For Official Use **NEA/NSC/DOC(2005)6**

Organisation de Coopération et de Développement Economiques
Organisation for Economic Co-operation and Development

19-May-2005

English - Or. English

NUCLEAR ENERGY AGENCY
NUCLEAR SCIENCE COMMITTEE

NEA/NSC/DOC(2005)6
For Official Use

NUCLEAR SCIENCE COMMITTEE
and
COMMITTEE ON THE SAFETY OF NUCLEAR INSTALLATIONS

OECD/DOE/CEA VVER-1000 Coolant Transient Benchmark Summary Record of the Third Workshop (V1000-CT3)

4-5 April 2005
Garching, Germany

English - Or. English

JT00184374

Document complet disponible sur OLIS dans son format d'origine
Complete document available on OLIS in its original format

NUCLEAR SCIENCE COMMITTEE
and
COMMITTEE ON THE SAFETY OF NUCLEAR INSTALLATIONS

OECD/DOE/CEA VVER-1000 Coolant Transient Benchmark - Third Workshop (V1000-CT3)

Garching, Germany
4-5 April 2005

Hosted by
Gesellschaft für Anlagen- und Reaktorsicherheit (GRS) mbH
Forschungsgelände
D-85748 Garching, Germany

SUMMARY RECORD

Content:

Background and Purpose of the Benchmark Workshop

The Nuclear Energy Agency (NEA) of the Organisation for Economic Cooperation and Development (OECD) has completed, under the sponsorship of the Nuclear Regulatory Commission (NRC), a PWR Main Steam Line Break (MSLB) Benchmark against thermal-hydraulic/neutron kinetics codes. Recently another OECD/NRC coupled code benchmark was completed for a BWR turbine trip (TT) transient. During the course of defining and coordinating the OECD/NRC PWR MSLB and BWR TT benchmarks, a systematic approach was established to validate best estimate coupled codes. This approach employs a multi-level methodology that not only allows a consistent and comprehensive validation process but also contributes to determining additional requirements as well as to preparing a basis of licensing application of the coupled calculations for a specific reactor type and to developing a safety expertise in analyzing reactivity transients. Professional communities have been established during the course of these benchmark activities that allowed in-depth discussions of different aspects of assessing neutron kinetics models for a given reactor and on ways to implement best-estimate methodologies for transient analysis using coupled codes. The above examples demonstrate the benefit of establishing such international coupled standard problems for each type of reactor.

Further continuation of the above activities is the development of a VVER-1000 coolant transient (V1000CT) benchmark, which defines coupled code standard problems for validation of thermal-hydraulics system codes for application to Soviet-designed VVER-1000 reactors based on actual plant data. The overall objective is to assess computer codes used in the safety analysis of VVER power plants, specifically for their use in analysis of reactivity transients in a VVER-1000. In performing this work the PSU, USA, and CEA-Saclay, France, have collaborated with Bulgarian organizations, in particular with the KNPP and the INRNE. The V1000CT benchmark consists of two phases: V1000CT-1 is a simulation of the switching on of one main coolant pump (MCP) when the other three MCPs are in operation, and V1000CT-2 concerns calculation of coolant mixing tests and main steam line break (MSLB) scenarios. Each of the two phases contains three exercises.

The reference problem chosen for simulation in Phase 1 is a MCP switching on when the other three main coolant pumps are in operation in a VVER-1000. It is an experiment that was conducted by Bulgarian and Russian engineers during the plant-commissioning phase at the Kozloduy NPP Unit #6 as a part of the start-up tests. The test was done, as it is important for the safety of the NPP with VVER-1000, model 320. The reactor is at the beginning of cycle (BOC) with average core exposure of 30.7 EFPD. At the beginning of the experiment there are three pumps in operation – 1st, 2nd and 4th main coolant pumps and the reactor power is at 27.47% of the nominal power level (824 MWt). The control rod group #10 is inserted into the core. The group position in axial direction is at about 36% withdrawn from the bottom of the reactor core. Analysis of the initial three-dimensional (3-D) relative power distribution showed that this insertion introduced axial neutronics asymmetry in the core. At the beginning of the transient there is also a radial thermal-hydraulic asymmetry coming from the colder water introduced in ¼ of the core when MCP #3 is switched on. This causes a spatial asymmetry in the reactivity feedback, which is propagated through the transient and combined with insertion of positive reactivity. In summary, this event is characterized by rapid increase in the flow through the core resulting in a coolant temperature decrease, which is spatially dependent. This leads to insertion of spatially distributed positive reactivity due to the modelled feedback mechanisms and non-symmetric power distribution. Simulation of the transient requires evaluation of core response from a multi-dimensional perspective (coupled three-dimensional neutronics/core thermal-hydraulics) supplemented by a one-dimensional simulation of the remainder of the reactor coolant system. Three exercises are defined in the framework of Phase 1:

a) Exercise 1 – Point kinetics plant simulation;

b) Exercise 2 – Coupled 3-D neutronics/core thermal-hydraulics response evaluation;

c) Exercise 3 – Best-estimate coupled 3-D core/plant system transient modelling.

