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An Integral Effect Test Program for SMART Design using the VISTA ITL Facility

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1. Introduction

An integral effect test (IET) program is being progressed by the Korea Atomic Energy Research Institute (KAERI) using the VISTA integral test loop (VISTA ITL). The VISTA ITL is a modified version of an existing VISTA facility [1] to have the simulation capability of small-break loss of coolant accident (SBLOCA) for the SMART design.

The reference plant of the VISTA ITL is a 330-MW (thermal) class integral type reactor, SMART [2], which is being developed by the KAERI. The SMART reactor is characterized by the introduction of simplified and improved safety systems such as passive residual heat removal system (PRHRS) and its integral arrangement of the reactor vessel assembly, which makes it possible to remove the large-size pipe connections between major components. It excludes the occurrence of large break loss of coolant accidents (LBLOCA), and the SBLOCA is a major concern for safety analysis. Therefore, the VISTA ITL will be used to investigate various thermal-hydraulic phenomena during the SBLOCA. The break flow rate, safety injection flow rate, and thermal-hydraulic behaviors of major components are measured for a typical break size and break locations. The acquired data will be used to validate the related thermal-hydraulic models of the safety analysis code, TASS/SMR [3], which can assess the capability of SMART to cope with the SBLOCA scenario. As it is capable of simulating various transient and accident conditions for the SMART design, it will greatly contribute to the enhancement of its safety and performance.

This paper presents an overview of the VISTA ITL test program for SMART design, and the main focus is on the scientific design characteristics of the VISTA ITL.

2. Scientific Design of the VISTA ITL

2.1 The Existing VISTA Facility

The existing VISTA facility [2] is an integral effect test facility to simulate the primary and secondary systems as well as the major safety-related systems of the SMART-P. The reactor core is simulated by electric heaters with a capacity of 818.75 kW, which is about 120% of the scaled power. The scaled full power is 682.29 kW. Unlike the integrated arrangements of the SMART-P, the VISTA primary components including a reactor vessel, a main coolant pump, a steam generator, and three pressurizers are connected to each other by pipes for an easy installation of the instrumentation and a simple maintenance. The secondary system with a single train of a feed water supply tank (FWST), the feed water line, the steam generator (SG) secondary side, and the steam line is simply designed to remove the primary heat source. A single train of the PRHRS is also installed. Besides these major systems, a make-up water system and a feed water system are installed to control the feed water supply and its temperature.

The VISTA facility is designed to be operated by a combination of manual and automatic operations. The controlled components include the electrical heating rod, the main coolant pump, the feed water control valve, the steam pressure control valve, the FWST heater, and the makeup pump. All the safety related accidents should be initiated and controlled by automatic control logics as they require automatic reactor trip logics to initiate the PRHRS. The corresponding trip logics, tables, and set points are programmed to control a sequence of events.

2.2 Design Concept of VISTA ITL

In formulating the design concept, we have to consider the existing VISTA facility, which is being operated to simulate the SMART-P design. The scale ratios of the existing VISTA facility with respect to SMART are summarized in Table 1. The existing VISTA facility [2] is modified to have the simulation capability of SBLOCA by installing steam pressurizer, safety injection system and break simulation system, etc.

Table 1. Scaling ratios of the existing VISTA facility with respect to SMART and SMART-P

Parameter	SMART	VISTA	Ratio
Power (MWt)	330	0.682	1/483.66
Flow rate scale			
Primary loop (kg/s)	2090	3.54	1/590.99
Secondary loop (kg/s)	160.8	0.25	1/643.20
Length scale (L_R)			
Length of RPV (m)	18.054	3.7	1/4.88
Length of SG (m)	3.7	2	1/1.85
Height (Core-SG) (m)	4.4	1.59	**1/2.77**
Height (SG-PRHRS) (m)	10	3.1	1/3.23

