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ORGANISATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT

NUCLEAR ENERGY AGENCY

Nuclear Science Committee

and

Committee on the Safety of Nuclear Installations

Summary of the Second Workshop on

OECD/NRC BOILING WATER REACTOR TURBINE TRIP BENCHMARK

15-16 October 2001
Paul Scherrer Institute, Villigen, Switzerland

Introduction

The meeting was opened by Dr. Paul Coddington from PSI, the Chairman of the Organising and Program Committee of the Workshop. He chaired the Introductory Session 1. The deputy director of the PSI Nuclear Energy Department, Dr. Konstantin Foskolos, welcomed the participants on the behalf of PSI and gave an overview of the nuclear research performed at PSI. The participants introduced themselves and the organisations they represented. 26 participants representing 15 organisations from 8 countries attended the 2nd Workshop. The actual number of participants having submitted results and presentations for the Second Workshop was larger than the number of attendees. The list of participants is provided in Annex 1. Some participants (denoted by stars) had to cancel their trip but they submitted presentations. The agenda, provided as Annex 2, was reviewed and adopted after minor changes.

Prof. José-María Aragonés summarised the on-going and planned activities in the area of three-dimensional (3D) coupled transient simulations, promoted by NSC/NEA/OECD. Prof. K. Ivanov presented the new VVER-1000 coupled code benchmark problem. It is based on real plant - Kozloduy NPP, and there are measured data for initial steady state and transient, based on the data collected during a test performed at Unit 6. The benchmark has already been endorsed by NSC as an International OECD/DOE benchmark problem and a first draft Specification has been prepared by PSU under the DOE sponsorship. This benchmark is at the stage of identifying the interested parties, including those from central and eastern European countries operating VVER reactors. These countries have their research forum, called AER, and this benchmark could be the first real scientific co-operative project between NEA, OECD and AER. In order to facilitate a possible agreement on this, it was suggested that the draft of the specification is sent to AER members for consideration and discussion AER at its next meeting to be held mid-May 2002 in Moscow. By the time of the next BWRTT meeting in Rossendorf, AER is expected to provide a statement as to whether or not they wish to co-organise the benchmark. Documents concerning the final approval of the benchmark and the participation of AER will be submitted to the NSC at its June 2002 meeting. The contact at AER is Pertti Siltanen from FORTUM, Finland.

On behalf of Prof. T. Downar, K. Ivanov presented the proposal by Purdue University for a control rod ejection transient benchmark for a partially MOX fuelled PWR. Further K. Ivanov presented information about the NRC activities concerning the coupled code TRAC-M/PARCS development and validation.

K. Ivanov reviewed the OECD/NRC BWR TT benchmark activities after the 1st Benchmark Workshop last year in Philadelphia. The Specification has been published as an NEA/OECD report, and a FAQ e-mail discussion forum has been established through the OECD server; a benchmark Web page and ftp site have also been established. The benchmark team, in developing their models and performing the benchmark calculations, has assisted participants. Dr. E, Sartori provided information about the Special Session being organised at PHYSOR 2002 in Seoul, Korea, on Numerical and Computational Issues of Coupled 3D Kinetics/Thermal-Hydraulic System Code Simulations: OECD/NRC BWR TT benchmark. The participants intending to contribute papers were identified. The deadline for abstracts is January 15, 2002 and the deadline for full papers is end of May 2002. K. Velkov will be co-ordinating the participation from Europe, K, Ivanov from USA and Asia and E. Sartori will be supervising the organisation of the Special Session.

Technical Sessions

Dr. K. Velkov from GRS and Andy Olson from EXELON chaired Session 2 on the Phase 1 of the Benchmark. In her presentation Mónica Vela García from PSU presented a summary of the submitted participants' results for the First Exercise in the form of tables and graphs. The comparative analysis was made based on the assumptions that where measured data is available it was chosen as reference predictions and where code-to-code results were compared at this point, the EXELON RETRAN results are considered as reference results. This assumption is made only for these preliminary comparisons since the EXELON results were already extensively verified with the measured data while most of the participants are still developing and tuning their models. However, in the final analysis to be published, for the code-to-code result comparisons, the reference solution will be generated using statistical and/or ACAP methods. ACAP is an automated assessment computer tool developed by ARL, PSU for NRC. It is especially advanced for analysis of time history data and code-to-data comparisons. Eleven participants from seven countries have submitted their results for the first exercise so far. The misunderstandings in the format of submitted results were addressed. Andy Olson from EXELON discussed the observed modelling issues, causing deviations in the participants' solutions for the first exercise. He made an analysis in depth of the key parameters for analysing BWR TT events as pressure response (which is a function of the steam line model, steam bypass model, non-equilibrium effects modelling at steam-water surfaces and core exit/separator region modelling) and core flow response (which is a function of jet pump model, and separator modelling). Further the participants presented their models, the obtained results and performed parametric variations for the first exercise (papers 10 through 17, see Annex 2). Such sensitivity studies included - but were not limited - to the effect mass flow through the bypass valve, the impact of the direct heating model, steam line and steam bypass system modelling parameters (including the detail of nodalisation and the turbine bypass valve flow area), nodalisation of the reactor vessel, and jet pump modelling.

