Unclassified **NEA/NSC/DOC(2007)11**

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

07-Nov-2007

English - Or. English

NUCLEAR ENERGY AGENCY
NUCLEAR SCIENCE COMMITTEE

Cancels & replaces the same document of 06 June 2007

OECD/DOE/CEA PBMR COUPLED NEUTRONICS/THERMAL HYDRAULICS TRANSIENT BENCHMARK - THE PBMR-400 CORE DESIGN

Summary Record of the Third Workshop (PBMRT3)

1-2 February 2007
NEA Headquarters, Issy-les-Moulineaux, France

This document is now classed as "Unclassified".

JT03235365

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

NEA/NSC/DOC(2007)11
Unclassified

English - Or. English

NUCLEAR SCIENCE COMMITTEE

OECD/NEA/NSC PBMR COUPLED NEUTRONICS/THERMAL HYDRAULICS TRANSIENT BENCHMARK THE PBMR-400 CORE DESIGN - Third Workshop

OECD Headquarters, Paris
1 – 2 February 2007

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 accepted, through the Nuclear Science Committee (NSC), the inclusion in its programme of the Pebble-Bed Modular Reactor (PBMR) coupled neutronics/thermal hydraulics transient benchmark problem. The PBMR is a High-Temperature Gas-cooled Reactor (HTGR) concept, developed to be built in South Africa. The benchmark has the purpose of verifying existing and new methods for analysis of a set of well-defined transient cases.

Other similar and recent efforts of pebble bed reactor transient analysis code–to-code comparisons and benchmarking include the PBMR 268MW benchmark problem that served as the predecessor to this effort, and the work under the IAEA CRP-5 project (TECDOC2 in preparation). The OECD benchmark includes additional steady-state and transient cases including reactivity insertion transients. Furthermore it makes use of a common set of cross sections (to eliminate uncertainties between different codes) and includes specific simplifications to the design to limit the need for participants to introduce approximations in their models. It has attracted wider participation.

The purpose of the first workshop was to introduce participants to the benchmark exercise, obtain feedback on the benchmark definition and to establish the possible range of methods and codes that could be used in the code-to-code comparisons. It was also important to establish which experiments might be available to include in later phases of the benchmark effort. Therefore, the presentations of P. Pohl on the AVR and the identification of possible experiments that may be of interest, as well as the presentation of Y. Sun on the experiments carried out, in progress and planned at the HTR-10 reactor, were of great interest to identify possible test cases.

The second workshop took place on 26 and 27 January 2006 at the OECD/NEA Headquarters. The details of the meeting are available in NEA/NSC/DOC(2006)29. Presentation of the status of work related to the PBMR benchmark was presented by ten different participants. The information presented varied from details of the methods and codes employed to the results obtained for the Steady-state cases. The improvements in the benchmark definition (clarifications and additions) were also discussed. The multi-dimensional cross-section tables and the difficulties experienced with the generation of cross sections based on MICROX-2 (for the range of buckling terms required) was explained and the alternative method, to use the Spectrum code pre-processor of TINTE, was proposed and accepted. The focus of the meeting was the steady-state results for Case 1 (neutronics) and Case 2 (thermal hydraulics). Comparisons were made between the results of different participants and some discrepancies were identified, including mesh effects, differences in k-eff, misinterpretation of definitions (outlet pressure, temperatures) and interpretations of the requested results (mesh for reporting, power densities, geometrical range used for averaging). Some of the differences seen could be resolved immediately but others required more detailed analysis or re-evaluation. Participants were requested to submit all updated results by April 2006. ZZ-PBMR-400 (NEA 1746/02), distributed in December 2006, contains all the information, presentations and specification available on 1 December 2006.

A special session was organised at the PHYSOR 2006 conference held in Vancouver, Canada during September 2006. Feedback from this session was provided at the PBMR3.0 meeting (see below).

The technical topics presented at this third workshop are shown below per session. In addition, the workshop programme is attached in Annex I with the list of participants in Annex II. The focus of the third workshop was to:

- Give an update on the status of the benchmark and the future plans. The changes or clarifications made to the benchmark definition were discussed.
- Present and update steady state results and re-analysis. It is clear that some discrepancies still remain. Some time was spent to try and resolve them.
- Show and discuss first results on the steady-state (Exercise 3) coupled neutronics-thermal hydraulics case.