In addition to the measured (experiment) scenario, extreme calculation scenarios were defined in the frame of Exercise 3 for better testing 3-D neutronics/thermal-hydraulics techniques. The proposals concerned: rod ejection simulations with scram set points at two different power levels.

Since the previous coupled code benchmarks indicated that further development of the mixing computation models in the integrated codes is necessary, a coolant mixing experiment and a MSLB scenario are selected for simulation in Phase 2 of the benchmark. The introduction as an additional option of CFD modelling of the vessel with specific boundary conditions rather than core boundary conditions and CFD modelling of the mixing is also included as Exercise 1 of Phase 2. For this specific case additional data from KNPP Unit #6 is made available. The selected mixing experiment was conducted at KNPP #6 as part of the plant commissioning phase. This asymmetric experiment includes single loop cooling and heating-up at 9 % of nominal power with all MCP in operation. It will be used to test and validate vessel-mixing models (CFD, coarse-mesh and mixing matrix). Vessel boundary conditions and core power distribution are part of this exercise specification.

The transient to be analyzed in Phase 2 is initiated by a MSLB in the VVER-1000 NPP between the steam generator and the steam isolation valve, outside of the containment. This event is characterized by a large asymmetric cooling of the core, stuck rods and a large primary coolant flow variation. Two scenarios are defined: the first scenario is taken from the current licensing practice and the second one is derived from the original one using aggravating assumptions to enhance the code-to-code comparisons. The main objective is to clarify the local 3-D feedback effects depending on the vessel mixing. Special emphasis is put on testing 3-D vessel thermal-hydraulics models and coupling of 3-D neutronics/vessel thermal-hydraulics. The MSLB scenario simulation is divided into two exercises: Exercise 2 consists of coupled 3-D neutronics/vessel thermal-hydraulics simulation using specified vessel thermal-hydraulic boundary conditions, and Exercise 3 consists of best-estimate coupled 3-D core/3-D vessel/plant system modelling.

In June 2002 the Nuclear Science Committee (NSC) of NEA/OECD, at its annual meeting in Paris, approved and endorsed the developed V1000CT benchmark problem to become an international standard problem for validation of the best-estimate safety codes for VVER applications. Collaboration with the AER Working Group D involved in VVER safety research on the proposed VVER-1000 coolant transient benchmark has been established and the AER participates actively in the benchmark activities. The co-operation of this working group with the V1000CT benchmark group was endorsed by the OECD/NEA NSC, and is supported by the Safety Division. The AER Working Group meeting was held on 6-7 April, 2005 at the same place in Garching, Germany

The technical topics presented at this workshop are shown below. In addition, the proposed workshop programme is attached in Annex I.

- Review of the benchmark activities after the 2nd Workshop
- Discussion of participant's feedback and introduced modifications to the Benchmark Specifications
- Presentation and discussion of final results from Exercise 1 of Phase 1
- Presentation and discussion of final results from Exercise 2 of Phase 1
- Presentation and discussion of final results of Exercise 3, Phase 1
- Presentation and discussion of modelling issues and preliminary results of Exercise 1, Phase 2
- Discussion of the draft of the Specifications for Exercises 2 and 3 of Phase 2
- Defining work plan and schedule, actions to progress in completing the 2 phases

Session 1 – Introduction: *Chair S. Langenbuch*

The meeting was opened by Dr. Siegfried Langenbuch, Head of Reactor Dynamics Department at GRS that was hosting the meeting. He welcomed the participants on behalf of GRS and wished them a successful meeting. Dr. Enrico Sartori welcomed the participants on behalf of the NEA Secretariat and thanked in particular the local organizers for their hospitality. He presented the current activities of the Nuclear Science Committee (NSC) at NEA/OECD.

The meeting was attended by 34 participants from 10 countries (see Annex II). The agenda was approved with minor adjustments (see Annex I).

K. Ivanov from PSU, USA, reviewed the status of V1000CT-1 (Phase1) benchmark activities while E. Royer from CEA, France, gave an overview of the status of V1000CT-2 (Phase 2) benchmark activities.

Session 2: *Chair*: *E.Royer*

B. Ivanov from PSU, USA, presented a comparative analysis of the results submitted by the participants for Exercise 1 of the first phase of the benchmark. Eight participants from 6 countries have submitted their solutions for this exercise. The discussions during the Workshop revealed that two more sets of results for Exercise 1 of Phase 1 are to be expected – one from INRNE/CEA with CATHARE and one form the Kurchatov Institute with ATHLET. The comparisons demonstrate that while all of the participants' codes were able to predict the major trends of the MCP switching on transient (as compared to the measured data) there are differences in the participants' steady state and transient results. These discrepancies are mostly due to the differences in the modelling as reported by the participants. Typical differences are the utilization of the provided Steam Generator (SG) Boundary Conditions (BC), the MCP #3 rotor speed, and decay heat modelling as well as different vessel nodalization schemes and/or number of channels. The observed discrepancies in the predictions of the fuel temperature arise from differences in modelling of fuel rod (heat structure) such as gas gap conductance model, nodalization, and the relation used for obtaining the effective Doppler temperature. In order to provide a better basis for analysis of the participants' results in the report on the first exercise in preparation, it was suggested that a detailed questionnaire on the models used by the participants be prepared by the benchmark team and distributed to the participants. The other suggestions made in the follow-up discussion were:

- To divide the results in two groups – results obtained with thermal-hydraulic (T-H) codes, which use 1-D modelling of the vessel and T-H codes, which utilize 3-D vessel models
- The benchmark team to correct the measured data for the time delay of the measurement systems using a consistent time integration approach prior to comparison with the calculated participants' results
- If possible to account in some way for the measurement uncertainty ranges during the transient for different time histories.

