Lessons learned from the 50th OECD International Standard Problem Based on ATLAS DVI Line Break Test

Ki-Yong Choi*, Won-Pil Baek, Seok Cho, Hyun-Sik Park, Kyoung-Ho Kang, and Yeon-Sik Kim
Korea Atomic Energy Research Institute, (150-1 Deokjin-dong) 1045 Daedeokdaero, Yuseong, Daejeon, 305-353, Korea, Tel:+82-42-868-8928, Fax:+82-42-868-8362, E-mail:kychoi@kaeri.re.kr

1. Introduction

An international standard problem (ISP) exercise, ISP-50 was progressed with the ATLAS integral effect test results on 50% break of the cross section of a Direct Vessel Injection (DVI) nozzle of the APR1400. Lessons learned from this ISP-50 exercise were discussed in this paper, focusing on local 3-D phenomena such as a down-comer mixing, a radial peak cladding temperature (PCT) distribution, and an asymmetric inventory.

2. Outline of the ISP-50

The ATLAS ISP-50 was led by KAERI in collaboration with OECD/NEA and this program aims at; 1) better understanding of thermal-hydraulic phenomena in the upper annulus down-comer region during the DVI injection period, 2) generation of integral effect database for code development and validation, 3) investigation of the possible limitation of the existing best-estimate safety analysis codes. The ISP-50 exercise was progressed in two phases. In the first blind phase, the experimental results were locked except for actual test conditions and procedure until the calculation results were made available for a comparison. In the following open phase 2, the experimental results released to the participants. And a post-test calculation was performed based on the released experimental data. A total of 16 calculations were collected from 11 organizations and most leading thermal-hydraulic safety analysis codes were used, including APROS, ATHLET, KORSAR, MARS-KS, RELAP5/MOD3, CATHARE, and TRACE. Now, the ISP-50 is almost finished and a final integration report submitted to OECD/NEA is waiting for approval.

3. Comparison of Calculation Results

3.1 Comparison of steady state calculations

First, nodalization quantification was performed according to the method used in the BEMUSE Phase II [1]. The primary and the secondary side inventories were considered because they are the most influential factors to affect a transient calculation. Comparison of total volumes of the primary and the secondary system is shown in Fig.1. Compared with the primary inventory, the secondary inventory showed much larger errors.

As for the initial and boundary conditions, most participants showed reasonably good calculations. In particular, better agreements were achieved in the open calculation compared with the blind calculations.

Most calculations were performed by one dimensional modeling. Most participants applied two-dimensional modeling to the down-comer region. When multiple channels were used to take into account the effects of cross flow between two adjacent channels, this modeling can be treated as two-dimensional. The number of azimuthal sections showed a variation from 4 to 8 depending on calculations. As for the reactor pressure vessel, KTH and USNRC applied a 3-D vessel component in order to predict the 3-D behavior of the peak cladding temperature.

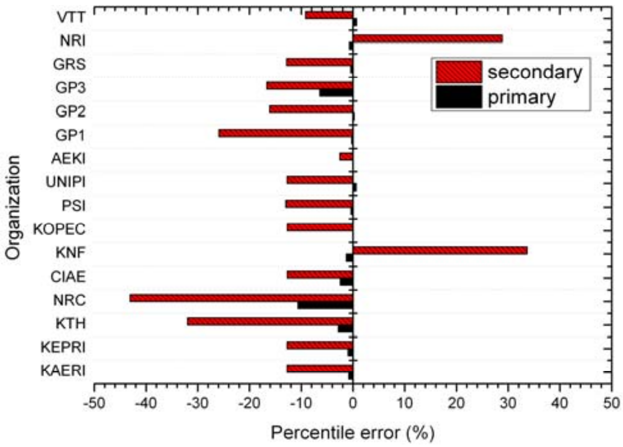

Fig.1 Comparison of inventory distributions

3.2 Comparison of transient calculations

Typical calculations for the primary pressure and the core water level are shown in Fig.2 and Fig.3. The primary pressure was excellently reproduced by most calculation, but the core water level was not properly predicted.

In addition to qualitative comparison, quantitative comparisons were performed based on the FFTBM [2]. Three time frames were taken into account. The first time frame corresponds to the pre-trip phase, the second extends to the post-trip phase, and the third includes the refill phase according to PIRT result. 22 key parameters were selected. The cut-off frequency of 1.0 Hz was used to all variables and the standard weighting factors in the literature were used with the consideration from the measurement uncertainty, the safety relevance and the relevance with respect to primary pressure. The comparison results were summarized in Table 1. Most calculations showed much better prediction accuracy, AA_{tot} were near 0.3, compared with the blind phase.

Most participants showed much improved prediction accuracy in the three time frames in the post-test calculation. Among the selected key parameters, the hot leg flow rate and the SIT flow rate were the most dominant parameters degrading the total prediction accuracy. Besides, as most participants experienced a difficulty in predicting the occurrence order and the timing of the loop seal clearing, the intermediate water level was not properly predicted. On the contrary, the prediction accuracy of the break flow rate was relatively good. It was due to the efforts of the participants to capture the measured flow rate and the primary pressure.

