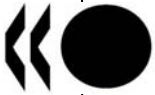


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**NUCLEAR ENERGY AGENCY
NUCLEAR SCIENCE COMMITTEE**

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

Summary Record of the First Workshop (PBMRT1)

**16-17 June 2005
OECD Headquarters, Paris, France**

JT00188349

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NUCLEAR SCIENCE COMMITTEE

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

OECD Headquarters, Paris
16 – 17 June 2005

SUMMARY RECORD

Content:

- Background and Purpose of the Benchmark Workshop
- Session I – General Session
- Session II – Benchmark Specification I
- Session III – Benchmark Cases
- Session IV – Examples of Benchmark results
- Session V – Discussions
- Session VI – Specific Issues I
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- Session VIII – Closing Session / Discussion and Closing
- Annex I – Workshop Programme
- Annex II – Workshop Participants

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, which has attracted the attention of the nuclear research and development community. The deterministic neutronics, thermal-hydraulics and transient analysis tools and methods available to design and analyse PBMRs have, in many cases, lagged behind the state of the art compared to other reactor technologies. This has motivated the testing of existing methods for HTGRs but also the development of more accurate and efficient tools to analyse the neutronics and thermal-hydraulic behaviour for the design and safety evaluations of the PBMR. In addition to the development of new methods, this includes defining appropriate benchmarks to verify and validate the new methods in computer codes.

The benchmark is complementary to other on-going or planned efforts in the reactor physics community. The PBMR 268MW benchmark problem, initiated by PBMR Pty Ltd, PSU (Penn State University) and NRG, served as the predecessor to this effort. The work will be concluded in 2005 and future efforts will focus on this benchmark. The PBMR 400MW core design is also a test case in the IAEA

CRP-5 (TECDOC2 in preparation) but important differences exist between the test case definitions and approaches. The OECD benchmark includes additional steady-state and transients cases including reactivity insertion transients not included in the CRP5 effort. 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.

The purpose of the first workshop, held at OECD Headquarters in Paris, 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 will 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 and the presentation of Y. Sun on the experiments carried out, in progress and planned at the HTR-10 reactor, were of great interest to already now start identifying possible test cases.

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

Session I – General Session: Chair F Reitsma

The meeting was opened by Dr. Enrico Sartori welcomed the participants on behalf of the NEA Secretariat. Frederik Reitsma then presented a short overview of the renewed interest in HTR's illustrated by the research reactors in Japan (HTTR) and China (HTR-10), support of the Generation IV (VHTR's), the European program, and in particular the two commercial programs in the pebble bed reactor design in South Africa and China. [2] The need for a benchmark exercise and code-to-code validation was discussed. Since most of the software tools used for pebble bed reactor design was not developed under a modern quality system there exists a need to verify the software in code-to-code comparisons and validate it against experiments.

The meeting was attended by 24 participants from 12 countries (see Annex II). The agenda was approved with some minor adjustments required due to the availability of participants (see Annex I).

The participants were given an opportunity to introduce themselves with a short description of what field they are working in and their interest in the benchmark or HTRs in general.

Mr Peter Pohl, from AVR GmbH, presented an overview of the AVR operational experience. This includes an historical overview, some information on the design and specific details seen as relevant to the HTR projects of today. Interesting aspects noted that the reactor was operated with a high coolant outlet temperature of 950 °C for nearly 30% of its operational life. Emphasis was placed on the ability of HTR's to achieve a very high fuel usage (>120% fuel can be achieved). The question of high fuel temperatures measured was also discussed with possible reasons discussed for example larger than expected bypass flows or wall effects. Efforts are underway to investigate the data again and to come to an understanding of the reasons why large differences was seen between the predicted and measured data. What is important to note that despite the very high temperatures measured the fission product releases were low for the modern UO₂ TRISO fuel. The HTR Manifesto of the AVR GmbH Company was then introduced and discussed. [3]