Session I – General Session: *Chair F Reitsma*

The session chairman welcomed everyone to the 3rd PBMR400 workshop. Reitsma gave a short overview of the current interest in HTRs and the need and motivation for the benchmark exercise.

The meeting was attended by 21 participants from 8 countries (see Annex II). The agenda was approved without any change (see Annex I). The participants were given an opportunity to introduce themselves with a short description of the field they are working in and their interest in the benchmark or HTRs in general.

Feedback was then provided on the updates made to the specification from the original specification. These include, amongst others, the clarification on the stagnant helium definitions, clarification on the definition of directional diffusion coefficients, the inclusion of the definition of buckling and the details of the KTA rules as well as clarification on the thermal-hydraulic boundary conditions. The decay heat data as calculated from the DIN 25463 standard was added and includes a log-log interpolation scheme that accurately represents the actual data over the first 100 hours of interest. The updated cross-section tables were also mentioned while the definitions of moderator temperature, fuel temperature and maximum fuel temperature were added.

The following presentation gave a summary of the special session on the OECD PBMR 400MW benchmark organised and held at the PHYSOR 2006 meeting in Vancouver, Canada, on 14 September 2006. In total five presentations were included in the special session and the PHYSOR 2008 international conference was earmarked for another special session.

Session II: Feedback by all participants I (Chair: E Sartori)

The session was the first of two sessions where participants gave feedback on the work they performed related to the benchmark exercises.

In the presentation from Purdue University, made by Jess Gehin, results were shown for steady cases 1-3 and for transient case 5b using the PARCS/THERMIX-DIRECT code. Comparisons with other participants' results show good agreement for the steady state cases. The work includes showing the effects of different void treatment using only a single diffusion coefficient. From Forschungszentrum Karlsruhe, Ron Dagan presented work on the resonance-dependent scattering kernel and its impact on HTGRs neutronic unit cell calculations. He concluded that an improved scattering kernel treatment for U^{238} has a significant effect on HTGR pebble bed calculations, up to 1500 pcm for a two-region heterogeneous fuel zone test case. The proposed correction, which should also be made in MCNP, introduces an 8% difference in the Doppler increase from 1200 – 1800K.

Brian Boer, from TU Delft, presented the DALTON-THERMIX(Direct) code package used to perform the three steady-state cases. Sensitivity results on mesh effects show consistent results with VSOP (coarser mesh) on k-eff. The changes in flux profiles are also shown. Results due to changes in the directional diffusion coefficients in the outer void region (between reflector and barrel) show a larger than expected influence on the k-eff and flux shapes. Exercise 3 and Exercise 1 results compare well, except for the fast flux that was higher in Exercise 3. A possible explanation can be differences in the energy release per fission or the differences in leakage from the calculational domain, but this could not be established during the meeting.

Bismark Tyobeka, from Pennsylvania State University, presented the DORT-THERMIX models to be used to investigate the transport effects in PBMR's. 3D TORT steady-state models. 2D DORT-TH transient capabilities were developed and compared with the NEM diffusion approach. Results from mesh studies, angular quadrature and scattering order, as well as void areas, were shown. The PBMR 268MW benchmark exercise was used in this initial study. The use of the so-called "grey curtain" to represent the control rods in the side reflector in 2D analysis, as is also done in this benchmark exercise, was shown to compare well with explicit 3D transport solutions when the core reactivity (k-eff behaviour) is compared. The presentation also provided detail on the coupling between DORT-TH and THERMIX, including mesh mapping and time-step control, and gave results obtained for a power change and fast control rod removal transient.

Session III. Feedback by all participants II (Chair: K Ivanov)

Two presentations were made from KAERI focussing on the neutronic and thermal-hydraulic aspects of the coupled code, respectively. Hyun Chul Lee presented the MASTER Hex-Z solver and HELIOS/CAPP coupled code. The Reactivity-equivalent Physical Transformation (RPT) approach makes it possible to "remove" the double heterogeneity by transforming the system to a single heterogeneous fuel system (equivalent cylindrical fuel model) that allows the use of conventional transport lattice codes such as HELIOS. This approach was verified with MCNP. The treatment of the void regions will not utilize the directional diffusion coefficients supplied but rather a single diffusion coefficient with discontinuity factors. Steady-state results for Exercise 1 & 3 were shown and compared with results from Purdue University. The use of a single diffusion coefficient with discontinuity factor also proved to work well and the effect of using only a single diffusion coefficient in the void region was judged to be small. The coupled scheme MARS-GCR/CAPP was presented by Seung Wook Lee with results of steady-state Exercise 2&3 focussing on the thermal hydraulic results and models. The MARS features and use of different elements to represent the PBMR core were summarised. Details of the pressure drop, temperatures (gas, moderator, fuel) were included and show good agreement between Case 2 (steady state) and Case 3 (coupled calculation). Preliminary results for the PLOFC-with-SCRAM transient showed expected trends and illustrated the coupled code functionality.