K. Ivanov presented a summary of two papers submitted by the benchmark team to the 14th AER Symposium and the NURETH-11 Conference. These papers describe the problem observed during the computation of the second exercise of the V1000CT-1 benchmark, which was discussed at the 2nd Benchmark Workshop in Sofia in April 2004. Unacceptably high deviations (in the range of ±11%) were discovered when comparisons of 2-D normalized power distributions, calculated by different codes, were performed. The papers outlined the steps taken for understanding this problem. The performed sensitivity studies narrowed down the possible sources of the deviations to two. As expected the first contributor was the differences in the methods used in the different codes for solving the diffusion equation in hexagonal geometry. The second contribution came from the fact that NEM cannot reduce its mesh size in hexagonal geometry i.e. cannot use more than one node per assembly. The VVER reflector properties were also found to enhance discrepancies by increasing flux gradients at the core/reflector interface thus highlighting more the difficulties in NEM to handle high exponential flux gradients. The simple test problems developed are made available to the benchmark participants. The results obtained will be compared as part of the 2nd Exercise of the V1000CT-1 benchmark to qualify the deviations caused by the hexagonal geometry solution methods.

Session 3: *Chair: J.Hadek*

B. Ivanov presented comparisons of the results submitted by the participants for Exercise 2 of the first benchmark phase. Ten participants from eight countries have submitted their results for this exercise (please note that NRI, Czech Republic has submitted two sets of results). The KAIST, Korea results were excluded from the comparisons as an outliner. The observed discrepancies in 2D normalized power distributions at Hot Zero Power (HZP) conditions (as discussed above) remain at Hot Power (HP) conditions and even increase due to the differences in the utilized T-H core models. Misinterpretations of the mass flow BC are observed, which also affect the disagreement between different codes. The Kiev University, Ukraine, and PSU, USA, use a 3-D core model in cylindrical geometry as compared to the multi-channel models used by the rest of the participants However, the Kiev University model is more detailed in the radial plane. The two sets of results submitted by NRI indicate the impact of different numbers of channels on the predictions. The results submitted by the University of Pisa, Italy, and FZK, Germany, with RELAP5/PARCS indicate the impact of axial nodalization on the results obtained. This presentation was followed by a discussion, which resulted in the following suggestions: request from the participants not only axial and radial power peaking factors but also volume peaking factors, and prepare a detailed questionnaire on the 2nd Exercise of Phase 1 on the models utilized by participants (for example fuel rod modelling). J. Hadek from NRI, Czech Republic discussed in his presentation the NRI solutions of the V1000CT-1 benchmark. The results obtained with DYN3D/ATHLET for the Exercises 1 to 3 of Phase 1 were presented. The calculated initial steady state and transient parameters are in good agreement with the measured data. In two consecutive presentations, B. Ivanov performed comparative analysis of the submitted results for the test and extreme scenarios of Exercise 3 of the V1000CT-1 benchmark. Seven participants from six countries have submitted their results for Exercise 3 while six participants from five countries have submitted their results for the extreme scenario of Exercise 3 of the Phase 1. From the comparisons presented it became clear that the major reason for the discrepancies observed for the extreme scenario is the different location of the ejected control rod. Two participants – FZR and NRI ejected a control rod at a location different from the specified one and they need to re-calculate their results. Participants suggested that the benchmark team prepare a detailed questionnaire on the 3rd Exercise of Phase 1 on the models utilized by participants in order to be able to analyze and explain the observed discrepancies in the code-to-code and code-to-data comparisons. It was decided to allow participants additional time to revise and re-submit their final results for Phase 1 of the V1000CT benchmark. The deadline for this final submission is June 30, 2005 (see Table 1).

E. Syrjälahti from VTT, Finland, presented the HEXTRAN-SMABRE calculations of Exercises 2 and 3 of Phase 1. She outlined the differences between the HEXTRAN-SMABRE model and the benchmark specifications – reflector modelling (reflector with albedo boundary conditions) and the provided SG feed-water boundary conditions were not used. The presentation demonstrated a consistent way of comparing calculated and measured data thus showing that the knowledge of the measurement time constants is very important for such comparisons. S. Aniel from CEA, France, discussed the solution of V1000CT-1 Exercise 2 using the FLICA4/CRONOS2 coupled code system. The coupled FLICA4/CRONOS2 code convergence in terms of spatial and temporal discretization was verified. The sensitivity of the code system predictions to the relation for determining Doppler effective temperature, and the fuel gap width has been studied and evaluated. The conclusion reached is that only the gap width has a real impact on the steady state and transient results. T. Höhne from FZR, Germany presented CFD simulation of Exercise 3 of Phase 1 using the results of DYN3D/ATHLET coupled code calculations. The CFD calculations are performed with CFX-5 with inlet boundary conditions provided by the DYN3D/ATHLET calculations. Four individual loop mixing scalars were utilized to obtain information about the contribution of each loop during the transient. The results showed a clear sector formation of the affected loops at the down-comer and core inlet. At the beginning of the start-up of loop #3 all active loops (loops # 1,2, and 4) cover a larger area. The resulting time-dependent temperature distribution at the core inlet can be used for the next iteration step – 3D reactor dynamics analysis with improved boundary conditions. K. Ivanov introduced the outline and schedule for the final report on Phase 1. In addition to the benchmark specifications (Volume I) three more volumes will be published:

- Volume II – “Results on V1000CT-1 Exercise 1- Point kinetics plant simulation”
- Volume III – “Results on V1000CT-1 Exercise 2 – Coupled 3-D neutronics/core thermal-hydraulics response evaluation”
- Volume IV – “Results on V1000CT-1 Exercise 3 – Best-estimate coupled code plant transient modelling”

Three reviewers were selected for each volume by the participants in the Workshop. For Volume II the selected reviewers are: E. Royer, S. Kliem, and E. Popov. For the Volume III the selected reviewers are: S. Langenbuch, P. Siltanen, and J.M. Aragones. For Volume IV the selected reviewers are: U. Grundmann, J. Hadek, and K. Velkov. The schedule for preparing, reviewing and publishing of the three volumes of the final report on Phase 1 is given in Table 1.

Session 4: *Chair: J. M.Aragones*

N. Kolev form INRNE, Bulgaria presented a description of Exercise 1 of Phase 2 including the available measured data. The objectives of this exercise were discussed as well as the submitted results, which form three clusters – system codes with multi-channel models, system codes with 3D vessel models (these two clusters belong to the so-called coarse mesh results), and CFD models (fine mesh results). So far six results were submitted – three of them represent the coarse mesh results and the other three represent fine mesh results. The deadline for submitting results for this exercise was extended to September 15, 2005 (see Table 1). In the follow-up presentation N. Kolev made a comparative analysis of the submitted coarse mesh results (ATHLET, CATHARE and RELAP-3D results as compared to the measured data). U. Bieder from CEA, France, discussed the modelling of mixing effects in a VVER-1000 reactor using Trio-U. Sensitivity studies were performed on geometry, meshing, discretization, turbulence modelling, and mass conservation. Based on the results of these studies a final calculation model was established, which produced very good agreement with measured data. E. Popov from ORNL, USA, presented a RELAP-3D simulation of the V1000CT-2 coolant mixing test (Exercise 1). The results obtained show that the coolant in part of the vessel (a sector of about 30-degree) almost does not mix. The highest degree of mixing occurs between loops 1 and 2, and 3 and 4, while the opposite loops do not mix. The six-segment reactor nodalization used in RELAP-3D predicts reasonable well the perturbed loop temperatures. The flow-rotation in the down-comer is not captured by the code. T. Höhne presented a CFD simulation of the thermal-hydraulic benchmark (Exercise 1) of V1000CT-2. The agreement with the Kozloduy experiment at the core inlet is very good. The results show a clear formation of the affected loop at the down-comer, lower plenum and core inlet. M. Böttcher from FZK, Germany discussed the status of the CFD modelling activities using CFX-5 for the V1000CT-2 benchmark. A CFD model for the upper plenum was developed and used to improve RELAP5 calculations. The development of a complete model is underway and coupled simulations of CFX-5 with RELAP5 and RELAP5/PARCS are planned.

Session 5: *Chair: E. Popov*

In his presentation, N. Kolev discussed Exercise 2 of Phase 2 in detail. He summarized the objectives of this exercise, different MSLB scenarios to be analyzed, the provided boundary conditions, core model specification, and the requested output. B. Ivanov presented the cross-section library to be used by the participants for Exercises 2 and 3 of the Phase 2. The cross-section library is being generated in the format similar to the cross-section library of Phase 1 of the V1000CT benchmark. HELIOS code Version 1.7 is being utilized to generate the cross-section library. The reflector model will be refined and improved. Sufficient plant data exist to validate the developed cross-section library. J. M. Aragones from UPM, Spain, discussed the heterogeneity and spectral effects at the core-reflector boundaries. Insights were given based on the analytical multi-group diffusion theory and multi-dimensional effects. First, the multi-group Analytic Coarse-Mesh Finite-Difference (ACMFD) method was summarized. Second, the equations for the reflector and core-reflector interfaces were derived. Finally, the heterogeneity and spectral effects at the core reflector boundaries were shown in 1-D and 2-D geometry including corner and transversal effects. P. Petkov from INRNE, Sofia, analyzed the issues connected with the VVER radial reflector modelling by diffusion codes. He introduced the 2-D real geometry transport theory code Mariko based on the method of characteristics. Mariko's VVER radial reflector models were presented as well as their application to generate core-reflector albedos and reflector discontinuity factors utilizing the Equivalence Theory. The performed sensitivity studies and subsequent comparisons between DYN3D and Marico indicated that on the outer reflector surface albedo boundary conditions should be used. These studies also have identified the required thickness of water and steel reflectors to be modelled, and the need for parameterization of reflector data. It was suggested that the reflector library can be prepared in a separate calculation using the Marico code and different parameterization approach. In such a case the participants will be provided with reference data and they have to develop their own routines to prepare code specific reflector libraries. In the follow-up discussion the participants did not accept this suggestion for the purposes of the Phase 2 of the V1000CT benchmark. It was agreed upon that the benchmark team improves and refines the utilized reflector model, and define a special HZP state for which measured data is available. This state will be used to validate the reflector model. The format and parameterization of the reflector data should be the same as for the rest of the material compositions and consistent with the cross-section library used for Phase 1 of the V1000CT benchmark. .

