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

**OECD/NRC Benchmark based on NUPEC BWR
Full-size Fine-mesh Bundle Tests - Second Workshop (BFBT-2)**

**27-29 June 2005
University Park, PA, USA**

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NUCLEAR SCIENCE COMMITTEE
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**OECD/NRC Benchmark based on NUPEC BWR
Full-size Fine-mesh Bundle Tests (BFBT) – Second Workshop
(BFBT-2)**

27-29 June 2005
University Park, PA, USA

Hosted by

The Pennsylvania State University (PSU), USA

SUMMARY RECORD

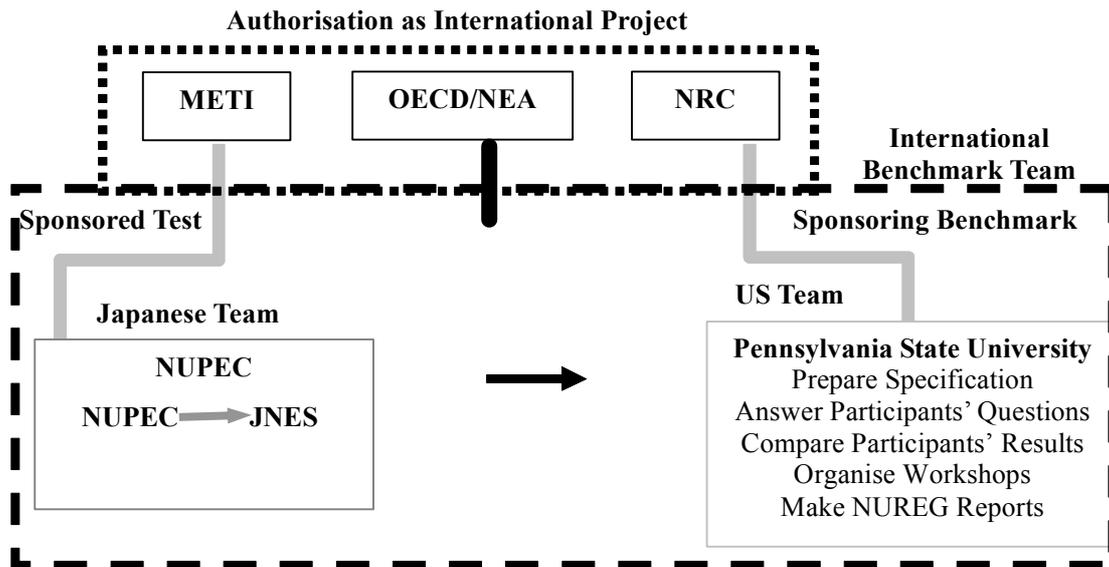
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Sponsorship

The second workshop for the BFBT benchmark was held on 27-29 of June 2005 in University Park, PA, USA, and is a follow up to the first workshop. The first workshop of the OECD/NRC Benchmark based on the NUPEC BWR Full-size Fine-mesh Bundle Tests (BFBT) – First Workshop (BFBT-1) was held on 4th October 2004. The workshop was hosted by the Japan Nuclear Energy Safety (JNES) Organization. The BFBT Benchmark is sponsored by the US Nuclear Regulatory Commission (NRC), the OECD, and the Nuclear Engineering Program (NEP) of the Pennsylvania State University (PSU). The experimental data was produced during a measurement campaign by the NUPEC, Japan, and sponsored by the Japan Ministry of Economy, Trade and Industry (METI).

The international benchmark team is organised based on the collaboration between Japan and the USA as shown.



Background and Purpose of the Benchmark Workshop

In the past decade, a large amount of effort has been made toward the direct simulation of the boiling transition (BT) for BWR fuel bundles. The most advanced sub-channel codes explicitly take into account droplet along with liquid and vapor. They predict the dry-out process as disappearance of the liquid film on the fuel rod surface without employing any semi-empirical correlations. Through a series of benchmark comparisons to full length/scale bundle data, it was verified that the codes are reliable in predicting the critical power of the conventional BWR fuel types. However, these sub-channel codes are not yet utilized in new fuel design. Adequacy of fuel lattice geometries, spacer configurations, etc., is still confirmed mainly by costly experiments using partial- and full-scale mock-ups. The main reason for this situation is a shortage of high resolution and full-scale experimental databases under actual operating conditions.

