Reflux Condensation in SBLOCA Tests of ATLAS Facility

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1. Introduction

The behavior of the reflux condensation heat transfer in a hot side steam generator (SG) U-tubes during a cold leg (CL) pipe and a direct vessel injection (DVI) line break in small break loss-of-coolant accident (SBLOCA) tests of the ATLAS facility was investigated including MARS code calculations. Among the SBLOCA tests, a 6”-CL pipe and 50%-DVI line break SBLOCA test were selected to investigate the behavior of the reflux condensation. A reflux condensation heat transfer seemed to occur from the time the SG U-tubes were half-empty to near the loop seal clearing (LSC). It was found that a transition regime existed between the reflux condensation heat transfer and reverse heat transfer. The remaining reflux condensate in SG U-tubes owing to the counter-current flow limit (CCFL) phenomenon and a separating effect of liquid carry-over and/or entrainment with steam moisturizing seemed to affect the thermal-hydraulic behavior of the transition regime. It was also found that the steam flowrate of the loop pipings and SG U-tubes seemed to have a strong effect on the duration time of the transition regime, e.g., a larger steam flowrate results in a longer duration. From a comparison of the reflux condensation behavior between the ATLAS tests and MARS code calculations, overall qualitative agreements were found between the two cases. The largest discrepancies were found in the SG inlet plenum water level between the two cases, and the authors suggest that the combination effects of the remaining reflux condensate in SG U-tubes and a separating effect of liquid carry-over and/or entrainment with steam moisturizing are the reasons for the discrepancies in the water levels of the SG inlet plenum, which seems to be difficult to simulate in the current version of the MARS-KS code. A comparison of critical flow models between the Trapp-Ransom and Henry-Fauske models for all SBLOCA (small break loss of coolant accident) scenarios of the ATLAS (Advanced thermal-hydraulic test loop for accident simulation) facility was performed using the MARS-KS code.

2. Methods and Results

From the review of the reflux condensation behavior in the 6″-CL pipe and 50%-DVI line SBLOCA tests, the well-known sequence of events (SOEs) can be interpreted more precisely, especially when related to the reflux condensation heat transfer. A comparison of SBLOCA SOEs for two different break tests is summarized along with the conventional SOEs, as shown in Figs. 1 and 2, respectively. As can be seen in these figures, there are three parallel phenomena occurring particularly in the SG U-tubes, e.g., the reflux condensation heat transfer, transition regime, and reverse heat transfer. As discussed before, the period of the transition regime is dependent upon the steam flowrate in the loop and U-tubes, e.g., a longer duration of the transition regime as a larger steam flowrate. (In this respect, the reverse heat transfer seems to be affected by the steam flowrate, e.g., a longer delayed reverse heat transfer as a larger steam flowrate.)