Session 6: *Chair: P. Siltanen*

N. Kolev discussed in detail the Specifications of Exercise 3 of V1000CT-2 including the objectives of this exercise, MSLB scenarios, primary and secondary systems, core modelling, the specified boundary conditions, and requested output. This presentation was followed by discussion of preliminary calculations of scenarios 1 and 2 for Exercise 2 of Phase 2 with the CATHARE point kinetics model.

Session 7: *Chair K.Velkov*

E. Sartori initiated a discussion about the schedule on Phase 2 of the V1000CT benchmark and next workshops. As a result, the following list of actions for V1000CT-2 in addition to V1000CT-1 was accepted by the participants in the Workshop. The following Table 1 is the combined list of actions agreed at the Workshop concerning both phases of the benchmark:

Table 1. Schedule for V1000CT: Actions decided at the 3rd Workshop

Nr.	Action	By whom	deadline	status
	General			
1	Place the presentations made at the WS on the Web (password protected)	E. Sartori	15-04-2005	
2	Produce summary record & CD-ROM with cumulative V1000CT information	K. Ivanov, E. Royer, E. Sartori	30-04-2005	
3	Distribute Summary to NSC & WPRS	E. Sartori	15-05-2005	
4	Present WS results to NSC	J.M. Aragonés	8-06-2005	
	V1000CT-1 (phase I)			
5	Send out questionnaire to participants for clarifying discrepancies	B. Ivanov, and K. Ivanov	15-04-2005	
6	Submit revisions of results relative to the 3 exercises	Participants	30-06-2005	
7	Prepare draft of Exercise 1 results (Vol. II)	B. Ivanov	20-09-2005	
8	Review draft of Exercise 1	E. Royer, S. Kliem, E. Popov	31-12-2005	
9	Prepare draft of Exercise 2 results (Vol. III)	B. Ivanov	31-12-2005	
10	Review draft of Exercise 2	S. Langenbuch, P. Siltanen, J.M. Aragones	31-03-2006	
11	Prepare draft of Exercise 3 results (Vol. IV)	B. Ivanov	30-04-2006	
12	Review draft of Exercise 3	U. Grundmann, J. Hadek, K. Velkov	31-05-2006	

13	Distribution of revised final draft to participants for final comments	B. Ivanov, and K. Ivanov	As appropr.	
14	Final reporting to NSC	J.M. Aragonés	June-2006	
15	Finalisation & publication of reports (Vol. I,II,III)	E. Sartori	Autumn2006	
	V1000CT-2			
16	Submit the final results of Exercise 1	Participants	15-09-2005	
17	Prepare specification of Exercises 2 & 3	E. Royer, N. Kolev	15-09-2005	
18	Prepare cross-section library	B. Ivanov	15-09-2005	
19	Organise special session at NURETH-11 & ad-hoc meeting to discuss further adjustments required for Exercises 2 & 3 specification	E. Royer	03-10-2005	
20	Final specification for Exercises 2 & 3	E. Royer, N. Kolev	15-12-2005	
21	Submit results of Exercises 2 & 3	Participants	28-02-2006	
22	Prepare comparison and present results for V1000CT4	E. Royer, N. Kolev	24-04-2006	
23	Organise V1000CT4 in conjunction with AER Group D meeting	F. D'Auria, E. Royer, E. Sartori	24/25-04-2006	
24	Prepare special issue of Phase I & II benchmarks for NSE or NT	K. Ivanov, E. Royer, Participants	In 2007	

Further, the status of V1000CT Benchmark special session at NURETH-11 was discussed. The session was organized by E. Royer and F. D'Auria. There are eight accepted papers for this session. Following the established procedure used in previous coupled code benchmarks it was suggested that a special journal issue will be also developed in which participants can publish their models, results, and sensitivity studies. The benchmark team has been approached by the Editor of Progress in Nuclear Energy (PNE) journal with an invitation for a special issue on Phase 1 of the V1000CT benchmark. The invitation has been accepted and the participants are requested to submit their papers on models, results and sensitivity studies on Phase 1 of the benchmark to K. Ivanov by August 31, 2005. There will be also a special issue on the Phase 2 of the V1000CT benchmark in 2007 most probably in Nuclear Science and Engineering.

Proceedings of the Workshop

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

Co-operation with AER

The AER Working Group D Meeting was held on 6-7 April 2005 at the same premises. The co-operation of this working group with the VVER-1000 benchmark group was endorsed by the OECD/NEA NSC and is supported by the Safety Division. The members of the AER WGD are participating actively in the OECD/DOE/CEA V1000CT benchmark. Examples of their contribution were some of the presentations made during the AER WGD meeting by N. Kolev, J. Hadek, and D. Popov, which were related to the Exercises 2 and 3 of Phase 2 of the V1000CT benchmark. The VVER-1000 reflector modelling was discussed again and it was suggested that it might be useful to propose a specific benchmark on this. The summary of this meeting has been prepared separately and is available to the AER participants.