The detailed void distribution inside the fuel bundle has been regarded as one of important factors in the boiling transition in BWRs. With regard to the sub-channel wise void distribution, it is clear that the cross flow across the sub-channel gap dominates void distributions. Most of the well-known sub-channel codes still employ the classical Lahey's Void Drift Model or its modified versions. Although there have been substantial efforts to establish a sound theoretical background of detailed void distributions, the numerical models that are verified in a wide range of geometrical and thermal-hydraulic conditions are not yet available. In this sense, this subject still remains the major unsolved problem in the two-phase flow of BWR fuel bundles. The main reason for this lack of resolution is the lack of reliable full bundle databases under operating conditions. Up to now, only partial bundle (3×3 or 4×4) test data under relatively low pressure (≈ 1 MPa) conditions have been made available.

It was during the 4th OECD/NRC BWR TT Benchmark Workshop on 6 October 2002 in Seoul, Korea, that the need to refine models for best-estimate calculations based on good-quality experimental data was discussed. The needs arising in this respect should not be limited to currently available macroscopic approaches but should be extended to next-generation approaches that focus on more microscopic processes. It is suggested that this international benchmark be based on data made available from the NUPEC (Nuclear Power Engineering Corporation) database. From 1987 to 1995, NUPEC performed a series of void measurement tests using full-size mock-up tests for both BWRs and PWRs. Based on state-of-the-art computer tomography (CT) technology, the void distribution was visualized at the mesh size

smaller than the sub-channel under actual plant conditions. NUPEC also performed steady-state and transient critical power test series based on the equivalent full-size mock-ups. Considering the reliability not only of the measured data, but also of other relevant parameters such as the system pressure, inlet sub-cooling and rod surface temperature, these test series supply the first substantial database for the development of truly mechanistic and consistent models for void distribution and boiling transition.

This international benchmark, based on the NUPEC database, encourages advancement in this uninvestigated field of two-phase flow theory with very important relevance to the nuclear reactors' safety margins evaluation. Considering the immaturity of the theoretical approach, the benchmark specification is being designed so that it systematically assesses and compares the participants' numerical models on the prediction of detailed void distributions and critical powers. Furthermore, the following points were kept in mind when establishing the benchmark specification.

- As concerns the numerical model of void distributions, no sound theoretical approach that can be applied to a wide range of geometrical and operating conditions has been developed.
- In the past decade, experimental and computational technologies have tremendously improved though the study of the two-phase flow structure. Over the next decade, it can be expected that mechanistic approaches will be more widely applied to the complicated two-phase fluid phenomena inside fuel bundles.
- The development of truly mechanistic models for critical power prediction is currently underway. These models must include elementary processes such as void distributions, droplet deposit, liquid film entrainment, etc.

The BFBT benchmark consists of two parts (phases), each part consisting of different exercises:

- Phase 1 – Void Distribution Benchmark

- Exercise 1 – Steady-state sub-channel grade benchmark
- Exercise 2 – Steady-state microscopic grade benchmark
- Exercise 3 – Transient macroscopic grade benchmark

- Phase 2 – Critical Power Benchmark

- Exercise 1 – Steady-state benchmark
- Exercise 2 – Transient benchmark

It should be recognized that the purpose of this benchmark is not only the comparison of currently available macroscopic approaches but above-all the encouragement to developing novel next-generation approaches that focus on more microscopic processes. Thus, the benchmark problem includes both macroscopic and microscopic measurement data. In this context, the sub-channel grade void fraction data are regarded as the macroscopic data and the digitized computer graphic images are the microscopic data.

The Second Benchmark Workshop (BFBT-2) took place at the University Park, PA, USA from June 27 to 29, 2005. The meeting was organized around the discussion of the Benchmark Specifications, as well as the presentation and discussion of modelling issues and preliminary results for Exercises 1 and 2 of Phase 1, and Exercise 1 of Phase 2. At the first workshop of the OECD/NRC BFBT Benchmark – BFBT-1 - a schedule for benchmark activities was accepted by the participants (see NEA/NSC/DOC (2004)15). According to this schedule the participants were requested to submit their results for Exercises 1 of Phase 1 and Phase 2 by April 30, 2005, which was postponed because of the delay in issuing the BFBT Benchmark Specifications. The Version 2 of the Specifications was distributed in May 2005 and the participants were requested to review the Specifications and were encouraged to start modelling of Exercises 1 of Phase 1 and Phase 2 as well as Exercise 2 of Phase 2. This was beneficial for the discussions at the 2nd Workshop where the participants were requested to present any available preliminary results, for the exercises of both phases. Presentations on related experience in BWR sub-channel modelling as well as on CFD modelling were also encouraged.

The technical topics, which were presented and discussed at the BFBT-2 workshop, are shown below.

