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# Investigation of a Station Blackout Scenario with the ATLAS Test

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## 1. Introduction

KAERI (Korea Atomic Energy Research Institute) has been operating an integral effect test facility, ATLAS (Advanced Thermal-Hydraulic Test Loop for Accident Simulation), for accident simulations pertaining to the OPR1000 (Optimized Power Reactor, 1000MWe) and the APR1400 (Advanced Power Reactor, 1400MWe) which are in operation and under construction in Korea, respectively [1,2].

After the Fukushima accidents due to the combination of an earthquake followed by a tsunami in east Japan on March 11, 2011, the concept of boundary between the design basis and beyond-design basis accidents became obscure. One scenario is the station blackout (SBO), which is defined as 'the loss of all alternating current (AC) power in a nuclear power plant' by the USNRC 10CFR50 Section 50.63, which has adopted a new safety regulation for the SBO in June of 1988. In any case the SBO that occurred in Fukushima seemed to go beyond the definition of the current SBO scenario. In the mean time, numerous researche has been conducted on the safety concern of the SBO for existing and advanced nulear power plants worldwide. From the internal review of an SBO scenario, it was concluded that the understanding of the thermo-hydraulic phenomena occurred within the reactor coolant system is a prerequisite although seemed to be quite a simple sequence of events. This was the motivation of an SBO test using the ATLAS facility.

For the understanding of the physical phenomena within the primary system, an SBO was assumed with simple intial and boundary conditions, e.g. start of an SBO at time zero, no diesel and AC powers, no auxiliary feedwater pumps (motor-driven and turbine-driven) etc. In this paper, overview of the SBO test results was described including a result of anaysitical calculations simulating the SBO test using the MARS code [3].

## 2.Results

### *2.1Overview of the station blackout test,SBO-01*

The SBO-01 test was performed at the same pressure as the reference plant, the APR1400. The temperature distribution along the primary loop was also preserved. The primary inventory was heated with core heaters to its specified steady state condition and was pressurized until the primary system reached a steady state condition. During the primary heat-up process, the secondary system was also heated up to a specified target hot condition by controlling the heat removal rate from the primary system. At a steady state condition, the core power generated by electrical heaters was balanced with the energy removal by the secondary system. The obtained steady state condition was maintained constant to stabilize the system behavior of the ATLAS for more than 10 minutes and then the test began by recording the DAS data. The core heater power was initially 8% of the scaled full power and programmed to then follow a decay power table. Using the decay power table, 120% of the ANS73 decay curve was simulated. From the sequence of events of the SBO scenarios, if the core is uncovered the core temperature will increase to very high values. To protect the core simulated by electrical heaters in the ATLAS, 500 oC was selected as the temperature limits for the PCT simulation and met at around 11,500 seconds in the test. Table 1 summarizes the major sequence of events of the SBO-01 test.

**Table 1. Summary of sequence of events of the SBO-01 test**

| Event | ATLAS Test | | Remark |
|---|---|---|---|
| | DAS | Test Time* | |
| SBO Start | 300 s | 0 s | |
| RCP/MFP Trip | 300 s | 0 s | |
| Turbine Trip | 300 s | 0 s | |
| Decay Power | 312 s | 12 s | < 8% |
| MSSV 1st | 315 s | 15 s | SG-1,2; 8.1MPa |
| RV Saturation | 5,000 s | 4,700 s | Core Exit |
| SG-1,2 Dryout | 5,300 s | 5,000 s | |
| PZR Full | 6,900 s | 6,600 s | |
| POSRV 1st | 8,200 s | 7,900 s | 17.03 MPa |
| PCT | 11,800 | 11,500 s | PZR=4.3m; 500 |

Note *: Test time is adjusted by setting the SBO start time to zero second.

### *2.2 Analysis of the SBO-01 Test*

For transient calculation, a text file describing the transient conditions is made to be run by the MARS code. The same transient conditions used in the SBO-01 experiment are implemented in the code so that the experimental transients can be reproduced.

In addition, the heat loss through SG vessels is accounted for in the code based on the analysis of previous post-test calculation results of FLB (Feedwater Line Break) test [4]. The heat loss through the SG vessel can't be neglected for the secondary system transient, compared with LOCAs (Loss of Coolant Accidents) where energy carried by the lost coolant through break much more overweigh the SG heat loss. Moreover, the heat loss through PZR is also considered, as the condensation of steam in the PZR can play an important role on the transient. Several events observed in the SBO-01 experiment are reproduced in the code calculation, as seen from SGs' pressure transient in Figs. 1 through 3.