In the following discussion of the results for Exercise 1, several issues were raised by the participants and addressed by Andy Olson:

(a) Bypass Valve (BV) modelling – the BV position versus time is provided as a part of the Specification. The question about the resolution of measurement was raised. A more detailed steam bypass system description and bypass valve data will be provided to the participants by the benchmark team. It was designed as a linear system and the linearisation approach will be described also.

(b) Core axial pressure drop – since there is no direct measurement it is important to clarify how this quantity is defined and which axial elevations are used. Two values for the core pressure drop are given in the Specifications – measured (from P1) and calculated. The pressures in the lower and upper plenums and the dome (mid-points of the volumes) are used. The difference comes from the different elevations used in the upper part of the reactor. There is a correlation, provided by the vendor, for the pressure drop across the separator.

(c) Axial void distribution – it is important to know where the values are calculated for different participants. For EXELON these are the node centre values.

(d) For jet pump modelling during steady state – a constant rotational pump speed should be considered. The inertia component for the jet pump model will be provided.

(e) Results for maximum dome pressure increase during the transient to be analysed instead of maximum dome pressure.

(f) The comparison of results to the measured data – there are time delays for the pressure measurements. The benchmark team will include them when comparing the submitted results with the measured data.

(g) Additional design information to be provided to participants include the initial pressure distribution in the reactor and additional data on bypass steam modelling.

Dr. Akitoshi Hotta from TEPSYS chaired Session 3 on Phase 2 of the Benchmark. Mónica Vela García from PSU presented the summary of participants' results submitted for the Second Exercise in a form of tables and graphs. Eight participants from five countries submitted results for the second phase and these results were compared and analysed. The comparisons still did not show very good agreement for HZP conditions, which is expected, but there are indications that the neutronics models have been developed and initialised well. Larger deviations were observed for the initial HFP conditions where the thermal-hydraulic feedback plays an important role. For example, discrepancies can be seen for the axial void fraction distribution predictions at the HFP steady state. It is accepted that K_{eff} is equal to 1.000 for the initial steady-state conditions. The deviations are larger for the transient predictions – most of the participants overpredict the power peak during the transient. K. Ivanov presented a discussion of the Phase 2 including the modelling issues identified in communication with the participants. These modelling issues included ADF modelling, correction of the moderator feedback mechanism to account for bypass density, core boundary condition model and provided boundary conditions, etc. Further the participants in their presentations discussed their models, coupling schemes and preliminary results as well as the results from different sensitivity studies. These studies included the role of timing of the scram in TT transient simulations, time-step size, orifice throttling, void correlation, inlet temperature/sub-cooling, cladding heat capacity, direct heat fraction and model, gas gap conductance, drift flux models, Doppler temperature model, number of thermal-hydraulic channels and spatial mapping schemes, impact of ADFs, and core pressure increase.

Also the participants requested additional data for each of the three types of thermal-hydraulic channels (hydraulic diameter at the channel inlet, outlet and along the axial direction and channel roughness) and detail flow distribution at the core inlet (i.e. for each bundle).

The above issues were addressed in the following discussion and led to some conclusions for Exercise 2 modelling and calculations, which the participants accepted:

(a) The benchmark team will provide the detailed flow distribution (i.e. for each thermal-hydraulic channel per assembly);

(b) The benchmark team will provide correlations as to how to distribute the bypass flow;

(c) Participants are responsible for benchmarking their own void correlation;

(d) Since the second exercise is designed for initialising the coupled core models comparisons will be performed only on a code-to-code basis and not with measured data. The comparisons with measured data will be performed for the third exercise.

(e) Xenon correction – since the total thermal absorption cross-sections are generated using CASMO-3 depletion calculations at nominal conditions they need to be corrected to account for the Xe concentration distribution at the initial steady state conditions of the turbine trip test 2. This 3-D spatial (node-wise) Xe concentration distribution is provided as a separate file at the benchmark ftp site. The participants need to implement the following correction formula in their neutronics model for each neutronics node "i":

$$\Sigma^{i*}_{a,2} = \Sigma^{i}_{a,2} - \Sigma^{i}_{Xe,2} + N^{i}_{Xe}\sigma^{i}_{Xe,2} \qquad (1)$$

where $\Sigma^{i}_{a,2}$, $\Sigma^{i}_{Xe,2}$ and $\sigma^{i}_{Xe,2}$ are provided in the cross-section tables, and N^{i}_{Xe} is provided in a separate file at the benchmark ftp site.