Annex I

OECD/DOE/CEA VVER-1000 Coolant Transient Benchmark - Third Workshop (V1000-CT3)

Garching, Germany, 4-5 April 2005
Hosted by: GRS

FINAL PROGRAMME (with details)[01]
([n] indicates paper identification on CD-ROM)

April 4th

Session 1 – Session Chair – Siegfried Langenbuch

09:00-09:30 Introduction and Welcome
GRS – *Siegfried Langenbuch*
OECD-NEA – *Enrico Sartori* [02]
Introduction of Participants [03]
09:30-10:00 Status of V1000CT-1 (Phase 1) Benchmark - *Kostadin Ivanov*[04]
10:00-10:30 Overview and status of V1000CT-2 Benchmark – *Nikola Kolev, Eric Royer* [05]

10:30-10:45 Coffee Break

Session 2 – Session Chair – Eric Royer

10:45-11:15 Comparative Analysis of Exercise 1 of the V1000CT-1 Benchmark – *Boyan Ivanov and Kostadin Ivanov*[06]
11:15-11:45 Summary of Submitted Papers to the AER Symposium and NURETH-11 in regard to Exercise 2 of V1000CT-1 – *K.Ivanov, S. Aniel, B. Ivanov, P. Siltanen, E. Royer, Y. Kozmenkov, U. Grundmann* [07]

11:45-13:15 Lunch

Session 3 – Session Chair – Jan Hadek

13:15-13:45 Comparative Analysis of Exercise 2 of the V1000CT-1 Benchmark – *Boyan Ivanov and Kostadin Ivanov* [08]
13:45-14.05 NRI ŘeŽ Solution of v1000CT-1 Benchmark, *Jan Hádek, Radim Meca, František Lahovský* [09]
14:05-14:50 Comparative Analysis of Exercise 3 of the V1000CT-1 Exercise – *Boyan Ivanov and Kostadin Ivanov*[10]
Comparative Analysis of Exercise 3 – Extreme Scenario of the V1000CT-1 Benchmark, *Boyan Ivanov and Kostadin Ivanov*[11]
14:50-15:10 HEXTRAN-SMABRE Calculation of the V1000CT-1 Benchmark, *Elina Syrjalähti,* [12]
15:10-15:20 Solution of V1000CT-1 Exercise 2 using FLICA4/CRONOS2 coupled code system, *S. Aniel, E. Royer* [13]
15:20-15:40 CFD simulation of Coolant Transient Benchmark V1000CT-1, Exercise 3 Using Results of DYN3D/ATHLET Coupled Code Calculation, *T. Höhne, Y. Kozmenkov* [14]
15:40-15:50 Outline and schedule for Final Report on Phase 1 – *Kostadin Ivanov* [15]

15:50-16:00 Coffee Break

Session 4 – Session Chair – José María Aragonés

16:00 -16:30 V1000CT-2 Analysis of Exercise 1 – *Nikola Kolev, Eric Royer, N.Petrov, U. Bieder, A. Aniel* [16]

April 5th

Session 4 (Cont.)– Session Chair – José María Aragonés

09:00-10:20 Participants' presentations

- Modeling of Mixing Effects in a VVER1000 reactor with Trio_U, *Ulrich Bieder, Gauthier Fauchet, Sylvie Betin* [17]
- RELAP-3D Simulation of the VVER-1000 CT2 Coolant Mixing Test", *Emilian Popov* [18]
- CFD-Simulation of the Thermalhydraulic Benchmark V1000CT–2, *Thomas Höhne, Ulrich Bieder, Nikola Kolev* [19]
- V1000CT-2 Benchmark – Status of CFD Modelling Activities Using CFX-5, *M. Böttcher*[20]

10:20-10:30 Coffee Break

Session 5 – Session Chair – Emilian Popov

10:30-11:00 V1000CT-2- Exercise 2 – *N. Kolev, E. Royer, N.Petrov, J. Donov, D. Popov, E. Lukanov, Y. Dinkov* [21]

11:00-11:20 Cross-section Library for the Exercises 2 and 3 of the V1000CT-2 Benchmark – *Boyan Ivanov, Kostadin Ivanov and Nikola Kolev*[22]

11:20-11:40 Heterogeneity and Spectral Effects at the core-reflector boundaries: Insights from Analytical Multi-group Diffusion Theory and Multi-dimensional Effects: *J.M. Aragonés, C. Ahnert, N. Garcia*[23]

11:40-12:00 WWER Radial reflector Modelling by Diffusion Codes, *P.T. Petkov, S. Mittag*[24a], [24b], [24c]

12:20-13:15 Lunch

Session 6 – Session Chair – Pertti Siltanen

13:15-13:45 V1000Ct-2 - Exercise 3 – *N. Kolev, E. Royer, N.Petrov, J. Donov, D. Popov, E. Lukanov, Y. Dinkov* [25a]
Preliminary calculation of Scenario 1 with CATHARE/Point Kinetics [25b]
Preliminary calculation of Scenario 2 with CATHARE/Point Kinetics [25c]