In a second part of the General Session (presented on Day 2), Prof. Yuliang SUN presented the history and plans of experiments carried out at the HTR-10 reactor [4]. The presentation included an overview of the reactor, its main characteristics and instrumentation. The focus was on the experiments, past, present and future carried out during the commissioning phases. Some of these are already available

through the CRP5 project of the IAEA. Experiments on the loss of primary cooling and reactivity insertion, both without scram, were already performed while safety demonstration tests under rated power of 10MW are planned. In future a He turbine-generator unit will also be installed. Opportunities to include some of the recent experiments, not part of CRP5, in future phases of the OECD PBMR benchmark program will be discussed in future.

Session II: Benchmark Specification: *Chair: H de Haas*

F Reitsma from PBMR Pty Ltd, South Africa, presented the benchmark problem based on the draft specification made available. [5] The focus of the presentation was on the motivation and objectives of the benchmark exercise, the reactor layout and the fuel and material properties. An update of the current single-shaft power conversion system layout was also given. The detailed reactor layout of the benchmark definition and justification of the simplifications introduced were also provided. When the core thermal-hydraulic description was presented, that was focussed only on the input required by the THERMIX/DIREKT/KONVECT modules employed by the originators of the benchmark, some deficiencies in the specification were identified. The application of other thermal-hydraulics modules (other than THERMIX and its derivatives) to the benchmark problem was seen to be essential. Some of the short-comings were identified at the meeting and additional feedback was promised by participants on how to update the definition.

Session III. Benchmark Cases: *Chair: P. Pohl*

Steady-state cases:

The steady-state case definitions were introduced by K Ivanov from Penn State University. The three exercises as defined in the benchmark specification were introduced as well as the rationale for their inclusion. The first two cases test the neutronics and thermal-hydraulics representation of the benchmark specification separately. Exercise 1 makes use of a simplified cross section library with no state parameter dependencies (single set of data) while Exercise 2 uses a given heat source (power distribution) to calculate the temperature distribution and other thermal and coolant flow properties. The last exercise represents the equilibrium cycle steady-state conditions and makes use of the state-parameter dependent cross section library and thus are a coupled neutronics – thermal-hydraulics calculation. This case also represents the starting conditions for the transient events.

Examples of preliminary steady state results for Exercise 1 were then presented by F Reitsma for VSOP99 used in the preparation of the benchmark definition and also compared to the TINTE code that will be used by PBMR to participate in the benchmark. [6] The purpose was to illustrate what the typical power, flux and thermal behaviour of the design looks like while the comparisons with TINTE shows that the cross section library was in principle correctly incorporated.

Transient cases:

The transient case definitions were then introduced by H Gougar from INL. The transient cases aim to capture both slow and fast transients possible in the pebble-bed reactor. The transient cases are defined in detail in the draft specification. The cases are: (1) DLOFC without SCRAM; (2) DLOFC with SCRAM; (3) PLOFC with SCRAM; (4) Load follow 100%-40%-100%; (5) Reactivity insertion by CRW and CRE and (6) Cold Helium Inlet. The definition led to very interesting discussions and many comments were received from the participants. This includes amongst other the clarification of boundary conditions, inclusion of natural convection, the reduction of the required analysis time, discussions of how to perform the load follow analysis and clarifications on control rod movement during the events. These will be included in the updated draft specification.

A second presentation on the transient cases was given by T Downar from Purdue University. [7] The focus was on refining the definition of Test Case 5 to include both sub-prompt and super-prompt 2D and 3D cases by performing the different cases with the PARCS code. PARCS results were also compared with the “Prompt Kinetics Approximation with Linear Energy Feedback Model” and point kinetics. This study was performed making use of the PBMR 268MW model developed earlier. The recommendations of the study were already included in the draft specification.

