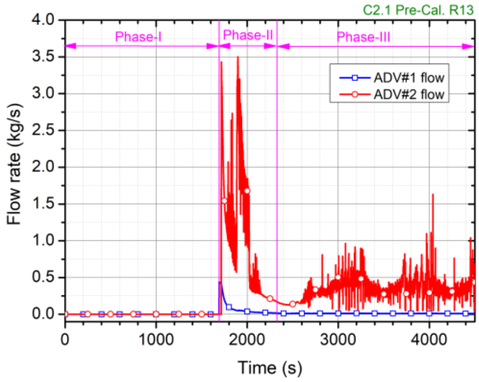

Fig. 6. Discharge flow rates from ADVs

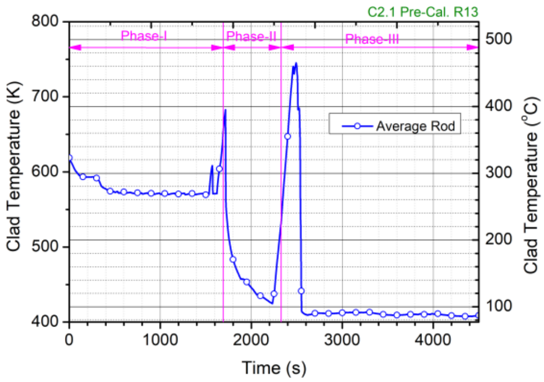

Fig. 7. Trend of the maximum clad temperature

From the observation of the calculation results described above, the authors divide the whole test period into three phases such as the primary pressure decrease to plateau and core heat-up, the safety injection from the HPSITs and SITs, and finally the long-term cooling safety injection from IRWST and clad temperature decrease.

4. Conclusion

The preliminary calculation for the C2.1 of the OECD-ATLAS3 project was performed to define a suitable boundary conditions and set-points. From the observation of the calculation results, three corresponding sub-phase were defined.

REFERENCES

[1] S. Cho, "RPV SBLOCA simulation with PECCS," Internal document, Rev.00, 2021.