- Review of the benchmark activities after the 1st Workshop
- Detailed discussion of test facility, test conditions and measurement techniques
- Discussion of the complete test data provided on the CD-ROM to the participants – key for using the data and format of the data
- Discussion of the Benchmark Specifications and how the benchmark cases have been selected
- Presentation and discussion of modelling issues and preliminary results of Exercise 1 of Phase 1
- Presentation and discussion of modelling issues and preliminary results of Exercise 2 of Phase 1
- Presentation and discussion of modelling issues and preliminary results of Exercise 1, Phase 2
- Discussion of the requested output, templates for submitting results
- Definition of work plan and schedule, actions to advance the 2 phases of the benchmark activities

Opening Session: Introduction and Welcome

The meeting was opened by L. Hochreiter (PSU). The Chair of NEP of PSU, J. Brenizer welcomed the participants and wished them a successful work. He presented an overview of the PSU NEP status and activities. G. Rhee from US NRC also welcomed the benchmark participants and discussed the benefit of the BFBT benchmark activities for the development of sub-channel and best estimate methods, which are very important for the risk-informed regulation. E. Sartori welcomed the participants on behalf of the OECD/NEA Secretariat and thanked in particular the local organizers for their hospitality. Dr. Sartori discussed the “Structures and Re-structuring of the Working Parties and Expert Groups at OECD/NEA”, and under which activities the BFBT benchmark is assigned.

The meeting was attended by 24 participants representing 15 organisations, from 8 countries (see Annex I). The agenda was approved with minor adjustments (see Annex II).

K. Ivanov (PSU) presented an overview of the BFBT benchmark activities between BFBT-1 and BFBT-2 benchmark workshops and summarized the status of the benchmark at time of the BFBT-2 workshop.

Session 1: Void Distribution Benchmark, Chair L. Hochreiter

Hideaki Utsuno (JNES) discussed in detail the “Test Facility and Measurement Techniques Used in the Void Distribution Measurements of the NUPEC BWR Full-size Fine-mesh Bundle Tests”, followed by a “Discussion of the Void Distribution Tests and How the Benchmark Cases Were Selected”. B. Neykov (PSU) presented “The Key and Format of the Test Data (Benchmark Database)”. These presentations were followed by a discussion in the form of questions from the participants and answers from H. Utsuno. The following clarifications were made:

- The measured void fraction distribution for a given test is in principle evaluated in one experimental test but some cases are duplicated, i.e. two separate tests were performed under the same conditions. There were two types of measurement – one of the CT-scanner and the other of the X-ray densitometer. The CT-scanner is located at the assembly exit and provides 2-D void distribution data at the top of the assembly. It takes 15 seconds for a scan for the CT scanner. (A further description for the steady-state is given in Chapter III of Ref. 5 of the Specification). For the transients, the same test was run 9 times to obtain 9 chordal averages, which were then used to obtain the bundle average void fraction. The averaged void fraction data out of 9 times measurements were provided in the benchmark database distributed on the CD-ROM by NEA/OECD to the benchmark participants. The CT scanned data were averaged 9 times and it is

the average that is reported. In the transient test measurements the first 10 seconds are a “null transient”.

- The presence of low positive or negative void fraction values in the measured data sets indicates sub-cooling conditions, meaning that the average density is higher than the saturated density. The comparisons of these conditions should be performed not on the void fraction basis but on the two-phase density basis. PSU need to look at the low power tests and compare the density, not the void fraction.
- The given accuracy in the Specifications is the accuracy of the measurement, i.e. the instrument accuracy.
- In regard to modelling heat losses as a first approximation, the participants can assume adiabatic modelling since during the tests the assemblies were very well isolated. The quality reported in the specification assumes no heat losses from the facility.

F. Audogan (PSU) presented “Discussion of Fuel Assembly Data and Spacer Grid Data for Phase 1”, which included a 3-D movie, prepared by the NEA/OECD team:

- For the grid spacer models there are some inconsistent data about provided dimensions in the Specifications. E. Sartori pointed out that the uncertainty of the spacer grid models can be addressed by performing sensitivity studies. It was noted that the grid loss coefficients calculated by one of the presented methods contain errors, which need to be corrected. PSU needs to further compare and document the grid loss calculations.
- Another uncertainty, which needs to be addressed, is associated with the heater rod properties given in the Specifications. These properties were taken from TRAC-PF1. PSU will check the thermal time constant for the heater rods used in the experiments. H. Utsuno said the time constant was 5 seconds which seems long. PSU could build a DATARH model for the rod.

A presentation on “Discussion on the Specification of Phase 1 Exercises 1-3” was given by B. Neykov (PSU). It was observed that there is an asymmetry in the measured sub-channel void distribution as well as in the 2-D CT-scanner predicted void distributions. This fact indicates a possible bias in the measurements since the radial power distribution has one-half symmetry. PSU needs to look at the CT scanned data to determine if there is a bias in the data from one side of the bundle to the other. i.e., the data does not show symmetry.