Session IV. Samples: *Chair: C. de Oliveira*

Preliminary transient case results were presented by F Reitsma. [8] The events were calculated by the TINTE code making use of a partly implemented benchmark cross section library. Once again, as in the case for the steady-state cases the purpose was to show the typical behaviour of the PBMR reactor design. A short introduction of the TINTE code, its different modules and features were also included in the presentation. Results showed very similar behaviour for the benchmark compared to the reference PBMR design calculations in most cases. A few areas were identified that need further investigations such as the lack of re-criticality for the DLOFC event without SCRAM.

Session V. Discussions of 1st day presentations: *Chair: F Reitsma*

A discussion session was held at the end of the formal proceedings of day 1. The focus was to get feedback on the benchmark definition and to document additional questions and concerns of participants. The technical ability of representatives to participate with available tools was also discussed. The general feedback from this session was that participants are positive about the benchmark specification and their ability to participate (technically) and that the deficiencies in the specification (mostly in thermal-hydraulics) could easily be resolved.

Session VI. Specific Issues I: *Chair: H. Gougar*

Cross section Libraries:

The cross section library philosophy was introduced by K Ivanov from Penn State University. [9] Some detail of the MICROX path used to prepare the cross sections were provided. The macroscopic cross sections for identified core and reflector regions in the core are given as five-dimensional tables that represent the dependence on fuel temperature, moderator temperature, fast and thermal leakage and xenon concentrations. The use of the multi-dimensional tables with the provided interpolation routines were previously successfully applied to other transient analysis and OECD coupled code benchmarks.

Details of the temperature ranges, xenon concentrations and fast / thermal buckling terms representing the leakage were discussed. The cross sections available, the representation of the data in the multi-dimensional tables including the key how to extract the data, and a list of additional kinetic and other parameters were also presented.

The difficulties currently experienced in generating cross sections over the total leakage or buckling range were discussed. The possibility to simplify the cross section representation by excluding one or more of the leakage feedback dependencies needs to be evaluated. The introduction of the leakage feedback in different codes can also be problematic since it will be very dependent on the methods employed and the mesh sizes used. The need for a more detailed definition of the buckling term used and a question about the linear dependence of cross sections on the xenon concentrations were also raised. More

work is required to finalise the cross section library definition and to study the cross section behaviour in more detail.

Thermal Hydraulic Data Specifics:

In the presentation of H de Haas from NRG he gave attention to the specific methods and correlations suggested in the benchmark and which are typically used in pebble-bed reactor designs. [10] The presentation focussed on the approach used in the THERMIX/DIREKT module of the PANTHERMIX code. A very important quantity is the change in the graphite thermal conductivity that is dependent on temperature but also on the fast fluence seen by the material and the temperature at which this fast fluence was administered. The pebble-bed also represents an interesting challenge as the effective thermal conductivity, normally represented by the Zehner-Schlünder or Robold correlations are used to include the different heat transfer phenomena in a pebble bed for example thermal conductivity through touching spheres and radiation between pebble surfaces. Attention was also given to the hydraulic properties like heat transfer between pebbles and coolant, the cross flow across the core allowed so natural convection can be simulated and the temperature calculations within the fuel spheres.

Coupling data such as overlays etc:

The presentation by K Ivanov from Penn State University was focused on the neutronics / thermal-hydraulics coupling required for the benchmark. [11] The PBMR feedback effects (as normal for thermal reactors) were discussed with special emphasis placed on large heat capacity of the core (that causes overall temperature changes to be slow) and the need to model the core temperatures in a heterogeneous way. Some pointers on spatial and temporal coupling were also given using the THERMIX-NEM coupling as an example. Notes on the convergence criteria employed and suggested criteria for the benchmark were discussed.

Fuel Kernel thermal-hydraulics model for fast reactivity transients:

The work performed by P Lourens from PBMR was presented by F Reitsma. [12] The thermal conductivity models employed to determine fuel temperatures during normal operation often does not take the coated particles and its thermal properties into account. In most cases this omission is acceptable since a rapid heat transfer takes place from the coated particle to the surrounding graphite matrix. However, if fast power transients occur the temperature differences between the coated particles and the surrounding graphite will be large and must be taken into account to be able to predict fast reactivity transients accurately.