For the HZP calculations of the 2nd Exercise, the Xenon correction should not be modelled;

(f) Additional output parameters are requested for comparisons – total reactivity and reactivity components time evolution during the transient.

(g) In a similar approach as for the MSLB benchmark two clusters of results will be formed for comparisons – one based on the specified 33-channel model and one for more detailed models.

Eric Royer from CEA, France, chaired Session 4 on the third phase of the benchmark. There were no preliminary results presented. Some modelling issues were discussed such as a need to include in the comparisons some local safety parameters as maximum cladding temperature or minimum critical power ratio, xenon correction and direct heating modelling, uncertainty range of the measured data and how to include the code-to-data comparisons. A question was also raised about the reference solutions for the extreme scenarios where no measured data are available.

Schedule and Future Workshops

Prof. José-María Aragonés from UPM chaired Session 5 on the future revised work plan and schedule of the benchmark activities. The discussion was focused on the deadlines and organisation of future Workshops. This summary of the 2nd Workshop will be published as an NEA/NSC document and distributed to participants, together with other material of the Workshop such as electronic copies of the presentations, etc., on a CD-ROM. The additional requested data will be provided to participants by the benchmark team by mid-November, 2001.

The deadline for final submission of results for Exercise 1 is February 28, 2002 and for Exercise 2 is March 31, 2002. The deadline for submission of preliminary results for Exercise 3 is April 30, 2002. The third BWR TT benchmark Workshop will be hosted by the FZR, Dresden, Germany, from May 28-30, 2002. The first two days - May 28-29 - will be devoted to the BWR TT workshop, and the last day – May 30 - will be for a starter workshop on the international coupled Kozloduy VVER-1000 benchmark problem.

The deadline for submission of the final results for Exercise 3 is July 31, 2002. A special session will take place at PHYSOR 2002, Seoul, Korea, (October 5-10, 2002) on Numerical and Computational Issues of Coupled 3-D Kinetics/Thermal-Hydraulics System Code Simulations: OECD/NRC BWR TT Benchmark. An ad-hoc Workshop on the OECD/NRC BWR TT benchmark is scheduled on October 5, 2002, in conjunction with the PHYSOR conference

Closing

The NEA secretariat expressed appreciation to the host organisation, PSI, and its staff, for their outstanding efforts in making this Workshop a success and for their generous hospitality.

Participants were taken on a guided tour of the PROTEUS facility after the closing of the Workshop.

***Note**:* The additional data provided by the PSI team is elaborated in Annex 3.

Annex 1

Second BWR-TT Workshop, PSI Villigen, 15-16 October 2001)

List of Participants

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*** regret not to have been able to attend**

Annex 2

FINAL PROGRAMME FOR THE SECOND BWR TT BENCHMARK WORKSHOP

PSI, Villigen, Switzerland
15th - 16th October 2001

([nn] indicates identification of papers presented)

Session 1 **-** Session Chair – *Paul Coddington*

1.1. Introduction and Welcome - *Konstantin Foskolos* - director of *PSI Nuclear Energy department director*
1.2. Introduction of Participants, Review and Approval of the Agenda
   - List of Participants [01], Proposed Agenda [02]
1.3. Brief report about discussions at NSC, NEA/OECD concerning 3D Transients and other issues – *José-María Aragonés*.
1.4. Kozloduy NPP VVER-1000 Coupled Code Benchmark Problem– *Boyan Ivanov and Kostadin Ivanov* [03]
1.5. Proposed Control Rod Ejection Transient Benchmark for a Partially MOX Fueled PWR – *Tom Downar (presented by K. Ivanov)* [04]
1.6. Information about NRC activities concerning coupled code development and validation - *Tom Downar (presented by K. Ivanov)* [05]
1.7. Review of the benchmark activities after the 1st Benchmark Workshop – *Kostadin Ivanov* [06]
1.8. Information about the Special Session at PHYSOR 2002 in Seoul, Korea, on Numerical and Computational Issues of Coupled 3-D Kinetics/Thermal-hydraulic System Code Simulations: OECD/NRC BWR TT Benchmark – *Enrico Sartori*
   - Final Announcement and Call for Papers for Physor-2002 [07]

