An Experimental Investigation of the Thermal Mixing in A Water Pool Using A Simplified I-Sparger

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1. Introduction

The SDVS (Safety Depressurization and Vent System) in the APR1400 is designed to cope with some DBEs (Design Bases Events) and beyond-DBEs related to overpressurization of the RCS (Reactor Coolant System). When the POSRV (Power Operated Safety Relief Valve) is actuated, steam from the pessurizer is discharged to the IRWST(In-containment Refueling Water Storage Tank) through I-spargers. When injected steam is condensed in the pool, it induces water motions and temperature variations in the pool, which effects on the steam jet condensation, vice versa. The B&C(Blowdown and Condensation) loop is a test facility for the thermal mixing through a steam sparger in a water pool. Thermal mixing tests provide basic understanding of the physics and some insights related to efficient pool mixing, dynamic load, and the IRWST design improvement etc.

2. Experimental Apparatus

The test is conducted at the B&C loop[1] with some modifications. The B&C loop consists of a pressurizer (design conditions:17.8MPa;370°C), a quench tank (Diameter:3m;Height:4m) whose size is equivalent to the effective water volume for an I-sparger in the IRWST of the APR1400, a sparger for steam discharge into quench tank. Using the prototype I-sparger, transient thermal mixing tests were performed[2,3].

Tests for the steady thermal mixing were investigated in this paper. To maintain constant blowdown steam flow for a considerable time, a simplified I-sparger having less discharge area than that of the prototype one is designed and control logics are developed to automatically manipulate discharge valves for steam flow control. A shcematic diagmram of the B&C loop for steady flow tests is shown in Fig. 1.

The steady tests consist of concentric and eccentric positions of the sparger in the quench tank. To obtain pool mixing temperature field, Using two types of T/C rigs installed in the tank as shown in Fig. 2, pool mixing temperature data were measured through a data acquisition system. For temperature contours, a linear interpolation is used to obtain temperature values for inner region between adjacent T/Cs. Local temperaures around the sparger also are measured. The test matrix for steady state pool mixing is summarized in Table 1.

3. Concentric Steady Tests

Total 36 tests of the concentric arrangement were performed for steam flux range of 120~440kg/m^2-s with respect to various pool temperatures. Temperature contours for 3 different steam flow conditions, e.g. 100, 200, and 300 kg/m^2-s, are shown in Fig. 3. The result shows that pattens of temperature distributions are distinct each other. For lower flow condition, contours are more non-symmetric betweens rigs and the bouyant effect seems to be dominant. For medium and high flows, contours tend to be symmetric and pool mixing seems to be controlled mainly by injected steam flow.

4. Eccentric Steady Tests

Total 9 tests of the eccentric arrangement were performed for steam flux range of 200~400kg/m^2-s with respect to several pool temperatures. Mixing patters related to injected steam flow rates are similar to those in the concentric tests as mentioned before. In this case, wall effect on the mixing is shown for high steam flow rates, which is reasonable for eccentric arrangement.

5. Conclusion

Pool mixing tests of steady steam flow rates were conducted for concentric and eccentric sparger arrangements. Temperature contours represent that mixing patterns are strongly dependent on steam flow rates, which provide a kind of mixing driving force. For eccentric arrangement, wall effect is shown in mixing patterns

Experimental results will be used in safety analysis and system design of the APR1400. Further tests related to mixing uncertainty at low range of steam flow will be considered.

Acknowlegement

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REFERENCES

[1] C.K. Park et al., Construction of the Blowdown and Condensation Loop, KAERI/TR-941/98, KAERI(1998).

[2] C.H. Song et al., Multi-dimensional Thermal-Hydraulic Phenomena in Advanced Nuclear Reactor Systems: Current Status and Perspective of the R&D Program at KAERI, The 10th Int. Topical Meeting on Nuclear Reactor and Thermal Hydraulics (NURETH-10), Seoul, Korea, Oct. 5-11, 2003

[3] Y.S. Kim et al., Experimental Study of Thermal Mixing of Steam Jet Condensation through an I-Sparger in a Quench Tank, Proceedings of KNS 2003 Fall Conference, Oct. 2003.

