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NUCLEAR ENERGY AGENCY
NUCLEAR SCIENCE COMMITTEE

SUMMARY OF THE SECOND PRESSURISED WATER REACTOR MAIN STEAM LINE BREAK WORKSHOP

22-23 June 1998
CIEMAT
Madrid, Spain

67331

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OECD NUCLEAR ENERGY AGENCY
Nuclear Science Committee

Second Pressurised Water Reactor Main Steam Line Break Workshop

22-23 June 1998 • CIEMAT, Madrid, Spain

Summary

1. Welcome and opening

The meeting was opened by Rafael Caro, Commissioner of the Spanish Nuclear Regulatory Council (CSN), who welcomed participants and introduced the hosting organisations (CSN, CIEMAT and DENIM-UPM). He recalled that this workshop is jointly sponsored by the OECD/NEA Committee on the Safety of Nuclear Installations (CSNI) and the Nuclear Science Committee (NSC) of which he is a long-standing Member.

Participants were then welcomed by Agustín Grau, Director of the CIEMAT's Institute of Energy Studies. He discussed the importance of benchmarks. More specifically, he emphasised that scientific activities must be justified by the direct interest and relevance they have for society. Benchmarks are one of the necessary steps to bridge over theory and models to their applicability.

José Maria Aragonés welcomed participants and mentioned that he is playing three different roles in this workshop: Member of the NSC, organiser of the workshop and participant in the benchmark. He recalled that the Main Steam-Line Break (MSLB) benchmark is the third in a series concerning transient analysis in PWRs commissioned by the NSC. He recalled the co-ordinating roles assured by Herbert Finnemann from Siemens/KWU, Roger Fraikin from Tractebel and Anthony Baratta from PSU for these benchmarks. The first two benchmarks have been widely used for code validation and the respective results have been reported in many international conferences.

Enrico Sartori welcomed participants on behalf of the OECD Nuclear Energy Agency.

The meeting was attended by 40 participants from 24 organisations and 11 countries. The list of participants is attached as Annex 1.

The technical session was introduced by Kostadin Ivanov. The detailed schedule and the papers distributed are listed in Annex 2.

2. Overview of the benchmark and discussion of first exercise

Kostadin Ivanov recalled the scope and objectives of the benchmark study and gave a general overview of ongoing and planned activities. Up to now fourteen participants from ten countries have been assisted in modelling the first exercise and have subsequently submitted their point kinetics (PK) results. The sources of modelling uncertainties were identified and addressed. These sources include the steam generator modelling, steam line nodalisation and steam line modelling for both intact and broken steam generators (SG). Some of the analysis assumptions concerning the mixing modelling, PK model input parameters, etc. were further clarified. It was pointed out that the updated information could be found in the Preliminary Report on First Phase (PRFP), Chapter 2.

3. Participants' presentations on Phase I Results I

Most participants in the benchmark made brief presentations of their models and results of their 'Point Kinetics' (PK) calculations. This session was subdivided in two parts, respectively chaired by Herbert Finnemann and Siegfried Langenbuch. Some of the presentations included results from parametric studies, which demonstrated sensitivity of power response during the MSLB transient to key input parameters and were object of the participants' interest. The following presentations were made:

- PWR MSLB calculation with SMABRE (TRAB-3D)
  (*A. Hämäläinen, E. Kaloinen, R. Kyrki-Rajamäki*)

- OECD/NEA benchmark MSLB in TMI
  (*R. Josefsson*)

- Analyses of the TMI-1 plant response during a MSLB transient using the RELAP5/Mod3.2 with the point kinetic option
  (*V. Sanchez, W. Hering, D. Cacuci, H. Finnemann, D. Knoll*)

- CATHARE point kinetics results
  (*F. Hakenholz, E. Raimond, S. Villalonga*)

- MSLB benchmark point kinetics results with ATHLET
  (*S. Langenbuch, H. Austregesilo, K.D. Schmidt, K. Velkov*)