F. Audogan (PSU) made two consecutive presentations on “Discussion of the Modelling Issues and Preliminary Results for Exercise 1 of Phase 1”, and “Derivation of Sub-channel Loss Coefficients and COBRA-TF Sample Deck for Exercise 1 of Phase 1”. The PSU benchmark team is utilizing the US NRC version of COBRA-TF as a sub-channel code for the BFBT benchmark to perform studies in order to support the modelling efforts of the benchmark participants. It was emphasized that the BFBT benchmark will help to differentiate between the void drift and turbulent mixing effects and will help to develop appropriate models in the codes.

B. Neykov (PSU) presented “Discussion of the Modelling Issues for Exercise 2 of Phase 1”. The PSU benchmark team is planning to use the CFD code FLUENT for calculation of Exercise 2 of Phase 1. The provided fine-resolution data in the framework of the BFBT benchmark can help validate the CFD codes, which after that can be used for performing numerical experiments, which can be utilized for improving the model in the sub-channel codes.

In his presentation “Sub-channel Analysis of Void Fraction by COBRA-TF”, S. Kakinoki from NFI, Japan, discussed the comparison of their preliminary results with experimental data. The analysis tends to show higher void fraction especially at low exit quality. More investigations are necessary on turbulence-mixing and sub-cooled boiling modelling.

L. Hochreiter (PSU) discussed the presentation submitted by A. Hotta from TEPSYS, Japan, entitled "Preliminary Results of Exercise 1 of NUPEC BFBT Benchmark Based on NASCA". This presentation deals with preliminary results of detailed void distributions predicted by the advanced sub-channel code, NASCA. First, the NASCA models and improvements are presented including an improved cross-flow model. Second, the presentation compares the code's predictions of regional averaged void distribution (5 rings - regions per bundle are utilized) with the measured data, followed by sub-channel based void distribution comparisons. It is concluded that the tests, included in the BFBT benchmark, are adequate to establish sub-models in a sub-channel code including the improved cross-flow model.

L. Hochreiter (PSU) also presented "Preliminary Results of Void Distribution Analysis" submitted by M. Naitoh from NUPEC, Japan. Comparisons of calculated and measured void distribution on a sub-channel and regional averaged bases are given for different cases. Based on these comparisons a problem for void comparison is identified. The calculations showed symmetric distribution. However, the experiments did not. The actual time-averaged void distribution is considered to be symmetric because of the symmetry of power, geometry, and flow conditions. Questions arise: Why is the measured void distribution not symmetrical? Why is the measured void fraction in the central region higher than in the periphery regions of some specific assembly types? Did the measurement error include the statistical error of X-ray counts? The proposal was made to symmetrize the experimental void distribution matrix. L. Hochreiter raised the following arguments such that. It is not clear whether the symmetrized voids distribution data measured is useful. A better approach would be to provide uncertainty ranges (bands) for the measured data. The variability of these uncertainty bands (standard deviations) can be addressed by plotting the individual data points and associated uncertainty ranges. Preliminary results for Exercise 1 of Phase 2 are also included in the presentation. It is important when such results are presented to have more information about the models utilized, and such model description will be requested from the participants when submitting their results.

In his presentation "Preliminary Results of Exercise 1/Phase 1 and Exercise1/Phase 2" C. Adamson (Westinghouse Electric Sweden AB) discussed MONA-3 models and preliminary results for Exercises 1 of Phase 1 and Phase 2. A more accurate spacer model is probably needed to predict the pressure drop. The presentation indicated that one must be careful with the gaps for large water rods, and that a critical film thickness of 90 micro meters worked well for dry-out.

D. Caruge (CEA) presented a "Proposal for Extension to Uncertainty Analysis". CEA will participate in the benchmark with the NEPTUNE code system. The main features of FLICA4 (which is a part of NEPTUNE), physical models, and numerical methods, were presented followed by the description of the CEA's experience with uncertainty analysis, obtained during the validation process of FLICA4. The KALIF software for sensitivity analysis was introduced. A proposal was made to the BFBT benchmark participants to extend the benchmark activities to include an uncertainty analysis exercise for void distribution (Exercise 1 of Phase 1) to take into account uncertainties on input data (boundary conditions, geometry, etc., provided by the Specifications) on models and produce results with "errors" and to compare with measurement uncertainties. The BFBT benchmark provides a good opportunity for such an exercise since it has a limited number of input data (compared to the previous coupled plant system benchmarks), the uncertainty range is already provided in the Specifications, and there are high-quality experimental measurements. What is needed is to define a probability density function.