Abdelkrim Sekhri from Necsa gave an overview of the OSCAR code system, the addition of directional diffusion coefficients and the planned inclusion of kinetics and coupling to TRACE or RELAP in future. He showed updated results for the neutronics only steady-state Exercise 1 case for four different void models using different mesh refinements. Abderrafi Ougouag presented an overview of the tools available and planned for HTR analysis at INL. The plan covered the whole range of activities, from cross-section data, cross-section generation, pebble packing and flow, to coupled neutronics thermal-hydraulics codes. The PEBBED code, coupled to THERMIX-KONVEK is the main workhorse. Improvements underway include the nodal solver, transport enhancements, improved resonance treatment (position dependent Dancoff factors) and modelling of radiation damage and effects on cross sections including possible annealing effects during high temperature transients.

In the last presentation of this session, Frederik Reitsma presented recent updates and future plans on the TINTE code system at Pebble Bed Modular Reactor (Pty) Ltd and the Research Centre in Jülich. A short summary of the code capabilities was given. The DIN 25485 standard was recently included into the code, compared to a simplified slightly conservative approach previously employed. Although the differences in decay heat are small and vary between 0% and 4%, the effect on the maximum fuel temperature was ~20°C at the peak. There was some discussion on the reverse engineering and verification and validation status, including a summary of comparisons made with the SANA and NACOK facilities. Finally, the improvement and extension of TINTE was discussed. The code is being extended to a multi-group code, with the option to do in-line spectrum calculations in addition to the current polynomial representation, which might not be adequate in multi groups. Also included is a new solution method for the time-dependent diffusion equation since the current direct solving algorithm is limited to two energy groups. The multi-group solution also allows better approximations of the non-local heat deposition (fast neutrons, gamma transport). The code, when available, can be used to test the multi-dimensional cross section tables with cross terms selected for this benchmark.

Session IV. Cross section library and related issues (Chair: B Tyobeka)

The updated cross-section library was discussed in this session. The previously used MICROX-2 calculational path was replaced by a new path very similar to the one used in TINTE. This was largely due to difficulties in code convergence when the whole range of buckling terms (representing the leakage into or out of a region) was introduced. The TISPEC code, developed as part of the MUPO code during the Dragon project, is used as the basis of a new utility program that generates the data for given input material definition and state parameters. The multi-dimensional cross-section tables with cross terms was extended to include radial and axial diffusion coefficients for all materials and a transport corrected cross section (to be used if transport codes are used). The thermal energy cutoff was also changed to 3.059 eV and the state parameter ranges updated, where appropriate. With this library only limited extrapolation of data (beyond the state-parameter range defined) was experienced in the range of transient cases defined. Clarification on the method of calculating the delayed neutron fractions and energy release per fission, was also given. A second presentation gave a short overview of the difficulties experienced in the creation of the new cross-section library using the Spectrum code. Sensitivity to the Xenon state parameter input values lead to a re-definition of the input data. The earlier set used led to large differences in k-eff and was judged to be unrealistic (too large) and thus was updated more in line with the equilibrium Xenon number densities. Variations in the buckling state parameters and sensitivity to allowing extrapolation (or not) was also discussed and showed by examples. The presentation was concluded by recommendations that will also be included in the updated benchmark specification.

Session V. Benchmark Steady State Cases 1 & 2 (Chair: G Strydom)

Pennsylvania State University prepared the comparisons between all the participant's contributions for Exercises 1 & 2. A summary of the cases was provided, and then all the results were compared and discussed in the session. Exercise 1 has 15 sets of results while 9 sets are available for Exercise 2. For detail please refer to the presentations since only a few remarks will be made here.