- THYDE-NEU results for PWR MSLB benchmark (*Y. Asahi*)

- Summary of NETCORP solution for point kinetics benchmark for PWR Main Steam Line Break
  (*Richard Kern – presented by K.N. Ivanov*)

- PWR MSLB benchmark first exercise results with RETRAN-3D
  (*A. Gomez, J. Iglesias*)

- Participation of U-Pisa and Zagreb into the MSLB benchmark
  (*F. D'Auria et al.*)

- Modelling of the TMI Main Steam Line Break with APROS
  (*I. Karppinen, E.K. Puska*)

- OECD PWR MSLB benchmark, Exercise 1: Point kinetics; calculation with ATHLET. Dependence of the results from several parameters
  (*S. Kliem*)

- Sensitivity studies for point kinetics results
  (*D. Panayotov, K.N. Ivanov*)

4. Overall comparison and discussion

This session was chaired by Adi Irani. It was pointed out that this is a preliminary comparison and discussion and can be found in Chapter 3 of the PRFP. The PSU TRAC-PF1/NEM results are used as "reference" in terms of a base solution for comparison and calculation of relative differences for each participants' results for a given parameter. The reasons for this choice were the following:

1) TRAC-PF1 is an advanced thermal-hydraulic system code with a three-dimensional (3-D) vessel model;

2) the TMI TRAC-PF1 model was already verified against the TMI-2 accident data and the TMI-1 RETRAN model;

3) this is the code used by the benchmark team and it is assumed that the PSU TRAC-PF1 input deck reproduces most closely the benchmark specifications.

Since for any benchmark a "reference" solution should be available to compare with it was decided that PSU and GPUN will iterate further comparing very closely the TRAC-PF1 and RETRAN-3D results to come up with a base solution.

The choice of some parameters and the rationale behind them was discussed at some length and A. Irani explained that providing a bounding model that maximises the effects so that results stay conservative drove the choice made. The presentations made are as follows:

- Comparison of results and discussion
  (*T.M. Beam, K.N. Ivanov, A.J. Baratta*)
- Discussion of first phase of benchmark
  (*K.N. Ivanov*)
- MSLB standard problem point kinetics predictions with RETRAN-3D
  (*A. Irani*)

5. Summary of conclusions for the first phase of the benchmark

Based on the discussion and upon the request of participants K.N. Ivanov agreed to provide additional information by 15 July 1998, in order to narrow down the modelling differences and subsequently the deviations in participants' obtained results. This information is designed to finalise the thermal-hydraulic (T-H) data of benchmark specifications, and analysis assumptions for the first exercise.

It was agreed to specify the following additional parameters:

1) area of aspirator junction;

2) pressure drop across tube support plates;

3) characteristics of vent valves;

4) details of steam line;

5) feedwater piping volume details;

6) loss coefficients of feedwater nozzles (details of nozzle);

7) pressure difference in RCS and steamline;

8) comparisons to include exchanged power between steam generators plus integrated water and steam break flow.

The agreed schedule is provided as Annex 3.

6. Overview and discussion of the second and third exercises

K. Ivanov recalled the objective of the second exercise and identified five important steps in performing this simulation. Ten participants from five countries have been assisted up to now in different aspects of modelling the second exercise. The participants' questions were summarised and subsequently addressed in Chapter 4 of the PRFP. Additional information is provided in this Chapter in order to help participants complete and initiate their coupled models. The noticed inconsistencies and typing errors in the specifications were also discussed. The complete definition of the second exercise also includes data provided at the official benchmark **ftp** site. The address is: **tashayar.nuce.psu.edu;** id: **mslb;** password: **MslB97.**

At the above site there are three directories containing the initial and boundary conditions (directory **3D-BC**), cross-section libraries (directory **XS-Lib**) and related information (**Xlib**). The cross-section libraries **nemtab** and **nemtabr** were updated on 26 February 1998 based upon the participants' request and this is the final version. The T-H core initial and transient boundary conditions will be updated in their final version by 1 August 1998.

