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Analysis of Critical Flow Test Results for the Simulation of Loss of Coolant Accidents

C. K. Park*, H. S. Park, Y. J. Yoon, C. H. Song
Korea Atomic Energy Research Institute (KAERI)
Yuseong P.O. Box 105, Daejeon 305-600, Korea
** ckpark1@kaeri.re.kr, http://theta.kaeri.re.kr*

1. Introduction

ATLAS [1] is an integral test facility which simulates thermal hydraulics during normal operations and accidents in an APR1400 reactor. KAERI has performed a series of critical flow tests to support the simulation of LOCAs at the ATLAS facility. This paper presents an overview of the critical flow test program and an analysis of the test results.

2. Overview of Critical Flow Test Program

The critical flow test program consists of steady state critical flow tests and transient tests. Subcooled water was discharged into a pool through a test section and the critical flow rate and stagnation condition were measured.

2.1 Test Facility

The critical flow tests have been conducted at the B&C test facility [2] at KAERI. The test facility consisted of a pressurizer, a quench tank, a nitrogen supply system, a quick opening valve, and piping and instruments (Figure 1).

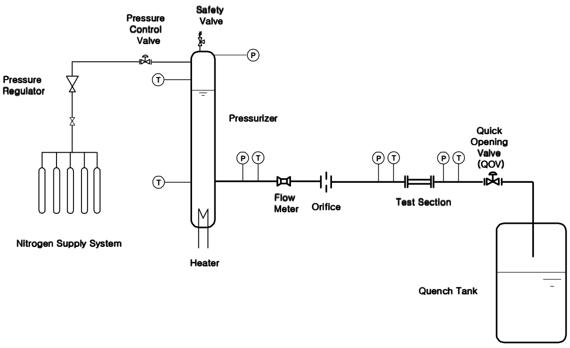

Figure 1. Schematic Diagram Critical Flow Test Facility

The volume of the pressurizer is 0.85 m^3. The main piping consisted of 2” Schedule 160 pipe and it connected the pressurizer and the quench tank. A test section was installed in the middle of the main piping. A nitrogen supply system was used to control the pressure of the pressurizer during the steady state tests. A venturi flow meter was used to measure the volumetric water flow rates, and several pressure and temperatures sensors were installed in the main piping (Figure 1).

Eight different shape test sections have been used for the test program. For the simulation of a small break loss of coolant accident (SBLOCA), 5 short length test sections with a small *L/D* ratio geometry were selected (Table 1) and 3 long nozzle type test sections were used to simulate the steam line (MSLB), feedwater line (FLB), and steam generator tube rupture (SGTR) accidents.

Table 1. Test Section Geometry

T/S No.	Diameter (*mm*)	Length (*mm*)	*L/D* Ratio
1	4	32	8
2	4	92	23
3	8	92	11.5
4	12	12	1
5	12	24	2
6	12	92	7.7
7	20	20	1
8	20	40	2

2.2 Test Matrix

The test program consisted of steady state and transient critical flow tests. The stagnation pressures and subcoolings during the steady state critical flow tests ranged from 2.0 to 6.0 *MPa* and from 0 ^{o}C to 64 ^{o}C, respectively.

Blowdown (transient) tests have been performed to determine the influence of the higher water pressure and temperature conditions not covered in the steady state tests. The test data from the transient tests can be used to assess the critical flow models and the corresponding computer codes. Subcooled water (0 – 20 ^{o}C subcoolings) with 10.0 and 15.5 *MPa* conditions in the pressurizer has been discharged into the quench tank through a test section.

3. Analysis of the Test Results and Discussion

3.1 Test Results of the Long Nozzle Type Test Sections

Test sections 2, 3, and 6 were selected for a simulation of the long nozzle type breaks (MSLB, FLB, SGTR, etc).

The critical flow rates through test section 3 for various pressure and temperature conditions have been compared with an empirical critical flow model [3] in Figure 2. As shown in the figure, the critical flow rates can be correlated by G_{ref} and ΔT^*_{sub}. Here, G_c is the critical mass flux and G_{ref} represents a cold water mass flux through a test section at the same pressure difference condition. And ΔT^*_{sub} is the subcooling divided by the temperature difference between the saturation temperature of the corresponding stagnation pressure and the reference temperature.

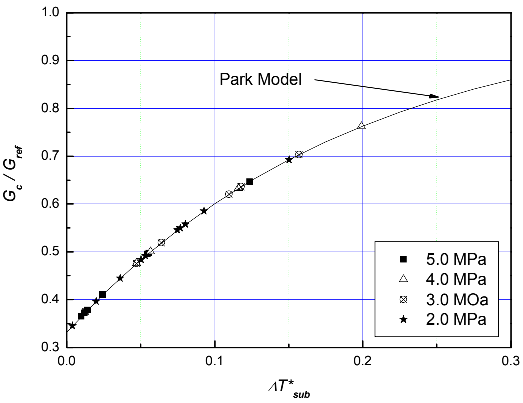

Figure 2. Comparison of Test Data of Test Section 3 with the Empirical Model of Park [3]

This result indicates that long pipe or tube ruptures in the APR1400 reactor can be simulated by a long nozzle (*L/D* > 8) type break nozzle. However, the break nozzles should be designed to have the same G_{ref} of the rupture. This problem can be solved if the two geometries have the same discharge coefficient.

3.2 Test Results of the Short Length Test Sections

The shape of the break geometry of the main piping in the SBLOCA condition is similar to a thick orifice ($L/D \le 2$). To investigate the scaling relationship between the original breaks and the reduced break nozzles, a series of critical flow tests have been performed by using short length test sections with small *L/D* geometries.

Figure 3 compares the test data for test sections 4 and 7 ($L/D = 1$). As seen in the figure, the nondimensional critical mass fluxes (G_c / G_{ref}) do not agree with each other for a given ΔT^*_{sub}. This result indicates that there is no scalability of the critical phenomena between the two geometries. Therefore, to properly simulate a SBLOCA in the APR1400 with the ATLAS facility, the break nozzles should be carefully designed. Since there is few test results for short length test sections with a larger diameter, more experimental studies are needed.

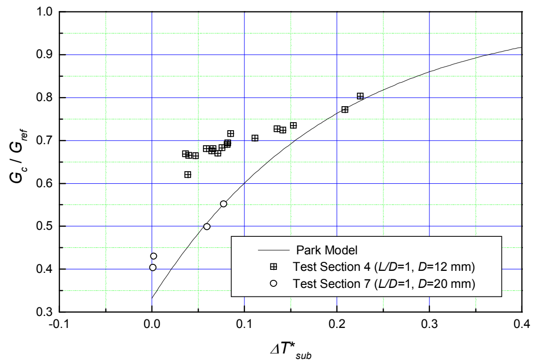

Figure 3. Comparison of Measured Critical Mass Fluxes between Test Sections 4 and 7

4. Conclusion

A series of critical flow tests have been performed to generate the design data of the break nozzles for a simulation of the loss of coolant accidents in an APR1400. The overall test program was presented. The test results show that, for pipe breaks with a large *L/D* test sections, the critical flow rate through the test sections can be correlated by G_{ref} and ΔT^*_{sub} and therefore a long nozzle type geometry can be used for the simulation of a LOCA. For the thick orifice type break nozzle geometry (SBLOCA), there is no scalability of the critical phenomena between the original break and the reduced test section. More experimental studies are needed.

ACKNOWLEDGMENTS

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