Area scale (A_R)			
Active core (m^2)	1.4005	0.002962	1/472.9
SG primary (m^2)	2.208	0.010097	1/218.68
SG secondary (m^2)	0.339	0.000462	1/733.77
Volume scale - Reference (V_R)			
Volume (m^3)			1/1310
Flowrate scale - Reference (W_R)			
Flowrate (kg/s)			1/787

- Ratio: Ratio of the VISTA ITL and SMART

Finally, we chose the 1/2.77-height and 1/1310-volume-scale design for the SMART, as summarized in Table 1. The reference scale ratios of length and area are based on the elevation difference between core and steam generator centers and the core flow area, respectively. The rationale for adoption of the reduced-height design is similar to the ATLAS design [4]. Table 2 shows the major scaling parameters of the VISTA ITL and its scaling ratios.

Table 2. Major scaling parameters and ratios of the VISTA ITL

Parameters	Scale Ratio	Value
Length, l_{0R}	l_{0R}	1/2.77
Diameter, d_{0R}	d_{0R}	1/21.75
Area, a_{0R}	d_{0R}^2	1/472.9
Volume, V_{0R}	$d_{0R}^2 \cdot l_{0R}$	1/1310
Time scale	$l_{0R}^{1/2}$	1/1.664
Velocity	$l_{0R}^{1/2}$	1/1.664
Power/Volume	$l_{0R}^{-1/2}$	1.664
Heat flux	$l_{0R}^{-1/2}$	1.664
Core power	$a_{0R} \cdot l_{0R}^{1/2}$	1/787
Flow rate	$a_{0R} \cdot l_{0R}^{1/2}$	1/787
Pump head	l_{0R}	1/2.77
Pressure drop	l_{0R}	1/2.77

2.3 Scientific Design of the Systems and Components

The VISTA ITL has been designed following the three-level scaling methodology of Ishii *et al.*[5] which consists of integral scaling, boundary flow scaling, and local phenomena scaling.

Figure 1 shows the schematic diagram of the VISTA ITL facility. The major components of reactor pressure vessel, steam generator, PRHRS and secondary system are preserved, but some changes are given to simulate the SBLOCA behavior of the SMART design. They include the steam pressurizer, safety injection system, steam generator bypass, hot leg, cold leg, PRHRS makeup tank, break simulator and break measuring system. They are designed to match the scaling ratios given in Table 2. The steam pressurizer is installed instead of the self-pressurized pressurizer of the existing VISTA facility. The SG bypass volume is added using a separate vessel and the volumes of the cold and hot legs are scaled down to have scaled down values compared with the SMART.

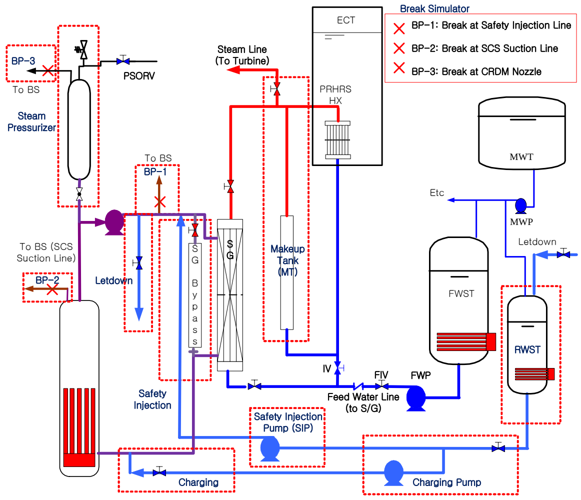

Figure 1. Schematic diagram of the VISTA ITL facility

3. Conclusion

A thermal-hydraulic integral effect test program for the SMART design has been introduced in this paper with discussions of the scientific design characteristics of the VISTA ITL, which is under construction. The VISTA ITL has the following characteristics: 1/2.77-height, 1/1310-volume and full-pressure simulation of the SMART. The VISTA ITL will be used extensively to improve the safety and performance of the SMART design and to validate various thermal-hydraulic analysis codes such as MARS and TASS/SMR.

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