7. Participants' presentations on the second and third exercises

Chair: José Maria Aragonés

Participants presented their 3-D core neutronics models, core T-H boundary conditions models, neutronics/T-H coupling schemes and spatial mesh overlays as well as preliminary steady-state and transient results they obtained with their codes. Sensitivity studies were performed by some participants on different modelling aspects and analysis assumptions concluded with suggestions for final definition of the second and third exercises. The following presentations were made:

- Plans concerning the second and third exercises
  (*R. Josefsson* – oral presentation)

- Status and summary of NETCORP solution for 3-D kinetics benchmark for PWR Main Steam Line Break
  (*R. Kern – presented by K.N. Ivanov*)

- TMI-I MSLB benchmark problem: Preliminary SAS-DIF3DK results for Exercise 2
  (*H.S. Khalil*)

- Preliminary results for MSLB-benchmark 3-D core calculations with QUABOX/CUBBOX – http://www.grs.de/mslb/main.htm
  (*S. Langenbuch, K.-D. Schmidt, K. Velkov, M. Zimmermann*)

- Multi-dimensional neutron kinetics analysis of the TMI SLB event
  (*A. Irani*)

- Preliminary results for the steady-state and guided-transient Phase 2 cases using SIMTRAN code: Studies on mesh sensitivity
  (*V. Aragonés and J.M. Aragonés*)

- Comparison of the preliminary point kinetics versus 3-D kinetics results obtained with TRAC-PF1/NEM for the EPRI TMI-1 MSLB problem
  (*K.N. Ivanov*)

- [Second PWR MSLB workshop: The FLICA-4-CRONOS-2-CATHARE-2 codes
  (*D. Caruge* – paper distributed)]

8. Review comments and suggestions for the second and third exercises
Chair: K.N. Ivanov

One of the major problems concerns the development of coupled 3D-neutronics/core T-H boundary conditions models by participants. Some of the inlet perturbations (of both liquid temperature and flow rate) should be specified as a fraction of the position across the core inlet. This requires either 3-D modelling of the vessel (TRAC-PF1) or some type of multi-channel model (as used by most participants). Since the initial and transient boundary conditions are provided based on the TRAC-PF1/NEM calculations correct interpretations of radial nodalisation and spatial mesh overlays of the TRAC-PF1/NEM TMI model is of a critical importance in developing compatible parallel channel models by participants. The first step is to convert the 3-D TRAC-PF1 core T-H model in 1-D parallel channel models, in which each neutronic assembly is coupled to a T-H channel. One must take into account that the core region in the TRAC-PF1/NEM model is contained within the three inner rings in the radial plane and uses the flow areas for these rings (p. 50 of PRFP – the total area of the inner rings is 4.560 m^2). One can then calculate the compatible assembly flow area to be used in multi-channel models – 0.02576 m^2). Based on this data participants can develop further coarser parallel channel models if they so desire. For the next step one needs to determine how to use the radial distributions of initial and boundary conditions provided in the specifications and data files. These distributions are extracted from the TRAC-PF1 output for the T-H cells located and numbered in the radial plane according to Figure 4.6 (p. 53 of the PRFP). The transient boundary conditions are extracted at core inlet i.e. for axial layer 3 as shown in Figure 4.5 (p. 52 of the PRFP). Additional participants can use the TRAC-PF1/NEM spatial mesh overlays in the radial plane as shown in Figure 4.10 (p. 57 of the PRFP), which is recommended for the purposes of the second exercise, or can develop their own radial mapping schemes, which is recommended for the third exercise.