In his presentation "Preparation of Input Data for MATRA, MARS (COBRA-TF), and CFX" D. Hwang (KAERI) presented the activities of the KAERI BFBT benchmark team using MATRA and MARS (COBRA-TF) for Exercise 1 and CFX for Exercise 2 of Phase 1. The presentation includes preliminary results for Exercise 1 with MATRA (all cases) and MARS (selected cases), and discussion of the geometrical modelling and mesh generation for Exercise 2 of Phase 1.

Claudio Delfino (ISL) presented "CFD Modelling Approach to Phase I of the BFBT Benchmark". He discussed the CFD analysis of the liquid/gas flow in a BWR fuel bundle, adopting a multi-field framework by providing the selected solver with adequate physical models for mechanistic flow regime description, including regime transitions, through user-defined external software routines. The work status at ISL on developing a novel approach to two-phase CFD, which focuses on achieving an optimal trade-off between model accuracy and computational efficiency, and planned work for Phase 1 of the BFBT benchmark were described.

W. Hering (FZK) discussed their contribution to the benchmark activities in his presentation "FZK Activities in the BFBT Benchmark". The available codes on different levels in FZK such as TRACE (system code), MATRA (sub-channel code), and the CFD code CFX in conjunction with the in-house tool Turbit-VOF will be utilized in the BFBT benchmark.

The participants' presentations on Phase 1 were followed up by a discussion on Phase 1 of the benchmark chaired by L. Hochreiter:

- Special attention was devoted to reviewing the selected cases to be calculated in the three exercises of Phase 1. It was suggested to replace/include more cases in Exercise 1 of Phase 1, which reflect flow rate variations.
- Additional uncertainty exercise – Exercise 4 of Phase 1 will be formulated from the benchmark team (PSU, JNES, and OECD) in cooperation with CEA on evaluation of uncertainties of void distribution predictions within the framework of Exercise 1 of Phase 1. The benchmark team will provide uncertainties of the input data and boundary conditions; in addition probability density functions of the input uncertainties will be generated in cooperation with CEA. The benchmark team was asked to find a way of weighting the data in terms of uncertainties.
- Low quality low power steady-state test (for example 4101-53) to be selected as the first calculation case for Exercise 2 of Phase 1, Participants should focus on this case and submit their results for a comparative analysis.
- List of participants in each exercise of each phase to be generated by the benchmark team in order to establish a more convenient e-mail exchange forum between participants in the same exercise to clarify modelling issue and share information.

Session 2: Critical Power Benchmark, Chair H. Utsuno

H. Utsuno presented "Discussion of the Critical Power Tests and How the Benchmark Cases were Selected". What are the criteria for CHF? The CHF was defined when the peak rod surface temperature became 14 °C higher than the steady-state temperature level before dry-out occurs. This was followed by the presentation given by B. Neykov on "Discussion on the Specification of Phase 2 Exercises 1-2". Additional exercise – Exercise 0 of Phase 2 will be formulated focused on single-phase and two-phase pressure drop calculations. There is test data for this exercise and it will help participants to initialize their sub-channel models before calculating Exercises 1 and 2 of Phase 2.

H. Utsuno presented two parts of "Assessment of a Boiling Transition Analysis Code against Data from BFBT". First, the models of the code TCAPE-INS/B were introduced followed by the results of the code assessment for void distribution and critical power predictions. Special attention was paid to the film flow analysis coupled with the sub-channel analysis.

The following two consecutive presentations, entitled "Discussion of Fuel Assembly Data and Spacer Grid Data for Phase 2 (including 3-D movie)" and "Presentation and Discussion of the Modelling Issues and Preliminary Results for Exercise 1 of Phase 2. Discussion of Sample Input Deck of COBRA-TF for Exercise 1 of Phase 2", were given by F.Aydogan.

L. Hochreiter from PSU presented the paper “IVA Simulations of Exercises 1 of Phase 1 and 2 of the OECD/NRC Benchmark Based on NUPEC BWR Full-Size Fine-Mesh Bundle Tests (preliminary)” submitted by N. Kolev (Framatome ANP). The results obtained with the IVA computer code are analyzed indicating that the void mixing computed based only on the transport equation is not enough to describe appropriately this process. In all cases the “void diffusion” from region with higher void to region with lower void is underestimated. Without appropriate turbulence modeling the accuracy of this method regarding predicting the local void fraction cannot be increased. Fine resolution is required in the future accomplished with appropriate constitutive relationships specially developed for the fine resolutions. Turbulence modeling in multiphase flow is the key phenomenon for taking into account the influence of the grids in a universal way into the predictive technologies avoiding the fitting of specific constants for specific arrangements.