The spread in the k-eff values has improved compared to the previously reported values but is still larger than expected in this case where the cross section data are provided and differences should be only due to different methods. Participants should revisit their results and ensure that the mesh is fully refined (this was shown to increase the k-eff in most cases). The current VSOP k-eff = 1.0 result should not be seen as the reference since it was only used to prepare the cross sections and thus its mesh was not fully refined. The standard deviation of 327 pcm should decrease if updated results with convergence mesh effects and the best available void treatment are compared. Power and flux profiles all show similar shapes and trends and generally lie within 10% of each other. These results will probably also benefit from mesh refinement and updates. A recommendation was made that participants should include more detail on models and difficulties encountered to facilitate possible explanations of differences and also to include a Figure of Merit for each code/participant.

Also the Exercise 2 thermal hydraulics results still show some variations in temperatures and pressures. In some cases this is due to misinterpretation of the benchmark specification, but some differences remain. The averaging of parameters over the calculational domain could also be different. The differences in maximum fuel temperatures are large, and since the radially averaged axial fuel sphere surface temperatures compare very well, they must be due to radial variations or definition differences. The definition of fuel, moderator, and maximum fuel temperature was again clarified and is included in the updated specification.

Session VI. Benchmark Steady State Case 3 (Chair: Han de Haas)

Results for Exercise 3 of the steady-state cases using the updated cross-section tables were compared and discussed in this session. Since the library was only made available late in 2006 results from only four participants were available at the meeting. The spread in the results was still quite large but this is probably due to the limited time available to complete the analysis. However, it does show that the cross-section library can produce reasonable results since all the flux, power and temperature shapes are similar and compare qualitatively with the Exercise 1 & 2 results. For example, using the average of the results provided by the participants, the peak fuel temperature is 20°C larger than for Exercise 2. It was interesting to note that although the percentage leakage from the core region was similar at around 14%, the leakage from the calculational domain varied between 0.3% and 3.6%. It was clear from the discussions that the use of the coupled case with full feedback is more challenging than the two separated cases.

Session VII. Transient cases (Chair. A Ougouag)

In the session a summary of all the transient cases was given by INL, followed by a presentation focussing on the transient analysis capabilities developed at INL and some preliminary results. Information was given on the CYNOD time-dependent analytical nodal solver in the cylindrical coordinate system, to be coupled with THERMIX-KONVEK. The Dodds' Transient Benchmark problem was run as verification and shows good agreement with the reference result. Results for Transient case 5b showed the control rod ejection problem. The general behaviour of the transient is as expected and the code seems to behave well.

Gerhard Strydom presented preliminary results for all the transient cases making use of the updated cross-section tables and the TINTE code. The results from the benchmark cases were also compared with the design calculations at PBMR and some noticeable differences were identified. The deposition of heat locally (all heat in the fuel elements) combined with the constant thermal conductivity selected for the reflector regions, have a significant effect on Transient Cases 1-3 where the heat transfer to the reflector structures is very important. Bear in mind that the decay heat source is also assumed to be deposited locally in the benchmark, which is of course not the case. For the reactivity addition transients (Case 5) significant differences between the polynomial cross-section approach and the multi-dimensional tables were noticed. These were later further explored in a second presentation (see the Agenda).

Results for the transient cases were then presented and discussed. For Case 1, the DLOFC without a SCRAM, no re-criticality was observed within the 100 hours specified for the transient duration. The too low thermal conductivity of the side reflector graphite lead to maximum fuel temperatures > 100 °C higher than expected and also occurring much later in the transient. For Case 4, the use of the ROMO model to move the control rods to keep the reactor critical was shown and this also raised questions as to the approach other participants would take. An external reactivity requirement could be one way of keeping the reactor critical during the transient or, alternatively, the control rods could be moved explicitly. In Case 5, the cusping effect (due to volume weighting of the cross sections of partially rodded nodes) was pointed out and should be corrected by a blackness theory or similar method.

A short presentation by Frederik Reitsma looked at the experiences in the IAEA CRP5 initiative on analysing the HTR-10 transient experiments. A short overview of the reactor design and models used was given. The test cases include steady-state temperature measurements, loss of primary flow without SCRAM, and a single control rod withdrawal without SCRAM. Some of the difficulties to model the side reflector temperatures were shown where the calculations were consistently out. One possible explanation was the lack of detailed helium flow information in the conus region and the leakages through the side reflector. The loss of coolant experiment also presented a challenge to simulate. Although the general trends and phenomena were correctly modelled, the analysis typically had either mispredicted the peak height or the time at which it occurs. The differences could not be resolved with the information available. The experiments at the HTR-10 is of utmost importance to the HTR community and inclusion of these or later experiments into the IRPhEP or similar format, where a more detailed specification is required and all uncertainties are quantified, should be pursued.

