Overview of Critical Flow Test Program for the Simulation of Loss of Coolant Accident and Preliminary Analysis of Test Results

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1. Introduction

ATLAS [1] is planned to simulate an APR1400 reactor. KAERI has been performing a series of critical flow tests to generate the design data of break nozzles for the simulation of loss of coolant accidents in the ATLAS. This paper presents an overview of the critical flow test program and a preliminary analysis of the test results. The test description and the test results are discussed, and the critical flow rates calculated by an empirical correlation and MARS code are compared to the measured data.

2. Overview of Critical Flow Test Program

The critical flow test program consists of steady state critical flow tests and blowdown tests. Subcooled water is discharged into a pool through a test section and critical flow rate and stagnation condition are measured.

2.1 Test Facility

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

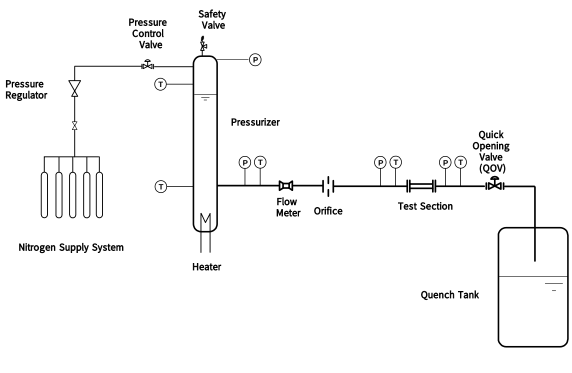

Figure 1. Schematic Diagram Critical Flow Test Facility

The volume of the pressurizer is 0.85 m^3. The main piping consists of 2" Scedule160 pipe and it connects the pressurizer and the quench tank. A test section was installed in the main piping. The 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).

Ten different shape test sections will be used for the tests. For the simulation of a small loss of coolant accident (SBLOCA), 7 test sections with small *L/D* ratio geometry are prepared (Table 1) and 3 long nozzle type test sections for the simulation of steam line, feed waterline, or steam generator tube rupture accident will be tested.

Table 1. Test Section Geometry

T/S No.	Diameter (*mm*)	Length (*mm*)	*L/D* Ratio
1	12	6	0.5
2	12	12	1
3	12	24	2
4	8	16	2
5	8	32	4
6	4	16	4
7	4	32	8
8	4	92	23
9	8	92	11.5
10	12	92	8

2.2 Test Matrix

Steady state critical flow tests are planned to investigate the characteristics of critical flow as a function of the break shape. The range of pressure for the steady state tests is limited by the volume of the nitrogen tanks and critical flow rates. The degree of subcooling is selected to cover the expected the subcoolings during the LOCAs in a nuclear power plant.

Blowdown (transient) tests will be performed to determine the influence of higher water pressure and temperature conditions not covered in the steady state tests. In addition, the data from the transient tests will be used to study the applicability of the steady state data on the prediction of the blowdown flow rate. Subcooled water of 10.0 and 15.5 *MPa* in the pressurizer is to be discharged into the quench tank through a test section.

Table 2. Test Matrix

Test	Pressure (*MPa*)	Subcooling (^oC)
Steady State Test	2.0	0, 2, 7, 12, 27
	3.0	0, 4, 14, 24, 34
	4.0	0, 5, 10, 30, 50
	5.0	0, 4, 14, 34, 64
Blowdown Test	10.0	0, 20, 40, 60
	15.5	0, 20, 40, 60

3. Preliminary Test Results and Discussion

3.1 Steady State Test Results of Test Section No. 9

Steady state critical flow tests for the test section No. 9 have been completed. This test section is proposed for the simulation of long nozzle type breaks. The critical flow rates for various pressure and temperature conditions have been compared to an empirical critical flow model for a subcooled water [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 critical mass flux, G_{ref} represents a cold water mass flux through a test section at the same pressure difference, and ΔT^*_{sub} is the subcooling divided by the temperature difference between the saturation temperature and ambient temperature.

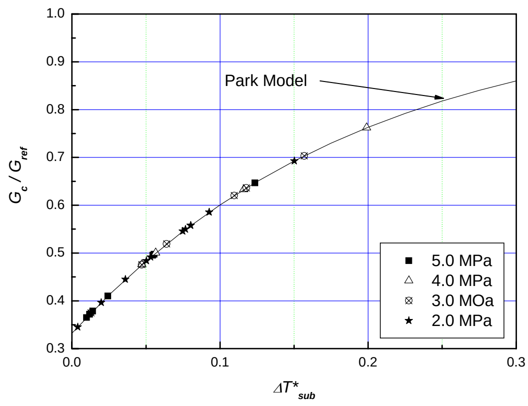

Figure 2. Steady State Critical Flow Rates and Empirical Model of Park [3]

3.2 Transient Test Results of Test Section No. 9

Several transient critical flow tests have been performed to establish a transient test procedure. Figure 3 shows the variation of critical flow rates during a transient test (stagnation pressure and subcooling were 5.7 *MPa* and 9 ^oC, respectively). The critical flow rate increased very rapidly as the valve has opened and it slowly decreased as the pressure decreased.

The empirical model [3] slightly over-predicts the flow rates but the agreement is excellent. MARS code was used to predict the same transient test. As seen in Figure 3, the code generally under-predicts the critical flow rates. Two critical flow models were considered and Henry-Fauske model is slightly better than Trapp-Ransom model.

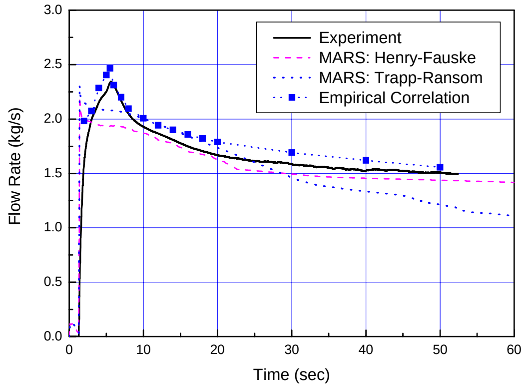

Figure 3. Comparison of Measured Critical Flow Rates to MARS Code and Empirical Model

4. Conclusion

A series of critical flow test are being performed to generate the design data of break nozzles for the simulation of loss of coolant accidents in the ATLAS. The overall test program was presented. The steady state tests for the test section No. 9 were completed and the results show that the critical flow rate through a long pipe can be correlated by G_{ref} and ΔT^*_{sub}. The critical flow rates were calculated using an empirical model and MARS code. Two models can successfully calculate the critical model for a long nozzle type test section.

REFERENCES

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[3] C.K. Park, An Experimental Investigation of Critical Flow Rates of Subcooled Water through Short Pipes with Small Diameters, Ph. D. Thesis, KAIST, Korea, 1997.