Session 2 – Phase I - Session Chair – *Kiril Velkov*

2.1 Presentation of Summary Tables & Graphs of Results Submitted – *Mónica-Vela García* [08]
2.2 Modeling Issues and Discussion of the Phase 1 – 'Key Parameters for Evaluating Rapid Pressurization Events' *Andy Olson* [09]
2.3 Presentation of results by participants
   - S. Langenbuch, K.-D. Schmidt, K. Velkov: The BWR Turbine Trip Benchmark for Peach Bottom 2 Exercice 1: ATHLET [10]
   - Hotta: Sensitivity Study of Bypass Direct Heating Model in Exercise 1 Using TRAC/BF1 - ENTRÉE [11]
   - C. Delfino: Analysis and Modeling of the Steam Lines and Steam By-pass System with the RELAP5.MOD3 Code [12]
   - A. Bousbia Salah, C. Delfino, F. D'Auria: BWR TT Benchmark Analysis Phase I (with RELAP5/MOD3.2) [12bis]
   - G. Mignot, B. Rameau, E. Royer: BWR Turbine Trip calculations with the CATHARE code. [13]
   - H. Utsuno: Peach Bottom Turbine Trip Benchmark Results from the code "SKETCH-INS/TRAC-BF1, Exercise 1 [14]

- W.Barten, H. Ferroukhi, P. Coddington: PSI Results of Exercise I for the OECD/NEA & USNRC BWR Turbine Trip Benchmark: Results and Parameter Variation using RETRAN-3D [15]
- S. Kawamura, Y. Takeuchi: PB2 Turbine Trip Simulation by TRACG(not presented orally) [16]
- Jorge Solis and Anthony Ulses: TRAC-M Application to the OECD/NRC BWR TT Benchmark - Exercise 1 Results [17]

2.4 Discussion of Results and Conclusions for Phase I

Session 3 – Phase II - Session Chair – *Akitoshi Hotta*

3.1 Presentation of Summary Tables & Graphs of Results Submitted – *Mónica Vela-García* [18]
3.2 Modeling Issues and Discussion of Phase 2 – *Jorge Solis and Kostadin Ivanov* [19]
3.3 Presentation of results by participants

- S. Langenbuch, K.-D. Schmidt, K. Velkov: Results for the BWR Turbine Trip Core Transient by QUABOX/CUBBOX [20]
- D.J. Lee, T. Downar and T. Ulses: Preliminary Results: Peach Bottom Turbine Trip - TRAC-M/PARCS Exercise 2 Analysis [21]
- D. Panayotov, E. Müller, H. Wijkström Results of OECD BWR TT Benchmark Calculations obtained with POLCA7 and POLCA-T codes [22]
- Barish Sarikaya and Kostadin Ivanov, PSU: One-dimensional Cross-Section Generation and Modeling [23]
- E. Royer, G. Mignot, B. Rameau: CRONOS2-FLICA4 results for exercise 2 [24]
- N. Todorova, E. Royer: Suitable thermal-hydraulic model for exercise 2 [25]
- H. Utsuno: Peach Bottom Turbine Trip Benchmark Results from the code "SKETCH-INS/TRAC-BF1", Exercise 2 [26]
- W.Barten, H. Ferroukhi, P. Coddington: Coupled 3D Kinetics/Core Thermal-Hydraulic BC Analysis with CORETRAN [27]
- U. Grundmann, U. Rohde: Three-dimensional Core Simulations for Exercise 2 with DYN3D [28]

Session 4 – Phase III - Session Chair – *Eric Royer*

4.1 Query / Answer session for relevant issues for Phase III
4.2 Presentation of first results
4.3 Discussion of difficulties and unresolved issues

Session 5 - Session Chair – *José-María Aragonés*

5.1 Defining work plan and schedule, actions to progress in completing the 3 phases
5.2 Status - Schedule of Publication
5.3 Plan for presentations at conferences and publishing in journals
5.4 Discussion
5.5 Conclusion and Closing Remarks

Visit to PROTEUS Facility at PSI

Annex 3

Summary of data and items the benchmark team has to provide to participants as a result of the discussions at the 2nd workshop.

1) Templates for the requested output in Excel format for the 1st and 2nd exercises

2) Additional information to be provided:

- More detailed steam bypass system description and bypass valve data together with the linearization approach.
- Vendor correlation for the pressure drop across the separator;
- The inertia component for the jet pump model;
- Initial pressure distribution in the reactor;
- Data for each of the three types of thermal-hydraulic channels (hydraulic diameter at the channel inlet, outlet and along the axial direction and channel roughness);
- Detail flow distribution at the core inlet (i.e. for each thermal-hydraulic channel per assembly);
- Correlations how to distribute the bypass flow;