B. Neykov presented “Discussion of the Requested Output, Templates for Submitting Results, and Sample Results”, which was followed by a presentation, entitled “Techniques for Comparisons of Calculated Results with Measured Data (Code-to-Data) and to Other Calculated Results (Code-to-Code)”, given by K. Ivanov.

The follow-up discussion on Phase 2 of the BFBT benchmark focused on:

- The definition of the new additional Exercise 0 on pressure drop calculations and which test cases to be selected for inclusion in this exercise.
- PSU needs to look at the effects of the heater rod resistivity for post situations. Concern is that in post dry-out, with higher temperatures, the power has a larger uncertainty due to the electrical resistivity changes with temperature.
- The six most increased thermo-couple (TC) measured temperature data out of 100 TCs are provided in the benchmark data base for the dry-out tests. Penn State will look at the CHF data to see if there is any bias in the data due to the rod properties.
- It was proposed that the benchmark team also prepares templates in EXCEL for submitting results for each exercise for each phase with description of how the calculated data should be averaged for each exercise and case. For the microscopic scale (level) data it is recommended to use visualization method and graphical representation. For the sub-channel (macro-) level results it is recommended to request from participants not only the void fraction but also 2-D mass flux distribution (for each sub-channel).

To summarize, the most important changes suggested for Version 4 of the Specifications are as follows:

- Adding some clarification on the CT scanner functionality and the measurement methods;
- Resolving the inconsistency in the geometrical dimensions for the grid spacers;
- Adding Exercise 4 to Phase 1 concerning the uncertainty analysis of the void distribution benchmark of Exercise 1 of Phase 1 as proposed by CEA;
- Defining Exercise 0 of Phase 2, which is a single and two-phase pressure drop calculation using the test data;
- Revising the output requested to reflect participants’ suggestions during the workshop.

In this way the BFBT benchmark was extended and now consists of the following exercises:

Phase 1 – Void Distribution Benchmark

- Exercise 1 – Steady-state sub-channel grade benchmark
- Exercise 2 – Steady-state microscopic grade benchmark
- Exercise 3 – Transient macroscopic grade benchmark
- Exercise 4 – Uncertainty analysis of the steady state sub-channel benchmark

Phase 2 – Critical Power Benchmark

- Exercise 0 - Pressure drop benchmark
- Exercise 1 - Steady-state benchmark
- Exercise 2 - Transient benchmark

Closing Session: Conclusions and Recommendations, Chair: E. Sartori

L. Hochreiter and E. Sartori initiated a discussion about the BFBT benchmark schedule, actions to be carried out to achieve progress and the next workshop. As a result, the following BFBT schedule and list of actions were accepted by the workshop participants:

Action	Deadline	Who
Send List of Actions and CD-ROM with the BFBT-2 workshop materials to the benchmark participants	Mid-July, 2005	E. Sartori and K. Ivanov
Prepare summary record of the workshop	End of July, 2005	K. Ivanov, H. Utsuno, and E. Sartori
Complete the final version of the Benchmark Specification (Version 4)	End of August, 2005	L. Hochreiter, K. Ivanov, H. Utsuno, E. Sartori and D. Caruge
Submit to PSU preliminary results on Exercise 1 of Phase 1, one case of Exercise 2 of Phase 1, and Exercises 0 and 1 of Phase 2	End of December, 2005	Benchmark Participants
Provide feedback to the participants in terms of comparisons of the submitted results	End of February, 2006	K. Ivanov and L. Hochreiter
Organize and conduct BFBT-3 workshop in Pisa	April 26-28 2006	F. D'Auria, K. Ivanov and E. Sartori

L. Hochreiter and E. Sartori also provided conclusions and closing remarks. This benchmark, with its large set of good quality and very detailed data, will substantially contribute to refining models for best estimate calculations based on good quality experimental data for two-phase flow analyses. In particular the BFBT benchmark is a challenging one, but will contribute to the advancement of refined modelling. Refined modelling is needed as simplified, conservative approaches are not conservative in all cases as certain benchmark studies have demonstrated.

Proceedings of the Workshop

Participants will receive with these proceedings a CD-ROM containing all papers discussed at the meetings.

Next workshop

The University of Pisa offered to host the 3rd workshop from 26-28 April 2006 in conjunction with the 4th Workshop of the OECD/DOE/CEA V1000CT Benchmark.

Additional information

1. Hideaki Utsuno (JNES) has provided the following additional information following the BFBT workshop in order to address some of the questions raised during the discussion in the framework of the BFBT-2 workshop.

