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**NUCLEAR SCIENCE COMMITTEE  
and  
COMMITTEE ON THE SAFETY OF NUCLEAR INSTALLATIONS**

**Summary of the OECD/NRC Boiling Water Reactor Turbine  
Trip Benchmark - Fifth Workshop (BWR-TT5)**

**21-22 January 2003  
Barcelona, Spain**

**English - Or. English**

NUCLEAR SCIENCES COMMITTEE  
and  
COMMITTEE ON THE SAFETY OF NUCLEAR INSTALLATIONS

**Fifth Workshop on the OECD/NRC Boiling Water  
Reactor Turbine Trip Benchmark (BWR-TT5)**

21 and 22 January 2003  
Barcelona, Spain

Hosted by

School of Industrial Engineering of Barcelona  
Technical University of Catalonia (UPC), Spain

**SUMMARY**

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**Background and Purpose of the Benchmark Workshop**

The fifth and final workshop for the BWR TT Benchmark was held on 21<sup>st</sup> and 22<sup>nd</sup> January 2003. The workshop was hosted by the School of Industrial Engineering of Barcelona Technical University of Catalonia (UPC), Spain. 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 four workshops held in Philadelphia, Pa, USA [NEA/NSC/DOC(2000)22], PSI Villigen, Switzerland [NEA/NSC/DOC(2001)20], FZ Rossendorf, Germany [NEA/NSC/DOC(2002)11] and Physor-2002 conference at Seoul, Republic of Korea [NEA/NSC/DOC(2002)15].

The purpose of this fifth workshop was to discuss the results from Phase III (best-estimate and extreme scenarios) of the benchmark and to finalize the content and format of the Final Benchmark Comparative Analysis reports on each benchmark exercise to be published next year both as OECD/NEA

and US NRC NUREG documents. Participants in the benchmark were invited to make presentations (15-20 minutes) on their experience in analyzing BWR TT transients and to provide conclusions and recommendations based on the work carried out.

## Introduction

The meeting was opened by Dr. Ferran Puerta Sales, Director of the School of Industrial Engineering of Barcelona (ETSEIB) that was hosting the meeting. He welcomed the participants, introduced the role and the scope of the school, and stressed the importance nuclear engineering has for their teaching programme. Two nuclear power plant sites (Ascó and Vandellós) are located nearby, with which the school has close working contacts. Prof. Reventos chaired the first session and stressed the high relevance of the refined modelling methods which these benchmarks address. Because nuclear engineering is important to the school, it is an appropriate place to host the workshop, allowing also the involvement of the students. Of particular interest is the fact that the reports that issue from this activity will also be NUREG reports. Enrico Sartori welcomed participants on behalf of the OECD/NEA and thanked the local organisers for their hospitality.

The meeting was attended by 31 participants from 8 countries (see Annex I). The agenda was approved with minor adjustments (see Annex II).

### Session 2: *Chair: W. Baten*

Andy Olson presented the proposed content and format of the final report on Exercise 1 as well as the comparative analysis of the final results of Exercise 1. Fourteen participants from eight countries have submitted their results for Exercise 1. Kostadin Ivanov initiated a discussion of the report. The following decisions were taken:

- To verify which results from participants are missing and contact them by e-mail to ensure that all the results have been submitted
- To verify which results deviate considerably from the reference results, and to contact by e-mail the corresponding participant to ensure that the results submitted are the correct ones
- To verify the uncertainty of the measurements of different parameters. Calculated results should be evaluated with a degree of accuracy comparable to the corresponding uncertainty in measured data.
- To verify whether the submitted results include the instrument delay times. In principle, the participants should submit their results as calculated and the benchmark team would correct them for the instrument delay
- For all parameters for which there are no measured data available the Exelon results will be used as reference both because these are based on long specific experience and for convenience.
- To perform an additional comparison and statistical analysis over the first 1.5 s of the transient (in fact it is the most important and significant part) in addition to the comparison of the full 5 seconds of the simulated transient time
- With regard to the applied statistical methods in the framework of the ACAP tool for analyzing time histories the combined Figure of Merit should not be used.
- The reference results should be provided in a separate Appendix. In this Appendix extensive comparison between the Exelon results and measured data, where available, should be provided.
- To include in the final CD ROM all the e-mail messages with questions and answers exchanged among all participants

The following actions and schedule have been accepted by the participants in the Workshop relative to the report of Exercise 1:

- Questionnaire to be sent out by end of February 2003
- Participants provide by end of March 2003 a description of the codes used
- A first draft of the report to be prepared by the end of May 2003, which should be sent to reviewers for comments/ corrections, then distributed to participants for final checking
- The report should be ready for final editing by the end of September 2003
- Publication of report in October/November 2003