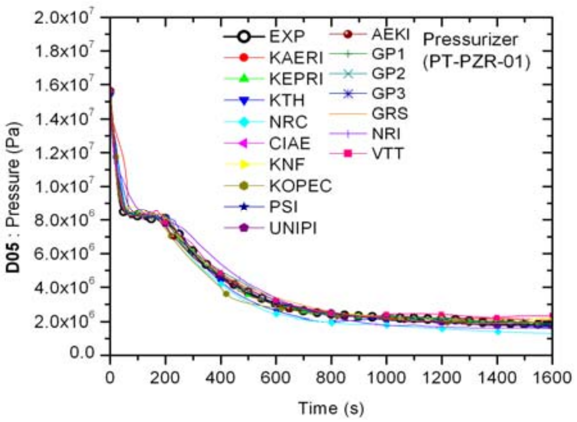

Fig.2 Comparison of primary pressure

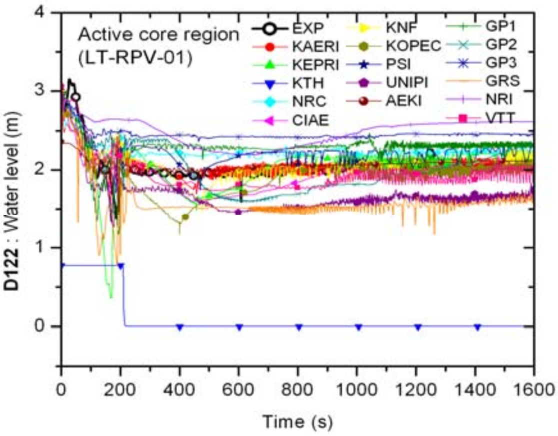

Fig.3 Comparison of core water level

4. Lessons Learned from ISP-50

Azimuthal temperature stratification was predicted by most calculations even in lower down-comer region. It was observed that the cold ECC water was well mixed with the hot inventory. However, this vigorous and instant mixing was not predicted appropriately by almost all participants. This incorrect prediction seems to be due to limitation of the one-dimensional code.

A strong multi-dimensional PCT distribution was also highlighted in this ISP-50 exercise. The maximum PCTs were observed in the side region of the core, not the center region. It has been estimated from three dimensional code calculations that the mass flux distribution over the core cross section, peaking at the center, seems to be the most plausible reason for the maximum PCT in the side region of the core. A negative mass flux at the side region of the core was obtained in the code calculation. Three-dimensional aspect in the core region is worthy of further investigation.

Table 1 Improvement of AA_{tot} between blind and open calculation

Grp.	Partic'nt	Time of interval								
		0 ~ 24 s			0~ 300 s			0 ~ 2000 s		
		N=512			N=1024			N=4096		
		blind	open	I(%)[1]	blind	open	I(%)[1]	blind	open	I(%)[1]
A	KAERI	0.1	0.110	**10.0**	0.25	0.210	**-16.0**	0.333	0.322	**-3.3**
	KEPRI	0.134	0.123	**-8.2**	0.271	0.213	**-21.4**	0.34	0.359	**5.6**
	KTH	0.147	0.137	**-6.8**	0.298	0.241	**-19.1**	0.417	0.353	**-15.3**
	USNRC	0.121	0.076	**-37.2**	0.218	0.162	**-25.7**	0.32	0.348	**8.8**
B	CIAE	0.093	0.092	**-1.1**	0.112	0.135	**20.5**	0.196	0.201	**2.6**
	KNF	0.122	0.097	**-20.5**	0.158	0.159	**0.6**	0.331	0.302	**-8.8**
	KOPEC1	0.403	0.096	**-76.2**	0.385	0.229	**-40.5**	0.672	0.372	**-44.6**
	KOPEC2	0.402	-	-	0.398	-	-	0.634	-	-
	PSI	-	0.091	-	-	0.160	-	-	0.262	-
	UNIPI	0.118	0.067	**-43.2**	0.22	0.187	**-15.0**	0.267	0.278	**4.1**
C	AEKI	-	0.099	-	-	0.243		-	0.265	-
	GP1	0.08	0.078	**-2.5**	0.383	0.192	**-49.9**	0.444	0.324	**-27.0**
	GP2	-	0.115	-	-	0.251	-	-	0.379	-
	GP3	-	0.107	-	-	0.171	-	-	0.352	-
	GP4	0.155	-	-	0.317	-	-	0.546	-	-
D	FORTUM	0.086	-	-	0.249	-	-	0.397	-	-
	GRS	0.102	0.109	**6.9-**	0.222	0.206	**-7.2**	0.411	0.310	**-24.6**
	NRI	0.124	0.127	**2.4**	0.213	0.216	**1.4**	0.405	0.316	**-22.0**
	VTT	0.113	0.090	**-20.4**	0.251	0.211	**-15.9**	0.384	0.298	**-22.4**

[1] Improvement, I is defined by (open-blind)/blind in percentile

5. Conclusions

The ISP-50 is the first-ever international cooperative program focusing on the DVI line break LOCA. In general the present ISP-50 gives a wide and very valuable outlook of the actual status of code performance in that various codes were tested against the same test data. Different results with the same code depending on users, which was observed apparently in the blind calculation phase, confirms that user effects is still one of the major issues connected with the system thermal-hydraulic code applications. A feedback on the CSNI Integral Test Facility validation matrix issued on July 1996 could be envisaged.

Acknowledgements

The authors are grateful to all the international participants for their engagement in the ISP-50 by contributing calculations, meeting, and comments made all along these exercises.

REFERENCES

[1] OECD/NEA, "Re-Analysis of the ISP-13 Exercise, Post Test Analysis of the LOFT L2-5 Test Calculation," BEMUSE PHASE II Report, NEA/CSNI/R(2006)2, 2005.

[2] A. Prosek, F. D'Auria, B. Mavko, "Review of Quantitative Accuracy Assessments with Fast Fourier Transform Based Method (FFTBM)," Nuclear Engineering and Design, 217, 179-206, 2002.