(a) Test Operating Cycle

The test operating cycle was of a week. For example, the operation started with the heat-up of the facility on Monday and its cooling-down on Friday. The actual test was done in the middle of the week from Tuesday to Thursday. The facility was off operation on the weekend.

(b) Electrical resistivity changes

The electrical resistivity change was measured for the Test assembly 1 before and after the void fraction measurement. After the test, the electrical resistivity of each rod was increased and the increase was within +2 %.. The rod power is calculated as follows, $P_i = V^2/R_i$, where

P_i : power of rod i

R_i : electrical resistivity of rod i

V : electrical voltage which is common among rods.

Please note that the electrical resistivity is lower with the higher power rod.

The review of the rod temperature increases during post dry-out, provided in the benchmark data-base, reveals that the maximum temperature is almost 400 °C and the duration of the dry-out is a few seconds. The effect of the heat-up due to the dry-out on the electrical resistivity was not evaluated. The main reason that causes the electrical resistivity to change may come from the thermal cycle between a room temperature and the test operating temperature. Therefore, as a first guess, it is suggested to use +2% for the electrical resistivity change during the post dry-out tests.

2. After the BFBT-2 workshop G. Rhee from US NRC has suggested to the benchmark team to add an exercise for the uncertainty analysis of the critical power benchmark (Exercise 3 of Phase 2). Since this proposal was not brought up during the meeting, it will be presented during the next workshop in April 2006.

Annex I

**OECD/NRC BWR BFBT Benchmark
List of participants in the benchmark and in the Workshop
Workshop, PSU, 27-29 June 2005**

Participants in the workshop are identified by *, the others have confirmed their participation in the benchmark by signing the Conditions for Release, Rules and Restrictions Applying to the BFBT data and have received the data on CD-ROM consequently

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Annex II

**OECD/NRC Benchmark based on NUPEC BWR
Full-size Fine-mesh Bundle Tests (BFBT) – Second Workshop
(BFBT-2)**

Reber Building
University Park, PA
USA

27-29 June 2005

Hosted by

The Pennsylvania State University, USA

FINAL PROGRAMME [B0201]

Day 1: 27 June 2005

08:00 a.m. – 08:30 a.m. Continental breakfast (125 Reber)

08:30 a.m. – 08:45 a.m. Introduction and opening remarks – *L. Hochreiter*

Introduction of Participants [B0202a],
List of Benchmark Participants [B0202b]

08:45 a.m. – 09:15 a.m. Welcome remarks on the behalf of

NEP, PSU – *J. Brenizer* [B0203]
US NRC – *G. Rhee*
NEA, OECD – *E. Sartori* [B0204]

09:15 a.m. – 09:45 a.m. Overview and status of benchmark activities – *K. Ivanov* [B0205]

Technical Sessions on Phase 1 – Void Distribution Benchmark – Chair L. Hochreiter (Reber 135)

09:45 a.m. – 10:30 a.m. Detailed discussion of the test facility and measurement techniques – *H. Utsuno* [B0206]

10:30 a.m. – 11:00 a.m. Coffee break – 125 Reber

11:00 a.m. – 11:45 a.m. Discussion of the void distribution tests and how the benchmark cases were selected – *H. Utsuno* [B0206 continuation]

11:45 a.m. -12:30 p.m. Key and format of the test data (benchmark database) – *B. Neykov* [B0207]

12:30 p.m. – 01:30 p.m. Lunch – 125 Reber

01:30 p.m.- 02:15 p.m. Discussion of fuel assembly data and spacer grid data for Phase 1 (including 3-D movie) – *F. Aydogan and E. Sartori* [B0208a] / [movie]

02:15 p.m. – 02:45 p.m. Presentations and discussions on the specification of Phase 1 Exercises 1-3 –
B. Neykov [B0209]

02:45 p.m. – 03:30 p.m. Presentation and discussion of the modelling issues and preliminary results
for Exercise 1 of Phase 1 – *F. Aydogan* [B0210]

03:30 p.m. – 04:00 p.m. Coffee Break

04:00 p.m. – 05:00 p.m. Derivation of sub-channel loss coefficients and COBRA-TF sample deck for
Exercise 1 of Phase 1 – *F. Aydogan* [B0211]

Day 2: 28 June 2005

08:00 a.m. – 08:30 a.m. Continental breakfast (125 Reber)

08:30 a.m. – 09:00 a.m. Presentation and discussion of the modelling issues for Exercise 2 of Phase 1
– *B. Neykov* [B0212]

