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A Counterpart Test of the VISTA-ITL SB-SIS-07 using the FESTA (SMART-ITL) Facility for the SMART Design

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1. Introduction

An integral type reactor, SMART [1], has been developed in KAERI, Korea and it has been licensed from Korean regulatory body in July 2012. The SMART design is characterized by the introduction of simplified and improved safety systems such as PRHRS, and its integral arrangement of the reactor vessel assembly. The integrated reactor vessel assembly consists of a reactor core, eight steam generators, four reactor coolant pumps, and a steam pressurizer, and it has four trains of a secondary system and passive residual heat removal system.

The SMART design was fully assessed through various thermal-hydraulic validation tests during the licensing review process. Among them, a small-scale integral effect test facility of VISTA-ITL [2] was used to investigate various thermal-hydraulic phenomena during design basis accident scenarios such as SBLOCA and CLOF, and the acquired data were used to validate the related thermal-hydraulic models of the safety analysis codes such as MARS-KS [3] and TASS/SMR-S [4]. The VISTA-ITL facility is a reduced height, 1/1310-volume scaled test facility with a single train of a secondary system and PRHRS.

Recently, a large-scale integral effect test facility of FESTA [5] was constructed in KAERI and a set of integral effect tests for design basis accident scenarios is also being performed. The FESTA facility is a full height, 1/49-volume scaled test facility with four trains of a secondary system and PRHRS, and it can be used to investigate the integral performance of the inter-connected components and possible thermal-hydraulic phenomena occurring in the SMART design and to validate its safety for various design basis accidents and broad transient scenarios. The role of FESTA could be extended to examine and verify the normal, abnormal, and emergency operating procedures required during the construction phases of SMART.

It could be called as a counterpart test when similar experiments are performed in differently scaled facilities. It is clear that transient scenarios measured in the experimental rigs cannot be directly extrapolated to the plant conditions. Nevertheless one of the objectives of counter-part tests is to evaluate the influence of the geometric dimensions of the loops upon the evolution of a given accident. [6] In this paper the counterpart test results with both the VISTA-ITL and FESTA facilities will be compared on a SBLOCA scenario of the SIS line break for the SMART design.

2. Test Facilities and Their Scaling

2.1 VISTA-ITL

VISTA-ITL is a small-scale thermal-hydraulic integral effect test facility for the SMART design to investigate the thermal-hydraulic characteristics of the SMART design during major design basis accident (DBA) conditions of a SBLOCA, and is a modified version of an existing VISTA facility [7] based on Ishii and Kataoka's scaling methodology [8]. The major scale ratios are summarized in Table I.

Table I: Comparison of major scaling parameters and their scale ratios

Parameters	Scale Ratio	FESTA	VISTA-ITL
Length, l_{0R}	l_{0R}	1/1	1/2.77
Diameter, d_{0R}	d_{0R}	1/7	1/21.746
Area, a_{0R}	d_{0R}^2	1/49	1/472.9
Volume, V_{0R}	$d_{0R}^2 \cdot l_{0R}$	1/49	1/1310
Time scale	$l_{0R}^{1/2}$	1/1	1/1.664
Velocity	$l_{0R}^{1/2}$	1/1	1/1.664
Power/Volume	$l_{0R}^{-1/2}$	1/1	1.664
Heat flux	$l_{0R}^{-1/2}$	1/1	1.664
Core power	$a_{0R} \cdot l_{0R}^{1/2}$	1/49	1/787
Flow rate	$a_{0R} \cdot l_{0R}^{1/2}$	1/49	1/787
Pump head	l_{0R}	1/1	1/2.77
Pressure drop	l_{0R}	1/1	1/2.77

The scale rations of length and area are based on the elevation difference between the core and steam generator and core flow area, respectively. Design pressure and temperature of the VISTA-ITL are 172 bar, 350°C, respectively, and its major components consist of a primary system, secondary system, PRHRS, auxiliary system, safety injection system, break system, and break measuring system.

2.2 FESTA

SMART-ITL was designed following a three-level scaling methodology consisting of integral scaling, boundary flow scaling, and local phenomena scaling. The major scale ratios are also summarized in Table I. Its height is preserved to the full scale, and its area and volume are scaled down to 1/49 compared with the prototype plant, SMART. The maximum core power is 2.0 MW, which is about 30% of the scaled full power. The design pressure and temperature of SMART-ITL can simulate the maximum operating conditions, that is, 18.0 MPa and 350^{o}C. The major components of the FESTA facility include a primary system, secondary system, PRHRS, auxiliary system, safety injection system, break system, and break measuring system.

3. Counterpart Test Results and Discussions

3.1 Typical SBLOCA Scenario

As a safety injection system (SIS) line is broken in the SMART design, the primary system pressure decreases with the discharge of the coolant through the break. When the primary pressure reaches the low pressurizer pressure (LPP) set-point, the reactor trip signal is generated with a certain delay. As the turbine trip and loss of off-site power (LOOP) are assumed to occur consequently after the reactor trip, the LOOP occurs, the feedwater is not supplied, and the RCP begins to coastdown. With an additional delay, the control rod is inserted. When the PRHRS actuation signal is generated by the low feedwater flowrate after the LPP, the SG is isolated from the turbine by the isolation of the main steam and feedwater isolation valves, and is connected to the PRHRS. The safety injection actuation signal was generated when the RCS pressure reaches below the safety injection actuation signal, and the SI water is injected with a certain time delay. The break nozzle diameter is 50 mm in the SMART design and the scaled-down values are 1.77 and 7.26 mm in the VISTA-ITL and FESTA, respectively. The set-points of LPP and SIAS were P_{LPP} and P_{SIAS}, respectively.