The other problem addressed concerns how to define the initial steady state for the modelled MSLB transient. This state has to satisfy two conflicting requirements. The first one is to be compatible with the PK calculation especially in regard to the value of tripped rod worth. In the current licensing bounding methodology this is usually accomplished by adjusting the initial insertion position of Group 7 (and in some cases Group 6 also). However, this adjustment changes the original initial steady state (Hot Full Power (HFP) with Groups 1-6 completely withdrawn from the core (wd) and Group 7 is 90% wd) in terms of radial and axial power distribution. In addition different codes will most probably calculate different initial insertion positions for Group 7 (or Group 6). It was suggested to modify the scram simulation – not all the rods, which are supposed to be inserted during the scram, will be inserted. The PSU benchmark team, based on TRAC-PF1/NEM calculations, will investigate and define a scram simulation model, which matches the required tripped rod worth. In addition to the base scenario an additional scenario with a return to power, predicted with 3-D kinetics models, will be defined by specifying another scram simulation model. For the purposes of detailed steady-state comparisons four steady states will be defined: the initial steady state at Hot Zero Power (1) and HFP conditions (2), and steady states at HZP for both scenarios after scramming (3 and 4).

9. Discussion of the second and third phases of the benchmark

The updated initial and transient boundary conditions together with an additional information will be provided to participants by 1 August 1998. This will finalise the benchmark specifications for the second and third exercises.

Additional issues to be addressed in the second phase are as follows:

1) Initial conditions and transient boundary conditions, including the requested additional parameters.

2) Initial steady state.

3) Decay heat model; it was recommended that participants use the one built in their codes to the extent possible and to preserve compatibility with ANS'79.

4) Define steady states for comparison (table with all the initial conditions).

5) Detailed description of tripped rod worth calculations.

6) Define time of scramming for second exercise.

7) Analyse a problem with a return to power situation.

One issue that needs attention: what do we gain from moving from 1-D to 3-D?

In case participants have any additional comments and suggestions with regard to the second and third exercises' discussion they are encouraged to contact K. Ivanov as soon as possible and no later than 23 July 1998.

The detailed schedule is provided in Annex 3.

10. Further benchmarks.

A further proposal for a benchmark was introduced by K.N. Ivanov and circulated for comments. It concerns the second of the BWR Turbine Trip Transients performed at the Peach Bottom-2 BWR/4 NPP in 1997. The Turbine Trip Transient in a BWR is a pressurisation event in which the coupling between core phenomena and system dynamics plays an important role. Like in the PWR-MSLB benchmark, three phases are defined that would contribute to validating 3D-core/T-H coupling codes for BWRs.

The measured data would be made available for the benchmark.

This benchmark was endorsed by the OECD/NEA NSC at its last meeting.

11. Conclusions of the workshop

E. Sartori concluded that for this series of exercises the term 'benchmark' is an understatement. In fact participants work here at the edge of present developments in the coupling of neutronics and thermal-hydraulics and this important exercise moves ahead its development and leads to a common background understanding of the key issues. In conclusion, it will be of great benefit to the organisations working in this field. He thanked in particular Kostadin Ivanov, Tara Beam and

Anthony Baratta for the great job they have accomplished in co-ordinating this activity and in analysing and reviewing the results submitted. He thanked the hosts for making their facilities available and for the generous treatment of participants.

J.M. Aragonés thanked all the participants for their attendance and contribution to the success of the workshop. He announced the forthcoming *International Conference on Mathematics and Computation, Reactor Physics and Environmental Analysis* **(M&C'99)** to be held from 27-30 September 1999 at the DENIM-UPM, Madrid, Spain. A special session will be devoted to coupled neutronics and thermal-hydraulics. The URL of the website is: http://www.din.upm.es/mc99. Full papers of at most ten pages are due by 15 March 1999. These papers will be reviewed before publication.

Annex 1

OECD Nuclear Energy Agency **Thursday, 24 June 1998**

MSLB2 (Main Steam Line Break Benchmark 2nd Mtg 22-23 June 98, Madrid)

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* Regret not being able to attend.

