NUCLEAR SCIENCES COMMITTEE
and
COMMITTEE ON THE SAFETY OF NUCLEAR INSTALLATIONS

Fourth Workshop on the OECD/NRC Boiling Water Reactor Turbine Trip Benchmark (BWR-TT4)

Seoul, Republic of Korea
6th October 2002

Hosted by
PHYSOR-2002 Conference

SUMMARY

Content:

Background and Purpose of the Benchmark Workshop

The fourth workshop for the BWR TT Benchmark was held on 6th October 2002 in Seoul, Republic of Korea. The workshop was hosted by the PHYSOR-2002 Conference held on the same premises. The BWR Turbine Trip (TT) Benchmark is sponsored by the US Nuclear Regulatory Commission (NRC), the OECD, and the Nuclear Engineering Program (NEP) of the Pennsylvania State University. Exelon Nuclear and EPRI, USA, assist in the analysis of the benchmark.

Further background information on this benchmark can be found in the summaries of the previous three workshops held in Philadelphia, Pa, USA [NEA/NSC/DOC(2000)22], PSI Villigen, Switzerland [NEA/NSC/DOC(2001)20], and FZ Rossendorf, Germany [NEA/NSC/DOC(2002)11].

The purpose of this fourth workshop was to present and discuss final results of Phases I and II, and the progress achieved in Phase III of the benchmark, and to take further action for completing the study and for its presentation at a final workshop in January 2003.

Introduction

The meeting was opened by Prof. Kostadin Ivanov from the NEP of the Pennsylvania State University. Dr. Enrico Sartori welcomed participants on behalf of OECD/NEA. Prof. José Maria Aragonés, on behalf of the NEA Nuclear Science Committee (NSC), summarised the discussions and decisions that

took place at the June 2002 NSC meeting relevant to the area of transient benchmarks. He recalled that this benchmark is also sponsored by the NEA Committee on the Safety of Nuclear Installations. The Expert Group of the OECD/NEA on Transient Analysis actually consisted of different expert groups that were organised around specific expertise needed for carrying out the tasks. The reports produced by the benchmarks are used for further validation of codes being developed. He made reference to the second meeting of the EC 5th framework CRISSUE-S initiative (Revisiting Critical Issues In Nuclear Reactor Design/Safety by Using Three-Dimensional (3-D) Neutronics/Thermal-hydraulics Models: State-of-the-Art) held in Paris on 5 and 6 September 2002. He acknowledged the input that several members of the group provided to the benchmarks completed or being completed.

The meeting was attended by 23 participants from 8 countries (see Annex I). The agenda was approved without change (see Annex II).

Session 1: *Chair*: *Akitoshi Hotta*

K. Ivanov presented an update of the current schedule concerning the publications of the **MSLB** (TMI-1 main steam-line break benchmark) and **BWRTT** (Peach Bottom 2 BWR Turbine Trip Transient) benchmarks (see paper [03], Annex 2)

Concerning MSLB, the first three reports have been completed and are published (the third one was actually being printed at the time of the workshop). The full report is available on CD-ROM as it has more than 1000 pages). The last volume concerning the best estimate solution for the Coupled 3-D Core/System Analysis is being finalised and will be printed early 2003.

The fourteen papers presented in a special session at the Milwaukee ANS Annual meeting are being finalised for publication in Nuclear Technology. The status of some papers needs to be verified and some of the reviews are completed. The special issue will be printed in 2003.

Concerning the BWRTT, the PSU team completed the analysis of Phases 1 & 2, but because of time constraints could not complete in time for the workshop the full ACAP analysis for Phase 3 (best estimate 3-D Core/System coupling). It was suggested, and accepted, that the deadline for submitting the final results for Exercise 3 including the extreme scenarios is 15 December 2002.

The next meeting is scheduled for 21-22 January 2003 and will be hosted by the Technical University of Catalonia (UPC) Barcelona, Spain. The workshop Program Committee Chair will be Francesc Reventos, who offered to host it. It will be held in conjunction with the EU 5th framework programme CRISSUE-S workshop scheduled for the following two days.