Session 7 – Session Chair – Kiril Velkov

14:05-14:25 Discussion of the schedule on Phase 2 and next workshops, List of Actions [26]

14:25-14:45 Discussion of the Special Session at NURETH-11 and a subsequent Special Journal Issue

14:45 15:00 Coffee Break

15:00-15:30 Conclusion and closing remarks

Annex II

V1000CT3 (3rd Workshop on VVER-1000 Coolant Transients, Garching, 4-5 April 2005)

List of Participants

BULGARIA

BAKALOV, Ivan Georgiev
Enpro Consult. Ltd.
G.M. Dimitrov Blvd
1797 Sofia
Tel: +359 2 9711 416
Fax: +359 2 9711 421
Eml: ibakalov@enproco.com

KOLEV, Nikola
Institute of Nuclear Research
and Nuclear Energy
Tsarigradsko shaussee 72
1784 Sofia
Tel: +359 2 7144502
Fax: +359 2 9753619
Eml: npkolev@inrne.bas.bg

LUKANOV, Evgeni
Engineering Support Division
Kozloduy Nuclear Power Plant
3321 Kozloduy
Tel: +359 973 72045
Fax: +359 973 72762
Eml: lukanov_ep@npp.cit.bg

PETKOV, Petko
Institute for Nuclear Research
and Nuclear Energy
72 Tzarigradsko chaussee, blvd
BG-1784 Sofia
Tel: +359 2 7144 392
Fax: +359 2 9753 619
Eml: ptp@inrne.bas.bg

POPOV, Dimitar
Safety Analysis Section,
Engineering Support Division IO-2
Kozloduy NPP
3321 KOZLODUY
Tel: +359 973 72386
Fax: +359 973 72762
Eml: dmpopov@npp.cit.bg

CZECH REPUBLIC

HADEK, Jan
Nuclear Research Institute Rez plc
250 68 Rez near Prague
Tel: +420 2 6617 2169
Fax: +420 2 6617 2334
Eml: hdj@ujv.cz

FINLAND

SILTANEN, T. Pertti J.
Fortum Nuclear Services Ltd.
P.O. Box 100
Keilaniementie 1, Espoo
FIN-00048 FORTUM
Tel: +358 1045 32412
Fax: +358 1045 33403
Eml: Pertti.Siltanen@fortum.com

SYRJÄLAHTI, Elina
VTT PROCESSES / Nuclear Energy
P.O.Box 1604
FIN-02044 VTT
Tel: +358 20 722 5017
Fax: +358 20 722 5000
Eml: Elina.Syrjalahti@vtt.fi

FRANCE

ANIEL-BUCHHEIT, Sylvie
DEN/DM2S/SFME/LETR
Laboratoire d'Etudes Thermiques des React
Commissariat à l'Energie Atomique (CEA)
Centre d'Etudes de Saclay
F-91191 Gif-sur-Yvette CEDEX
Tel: +33 1 69 08 64 88
Fax: +33 1 69 08 85 68
Eml: sylvie.aniel@cea.fr

BIEDER, Ulrich
DEN/DER/SSTH/LMDL
CEA Grenoble
17 rue des Martyrs
38054 GRENOBLE
Tel: +33 4 38 78 95 14
Fax: +33 4 38 78 5036
Eml: ulrich.bieder@cea.fr

OLIVERI, Jorge | Tel:
Institut de Radioprotection et de | Fax: +33 +33 1 58 35 96 02
Surete Nucleaire IRSN | Eml: jorge.oliveri@irsn.fr
B.P. 17
92262 Fontenay-aux-Roses Cedex
FRANCE

ROYER, Eric | Tel: +33 1 69 08 21 61
Centre d'Etudes de Saclay | Fax: +33 1 69 08 85 68
CEA/DEN/DM2S/SFME | Eml: eric.royer@cea.fr
91191 Gif-sur-Yvette Cedex

SABOTINOV, Luben | Tel: +33 1 58 35 71 59
Institut de Radioprotection et de | Fax: +33 1 58 35 96 02
Surete Nucleaire IRSN | Eml: luben.sabotinov@irsn.fr
B.P. 17
92262 Fontenay-aux-Roses Cedex

GERMANY

BOETTCHER, Michael | Tel: +49 7247 82 2564
Institute of Reactor Safety (IRS) | Fax: +49 7247 82 3718
Forschungszentrum Karlsruhe GmbH | Eml: boettcher@irs.fzk.de
Hermann-von-Helmholtz-Platz 1
D-76344 Eggenstein-Leopoldshafen

GRUNDMANN, Ulrich | Tel: +49 (351) 260 3037
Institute of Safety Research | Fax: +49 (351) 260 2383
Forschungszentrum Rossendorf | Eml: U.Grundmann@fz-rossendorf.de
Postfach 510119
D-01314 DRESDEN

HOEHNE, Thomas | Tel: +49 351 260 2425
Forschungszentrum Rossendorf | Fax: +49 351 260 2383
Postfach 510119 | Eml: T.Hoehne@fz-rossendorf.de
01314 DRESDEN