ANNEX 2

OECD NUCLEAR ENERGY AGENCY
Nuclear Science Committee

Second Pressurised Water Reactor Main Steam Line Break Workshop

22-23 June 1998 ❧ CIEMAT, Madrid, Spain

Final Programme

JUNE 22, 1998

8:30-9:00 Workshop registration and information (*M.L. Marco*)

9:00-9:30 Welcome and opening (*R. Caro, A. Grau, J.M. Aragonés, E. Sartori*)

9:30-9:45 Overview of the benchmark (*T.M. Beam, K.N. Ivanov, A.J. Baratta*) "Preliminary report on first phase (PRFP) of the OECD PWR MSLB benchmark"

9:45-10:00 Discussion of first exercise (*T.M. Beam, K.N. Ivanov, A.J. Baratta*)

10:00-11:00 Participants' presentations on Phase I Results I (*Chair: H. Finnemann*)

- 10:00-10:15 PWR MSLB calculation with SMABRE (TRAB-3D) (*A. Hämäläinen, E. Kaloinen, R. Kyrki-Rajamäki*)
- 10:15-10:30 OECD/NEA benchmark MSLB in TMI (*R. Josefsson*)
- 10:30-10:45 Analyses of the TMI-1 plant response during a MSLB transient using the RELAP5/Mod3.2 with the point kinetic option (*V. Sanchez, W. Hering, D. Cacuci, H. Finnemann, D. Knoll*)
- 10:45-11:00 CATHARE point kinetics results (*F. Hakenholz, E. Raimond, S. Villalonga*)

11:00-11:30 Break

11:30-13:30 Participants' presentations on Phase I Results II (*Chair: S. Langenbuch*)

- 11:30-11:45 MSLB-Benchmark point kinetics results with ATHLET (*S. Langenbuch, H. Austregesilo, K.D. Schmidt, K. Velkov*)

	11:45-12:00	THYDE-NEU Results for PWR MSLB Benchmark (*Y. Asahi*)
	12:00-12:15	Summary of NETCORP solution for point kinetics benchmark for PWR Main Steam Line Break (*Richard Kern – presented by K.N. Ivanov*)
	12:15-12:30	PWR MSLB benchmark first exercise results with RETRAN-3D (*A. Gomez, J. Iglesias*)
	12:30-12:45	Participation of U-Pisa and Zagreb in the MSLB benchmark (*F. D'Auria et al*. – oral presentation)
	12:45-13:00	Modelling of the TMI Main Steam Line Break with APROS (*I. Karppinen, E.K. Puska*)
	13:00-13:15	OECD PWR MSLB benchmark, Exercise 1: Point kinetics; Calculation with ATHLET. Dependence of the results from several parameters (*S. Kliem*)
	13:15-13:30	Sensitivity studies for point kinetics results (*D. Panayotov, K.N. Ivanov*)
13:30-15:00	Lunch	
15:00-17:30	Overall comparison and discussion (*Chair: A. Irani*)	
	15:00-16:00	Comparison of results and discussion (*T.M. Beam, K.N. Ivanov, A.J. Baratta*)
	16:00-17:00	Discussion of first phase of benchmark (*K.N. Ivanov*)
	17:00-17:30	MSLB standard problem point kinetics predictions with RETRAN-3D (*A. Irani*)

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8:30-9:30	Summary of conclusions for the first phase of the benchmark (*K.N. Ivanov*)	
9:30-11:00	Overview and discussion of the second and third exercises (*K.N. Ivanov*)	
11:00-11:30	Break	
11:30-13:30	Participants' presentations on the second and third exercises I (*Chair: J.M. Aragonés*)	
	11:30-11:50	Plans concerning the second and third exercises (*R. Josefsson* – oral presentation)
	11:50-12:10	Status and summary of NETCORP solution for 3-D kinetics benchmark for PWR Main Steam Line Break (*R. Kern – presented by K.N. Ivanov*)
	12:10-12:30	TMI-I MSLB Benchmark Problem: Preliminary SAS-DIF3DK results for Exercise 2 (*H.S. Khalil*)