The first volume (specification) of BWRTT was already published and the other three volumes (final reports of the three exercises) will be finalised following the final workshop scheduled for end of January 2003. A questionnaire for each exercise, aiming at describing the characteristics and options of the codes used, as well as deviations from the benchmark specification, will be circulated to participants. This information will be integrated into the final reports.

Fifteen papers concerning the BWRTT benchmark were presented in three special sessions of Physor-2002 (7-10 October 2002, Seoul). They are listed in Annex 3.

These papers will be published, as well as the final results, in a special issue of Nuclear Science and Engineering.

E. Royer then presented the project concerning the **V1000CT** (VVER-1000 Coolant Transient) benchmark (see also summary of 3rd BWRTT Workshop NEA/NSC/DOC(2002)11). This benchmark is based on reference plant data from Kozloduy-6, VVER-1000 Model V320, and on measured data from Kozloduy-6, and supplementary mixing data from Kalinin-1,2. The international organiser is OECD/NEA (NSC & CSNI): sponsors are: US-DOE and CEA; co-ordinators: Penn State, INRNE and CEA. Collaborations have been established with the AER Working Group D, the KNPP (Kozloduy Nuclear Power Plant), the Moscow Engineering Physics Institute (MEPhI) and the Argonne National Laboratory ANL. Experts from 26 organisations have expressed interest in participating. This benchmark is divided into two parts:

a) Part I: V1000CT-1: Main Coolant Pump (MCP) Switching On, led by PSU. Part one consists of three exercises. Exercise 1 - Point Kinetics Plant Simulation, Exercise 2 - Coupled 3D Kinetics/Core Thermal-Hydraulic Response Evaluation, and Exercise 3 - Best-Estimate Coupled 3D Core/Thermal-Hydraulic Plant Transient Modelling.

b) Part II: V1000CT-2: Coolant Mixing Tests and Main Steam-Line Break (MSLB), led by CEA-INRNE. Part two consists also of three exercises. The first concerns the calculation of VVER-1000 mixing experiments, namely the comparison of CFD and coarse mesh calculations with measured data, using specified vessel boundary conditions and core power distribution. The second exercise concerns VVER-1000 MSLB transients, in particular coupled 3-D neutronics/vessel T-H simulation using specified vessel thermal hydraulic boundary conditions and the comparison of different mixing models (coarse mesh, CFD, mixing matrix). Finally a best-estimate coupled simulation (plant, 3-D vessel and core) is carried out as a third exercise.

The estimated period required for completing the benchmarks and publishing the results is 4.5 years (i.e. including the starter meeting in Rossendorf in May 2002, the final workshop in June 2006 and publication of results at the end of 2006). The final version of the specification for V1000CT-1 will be published by the end of 2002. The first workshop is scheduled for 12-13 May 2003 and will be hosted by CEA in Saclay, France. This workshop will be held in conjunction with the AER (Atomic Energy Research on VVER reactors) WG D annual meeting, also hosted by CEA.

A Web page has been designed for this benchmark and a specific list-server for facilitating communication and archiving queries and answers from participants is being set up. The web page and the list server will be operational by the end of 2002.

K. Ivanov presented the comparison of the final participants' results for Exercise 1. Fifteen results have been submitted and subsequently analysed by the benchmark team (see "Comparative Analysis of the Final Results of Exercise 1", B. Akdeniz, and K. Ivanov [05]). In the following discussion several important issues for the final report on the 1st Exercise were addressed:

(a) It was suggested by Dr. A. Hotta and accepted by the participants that as much as possible experimental data be utilised (for example the total Jet Pump Flow) for comparisons with the participants' results;

(b) It was suggested by E. Royer and accepted by the participants that the measurement uncertainties bands be included on the plots when comparing calculated with measured data;

(c) For the parameters with no reliable measured data available (code-to-code comparisons), it was suggested by Dr. S. Langenbuch, and accepted by the participants, that the benchmark team would generate statistical averages of participants' results and compare them with the Exelon results. These comparisons would be presented at the final benchmark workshop and

participants would then decide on the choice of reference solutions for code-to-code comparisons.