A method was suggested to introduce the solution of a representative micro-system representing the coated particles within discretized fuel pebble shells. The time-dependent algorithm developed to solve for the temperatures in a pebble was introduced into a test code and results were presented for a steady-state and power ramp case. The module is to be developed further and implemented into the TINTE software.

Session VII. Specific Issues II: Chair: K. Ivanov

The presentations invited from all participants were included in this special session. The presentations provided an overview of the expectations of participants, the codes and methods they may use to participate or any additional information they wished to share with the meeting.

1. The Reactor Physics Analysis Capabilities at INL with the PEBBED Code was presented by Hans Gougar from INL [13]
The presentation provides an overview of the code capabilities and recent developments that includes coupling to THERMIX (KONVEK), leakage feedback and an update of its diffusion

solver (nodal). Recently studies on pebble dynamics were also added including packing densities and core compaction induced by an earthquake. Information on cooperation in the areas of cross section generation (COMBINE and MICROX), rigorous treatment of Dancoff factors, radiation damage effects of graphite amongst other, were also shared.

2. PBMR Transients Modeling with DSNP System, by E. Shwageraus, A. Galperin, B. Tavron, D. Saphier [14]

The DSNP code system (Dynamic Simulator for Nuclear (and other) Power Systems) was introduced. The code is capable to model various reactor types and a wide range of transients. The code is fully modular and this allows easy modification or upgrades of components and allows analysis on different levels of sophistication. Some examples were shown to illustrate the code capabilities including a 200MW Pebble type HTR.

3. The Coupled Thermal-hydraulics / neutronics code MARS/MASTER, by Jae-Jun Jeong [15]

An overview of the code, its components and the coupled code and the role it plays within KAERI's activities was provided. MARS, the best estimate thermal hydraulic system code, has many LWR modules but also includes hydrodynamics for porous media that can be used for gas cooled reactor applications. Features of the MASTER core neutronics design and analysis code were also presented as well as how the two codes are coupled. Although developed for LWR's good progress has been made for Gas cooled reactor applications with many models developed, adjusted or planned.

4. MCNP and Thermal-Hydraulics Coupling for PBMR. by C. N. Sökmen, M. Tombakoglu, A. Karahan, C. Celik [16]

The combination of using MCNP and a thermal-hydraulic model T-Bed was used to model the PBMR 400MW CRP-5 benchmark. An overview of the coupled model and details of the MCNP fuel sphere and core model were included. Features and restrictions of the T-Bed model include 2D heat equation for the surface temperature in the core and reflector, 1-D conduction for the fuel temperature, parallel equal pressure drop channels for the helium flow through the pebble bed (no cross flow) and convection of helium. Results and illustrations of the coupled code's convergence behaviour were also discussed.

5. The KIKO3D 3D dynamic code by A. Keresztúri, Gy. Hegyi [17]

The general features and validation of the KOKO3D-ATHLET code were presented with a specific view of which models and data are missing for the PBMR application. The code system, focussed on VVER analysis, will need some modifications to be able to model the benchmark. Although R-Z geometry is not available the hexagonal presentation could be used while the use of directional dependent diffusion coefficients should be easy to add. The shape function module used to solve the time dependent diffusion equation can also easily be adapted to solve the heat conductance equation over the core. Absorbers and the reflector can be presented by pre-calculated parameter dependent albedo matrices. Plans to overcome some of the missing features required in ATHLET for PBMR's were also introduced. Details on the coupling options of the two codes and validation results for LWR's are included.