12:30-12:55 Preliminary results for MSLB benchmark 3-D core calculations with QUABOX/CUBBOX – http://www.grs.de/mslb/main.htm (*S. Langenbuch, K.-D. Schmidt, K. Velkov, M. Zimmermann*)

12:55-13:15 Multi-dimensional neutron kinetics analysis of the TMI SLB event (*A. Irani*)

13:15-13:35 Preliminary results for the steady-state and guided-transient Phase II cases using SIMTRAN code: Studies on mesh sensitivity (*V. Aragonés and J.M. Aragonés*)

13:35-13:55 Comparison of the preliminary point kinetics vs. 3-D kinetics results obtained with TRAC-PF1/NEM for the TMI-1 MSLB problem (*K.N. Ivanov*)

[Second PWR MSLB workshop: The FLICA-4-CRONOS-2-CATHARE-2 Codes (*D. Caruge* – paper distributed)]

14:00-15:15 Lunch

15:15-16:00 Review comments and suggestions for second and third exercises (*K.N. Ivanov*)

16:00-17:00 Discussion of the second and third phases of the benchmark (*K.N. Ivanov*)

17:00-17:30 Summary and conclusions of the workshop (*E. Sartori, J.M. Aragonés*)

ANNEX 3

OECD MSLB Benchmark Schedule

23 June 1998

1.	December 15, 1996	**	Specifications
2.	February 14, 1997	**	Distribution of first draft to potential participants from NSC and CSNI/PWG2 for comments and feedback
3.	March 15, 1997	**	Comments and feedback from NRC, GPUN and NSC and TG-THA, OECD
4.	April 7, 1997	**	Second revised draft of specifications (*This is the version to be distributed by NSC to the OECD participants.*)
5.	April 23-25, 1997	**	First workshop in Washington, D.C. (*Objective: To finalise the second draft taking into account the comments and feedback from NRC, GPUN, NSC and TG-THA.*)
6.	June 9-11, 1997	**	NSC meeting in Paris (*Short presentation on status of the Benchmark at NSC. Review of comments and changes to final draft.*)
7.	October 1, 1997	**	Final draft of specifications
8.	January 15, 1998	**	Deadline for submitting results for the first benchmark exercise (*point kinetics*)
9.	June, 1998	**	First draft of analysis (*point kinetics*)
10.	June 22-23, 1998	**	Second benchmark workshop – Europe (Spain) (*Present point kinetics results and discuss how 3-D results are coming along.*)
11.	July 15 1998		Distribute specification of additional parameters for Phase I and summary of second meeting
12.	August 1, 1998		Distribute final boundary conditions for Phase II
13.	October 1998		Ad-hoc meeting in connection with the Reactor Physics Conference at Long Island, USA
14.	November 1, 1998		Deadline for submitting Phase I results

15.	December 1998	Issue final draft for Phase I results, distribute to participants for comments
16.	January 31, 1999	Deadline for approving final report for Phase I by participants
17.	January 31, 1999	Deadline for submitting Phase II results (3-D kinetics/core T-H boundary model)
18.	March 1999	Issuing of final report of Phase I
19.	March 15-16, 1999	Third meeting at GRS, Garching, Germany for discussing Phase II results
20.	June 1, 1999	Deadline for submitting final results for Phase II
21.	July 1999	Issuing final report of Phase II
22.	September 1999	Ad-hoc meeting in connection with the M&C Conference in Madrid
23.	September 1, 1999	Deadline for submitting results for the third benchmark exercise (*Best-estimate coupled simulation*)
24.	November 1, 1999	Third draft of analyses (*Best-estimate coupled results*)
25.	January 2000	Third benchmark workshop – Paris, France
26.	March 2000	Final draft report for Phase III
27.	June 2000	PWG2/NSC approval/issuance of final report