K. Ivanov further presented the comparisons of the final participants' results for Exercise 2. Nineteen results have been submitted and subsequently analysed by the benchmark team (see "Comparative Analysis of the Final Results of Exercise 2", B. Akdeniz, and K. Ivanov [06]). As a result of the discussion, the following decisions were made with regard to the final report of Exercise 2:

(a) The participants' results would be compared for two snapshots – at the time of maximum power before scram and at the end of transient (EOT), i.e. at 5 seconds;

(b) For the second Exercise only code-to-code comparisons would be performed;

(c) The statistical averages of the participants' solutions would be used as reference solutions (assuming that the outliers – results which deviate by more than two standard deviations from the average solution – will be removed from statistical procedures).

Session 2: *Chair: Atsushi Ui*

K. Ivanov presented the comparison of participants' results for Exercise 3 – Best-estimate scenario. Twelve results have been so far submitted and subsequently analysed by the benchmark team (see "Comparative Analysis of the Best-Estimate Scenario's Results of Exercise 3", B. Akdeniz, and K. Ivanov [07]). As a result of the follow-up discussion the following decisions were made:

(a) The requested Maximum Cladding Temperature is to be interpreted as Maximum Nodal Cladding Temperature;

(b) In regard to the comparison of local parameters:

- For the requested absolute parameters, the comparisons will be performed in two clusters - for coarse mesh models (33 channels) and for the fine-mesh models (764 channels)

- For the relative power distributions at the time of the snapshots, two additional clusters of comparisons will be introduced distinguishing the results based on total power and those based on fission power.

K. Ivanov presented the comparison of participants' results for the extreme scenarios of Exercise 3. So far six results have been submitted and analysed by the benchmark team (see "Comparative Analysis of the Extreme Scenario's Results of Exercise 3", B. Akdeniz, and K. Ivanov [08]). The following issues were addressed during the discussion:

(a) Dr. S. Langenbuch pointed out the differences observed in the predicted time histories of reactivity components. Some of the deviations might be coming from the way the reactivity edits are calculated in the different codes;

(b) Dr. A. Hotta explained that for the extreme scenarios the Safety Relief Valves (SRVs) modelling is very important. The time of the valves opening affects the results obtained. Participants have to follow the instructions provided in the benchmark team guidelines for the SRVs modelling and provided by the benchmark team.

(c) Dr. K. Velkov requested the exact location of the SRVs. He proposed an additional extreme scenario – Scenario # 4 – in which no scram, no bypass and no activation of the SRVs will be modelled. This scenario will provide better comparison of physical models of the participants' codes. It was decided by the participants to add Scenario 4 to the Benchmark and the results for Scenario 4 have to be submitted also by 15 December 2002.

Presentations were made by participants on their results and specific sensitivity studies. These presentations gave much insight into the modelling features used with the different codes. Some participants discussed the importance of parameter choice in obtaining best estimate and converged solutions. These presentations are made available to the BWR TT benchmark participants on CD-ROM and are the following:

- ATHLET_QUABOX/CUBBOX Results for the BWR TT Benchmark - Exercise 3 and Extreme Cases S. Langenbuch, K.-D. Schmidt, and K. Velkov. [09]

- "OECD BWR TT Benchmark Exercise 3: Results Obtained with POLCA-T Code": D. Panayotov [10]

- "Exercise 3 calculation of the OECD/NRC BWR TT Benchmark with DYN3D-ATHLET and comparison with Exercise 1", S. Kliem, U. Rohde, U. Grundmann [11]

- Computation of Exercise 3 with CATHARE-CRONOS-FLICA": G. Mignot, B. Rameau, E. Royer [12]

- OECD/NRC Peach Bottom Turbine Trip Test 2 Benchmark: Exercise 3 Results Using RELAP5/ PARCS Coupled Codes. J. Vedovi, A. Bousbia Salah, F. 'Auria and K. Ivanov [13]

Actions and Schedule for BWR-TT

- Deadline for submitting final Phase III results: 15 December 2002 (Participants)

- Prepare final BWRTT workshop for 21-22 January 2003) (PSU, OECD/NEA)

- Invite the participants in the PHYSOR BWR TT Benchmark Special Sessions to submit final revised papers to NSE: 31 December 2002 (PSU, OECD/NEA, NSE Editors)

- Prepare three reports on the final results for Exercises 1,2 and 3 – by the end of 2003 (PSU)

Actions and Schedule for V1000-CT

- Publish specification for Part 1 – by end of 2002 (OECD/NEA)

- Activate V1000CT Web page and List-server (OECD/NEA)

- Prepare 1st Workshop for 12-13 May 2003 (CEA, PSU)

- Contact FZR for presentation of experimental data that could be made available for transient analysis.