Session VIII. Discussion and closing (Chair: F. Reitsma)

During the closing session an action list was drafted (enclosed as pages 9 and 10). Participants were also reminded that abstracts for the PHYSOR 2008 meeting are due on 5 October 2007 and therefore that submissions will most probably be needed before the next benchmark meeting that was scheduled preliminarily from 31 January to 1 February 2008 at the OECD/NEA Headquarters in Paris. The possibility of having the last benchmark meeting coinciding with PHYSOR 2008 was also mentioned and would be investigated. The chairman thanked all the participants and the meeting was adjourned.

Proceedings of the Workshop

As well as with this summary, participants will receive 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.

Task list / Outstanding issues - PBMRT3 meeting

- Specification / information to be finalised:
  - Treatment of cusping effect (Case 5) needs to be decided.
    Action: NRG do transport XS weighting to get D's; rest by volume weighting; testing by PBMR
  - Energy release per fission value on library too low.
    Action: PBMR to check and make suggestion / correction; NRG to send WIMS values; Will be updated if any other reason emerges for library update
  - Kernel / fuel element detailed thermal-hydraulics model needed for fast transients – Action: PBMR to discuss with IKE; FZK to assist
  - PLOFC (Case 3): Treatment of 60 bar constant or keep gas inventory constant and allow pressure to change.
    Action: PBMR to make proposal on coupled to large volume and temperature to simulate actual conditions; Iterate with KAERI, Update specification
- Point kinetics parameters to be supplied. Is there still a need?
  Action: No action now, only upon new requests
- Transport cross sections now added to dynamic library.
  - Investigate if transport cross sections for the test library (Case 1) can be given.
    Action: PBMR to check and report to B Tyobeka / meeting
  - Test the supplied cross sections in transport codes
    Action: B Tyobeka in DORT-TD; B Boer to follow up with US (CdeO)
- All results submitted must be for converged results / meshes refined to show this (or explanations if not achieved).
  Action: Update template to state this in submission, give detail, PBMR to add to templates
- ALL:
  - Convergence criteria used to be given by participants
  - Boundary conditions used to be clearly stated
  - Figure of merit (proposed by PSU – to facilitate this as part of statistical analysis)
  - Add heat flux (heat loss) to outside system as a required result (as already supplied by some participants); Spec will reflect this and the template.
  - Add temperature distribution in CB and RPV? No, not to be included
- Temperature definitions: Terms to be used: Moderator temperature (all graphite in core / region average); Fuel temperature (inner fuel sphere region over 5cm diameter); and Central Fuel kernel temperature (specification and templates to be consistent. (Distinction between kernel and graphite temperature for Case 5b)
  Action: PBMR to make sure it is correct in the updated specification.
- ALL:
  - Need short summaries of codes / methods to be used from all participants. Length: 1page for code with template (PSU)?
    Action: All; **31 July 2007** -> These will be included in an Appendix of the final report.
- Generation of a reference calculation for Case 1. (VSOP mesh refinement will lead to cross sections being updated). CITATION stand-alone calculations will be done to update VSOP reference result (PBMR)
  Action:, MCNP was mentioned at previous workshop. What to do with cross sections – VSOP isotopic vector can be used. (such a comparisons was done by PBMR – HTR2006 conference). Updated VSOP/ CITATION results.
- Proposal for simplified problem from Korea. Core region and reflector region. Only for work in progress, this is not part of the specification. One or two region problem with an analytic solution? PBMR to make call after update of the results received on Case 1 and 2; Dodd benchmark problem