**Session 3:** *Chair: A. Olson*

Juswald Vedovi presented the content and format of the final report on Exercise 2 as well as the comparative analysis of the final results of Exercise 2. Eighteen results from fourteen participants, representative of ten countries, have been submitted for Exercise 2. Kostadin Ivanov initiated a discussion of the report as a result of which the participants have taken the following decisions:

- To include the PSU results for Exercise 2, obtained with TRAC-BF1/NEM
- To remove the FZR results related to the 1-D kinetics model
- To check out completeness and correctness of all results provided by participants

The participants in the Workshop have accepted the following actions and schedule for the report on Exercise 2:

- Questionnaire to be sent out by the end of April 2003 to identify sources of discrepancies
- Questionnaire to be returned by participants by the end of May 2003
- Draft report to be prepared by the end of July 2003
- Final editing of the report by the end of November 2003
- Publication of report at the beginning of 2004.

**Session 4:** *Chair: H. Utsuno*

Juswald Vedovi presented the content and format of the final report on Exercise 3 as well as the comparative analysis of the final results of Exercise 3. Fifteen results from thirteen participants, representative of eight countries, have been submitted for Exercise 2. Kostadin Ivanov initiated a discussion of the report as a result of which the participants have taken the following decisions:

- To include a figure comparing the axial power at steady state submitted by participants, as well as at the time of maximum power to show its variation between these two times
- To modify the sentence “at maximum power before scram” into “at maximum power”: for all the figures where it appears
- To show the reactivity results only for the first 1.5 s, in order to visualize better the most important transient interval
- To modify the figure collecting the results for the cladding temperature, and remove inconsistent use of temperature data in Kelvin and in Celsius .
- Two statements should be included into the final report: a) concerning the pressure wave propagation into the vessel; b) the results obtained within the benchmark are very satisfactory.

The participants in the Workshop have accepted the following actions and schedule for the report on Exercise 3:

- Extended Questionnaire to be sent out by the end of June 2003 to identify assumptions made in the best estimate and extreme scenarios, as well as information on the coupling scheme used.
- Participants to return the Questionnaire by end September 2003
- Draft report to be prepared for the end of January 2004 for reviewers
- Final editing of the report during summer 2004
- Publication of the report by the end of 2004.

**Session 5:** *Chair: S. Langenbuch*

Kostadin Ivanov presented a comparative analysis with summary tables and graphs of results submitted for Extreme Scenarios of Exercise 3. Twelve participants from eight countries have submitted their results for the extreme scenarios of Exercise 3. Several participants pointed out the importance of the introduced extreme scenarios, which represent challenges for modelling the existing strong interactions between neutronics and thermal-hydraulics. As a result of the ensuing discussion, the following decisions were made regarding the final report:

- For all the extreme scenarios the presented results should be limited to Pressure, Power, and Reactivity time histories
- For all the figures concerning the pressure response during the extreme scenarios (relating to SRVs set-points) the focus should be on the pressure difference among the participants before reaching the opening set points of the SRVs
- For the extreme scenarios the figures showing SRV flow rate as a function of time will be omitted
- A statement explaining that SRVs and Bypass Valves are sufficient to stabilize the power of the reactor needs to be added
- Identification of reasons why some participants report a higher power peak for extreme scenario 2 instead rather than for extreme scenario 1
- Additional figures for each participant comparing the results among best-estimate and extreme scenarios (i.e. 5 curves) should be added. This applies to Power, Pressure and Reactivity time histories.
- The name of the extreme scenario 3 has to be changed because it is confusing
- The final report should state that the fuel peaks are not challenging for the fuel integrity
- The physical description of all the extreme scenarios, with particular care about extreme scenario # 3 should be included in the final report.
- For extreme scenario # 4, the questionnaire should ask participants to provide both Turbine Flow Rate and Enthalpy
- A description should be included in the report of the range of validity of cross sections and the importance of the enthalpy or energy released to the fuel for safety evaluation. Also should be included is the evaluation of the energy released to the fuel, carried out separately.
- Use for the reactivity the unit  $\$$  instead of  $dk/k$
- Results for extreme scenario # 4 should be compared in two different clusters - results predicting a prompt criticality on the one hand and those with no prompt criticality prediction on the other
- Verification as to why the power peak results are different between exercises # 3 and # 4 for some participants
- Figures related to the SRVs opening should be included as annexes on the CD-ROM version of the report. The paper version of the report should include a table, collecting the opening time for each SRV provided by each participant. This information has to be requested in the questionnaire.

