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Development of a phenomena identification ranking table for simulating a station blackout transient of a pressurized water reactor with a thermal-hydraulic integral effect test facility

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ABSTRACT

KAERI (Korea Atomic Energy Research Institute) will launch an OECD/NEA project by utilizing a thermal-hydraulic integral effect test facility, ATLAS (Advanced Thermal-hydraulic Test Loop for Accident Simulation) from April, 2014. In the OECD-ATLAS project, design extension conditions (DECs) such as a station blackout (SBO) and a total loss of feed water (TLOFW) will be experimentally investigated to identify the major thermal-hydraulic phenomena of high risk multiple failure accidents considering magnified safety concerns after the Fukushima accident. A SBO is one of the most important DECs in that without any proper operator actions, a total loss of heat sink leads to core uncover, to core damage, and ultimately a core melt-down scenario under high pressure. Due to this safety importance, a SBO is considered to be a base test item of the OECD-ATLAS project.

In this study, a phenomena identification ranking table (PIRT) has been developed for identifying the major parameters affecting the thermal-hydraulic phenomena in SBO transients. Development of a PIRT for the SBO transients is expected to contribute to making strategy for performing a thermal-hydraulic integral effect test with ATLAS which includes determination of proper test conditions and improvement of measurements. The primary safety criterion (PSC) was determined to be the core mixture level from the expert panel discussion. As for the major components of the nuclear power plant, the rank of the importance and the knowledge level were summarized for each of the three temporal phases. Taking into account the important phenomena from the PIRT result, it can be confirmed that ATLAS has a capability of simulating the major thermal-hydraulic phenomena during a SBO transient as realistically as possible. The present PIRT will be directly used to make strategy for performing a thermal-hydraulic integral effect test with ATLAS in the framework of the OECD-ATLAS project.

1. Introduction

The Fukushima accident attracted international attention to high risk multiple failures whose occurring frequency is low but high core damage is expected from its occurrence. In particular, design extension conditions (DECs) not seriously considered from a design basis are considered as high risk multiple failure accidents as safety concerns regarding severe accidents have magnified after the Fukushima accident. These DECs such as a station blackout (SBO) and a total loss of feed water (TLOFW) need to be re-considered from the viewpoint of the ‘‘defense in depth’’ concept.

Considering the high-lighted safety concerns on the high risk multiple failures, KAERI (Korea Atomic Energy Research Institute) is endeavoring to launch an OECD/NEA project by utilizing a thermal-hydraulic integral effect test facility, ATLAS (Advanced Thermal-hydraulic Test Loop for Accident Simulation) (Beak et al., 2005). In the OECD-ATLAS project, DECs such as a SBO, a TLOFW, and a medium break loss of coolant accident (LOCA) will be experimentally investigated to identify the major thermal-hydraulic phenomena of these high risk multiple failure accidents. A proposed test matrix of the OECD-ATLAS project is summarized in Table 1.

A SBO is one of the most important DECs in that without any proper operator actions, a total loss of heat sink leads to core uncover, to core damage, and ultimately a core melt-down scenario under high pressure. Due to this safety importance, a SBO is

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Table 1
Proposed test matrix of the OECD-ATLAS Project.

Topics	Number of tests	Remarks
A1-Prolonged SBO		
-Asymmetric 2nd cooling	1	Asymmetric FW supply and additional failure (ex. Stuck open of MSSV)
-Asymmetric passive 2nd cooling	1	Asymmetric passive FW supply (ex. PAFS)
A2-SBLOCA during SBO		
-SBO+RCP seal failure	1	Effects of leakage flow rate
-SBO+SGTR	1	TISGTR
A3-TLOFW		
-1ry & 2nd bleed+1ry feed	1	With additional failure such as stuck open POSRV, ATWS, and a SGTR
A4-MBLOCA		
-PZR surge line break (10-inch)	1	Safety injection through cold leg (DVI)
A5-Open items	2	Counterpart test for addressing scaling issues
Total	8	

considered to be a base test item of the OECD-ATLAS project as shown in Table 1.

In order to simulate a SBO transient in a thermal-hydraulic integral effect test as realistically as possible, the expected thermal-hydraulic phenomena should be precisely examined in advance. In this study, a phenomena identification ranking table (PIRT) has been developed with an aim of identifying the major parameters affecting the thermal-hydraulic phenomena in the SBO transients. In general, the PIRT process can be widely used to improve a safety analysis code for a new application and to establish experimental programs and to support the resolution of the licensing issues (Song et al., 2012). Development of a PIRT for a SBO transient is expected to contribute to making strategy for performing a thermal-hydraulic integral effect test with ATLAS which includes determination of proper test conditions and improvement of measurements.

2. Methodology of the PIRT development

By developing a PIRT, major phenomena can be identified for a given set of events and processes. And then the PIRT can serve as guides to make a cost-effective experimental program and code improvement and also to develop the test and validation matrix. The PIRT process used in this study follows the commonly accepted methodology in the area of PIRT development (Wilson and Boyack, 1998). Based on the general process of the PIRT development as shown in Fig. 1, the PIRT has been developed by consensus of Korean expert panelists from industry, regulatory commission, academia, and research institute, etc. In order to facilitate a panel discussion by providing detailed information on the thermal-hydraulic phenomena during a SBO transient, a scoping analysis was performed with a best-estimate safety analysis code, MARS (Bae and Chung, 2009). Based on the scoping analysis results, the major important thermal-hydraulic phenomena were identified and the importance and knowledge levels were ranked for the individual phenomenon in the specific temporal phases.

2.1. Scoping analysis for a SBO transient

In the process of a PIRT development, particular attention should be paid to understanding the thermal-hydraulic phenomena during the designated transients in order to identify the important phenomena and plant response as correctly as possible. In general, with an aim of providing information on the thermal-hydraulic phenomena for the development of a PIRT, scoping analysis is performed using a best-estimate safety analysis code. In this study, a scoping analysis was performed using MARS code for a prolonged SBO transient. The objectives of present scoping analysis can be summarized as follows:

- Determining the temporal phase during a prolonged SBO transient.
- Identifying the major thermal-hydraulic phenomena during a prolonged SBO transient.
- Determining the primary safety criteria (PSC) or Figure of Merit (FOM).
- Providing information to determine the rank of each phenomenon.

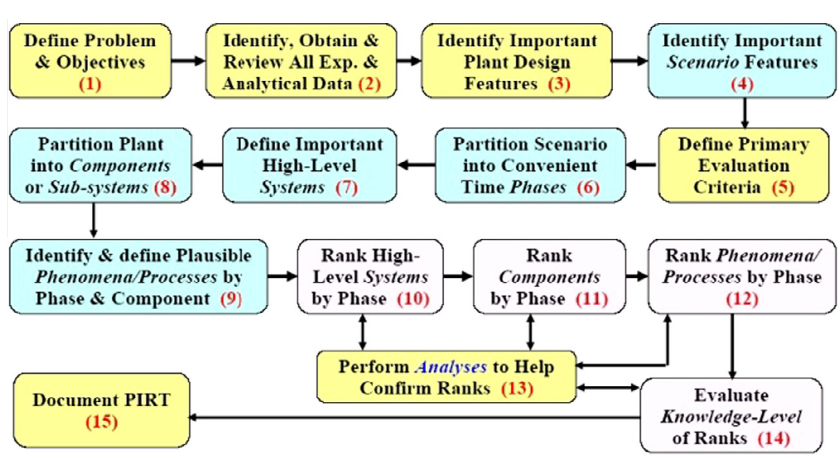

Fig. 1. Typical process of a PIRT development.