Transactions of the Korean Nuclear Society Spring Meeting
Taebaek, Korea, May 26-27, 2011

A Hydraulic Test for SMART Reactor Flow Distribution: Run No. SCOP-E-01

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1. Introduction

In order to analyze the hydraulic design characteristics of a SMART reactor, a test facility named "SCOP" was constructed. The SCOP was designed with a linearly reduced scale of 1/5 as a prototype reactor to preserve the flow distribution characteristics. Among the test matrix, a single test was performed at lower pressure and temperature condition with a similar velocity scale as the SMART reactor, which yields a scaling ratio of 1/20 of Reynolds number when compared with the SMART flow conditions. The distributions of core outlet pressures and core inlet flow rates were measured respectively for an analysis of the reactor thermal margin. To verify the hydraulic design of the reactor, the segmental and overall pressure losses along the main coolant flow paths were measured in the model.

2. Design and Scaling

2.1 Scaling Ratio

In order to preserve the flow characteristics, the SCOP was linearly reduced with a scaling ratio of 1/5 and the flow geometry of the SMART reactor. The scaling relations adapted in the SCOP facilities with respect to the SMART reactor are summarized in Table 1.

Table I: Summary of Parameter Scaling ~~of SCOP~~

	SMART	Scaling Ratio	SCOP
Temperature, ^oC	310	-	60
Pressure, MPa	15	-	0.2
Length Ratio, -	1	l_R	1/5
Height Ratio, -	1	l_R	1/5
Diameter or Width Ratio, -	1	l_R	1/5
Area Ratio, -	1	$\boldsymbol{l_R^2}$	1/25
Volume Ratio, -	1	$\boldsymbol{l_R^3}$	1/125
Aspect Ratio, -	1	-	1.0
Velocity Ratio, -	1	$\boldsymbol{V_R}$	1.0
Mass Flow Ratio, -	1	$\boldsymbol{\rho_R V_R l_R^2}$	1/17.9
Density, kg/m^3	704	$\boldsymbol{\rho_R}$	983.2
Density Ratio	1	$\boldsymbol{\rho_R}$	1.40
Viscosity, Ns/m^2	8.43e-5	$\boldsymbol{\mu_R}$	4.66e-04
Viscosity Ratio, -	1	$\boldsymbol{\mu_R}$	5.53
Core Re Ratio, -	1	$\frac{\rho_R V_R D_R}{\mu_R}$	1/1.12
Ex-Core Re Ratio, -	1	$\frac{\rho_R V_R D_R}{\mu_R}$	1/19.8
DP Ratio, -	1	$\boldsymbol{\rho_R V_R^2}$	1.4

2.2 System Configuration

An overall configuration of the test facilities are shown in Fig. 1. Although the reactor circulation pumps of SMART are running inside the reactor, the SCOP adapts external type pumps with a preservation of flow geometry through the diffuser. Each of the four external loops has a pump, heater, heat exchanger and flow meter. The loop temperature is controlled ~~at each loop~~ by the heater power or heat exchanger secondary flow rate. At the discharge point of the flow meter, the pressure and temperature would be measured by PT transmitter and RTD respectively. The system pressure is controlled by a pressure control tank which is installed above the reactor simulator.

The core inlet flow distribution and outlet pressure distribution, in order to supply data to estimate thermal margins of the reactor were simulated by 57 simulators which conserve the pressure drop of the fuel assemblies. The steam generator, which is supposed to be inside of the reactor, is exposed to the outside of the pressure boundary in order to draw the instrumentation line efficiently. The shell type of the SG primary side was simplified to the cylindrical shaped simulator with a pressure drop adjustment with an orifice inside. The tube inside SG secondary part was neglected in the SCOP facilities since SG secondary is not an interested region. The simulators for 57 fuel assemblies and eight steam generators are calibrated accurately in the separated facilities named "CALIP".