**Closing Session:** *Chair: J. M. Aragonés*

In the final discussion the following recommendations have been made for preparing the final reports of the three exercises:

- In all the radial power distribution figures, the colour display of spectra has to be changed to improve the resolution: (the spectra should be a rainbow range) follow the rainbow sequence.
- Concerning the Figure of Merit, the results of the FFT and Mean Error techniques should not be combined but presented separately
- The background of all pictures should be white for improving the reproduction in the paper version of the report and their clarity
- A table at the beginning of the report, should identify each participant by a unique color used consistently throughout the report.
- Whenever, for some participant, missing or “strange” results were found, this participant should be contacted to avoid any miscommunication
- The benchmark team will contact the participant from JAERI and suggest to omit that solution as the numbers are completely out of the range of all other participants’ results. It is concluded that either there is a lack of compliance with the benchmark specification or the code used has a problem.

B. Karrasch commented that although Peach Bottom 2 does not cover all the safety analyses needed, participation in the BWRTT increases the trustworthiness of their results, as customers can see that results go with the mainstream of the others.

**Actions and Schedule for V1000-CT**

K. Ivanov presented the status and preliminary results of the V1000CT Phase I Benchmark. The following actions have been considered after the discussion among the participants:

- Prepare V1000CT Web site and List-server as well as FTP site to down load data. Data will be available also on CD-ROM
- Prepare 1<sup>st</sup> Workshop for 12-13 May 2003 (CEA, PSU)
- Objectives will be to:
  - Review of the benchmark activities after the Starter Meeting
  - Discussion of participants’ feedback and introduction of modifications to the Benchmark Specifications on Phase 1
  - Presentation and discussion of modeling issues and preliminary results from Exercise 1 of Phase 1
  - Presentation and discussion of modeling issues and preliminary results from Exercise 2 of Phase 1
  - Presentation and discussion of modeling issues and first results of Exercise 3, of Phase 1
  - Discussion of modeling issues of Exercise 1 of Phase 2 – CFD modeling and the available experimental data
  - Defining work plan and schedule, actions to progress in completing the 2 phases
- 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 (BFBT)**

A presentation following first discussions that took place during BWRTT4 of the NUPEC BWR Full Size Bundle Test was made by H. Utsuno of NUPEC. This benchmark aims at substantially refining models for best estimate calculations based on good quality experimental data. 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.

During the discussion it was pointed out that many experiments have been carried out on bundles and it is important to stress what range of parameters the new data cover. Clearly these experiments contain an important innovation, namely the provision of details with a resolution of 0.3 mm. These experiments will be very important for sub-channel methods development, void distributions, and critical power ratio.

Dr. Utsuno pointed out that the full set of data can be made available, but for the benchmark study a set of relevant cases will be selected.

It is recommended that an NSC expert group be established to conduct this benchmark exercise. The first proposal made at BWRTT4 was already mentioned at the NSC Bureau meeting in December 2002. The new proposal will be submitted in the June 2003 NSC meeting for endorsement using a report describing scope, objective and expected impact.

### List of actions

- Penn State to modify the proposal of the benchmark specifications submitted by NUPEC in accordance with the comments of the workshop
- Penn State and NUPEC to finalize the proposal of the benchmark specifications and send it to NEA/OECD well before the June 2003 NSC meeting.
- Penn State to co-ordinate with US NRC the proposal of the benchmark specifications and the US NRC sponsorship of the benchmark activities.
- OECD/NEA to make an official request to NUPEC for releasing the BFBT experimental data.

### **Proceedings of the Workshop**

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

### **Co-operation with CRISSUE-S**

The CRISSUE-S third meeting was held during the days following BWR-TT5, on 23 and 24 January 2003, at the same premises. The co-operation of this working group with CRISSUES-S was endorsed by the OECD/NEA NSC and is supported by the Safety Division. Within this co-operation NEA offers to publish CRISSUE-S Reports as NEA reports, ensuring a wide distribution within the scientific community.

The summary of this meeting has been prepared separately and is available to CRISSUE-S participants.