KLIEM, Soeren | Tel: +49 (351) 260 2318
Forschungszentrum Rossendorf | Fax: +49 (351) 260 2383
Institute for Safety Research | Eml: kliem@fz-rossendorf.de
P.O. Box 510119
D-01314 DRESDEN

KOZMENKOV, Yaroslav | Tel: +7 +49 351 260 2167
FZ Rossendorf | Fax: +7 +49 351 260 3440
Institute of Safety Research | Eml: Y.Kozmenkov@fz-rossendorf.de
P.O. Box 510119
D-01314 DRESDEN

LANGENBUCH, Siegfried | Tel: +49 (89) 3200 4424
Gesellschaft fuer Anlagen und | Fax: +49 (89) 3200 4599
Reaktorsicherheit mbH | Eml: lab@grs.de
Forschungsinstitute
Postfach 13 28
D-85748 GARCHING

SANCHEZ-ESPINOZA, Victor Hugo | Tel: +49 7247 82 2283
Institute of Reactor Safety (IRS) | Fax: +49 7247 82 3718
Forschungszentrum Karlsruhe GmbH | Eml: sanchez@irs.fzk.de
Hermann-von-Helmholtz-Platz 1
D-76344 Eggenstein-Leopoldshafen

SCHMIDT, Klaus-Dieter | Tel: +49 89 3200 4425
Gesellschaft fuer Anlagen und | Fax: +49 89 3200 4599
Reaktorsicherheit | Eml: smk@grs.de
GRS mbH
Forschungsinstitute
D-85748 Garching

VELKOV, Kiril — Tel: +49 (89) 3200 4428
Gesellschaft fuer Anlagen und Reaktorsicherheit — Fax: +49 (89) 3200 49038
GRS mbH — Eml: vek@grs.de
Forschungsinstitute
D-85748 Garching

HUNGARY

KERESZTURI, Andras — Tel: +36 1 392 2297
Reactor Analysis Department — Fax: +36 1 395 9293
KFKI Atomic Energy Research Institute — Eml: kere@sunserv.kfki.hu
H-1525 BUDAPEST 114
P.O. Box 49

YAMAJI, Bogdan — Tel: +36 1 463 1633
Institute of Nuclear Techniques — Fax: +36 1 463 1954
Budapest University of Technology and Eco — Eml: yamaji@reak.bme.hu
Muegyetem rkp 9
1111 Budapest

ITALY

DEL NEVO, Alessandro — Tel: +39 (050) 3135 360
Department of Mechanics — Fax: +39 (050) 3135 384
Nuclear and Production Engineering — Eml: a.delnevo@ing.unipi.it
DIMNP PISA UNIVERSITY Via Livornese 1291
S. Piero a Grado (PI)

MUELLNER, Nikolaus — Tel: +39 050 3135 373
Universita di Pisa — Fax: +39 050 3135 384
Via Livornese 1291 — Eml: nikolaus.muellner@univie.ac.at
I-56122 San Piero e Grado

PETRUZZI, Alessandro — Tel: +39 050 3135 377
Universita di Pisa — Fax: +39 050 3135 384
DIMNP — Eml: a.petruzzi@ing.unipi.it
Via Diotisalvi 2
56100 PISA

RUSSIAN FEDERATION

KOTSAREV, Alexander — Tel: +7 (095) 196 77 50
RRC "Kurchatov Institute", — Fax:
Institute of Nuclear Reactors — Eml: kot@vver.kiae.ru
Kurchatov Sq. 1
123182 Moscow

NIKONOV, Sergey — Tel: +7 095 196 7683
Russian Research Center — Fax: +7 095 196 6172
Kurchatov Institute — Eml: niks@vver.kiae.ru
Kurchatov Square 1
Moscow 123182

SPAIN

ARAGONES BELTRAN, Jose Maria — Tel: +34 91 336 3108
Dpto. Ingenieria Nuclear — Fax: +34 91 336 3002
ETSI-Industriales — Eml: arago@din.upm.es
Univ. Politecnica de Madrid
Jose Gutierrez Abascal 2
E-28006 MADRID

UNITED STATES OF AMERICA

IVANOV, Boyan — Tel: +1 (814) 865 3926
Nuclear Engineering Programme — Fax: +1 (814) 865 8499
The Pennsylvania State University — Eml: bivanov@psu.edu
16 Reber Building
University Park PA 16802-1408

IVANOV, Kostadin
Professor
Nuclear Engineering Programme
The Pennsylvania State University
230 Reber Building
University Park PA 16802
Tel: +1 (814) 865 0040
Fax: +1 (814) 865 8499
Eml: kni1@psu.edu

POPOV, Emilian
Thermal Hydraulics and
Irradiation Engineering Group
Oak Ridge National Laboratory
P.O. Box 2009
Oak Ridge, Tennessee 37831-6167
Tel: +1 (865) 574 6515
Fax: +1 (865) 574 2032
Eml: popove@ornl.gov

International Organisations

SARTORI, Enrico
OECD/NEA Data Bank
Le Seine-Saint Germain
12 boulevard des Iles
F-92130 ISSY-LES-MOULINEAUX
Tel: +33 1 45 24 10 72 / 78
Fax: +33 1 45 24 11 10 / 28
Eml: sartori@nea.fr