3.2 Comparison of Counterpart Test Results

Figures 1 through 4 show the comparison results of counterpart tests acquired using both the VISTA-ITL and FESTA facilities on a SBLOCA scenario for the SMART design.

As shown in Fig. 1, their pressurizer pressures show similar trends but the decrease rate is a little slower in the VISTA-ITL than in the FESTA. It is possibly affected by the relatively larger heat structure in the VISTA-ITL than in the FESTA, as the small-scale IET facility has the comparatively larger heat structure than the large-scale IET facility.

As shown in Fig. 2, the collapsed core water levels of both VISTA-ITL and FESTA are maintained much higher than their core top levels, and therefore the core rod temperatures does not show any abrupt increase. The geometry difference of the VISTA-ITL from the FESTA is due to its modification from the original VISTA facility, and its geometry is locally distorted. However, their overall thermal-hydraulic behaviors show good agreement. As shown in Figs. 3, their secondary system pressures show very similar trends with each other. In Fig. 4, their feedwater flowrates show very similar trends with each other even though their initial values are different. The initial feedwater flow rate in the VISTA-ITL maintained 100% of the scaled value but that in FESTA maintained 20% of the scaled value.

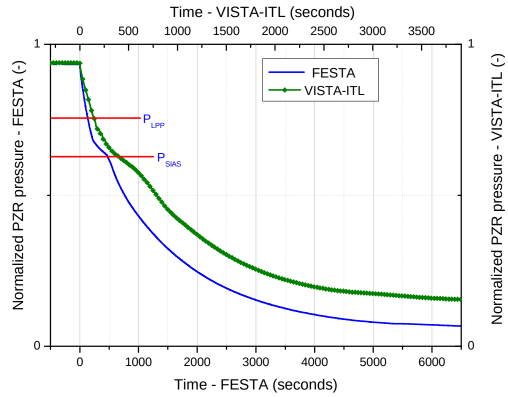

Fig. 1. Comparison of primary pressures during the transient

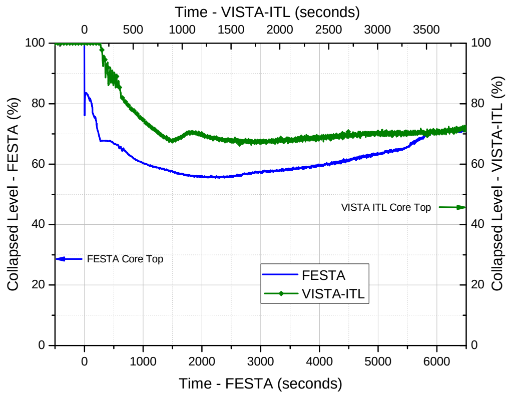

Fig. 2 Comparison of collapsed water level in the core

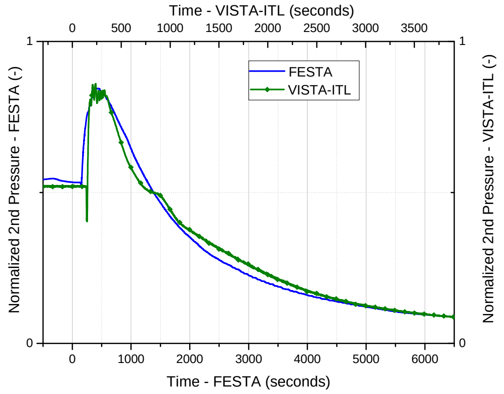

Fig. 3. Comparison of secondary pressures during the transient

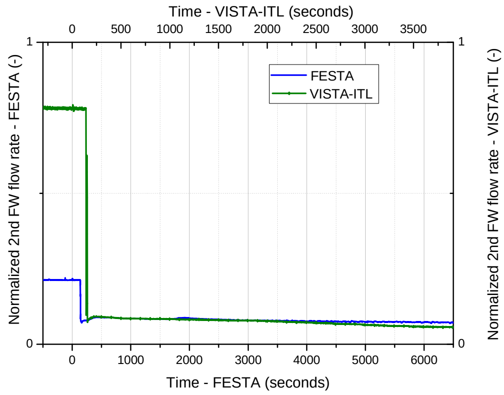

Fig. 4. Comparison of secondary system flow rates during the transient

5. Conclusions

As counter-part tests for an SBLOCA for the SMART design, two integral effect test facilities of VISTA-ITL and FESTA were used, and their results were compared to better understand the phenomena expected to occur in the SMART design. The initial and boundary conditions were appropriately provided for the tests. The overall trend of the major thermal-hydraulic parameters showed a good agreement. Although there are minor differences in the primary system, their agreement was very excellent in the secondary system. Therefore, these two IET facilities of VISTA-ITL and FESTA can be used together to simulate the thermal-hydraulic behavior of the SMART design.

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