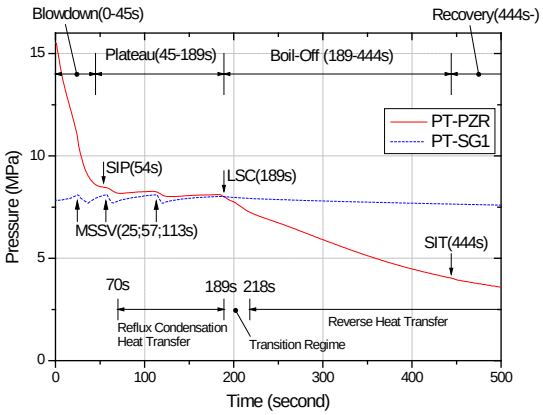


Fig. 1 SOEs for a 6″ CL pipe break SBLOCA test

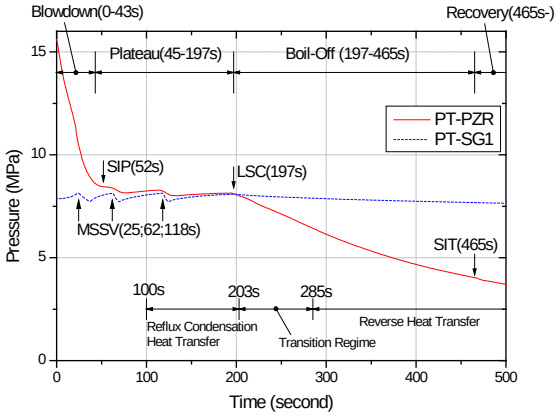
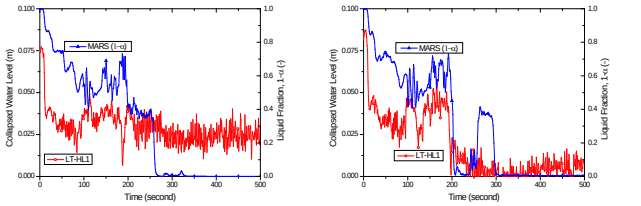


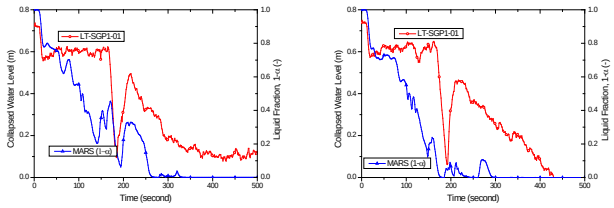
Fig. 2 SOEs for a 50% DVI line break SBLOCA test

Comparisons of the water levels between the ATLAS test data and MARS calculations for the hot leg and SG inlet plenum are shown in Figs. 3-4, respectively. (The water levels for MARS analyses were represented by a liquid fraction, e.g., 1-α, and here α means void fraction.) In the comparison of the hot leg water levels, the 50%-DVI line break test showed quite a good agreement between the test data and calculations, as shown in Fig. 3. Although the 6"-CL pipe break test showed quite a good agreement until 250 s, after that point, different behavior was observed shown in the figure. This seems to be due to the different behavior in the SG inlet plenum. During the reflux condensation heat transfer, the hot leg water level tends to be directly dependent upon the SG inlet plenum water level. The water level depletion in the hot leg after 250 s, as shown in Fig. 3, seemed to be due to the water level depletion in the SG inlet plenum, as can be seen in Fig. 4. (It is noted that the difference of initial water levels between the test data and calculations was due to a measurement error in the test.)



(a) 6"-CL pipe break (b) 50%-DVI line break

Fig. 3 Comparison of hot leg water level between ATLAS test data and MARS calculations



(a) 6"-CL pipe break (b) 50%-DVI line break

Fig. 4 Comparison of SG inlet plenum water level between ATLAS test data and MARS calculations

3. Summary and Conclusions

The behavior of the reflux condensation heat transfer in a hot side SG U-tubes during a CL pipe and a DVI line break in SBLOCA tests of the ATLAS facility was investigated including MARS code calculations. Among the SBLOCA tests, a 6"-CL pipe and 50%-DVI line break SBLOCA test were selected to investigate the behavior of the reflux condensation. A reflux condensation heat transfer seemed to occur from the time the SG U-tubes were half-empty to near the LSC.

It was found that a transition regime existed between the reflux condensation heat transfer and reverse heat transfer. The remaining reflux condensate in SG U-tubes owing to the CCFL phenomenon and a separating effect of liquid carry-over and/or entrainment with steam moisturizing seemed to affect the thermal-hydraulic behavior of the transition regime. It was also found that the steam flowrate of the loop pipings and SG U-tubes seemed to have a strong effect on the duration time of the transition regime, e.g., a larger steam flowrate results in a longer duration.

From a comparison of the reflux condensation behavior between the ATLAS tests and MARS code calculations, overall qualitative agreements were found between the two cases. The largest discrepancies were found in the SG inlet plenum water level between the two cases, and the authors suggest that the combination effects of the remaining reflux condensate in SG U-tubes and a separating effect of liquid carry-over and/or entrainment with steam moisturizing are the reasons for the discrepancies in the water levels of the SG inlet plenum, which seems to be difficult to simulate in the current version of the MARS-KS code.

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