6. Coupled Neutronics / Thermal Hydraulics, EVENT-THERMIX. by B. Boer, J. L. Kloosterman, D. Lathouwers [18]

The aims and plans at Delft University of Technology with the coupled code EVENT-THERMIX were presented. The goal is to perform VHTR research for design optimization. Current plans are to couple EVENT (from Georgia Tech), a code that uses a variational finite element spherical harmonics method to solve even-parity multi-group transport equations to the THERMIX-DIREKT (FZJ/NRG) code.

7. UK Activities in Support of Gas Reactor Development by R. Stainsby, R.E. Sunderland, J.T. Murgatroyd [19]

A summary of the UK experience and expertise in the area of GCR/HTGR was provided with the current activities focused around European and International programmes with the aim to retain the nuclear capabilities and skills. In Generation IV UK interest is in VHTR and Gas Cooled Fast

Reactor (GFR) systems and some technical studies underway. Efforts to create a re-fuelling algorithm for WIMS as well to couple WIMS with a HTR thermal hydraulics model is on-going.

8. Highlights on recent IAEA HTGR coordinated research projects by M. Methnani [20]

An overview of the HTGR coordinated research projects were provided with CRP-5 on Core Methods Benchmarking closely related to this benchmark effort. A summary of the CRP-5 benchmark cases and participating institutes was given. Specific cases of interest to the participants were highlighted including the ASTRA experiments, HTR-10 initial criticality and some safety events, and the PBMR 400MW core design. The next CRP-5 meeting is to be held from 5-9 September 2005 in Vienna. An overview of CRP-6 (Advances in HTGR Fuel Technology) and CRP-7 (HTGR Process Heat Applications) was also given.

A discussion was held on the variation of methods and codes to be applied in the benchmark exercise. Once again the essence to have thermal-hydraulics codes available that is not based on the THERMIX family was emphasised. The wide variation in the tools available to participants was very encouraging and will contribute to the success of the benchmark.

Current and planned activities carried out within the OECD Nuclear Science Committee working groups and relative to HTR benchmarks were briefly presented by E. Sartori. [21]

One part of these activities are carried out within the Working Party on scientific issues of Reactor Systems (WPRS) and concerns on the one hand a computational benchmark for an HTR fuelled with Reactor Grade Plutonium, for Reactor Grade Pu/Th and U/Th pebbles. This benchmark is nearing conclusion. On the other a benchmark based on measurements of the absorber rod worths in LEU-HTR PROTEUS configurations. The corresponding specification was issued and distributed.

Other activities are carried out or planned within the International Reactor Physics Experiments Evaluation (IRPhE) Project, aimed at documenting and evaluating reactor physics experiments of great value in a standard, quality assured and peer reviewed form. Several evaluations concern HTRs, namely:

- HTTR-GCR-RESR-001, CRIT-REAC-COEF-POWDIS, Evaluation of the High Temperature Engineering Test Reactor
- HTR10-GCR-RESR-001, CRIT, Evaluation of the Initial Critical Configuration for the HTR-10 Pebble Bed Reactor
- VHTRC-GCR-RESR-001, CRIT-COEF, Very High Temperature Reactor Critical Assembly (VHTRC) Temperature Coefficient Benchmark
- ASTRA-GCR-RESR-001: critical assembly,
 - i. Criticality changes with filling heights 268.9 to 320.8 cm
 - ii. Control rod worth of control rods CR1, CR2, CR4, CR5
 - iii. Control rod worth for control rods inserted varying distances from the core in the side reflector
 - iv. Interference effects of control rods combinations
 - v. Differential reactivity of CR5 and MR1
 - vi. Radial and axial flux distributions (measured U-235 reaction rates)
- There is a plan to include also experiments from the AVR reactor.