09:00 a.m. – 10:30 a.m. Participants' presentations on modelling of Exercises 1 and 2 of Phase 1

- *S. Kakinoki, T. Ikeno, K. Matsuura*, "Sub-channel Analysis of Void Fraction by COBRA-TF (preliminary)" [B0213]
- *Hotta*, "Preliminary Results with NASCA" [B0214]
- *D. Caruge, M. Martin, J.M. Martinez and E. Royer*, "What about Uncertainty Analysis in the Benchmark?" [B0215]

10:30 a.m. – 11:00 a.m. Coffee break (125 Reber)

11:00 a.m. – 12:30 p.m. Participants' presentations on modelling of Exercises 1 and 2 of Phase 1

- *C. Adamson*, "Models for MONA-3" [B0216]
- *N. Kolev*, "IVA Simulations of Exercises 1 of Phase 1 and 2 of the OECD/NRC Benchmark Based on NUPEC BWR Full-Size Fine-Mesh Bundle Tests (preliminary)" [B0217a], [B0217b] (text)
- *D. Hwang*, "Preparation of Input Data for MATRA, MARS (COBRA-TF), and CFX" [B0218]

12:30 p.m. – 01:30 p.m. Lunch (125 Reber)

01:30 p.m. – 03:00 p.m. Participants' presentations on modelling of Exercises 1 and 2 of Phase 1

- *Claudio Delfino*, "CFD Modelling Approach to Phase I of the BFBT Benchmark" [B0219] [B0219a], [B0219b], [B0219c], [B0219d], [B0219e], [B0219f], [movie1], [movie2]
- *W. Hering, M. Böttcher, X. Cheng, H. Homann, M. Wörner*, "FZK Contribution to the OECD-BFBT Benchmark" [B0220], [movie]
- *M. Naitoh*, "Preliminary Results of Void Distribution Analysis" [B0221]

03:00 p.m. – 03:30 p.m. Discussion on Phase 1 – *L. Hochreiter*

03:30 p.m. – 04:00 p.m. Coffee break (125 Reber)

Technical Sessions on Phase 2 – Critical Power Benchmark – Chair H. Utsuno (135 Reber)

04:00 p.m. – 04:45 p.m. Discussion of the critical power tests and how the benchmark cases were selected – *H. Utsuno* [B0206 continuation]

04:45 p.m. – 05:30 p.m. Presentation and discussions on the specification of Phase 2 Exercises 1-2 – *B. Neykov* [B0222]

06:30 p.m. Banquet (Atherton hotel – Vanderbilt room)

Day 3: 29 June 2005

08:00 a.m. – 08:30 a.m. Continental breakfast (125 Reber)

08:30 a.m. – 09:00 a.m. Discussion of fuel assembly data and spacer grid data for Phase 2 (including 3-D movie) – *F. Aydogan* [B0223a], [movie]

09:00 a.m. – 09:30 a.m. Presentation and discussion of the modelling issues and preliminary results for Exercise 1 of Phase 2. Discussion of sample input deck of COBRA-TF for Exercise 1 of Phase 2 – *F. Aydogan* [B0224]

09:30 a.m. – 10:30 a.m. Participants' presentations on modelling of Exercise 1 of Phase 2

- *H. Utsuno, Y. Masuhara and F. Kasahara*, "Assessment of a Boiling Transition Analysis Code against Data from BFBT (Part 1)" [B0225]
- *H. Utsuno, Y. Masuhara and F. Kasahara*, "Assessment of a Boiling Transition Analysis Code against Data from BFBT (Part 2) [B0225 continuation]

10:30 a.m. – 11:00 a.m. Coffee Break (125 Reber)

11:00 a.m. – 11:15 a.m. Discussion on Phase 2 – *L. Hochreiter*

11:15 a.m. – 11:30 a.m. Discussion of the requested output. Templates for submitting results, and sample results – *B. Neykov* [B0226]

11:30 a.m. – 11:45 a.m. Techniques for comparisons of calculated results with measured data (code-to-data) and to other calculated results (code-to-code) - *K. Ivanov* [B0227]

11:45 a.m. – 12:15 a.m. Action items and schedule of benchmark activities, Next workshop (BFBT-3), *L. Hochreiter and E. Sartori* [B0228]

12:15 a.m. – 12:30 p.m. Conclusions and closing remarks – *L. Hochreiter*

12:30 p.m. – 01:30 p.m. Lunch (125 Reber)

01:30 p.m. – 05:00 p.m.

Tour of the Pennsylvania State University TRIGA Reactor and Test Facilities

Tour of the US NRC/PSU Rod Bundle Test Facility

[.] indicate the identification on the CD-ROM