The loop flow, pressure, and temperature would be measured by using vortex flow meters and smart type pressure transmitters and RTDs. The major measured parameters inside the reactor simulators are pressures or differential pressures. In total, 210 points of static pressure and differential pressures were measured with a limited number of differential pressure transmitters by using sequentially operated solenoid valves. The system is operated under a lower constant temperature condition which is measured at two points inside the reactor vessel and at four points downstream of four flowmeters.

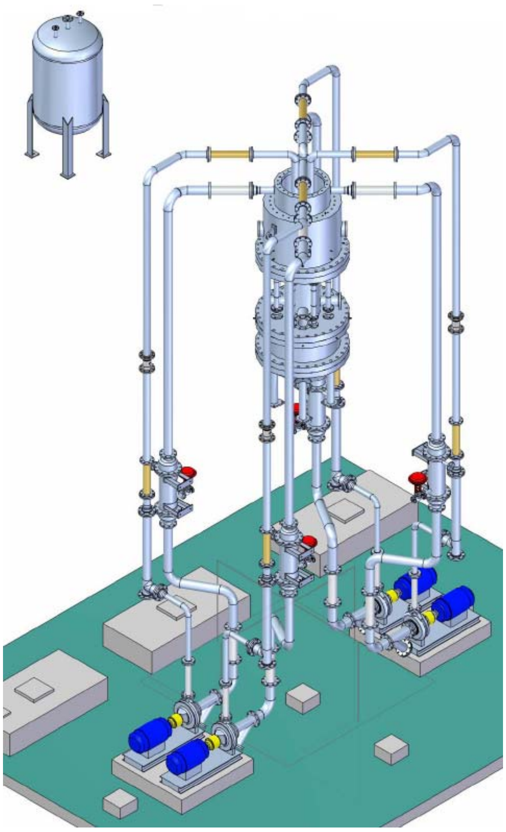

Fig. 1. Bird-eye View of SCOP Test Facility

3. Results

The test matrix consists of 18 steady state flow conditions, which include 9 symmetric and 3 asymmetric flow conditions of 4-loop operation, and 6 asymmetric flow conditions with 3-loop operation simulating a pump failure. As a first step, a single test case, SCOP-E-01, was performed in the current study, which is related to the symmetric flow condition. For the overall thermal hydraulic condition of the test, low and normal temperature conditions were selected. The major flow parameters are summarized in Table 3.

Table 3 Test Condition

Parameter	Values	Comment
Pressure 1, kPa	194.4	Core Shroud
Pressure 2, kPa	151.7	Average Core Exit
Total Differential Pressure, kPa	114.6	
Total Loop Flow, kg/s	116.4	Sum of the Loop Flow
Loop-01, kg/s	29.1	
Loop-02, kg/s	29.1	
Loop-03, kg/s	29.1	
Loop-04, kg/s	29.1	
Temperature, ^{o}C	61.0	At Lower Downcomer

The results set of SCOP-E-01 shows that the core inlet flow distribution covers 95.2% to 124% of the average fuel assembly flow rate. Although more than 10% larger flow rates were measured at the five fuel assemblies, no particulalry lower flow channels were detected. The normalized pressure drop has a range of 98% to 102%, which shows a fairly even distribution, which corresponds to 99.5% to 100.5% in absolute pressure values at core exit. More than 10 sectional pressure drops along the major flow path were measured, each of which again includes 8 measuring points in azimuthal angle.

3. Conclusions

In order to identify the flow and pressure distribution of the SMART reactor, a 1/5 linearly reduced scale of the test facility, SCOP, was designed. Among the test matrixes of the SCOP test program, a test having a uniform flow condition at each loop was performed. The results show that the data set shows good consistency at the measurement of the mass flow rate and pressure drops. The inlet flow distribution showed that the minimum channel flow ratio of SMART is higher than OPR1000 or APR1400. The core exit pressure was found to have a fairly even distribution. The data set of the current study will be contributed toward setting the final statistical results for the SMART reactor flow and pressure distribution. The data will be utilized for an analysis of the safety and system hydraulic performance of the SMART reactor.

Acknowledgement

The authors would like to gratefully acknowledge the financial support of Ministry of Education, Science and Technology

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