Electronic archives of primary reports from completed reactor physics experiments are also prepared within the IRPhE project. The following concern HTRs:

- IRPhE/HTR-ARCH-01, Archive of HTR Primary Documents
 - Graphite Moderated Critical Facility , CESAR at Cadarache
 - OTTO Pebble Bed Reactors
 - Gulf - HTGR Experiments
 - Zero Power MARIUS Reactor

- Pebble-bed KAHTER Critical Facility
 - Helium Cooled Fast Reactor Assessment Studies
 - Initial Evaluation of the Gas-Turbine Modules HTGCR
 - HTR IAEA reports on HTTR, PROTEUS and HTR-10
 - HTR Studies at IRI Delft
 - HTR Studies & experiments at PSI Villigen
- IRPhE-DRAGON-DPR, OECD HTR Dragon Project
 - IRPhE/AVR, Archive of Experimental High Temperature Reactor

Session VIII. Discussion and closing: *Chair: F. Reitsma*

In the final session a summary was made by the chairman and future deliverables and actions was discussed. [22] A short summary is provided below but the detailed technical comments will be dealt within the benchmark specification.

- The cross section library to be used for the benchmark exercise needs clarification. The dependence on fast / thermal leakage (buckling) may introduce problems depending on the solution method and mesh sizes used while data needs to be added for participants making use of transport solutions. The library should be thoroughly evaluated and compared to other cross section data sets. Attention must be given to the restrictive fast and thermal buckling input values yielding physical cross sections results in MICROX – to prevent excessive extrapolation with potential negative cross sections
- It is essential that not everyone use the same thermal-hydraulics models, i.e. THERMIX
- Additional detail that must be supplied was identified. Most of these are in the area of thermal-hydraulics definition. For example information on the KTA rules used for pebble bed reactors should be supplied while more detailed thermal properties (for participants that want to model thermal hydraulic properties explicitly) is required. Clear definitions on fuel, moderator and reflector temperatures need to be added. A method should also be suggested for fast transient fuel temperature calculations.
- The specified constant reflector graphite thermal conductivity is too low – higher constant value to be defined or a correlation must be provided
- An consistent energy release per fission (κ 's) must be provided and should be well defined – one suggestion is to use the current value from TINTE and exclude components that is included in the decay heat
- Simplifications with burnup chain (no FP's) introduces very high burnup – fission fractions may not be representative and a different solution needs to be found
- Decay heat as lookup table to be added to specification
- Supply of fuel kernel temperature theory / model for implementation

Actions and Deliverables:

A) From 1st meeting:

1. CD of meeting containing summary and all presentations and VSOP sample library – 1 September 2005 (F Reitsma/Sartori)
2. CD containing updated specifications, templates for results (End September 2005)
3. Ad-hoc meeting at M&C2005 conference if possible.

- B) The following deliverables are scheduled for the 2nd PBMR 400MW benchmark meeting to be held at OECD/NEA headquarters on 26-27 January 2006:
1. Steady state results for Exercise 1 & 2 (Neutronic and thermal hydraulic solutions)
 - a. Benchmark definition implemented into a code model
 - b. Cross section library functionality must be coupled (with feedback)
 - c. Thermal hydraulic solution method implemented
 2. Preliminary results for Exercise 3 (coupled case)
 3. Results for steady state cases to be sent to PSU (Kostadin Ivanov) by 15 November 2005.
- C) The following participants indicated that they will be participating in the benchmark subject to final permission from their institutes:

University of Stuttgart, Germany	ZIRCUS code system
Institute of Nuclear Energy Technology, Tsinghua University, P.R. China	VSOP, THERMIX
PBMR Pty Ltd, South Africa	TINTE
Purdue University	PARCS-THERMIX
Penn State University, USA	NEM-THERMIX
INL, USA	Pebbed-THERMIX
KAERI, Korea	MARS/MASTER
CEA + EDF, France	CRONOS / MAT4 DYN
NRG, Netherlands	PANTHERMIX
Hacette University, Turkey	MCNP/T-Bed
KFKI, Hungary	KIKO-3D
DELFT University, Netherlands	EVENT-THERMIX
Ben Gurion University of the Negev, Israel	DSNP
NNC Ltd, UK	WIMS-9

In summary it can be said that a detailed PBMR400MW benchmark definition was prepared and a lot of feedback was received at the meeting to be incorporated. An invitation is once again made to each participant to send comments or to ask for clarification.