- Prepare and publish the specification for Part 2 – by the end of 2003 (CEA, INRNE and OECD/NEA)

Proposal for an International Benchmark based on NUPEC BWR Full Size Bundle Tests

During the workshop, the need to refine models for best estimate calculations based on good quality experimental data was discussed. The needs arising in this respect are not limited to currently available macroscopic approaches but are now extending to next-generation approaches that focus on more microscopic processes. It is suggested that this international benchmark be based on data made available from the NUPEC database. This high quality data would encourage advancement in the insufficiently developed field of the two-phase flow theory. Considering that the present theoretical approach is relatively immature, the benchmark specification needs to be designed so that it would systematically assess and compare the participants' numerical models on the prediction of detailed void distributions and critical powers. Furthermore, the following points need to be borne in mind in establishing the benchmark specification:

1) As for the numerical model of void distributions, there has been no sound theoretical approach that could be applicable for a wide range of geometrical and operating conditions.

2) In the past decade, the experimental and computational technologies have been improved tremendously in studying the two-phase flow structure. In the next decade, it can be expected that mechanistic approaches will be more widely applied for the complicated two-phase fluid phenomena inside fuel bundles.

Development of truly mechanistic models for the critical power prediction is now underway. These models need to include the elementary processes such as the void distributions, the droplet deposit, the liquid film entrainment, etc.

Therefore, a benchmark problem was proposed including both macroscopic and microscopic measurement data. In this context, subchannel grade void fraction data are regarded as macroscopic data. On the other hand, digitised computer graphic images are considered as microscopic data.

A specific proposal will be submitted by the Expert Group for consideration at the OECD/NEA Nuclear Science Committee.

Proceedings of the Workshop

Participants will receive a CD-ROM with this summary containing all papers discussed at the meetings. The CD-ROM also includes all reports from previous workshops which discuss this benchmark.

Annex 1

Fourth Workshop on the BWRTT Benchmark, Seoul, Korea, 6.X.2002

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Annex 2

Workshop Programme

([nn] indicates the paper number as identified on CD-ROM)

List of Participants [01]
Agenda: [02]

Session 1 Chair: Akitoshi Hotta

1:00 - 1:15 p.m. Opening remarks on behalf of NSC/NEA
José-Maria Aragones

1:15 - 1:25 p.m. Update on the PWR MSLB Publications and BWR TT Schedule and Publications: K. Ivanov and E. Sartori [03]

1:25-1:40 p.m. Preparation of VVER-1000 CT Benchmarks :
K.Ivanov, B. Ivanov, N. Kolev, D. Caruge, and E. Royer [04]

1:40 - 2:15 p.m. Comparative Analysis of the Final Results of Exercise 1
B. Akdeniz, and K. Ivanov [05]

2:15 - 2:30 p.m. Discussions of the Report on the Results of Exercise 1

2:30 - 3:05 p.m. Comparative Analysis of the Final Results of Exercise 2
B. Akdeniz, and K. Ivanov [06]

3:05 - 3:20 p.m. Discussions of the Report on the Results of Exercise 2

3:20 - 3:35 p.m. Break

Session 2 Chair: Atsushi Ui

3:35 - 4:10 p.m. Comparative Analysis of the Best-Estimate Scenario's Results of Exercise 3
B. Akdeniz, and K. Ivanov [07]

4:10 - 4:30 p.m. Comparative Analysis of the Extreme Scenario's Results of Exercise 3
B. Akdeniz, and K. Ivanov [08]

4:30 - 4:45 p.m. Discussions of the Report on the Results of Exercise 3

4:45 - 6:00 p.m. Participant's Presentations of Their Results and Sensitivity Studies:

ATHLET_QUABOX/CUBBOX Results for the BWR TT Benchmark - Exercise 3 and Extreme Cases
S. Langenbuch, K.-D. Schmidt, and K. Velkov. [09]

"OECD BWR TT Benchmark Exercise 3: Results Obtained with POLCA-T ode" : D. Panayotov [10]