- CASE3 to be clarified:
  - Fuel and Moderator temperature coefficients to be reported – with clear definitions (use only as second phase if differences can not be resolved…)
  - Xenon distribution maps
  - make sure effects are similar before the transients are compared in detail?
  - Some additional information / sub cases needed for Steady-state Case 3?? Buckling/leakage values
  - Thermal conductivity
- Control rod withdrawal reactivity worth to be estimated with steady state calculations (in support of cases 5); Action: ARI, ARO steady state results- added to definition; all to do
- β_{eff} vs physical β in 2 groups.
  Action: PBMR to make sure / discuss with FZJ (G Strydom); K Ivanov to advice
- Spreadsheets to be put back on web page after updates.
  Action: PSU:15 June 2007.
- Transient case updates, Thermal conductivity 0.2 – 0.26 YES, Trickle flow Case 1; Slower change of mass flow for case 4 (6 minutes)
  Action: PBMR, with next update
- Checklist for Cases; Convergence, meshes, boundary conditions.
  Action: PSU to draft (15 June 2007), to be sent with update
- Reference solution to be found for Case 1 (Delft /DALTON) and 2 (KAERI)
  - The average of converged solutions will look better
  - PSU to judge how to / and if to use this (may not use the reference but the statistical approach)
- THERMIX codes (versions) to be followed up
  - 4 users of THERMIX-DIRECT to compare input data and clarify their differences.
- Questions on models to be drafted by PSU
- Transport cross section definition to be added to specification.

Target Dates (Revised from the draft dates at the meeting)

1	Updated benchmark specification with all clarifications from this meeting included. Draft document for comment distributed	PBMR Comment asked from all 15 June 2007
2	Specification document with feedback incorporated – send draft to OECD / made ready for publication	All give feedback: 31 August PBMR to update and send to OECD: 15 October 2007
3	Updates for Steady-Case 1&2. Drafting of comparison document will start) Code descriptions also submitted	All 31 August 2007
4	Steady-state case 3 results updated: Comparisons to be made and placed on web for all to analyse	All 31 August 2007
5	Multi-dimensional cross section library (status OK?, Update energy release per fission? Additional tests required?	To be frozen; If updated needed; 15 June
6	Transient cases draft (sent to PSU 1 September) PSU to put on webpage 30 September and ask comments. Specific questions to be raised	1 Sept / 30 Sept
7	Updated transient results to PSU Outline of Volume II (Results)	1 December

* Note that this table and the presentation included on the CD-ROM contain revised target dates (not the same as the draft in February) The CD-ROM distribution is planned for mid-June 2007.

Annex I

OECD/NEA/NSC
PBMR COUPLED NEUTRONICS/THERMAL HYDRAULICS TRANSIENT BENCHMARK
THE PBMR-400 CORE DESIGN– 3rd Workshop

1 – 2 February 2007

FINAL PROGRAMME [**P301**]
([n] indicates paper identification on CD-ROM)

Day 1: 1 February 2007

I. General Session (Chair: F. Reitsma)

1. 09:15 – 09:30 Introduction and opening remarks – introduction of participants [**P302**]
2. 09:30 – 09:35 Adoption of agenda
3. 09:35 – 10:20

3a Feedback on Benchmark Specification updates and PBMRT2.0 meeting [**P303**]
3b Feedback on special session at PHYSOR2006 [**P304**]

II. Feedback by all participants I (Chair: E Sartori)

4. 10:45 – 12:45 Presentations from all participants on progress and results.

4a Tony Ulses: “The Analysis of the PBMR-400 Benchmark Problem.” [**P305**]
4b Ron Dagan: “Resonance dependent scattering-kernel and its impact on HTGRs. Neutronic unit cell calculations" [**P306**]
4c B. Boer, D. Lathouwers, J.L. Kloosterman: “TU Delft modelling developments and results concerning PBMR400 steady state calculations” [**P307**]
4d Bismark Tyobeka: “DORT-TD/THERMIX models and results” [**P308**]
Discussions

III. Feedback by all participants II (Chair: K Ivanov)

5. 14:00 – 16:00 Presentations from all participants on progress and results.

5a Hyun Chul Lee: “Neutronics and Coupled Calculation of OECD/NEA Benchmark Problem with CAPP Code” [**P309**]
5b Seung Wook Lee: “Thermal Hydraulic and Coupled Calculation of OECD/NEA PBMR-400 Benchmark Problem with MARS-GCR/CAPP” [**P310**]
5c Abdelkrim Sekhri: “Updated steady state OSCAR-4 results and proposed thermal-hydraulic coupling” [**P311**]
5d Abderrafi Ougouag: “The HTR analysis tools at INL - status and future plans” [**P312**]
5e Frederik Reitsma “Recent updates and future plans on the TINTE code system at PBMR” [**P313**]
Discussions

IV. Cross-section library (Chair: Bismark Tyobeka)

6. 16:30 – 17:30 Update of status of supplied library and tests performed.