The meeting was well attended and the discussion has shown the big interest of participants and their organisation in this study.

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.

Annex I

OECD/DOE/CEA PBMRT01 PBMR Transients 1st Workshop

OECD Headquarters, Paris, 16-17 June 2005

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

I. General Session (Chair: F. Reitsma)

1. Welcome and opening remarks [02a] – introduction of participants [02b]
2. Adoption of agenda
3. Our HTGR Manifesto (P. Pohl) [03a],
AVR Experiences Overview (presentation) [03b], (paper) [03c]
4. Experiments carried out, in progress and planned at the HTR-10 Reactor (Y. Sun) [04]

II. Benchmark Specification I (Chair: H. de Haas)

5. Benchmark general description and specification (F. Reitsma) [05]
 - a. Motivation and objectives
 - b. Reactor layout
 - c. Fuel and Material specifications

III. Benchmark Cases (Chair: P. Pohl)

6. Steady state cases for PBMR-400 coupled code benchmark (K. Ivanov, F. Reitsma) [06]
7. Transient cases (T. Downar, H. Gougar)
 - H. Gougar: Phase II – Transient Benchmark [07a]
 - V. Seker, T.J. Downar: OECD/NEA Transient Benchmark Analysis with PARCS - THERMIX [07b]

IV. Samples (Chair: C. de Oliveira)

8. Samples of benchmark results (G Strydom, F Reitsma) (steady state, exercise 1)[08a], (Preliminary TINTE results) [08b], (decay power) [08c]

V. Discussions (Chair: F Reitsma)

9. Feedback from meeting participants (All)

VI. Specific Issues I (Chair: H. Gougar)

10. Cross section generation & modelling for PBMR-400 MW benchmark (K. Ivanov, R. Mphahlele) [09]

VI. Specific Issues I Cont. (Chair: H. Gougar)

11. OECD-PBMR Benchmark Thermal-hydraulics (J.B.M. de Haas) [10]
12. Neutronics/Thermal-hydraulics coupling – PBMR-400 benchmark (K. Ivanov) [11]
13. Fuel Kernel temperature profiles for fast reactivity transients (P. Lourens, F. Reitsma) [12a],
(movie source constant) [12b], (movie rampup rampdown) [12c]

VII. Specific Issues II (Chair: K. Ivanov)

14. Presentations from participants

- Pebble Bed Reactor Core Analysis Development at the INL by J. Cogliati, H. Gougar, A. Ougouag, D. Nigg, W. Terry, Woo Yoon [13]
- PBMR Transients Modeling with DSNP System, by E. Shwageraus, A. Galperin, B. Tavron, D.Saphier [14]
- Coupled Thermal-hydraulics / neutronics code MARS/MASTER, by J.-J. Jeong, W.J. Lee, K.S. Kim, J.M. Noh, H.K. Joo [15]
- PBMR-400 Neutronic Thermal-Hydraulic Coupled Equilibrium Analysis by C. N. Sökmen
- ~~The~~ KIKO3D and the Coupled KIKO3-ATHLET code by A. Keresztúri, Gy. Hegyi [17]
- Coupled Neutronics / Thermal Hydraulics, EVENT-THERMIX. by B. Boer, J. L. Kloosterman, D. Lathouwers, C. de Oliveira [18]
- UK Gas Cooled Reactor R&D by R. Stainsby [19]
- Highlights on recent IAEA Research Activities on HTGR by M. Methnani [20]
- Discussion on the variation of methods and codes to be applied in the benchmark exercise.

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

15. The OECD/NEA International Reactor Physics Experiments Evaluation Project – IRPhE [21]
16. Discussion of future actions and schedule [22]
17. Discussion of plans and next meeting
18. Any other business and closure of meeting

Annex II

List of Participants

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NEA/NSC/DOC(2005)13

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