"Exercise 3 calculation of the OECD/NRC BWR TT Benchmark with DYN3D-ATHLET and comparison with Exercise 1"
S. Kliem, U. Rohde, U. Grundmann [11]

Computation of Exercise 3 with CATHARE-CRONOS-FLICA" : G. Mignot, B. Rameau, E. Royer [12]

OECD/NRC Peach Bottom Turbine Trip Test 2 Benchmark: Exercise 3 Results Using RELAP5/PARCS Coupled Codes
J. Vedovi, A. Bousbia Salah, F. 'Auria and K. Ivanov [13]

Summary of the Workshop [14]

Annex 3

PHYSOR-2002 BWRTT Special Sessions

October 7 (Monday), 4:00 PM ~ 6:05 PM
Session 2C. OECD/NRC BWR TT Benchmark I
Chairs: K. Velkov & T. Downar

Paper	ID	Title	Authors
1	H2a12	OECD/NRC BWR Turbine Trip Transient Benchmark as a Basis for Comprehensive Qualification and Studying Best Estimate Coupled Codes	K. Ivanov, A. Olson, and E. Sartori
2	H0203	APPLICATION OF TRAC/BF1-ENTREE TO OECD /NRC BWR TURBINE TRIP BENCHMARK	A. Hotta and H. Shirai
3	H2a01	Analysis of the Boiling Water Reactor Turbine Trip Benchmark with the Code DYN3D	U. Grundmann and U. Rohde
4	H2a02	Best-Estimate Transient Analysis with SKETCH-INS/TRAC-BF1, Assessment against OECD/NEA BWR Turbine Trip Benchmark	H. Utsuno and F. Kasahara
5	H2a03	Computation of BWR Turbine Trip with CRONOS2 and FLICA4	E. Royer and N. Todorova

October 8 (Tuesday), 8:00 AM ~ 10:05 AM
Session 3C. OECD/NRC BWR TT Benchmark II
Chairs: E. Sartori & E. Royer

Paper	ID	Title	Authors
1	H2a04	Transient 3-D Neutron Kinetic Analysis with CORETRAN of a Core Thermal-Hydraulic Boundary Condition Model - Peach Bottom 2 Turbine Trip Benchmark Phase 2	H. Ferroukhi, W. Barten, and P. Coddington
2	H2a05	BWR Turbine Trip calculations with the CATHARE code	B. Rameau and G. Mignot
3	H2a06	OECD/NRC BWR Turbine Trip Benchmark: Simulation by POLCA-T Code	D. Panayotov
4	H2a07	Transients Modal Analysis Using TRAC-BF1/MODKIN	G. Verdu, R. Miro, D. Ginestar, and V. Vidal
5	H2a08	Analysis Of Exercises 1 and 2 of the OECD/NRC BWR Turbine Trip (TT) Benchmark by the Coupled Code System ATHLET-QUABOX/CUBBOX	S. Langenbuch, K. Schmidt, and K. Velkov

October 8 (Tuesday), 3:30 PM ~ 5:35 PM
Session 6C. OECD/NRC BWR TT Benchmark III
Chairs: U. Grundmann & K. Ivanov

Paper	ID	Title	Authors
1	H2a09	Peach Bottom 2 Turbine Trip Simulation using Best Estimate Coupled 3-D Core and Thermal-Hydraulic System, TRAC-BF1/COS3D	A. Ui and T. Miyaji
2	H2a10	Analysis of the OECD/NRC Turbine Trip Transient Benchmark with the Coupled Neutronic and Thermal-Hydraulics Code TRAC-M/PARCS	D. Lee, T. J. Downar, A. Ulses, B. Akdeniz, and K. N. Ivanov
3	H2a11	"Methodology for optimal grouping of thermohydraulic channels in 3D kinetics	G. Verdu, S. Gallardo, O. Rosello, A. Sanchez, and A. Gomez
4	H2a14	Peach Bottom BWR Turbine Trip Benchmark: PSI Analysis of Exercise 1 using RETRAN-3D	W. Barten, P. Coddington, and H. Ferroukhi
5	H2a17	SIMULATE-3K Peach Bottom Turbine Trip 2 Benchmark Calculations	L. A. Belblidia, G. M. Grandi, and C. Jonsson