## Annex 1

### Workshop Programme

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

**OECD/NRC Boiling Water Reactor  
Turbine Trip Benchmark – Fifth Workshop  
(BWR-TT5)**

21 - 22 January 2003

Barcelona, Spain

Hosted by  
School of Industrial Engineering of Barcelona  
Technical University of Catalonia (UPC), Spain  
auditorium Aula Capella

### AGENDA [01]

List of Participants [02]

**Session 1** – Chair: *Francesc Reventós*

- Introduction and Welcome on behalf of UPC - Dr. Ferran Puerta Sales, Prof. Francesc Reventós
- Opening remarks on behalf of OECD/NEA - E. Sartori

**Session 2** – Chair: *W. Barten*

Exercise 1

- Content and Format of the Final Report on EXERCISE 1 and Comparative Analysis of the Final Results of EXERCISE 1 – Bedirhan Akdeniz and Andy Olson [03]
- Discussion of the report – Kostadin Ivanov
- Discussion of schedule for publishing the report – Enrico Sartori

**Session 3** – Chair: *A. Olson*

Exercise 2

- Content and Format of the Final Report on EXERCISE 2 and Comparative Analysis of the Final Results of EXERCISE 2 – Bedirhan Akdeniz and Juswald Vedovi [04]
- Discussion of the report – Kostadin Ivanov
- Discussion of schedule for publishing the report – Enrico Sartori

**Session 4** – Chair: *H. Utsuno*

Exercise 3

- Content and Format of the Final Report on EXERCISE 3 and Comparative Analysis of the Final Results of EXERCISE 3 – B. Akdeniz and J. Vedovi [05]
- Discussion of the report – Kostadin Ivanov
- Discussion of schedule for publishing the report – Enrico Sartori



*Presentation of results by participants*

- W. Barten, H. Ferroukhi, P. Coddington: OECD/NEA and USNRC BWR Turbine Trip Benchmark: PSI Results of the Dynamical Response of the System and the Three-dimensional Core in Phase III using RETRAN-3D1. [06]
- H. Utsuno: OECD/NRC BWR Turbine Trip Benchmark Analysis with SKETCH-INS/TRAC-BF1, Best-Estimate Scenario of Exercise 3 [07]
- D. Panayotov, Ulf Bredolt: OECD BWR TT Benchmark Exercise 3: POLCA-T Code - Best Estimate Results (Simulation of PB2 TT2 test). [08]
- Discussion of Results

**Session 5** – Chair: *S. Langenbuch*

## Exercise 3

- Comparative Analysis with Summary Tables & Graphs of results submitted for **Extreme Scenarios** of Exercise 3 - Bedirhan Akdeniz and Kostadin Ivanov

*Presentation of results by participants*

- S. Langenbuch, K.-D. Schmidt, K. Velkov: Results for the extreme cases of BWR TT by ATHLET-QUABOX/CUBBOX [09]
- B. Karrasch, R. Velten: S-RELAP5/RAMONA5 (3D) Results for Exercise 3 and the four Extreme Scenarios [10]
- W. Barten, H. Ferroukhi, P. Coddington: OECD/NEA and USNRC BWR Turbine Trip Benchmark: PSI First Results of the Extreme Scenarios of Phase III using RETRAN-3D [11]
- Atusi Ui and Takamasa Miyaji: Peach Bottom 2 Turbine Trip Benchmark using TRAC-BF1/COS3D, Extreme Scenarios of Exercise 3 [12]
- H. Utsuno: OECD/NRC BWR Turbine Trip Benchmark Analysis with SKETCH-INS/TRAC-BF1, Extreme Scenario of Exercise 3 [13]
- D. Panayotov, Ulf Bredolt: OECD BWR TT Benchmark Exercise 3: POLCA-T Code Results of Extreme Cases.[14]
- D. J. Lee, T. Downar, T. Ulses, B. Akdeniz and K. Ivanov: TRAC-M/PARCS Results and Sensitivity Studies [15]
- B. Salah, J. Vedovi, G. Galassi and F. D'Auria: BWR TT Activities at University of Pisa with main connection to Phase III and the Extreme Scenarios [16]
- Mie Azuma and Akitoshi Hotta: Sensitivity studies in Extreme Scenarios Using TRAC/BF1 and Entree" [17]
- F. D'Auria, A. Petruzzi, K. Ivanov: CIAU Method for Uncertainty Evaluation I 3D TH/N coupled Codes [18]
- Discussion of Results

**Closing Session** – *José-Maria Aragonés*

- Status of next series of benchmarks
- B. Ivanov, K. Ivanov: Status of Preliminary Results of the V1000CT Phase I Benchmark [19],
- H. Utsuno, and K. Ivanov: Proposal of International Benchmark based on NUPEC BWR Full-Size Bundle Tests (BFBT) [20]
- E. Sartori, Proposed Schedule for BFBT
- Conclusion and Closing Remarks

**This summary [21]**

**Annex 2**

**Fifth Workshop on the BWRTT Benchmark,  
Barcelona, 21-22 January 2003**

**List of Participants**

**5th BWRTT Workshop  
21-22 January 2003**

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31 participants from 8 countries  
17 from academia (professors and students), 7 from industry and utilities, 6 from research/safety agencies