Development of the Verification and Validation Matrix for Safety Analysis Code SPACE

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1. Introduction

Korea Electric Power Research Institute (KEPRI) has been developed the safety analysis code, called as SPACE (*S*afety and *P*erformance *A*nalysis *C*od*E* for Nuclear Power Plant), for typical pressurized water reactors (PWR). Current safety analysis codes were conducted from foreign vendors, such as Westinghouse Electric Corp., ABB Combustion Engineering Inc., Kraftwerk Union, *etc*. Considering the conservatism and inflexibility of the foreign code systems, it is difficult to expand the application areas and analysis scopes. To overcome the mentioned problems KEPRI has launched the project to develop the native safety analysis code with Korea Power Engineering Co.(KOPEC), Korea Atomic Energy Research Inst.(KAERI), Korea Nuclear Fuel(KNF), and Korea Hydro & Nuclear Power Co.(KHNP) under the funding of Ministry of Knowledge Economy (MKE). As a result of the project, the demo-version of SPACE has been released in July 2009. As an advance preparation of the next step, KEPRI and colleagues have developed the verification and validation (V&V) matrix for SPACE. To develop the matrix, the preceding studies and experiments were reviewed. After mature consideration, the V&V matrix has been developed and the experiment plans were designed for the next step to compensate the lack of data.

2. PIRT Development

To classify the importance of expected phenomena and associated models in nuclear power plant operation, the phenomena identification and ranking table (PIRT) has been used based on the results of related studies and experiments. In this study, the PIRT were developed based on the importance on safety and the figure of merit (FOM) for the loss-of-coolant accident (LOCA) and the non-LOCA.

2.1 LOC PIRT

The thermo-hydraulic phenomena occurred in LOCA of available PWRs were identified and ranked according to the importance. This PIRT[1] were prepared to confirm the priority of models or correlations required in the new safety analysis code. To develop the PIRT, the 11 panels were participated in the committee and the colleagues of this project were joined as the reviewers. In this PIRT, to include all expected phenomena in PWRs, the cold-leg injection (CLI) and upper plenum injection (UPI) systems were also considered, which were treated as escape items in APR1400. As a result of the work, 64 phenomena were high ranked according to the degree of importance, frequency, and knowledge. And 28 items were selected as the subjects of uncertainty assessment of the code. The details are discussed in the reference 1.

2.2 Non-LOCA PIRT

There are less preceding studies about the non-LOCA PIRT in nuclear industries caused by the lower importance than those of LOCA. In recent studies, however, the main steam-line break (MSLB), steam generator tube rupture (SGTR), and rod ejection accident (REA) were raised as the remarkable design basis accident as the viewpoint of safety and economics. In fact, comparing the LOCA, it has been recognized that the non-LOCA has more actual importance in operation and maintenance of plants furthermore economics. Prior to the PIRT development, the feed-line break (FLB) and complete loss of flow (CLOF) were selected as key accidents addition to three accidents mentioned above (Table 1). The scenarios and related phenomena were derived based on the analysis results of the key accidents. As a result of this work, the 34 phenomena were ranked according to the importance and knowledge [2].

Table 1. Non-LOCA Key Accidents

Category	Accident
Increase in Heat Removal by the Secondary System	MSLB
Decrease in Heat Removal by the Secondary System	FLB
Decrease in Reactor Coolant System Flowrate	CLOF
Reactivity and Power Distribution Anomalies	REA
Decrease in Reactor Coolant Inventory	SGTR

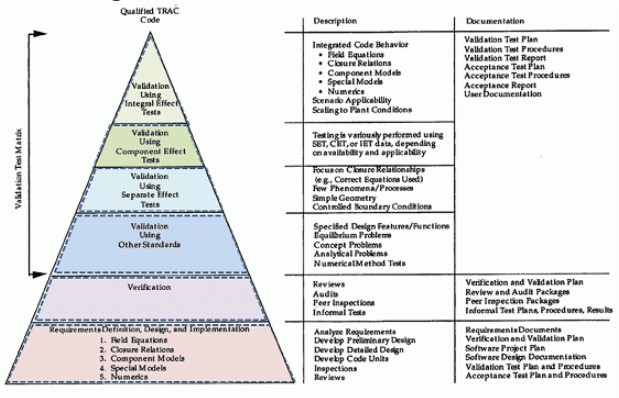
3. Case Study

3.1 V&V Matrix

To examine or estimate the phenomena occurred in nuclear power plants and to develop and verify the code system, various experiments or tests have been executed

and planned. And V&V approaches have been developed to implement the results of the experiments or tests. In the early 1980, Committee on the Safety of Nuclear Installations (CSNI) of OECD/NEA launched the 'Task Group on Status & Assessment of Codes for Transients & ECCS' and planned the International Standard Problems (ISPs). It issued the V&V matrix as a result of the works [3, 4]. In the case of NRC, it developed the V&V matrix for RELAP5 code [5] and TRAC-M [6] based on the long-term code V&V plan (Fig. 1).

Figure 1. TRAC-M Code V&V Plan of NRC



3.2 Experiments & Tests Review

The nuclear thermo-hydraulic experiments and tests were reviewed to build the matrix. There would be various experiments or tests sets in Korea. In this work, however, the MARS Users Group TH Data Bank was reviewed at first. The contents of the bank were compared the V&V matrix references of CSNI or NRC. For the next step, the separate effect tests (SETs) of KAERI were reviewed and matched to PIRT developed in this work. At last, the thermo-hydraulic experiments accomplished by labs of universities in Korea were reviewed. Through these reviews typical SETs and integral effect tests (IETs) were selected to satisfy the PIRTs (Table 2).

Table 2. Typical Selected SETs & IETs

Rank	Phenomena	SETs or IETs
1	Nucleate Boiling	USA-23,KA-24
2	Critical Heat	THTF 3.07.9 B/H/N/W, 3.09.10 I/J/K/L/M/N
3	Minimum Rewet Time	USA-23,KA-34,35,36
4	Film Boiling	USA-23,KA-36,39
…	…	…

4. Matrix Development

4.1 V&V Matrix Based on SET & CET

The V&V matrix to satisfy the PIRTs were developed based on SETs and component effect tests (CETs) to confirm the reliability of the code on the highly ranked phenomena and component models.

4.2 V&V Matrix Based on IET

To verify the feasibility of the code to the transient scenarios, the complementary matrix were developed based on IETs. For this work, the preliminary matrix was prepared considering the scale and availability of data sets and the review process was carried by the colleagues. As a result of this work 8 data sets were selected and 23 sets were reserved as additional candidates. And to compensate the lack of data sets, 3 items were selected as experiment plan [7].

5. Conclusion

The V&V matrix has been developed based on the review of preceding works done by KAERI, CSNI, NRC, *etc*. The matrix reflects the PIRTs and available data sets. As a result of this work, the detail works for the next step projects were planned.

Acknowledgements

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