6a F Reitsma: "The updated cross-section library and data" [**P314**]

6b F Reitsma: "Difficulties experienced and sensitivity of analysis to the updated cross-section library and data" [**P315**]

6c Questions and discussions, final acceptance of new library.

<u>Day 2: 2 February 2007</u>

V. Benchmark Steady State Cases 1 and 2 (Chair: G Strydom)

7. 08:30 – 10:00 Steady State Test case 1 & 2 - results and discussions

Clarification, summary of results received, comparisons, discussion of results.

7a K Ivanov: "Comparisons and analysis of final results of all participants of Exercise 1" [**P316**]

7b B Tyobeka: "Comparisons and analysis of final results of all participants of Exercise 2" [**P317**]

7c Discussions, draft conclusions on results, list of final clarifications to be requested.

VI. Benchmark Steady State Test Case 3 (Chair: Han de Haas)

8. 10:25 – 11:30 Steady State Test Case 3

Definition, summary of results, comparisons, discussion of results.

8a K Ivanov: "Comparisons and analysis of preliminary results of Exercise 3 [**P318**]

8b Discussions and Recommendations, list of clarifications needed.

VI. Transient Cases (Chair: Abderrafi Ougouag)

9. 11:30 – 12:30 Transient case Definition, First Results, Discussion of results.

9a A Ougouag:"Transient Case Definitions", A short reminder [**P319**]

9b A Ougouag: "INL Preliminary results for transient cases" [**P320**]

9c G Strydom: "TINTE Preliminary Results for all transient cases" [**P321**]

9d Discussion

VII. Transient cases - Continued (Chair: Abderrafi Ougouag)

10. 13:45 – 14:40 Specific issues on transient cases

10a G Strydom: "OECD Transient comparisons with standard TINTE approach – proposed changes" [**P322**]

10b F Reitsma: "Transient Cases on HTR-10 in CRP5 (results and lessons learned)" [**P323**]

10c Discussions, decision on proposed changes.

VIII. Discussion and closing (Chair: F. Reitsma)

11. 15:10 – 16:00 Discussion of future actions, special sessions at conferences / journal and schedule

12. 16:00 – 16:15 Discussion of next meeting and deliverables [**P324**]

13. 16:15 – 16:30 Any other business and closure of meeting

Annex II

List of Participants

FINLAND:

LEPPANEN, Jaakko, VTT Technical Research Centre of Finland

FRANCE:

SANCHEZ, Richard, Research Director, CEA Saclay

GERMANY:

BECKER, Bjoern, Forschungszentrum Karlsruhe GmbH
DAGAN, Ron, Forschungszentrum Karlsruhe GmbH

KOREA (REPUBLIC OF):

LEE, Hyun-Chul, Korea Atomic Energy Research Institute
LEE, Seung Wook, Korea Atomic Energy Research Institute

NETHERLANDS:

BOER, Brian, TU Delft
DE HAAS, J.B.M. (Han), Reactor Physics Analysis, NRG

RUSSIAN FEDERATION:

DUDNIKOV, Anatoly A., Institute of Nuclear Reactors, RRC, “Kurchatov Institute”
SHESTOPALOV, Alexey Alexeyevich, Institute of Nuclear Reactors, RRC, “Kurchatov Institute”

SOUTH AFRICA:

REITSMA, Frederik, Nuclear Engineering Analysis, PBMR Pty Ltd
SEKHRI, Abdelkrim, South African Nuclear Energy Corporation (Necsa)
STRYDOM, Gerhard, Nuclear Engineering Analysis, PBMR Pty Ltd

UNITED STATES OF AMERICA:

GEHIN, Jess C., Oak Ridge National Laboratory
IVANOV, Kostadin, Head of RDFMG, Pennsylvania State University
OUGOUAG, Abderrafi M., Idaho National Laboratory
SZILARD, Ronaldo H., Idaho National Laboratory
TYOBEBA, Bismark, Pennsylvania State University
ULSES, Tony P., Office of Research, USNRC.

INTERNATIONAL ORGANIZATIONS:

SARTORI, Enrico, OECD/NEA Databank
HASEGAWA, Akira, OECD/NEA Databank