Table 1 Test Matrix for Steady State Mixing Tests

Test ID	Pzr. Pressure (MPa)	Pool Water Temp. (°C)	Steam Mass Flux (kg/m^2-s)	Remark
SS-1~3	15.0	20,90,95	120	Simplified I-Sparger at Concentric Position
SS-4~9		20,40,60,70,80,90	200	
SS-10~16		20,40,60,70,80,90,95	260	
SS-17~22		20,40,60,70,80,90	300	
SS-23~29		20,40,60,70,80,90,95	340	
SS-30~33		20,70,90,95	400	
SS-34~36		70,90,95	440	
SS-37~39	15.0	25,60,90	200	Simplified I-Sparger at Eccentric Position
SS-40~42		25,60,90	300	
SS-43~45		25,60,90	400	

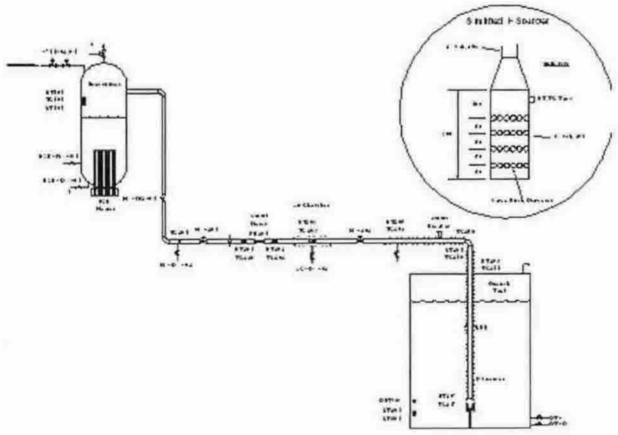


Fig. 1 Schemtic Diagram of B&C Test Facility

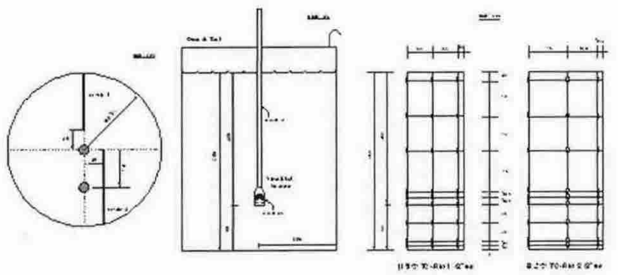
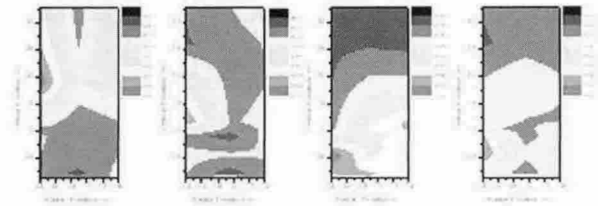
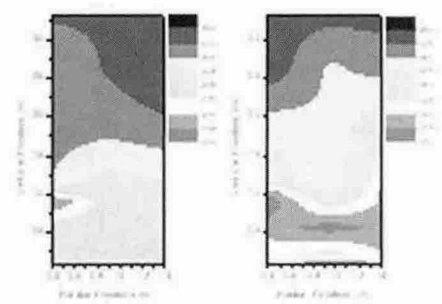


Fig. 2 T/C Arrangements for Temerature Measurements

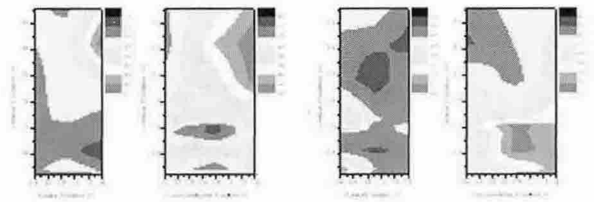


(a)q=200kg/m^2-s (b) q=300kg/m^2-s

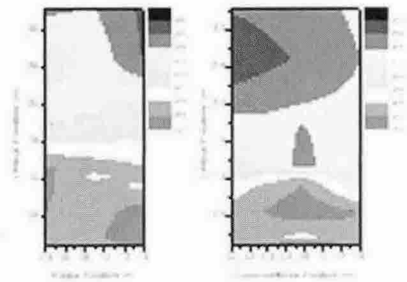


(c) q=400kg/m^2-s

Fig. 3 Contours of Rig-1and 2 for Concentric Tests with T_{pool}=20°C at t=50sec



(a) q=200kg/m^2-s (b) q=300kg/m^2-s



(c) q=400kg/m^2-s

Fig. 4 Contours of Rig-1and 2 for Eccentric Tests with T_{pool}=25°C at t=50sec