For the secondary system transients as shown in Figs. 1 through 3, the SG dryout time is well predicted as shown. However, the cyclic rate of MSSV opening and closing shown in Fig. 1 is a little faster in the calculation than that in the experiment, and the transients of accumulated MSSV mass flow in Fig. 2 also deviate between calculation and experiment. These are because the leakage from SG-1 MSSV is not modeled in the code. Because there is no leakage through SG-1 MSSV in the code calculation, the SGs' pressure did not decrease linearly after SG dryout in the calculation, compared with that in the experiment. The SGs' water level transients in the calculation (Fig. 3) are also consistent with those in the experiment, but they decrease below 0. Due to the range of calculated water levelsbeing modelled wider than that of the experiment, the calculated water levels were adjusted to the experiment conditions as shown in the figure.

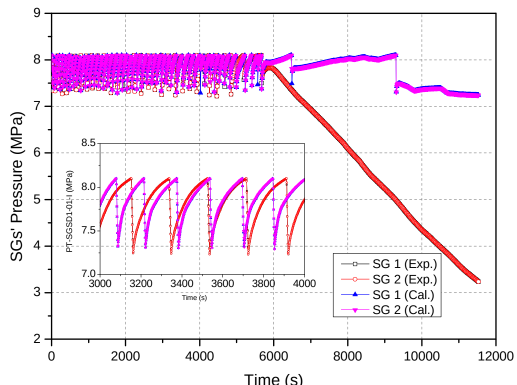

Fig. 1 SG pressure

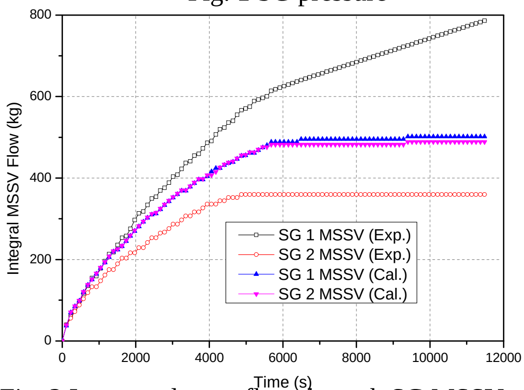

Fig. 2 Integrated mass flow through SG MSSVs

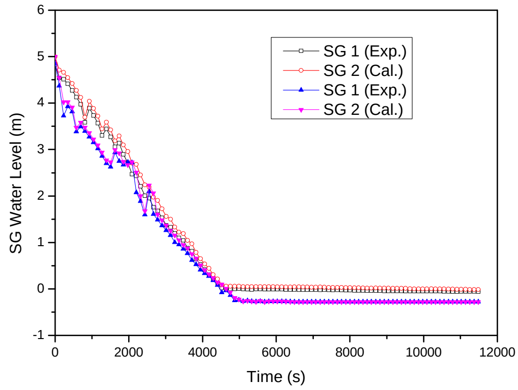

Fig. 3 SG water levels

## 3. Conclusions

From the overview of the SBO-01 test results, the station blackout scenario is characterized by the two typical phases: The 1st phase characterized by decay heat removal through secondary safety valves until the SG dryouts; The 2nd phase characterized energy release by blowdown of the primary system after the SG dryouts. During the 2nd phase, some physical phenomena of the change over pressurizer function, the pressurizer being full before the 1st POSRV opening, and the termination of normal natural circulation flow were identified. And finally, the PCT occurred at low core water level although under signifiant amounts of the PZR inventory, whose drainage seemed to be hindered due to the pressurizer function by the RV.

The transient of SBO-01 is well reproduced in the calculation using MARS code. It indicates the predictability of MARS code on the secondary side transients provided that the experimental conditions are precisely implemented in the code calculation. However, some deviations between the calculation and experiment are also observed. Based on the comparison and calculated results, it's inferred that these deviations are mainly contributed to the non-existant modeling of SG leakage which exists in the experiment, the neglect of RCS heat loss in the code calculation.

## REFERENCES

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