NEA/NSC/DOC(2004)4-Rev-2

NUCLEAR SCIENCES COMMITTEE
and
COMMITTEE ON THE SAFETY OF NUCLEAR INSTALLATIONS

OECD/DOE/CEA
VVER-1000 Coolant Transient Benchmark.
(V1000-CT) – 2nd Workshop

Sofia, Bulgaria
5-6 April 2004

Hosted by
INRNE and KNPP, Bulgaria

PROGRAMME

OECD/DOE/CEA
VVER-1000 Coolant Transient Benchmark
Second Workshop (V1000-CT2)

(Sofia, Bulgaria, 5-6 April 2004)

Sponsorship

The second workshop for the VVER-CT benchmark will be held on 5th and 6th April 2004 in Sofia, Bulgaria, and is a follow up to the first workshop hosted by the CEA-Saclay (Paris), France, on 12-13 May, 2003, and to the starter meeting hosted by the Forschungszentrum Rossendorf (FZR), Germany on 30 May, 2002. The V1000-CT Benchmark is sponsored by the US DOE, OECD, CEA, and the Nuclear Engineering Program (NEP) at the Pennsylvania State University (PSU). The NEP, PSU (USA), CEA-Saclay (France) and the Institute of Nuclear Research and Nuclear Energy (INRNE), Sofia (Bulgaria), perform these international benchmark activities in collaboration and with the assistance of the ANL (USA) and Kozloduy nuclear power plant (NPP) – KNPP (Bulgaria).

This workshop is held in conjunction with the Atomic Energy Research (AER) "VVER reactor safety analysis" Working Group D Meeting, scheduled for 7-8 April 2004 at the same place, in order to facilitate co-ordination and sharing of work.

Background and Purpose of the Benchmark Workshop

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

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

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

a) Exercise 1 – Point kinetics plant simulation;

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

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

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

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

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

In June 2002 the Nuclear Science Committee (NSC) of NEA/OECD, at its annual meeting in Paris, approved and endorsed the developed V1000CT benchmark problem to become an international standard problem for validation of the best-estimate safety codes for VVER applications. Collaboration with the AER Working Group D involved in VVER safety research on the proposed VVER-1000 coolant transient benchmark is established and the AER participates actively in the benchmark activities. The co-operation of this working group with the V1000CT benchmark group was endorsed by the OECD/NEA NSC, and is supported by the Safety Division. The AER Working Group meeting will be held during 7-8 April, 2004 at the same premises in Sofia, Bulgaria.

Scope and Technical Content of the Benchmark Workshop

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

- Review of the benchmark activities after the 1st Workshop
- Discussion of participant's feedback and introduced modifications to the Benchmark Specifications on Phase 1
- Presentation and discussion of submitted results from Exercise 1 of Phase 1
- Presentation and discussion of submitted results from Exercise 2 of Phase 1
- Presentation and discussion of modeling issues and preliminary results of Exercise 3, Phase 1
- Discussion of the draft of the Specifications for Exercise 1 of Phase 2
- Discussion of modeling issues of Exercises 1 and 2 of Phase 2 – CFD modeling and the available experimental data, and the MSLB scenario
- Defining work plan and schedule, actions to progress in completing the 2 phases

Organization of the Benchmark Workshop

The meeting is organized around the discussion of the Specifications of Phase II and submitted results on the Exercises 1 and 2 and preliminary results for Exercise 3 of Phase 1. Presentations on related experience in VVER core and system modeling as well as on CFD modeling are encouraged.

Participation in the Benchmark Workshop

As usual for Benchmark Workshops sponsored by the Nuclear Science Committee (NSC) and Committee on the Safety of Nuclear Installations (CSNI), participants is restricted, for efficiency, to experts (research laboratories, safety authorities, regulatory agencies, utilities, owners' groups, vendors, etc.) from OECD Member countries nominated by delegates to the Committees in consultation with official authorities concerned and with the assistance of members of the Nuclear Science Committee and the Committee on the Safety of Nuclear Installations (information about members are provided as Annex) and in particular to participants in this study.

The meeting is open to experts from Central and Eastern European Countries and the New Independent States of the ex-Soviet Union, who are in a position to provide a substantive contribution to this study. Participation of these experts will be arranged by the NEA Secretariat and it includes participants of AER organizations and Kiev University, Ukraine.

Organization and Programme Committee of the Benchmark Workshop

An Organization and Programme Committee has been nominated to make the necessary arrangements for the Second Benchmark Workshop and to organize the Sessions, draw up the final programme, appoint Session Chairmen, etc. Its members are:

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The Proposed Programme of the Benchmark Workshop

The proposed programme was drawn up by the Programme Committee and is enclosed as Annex

Language of the Benchmark Workshop

The official language of the Second Benchmark Workshop is English.

Proceedings of the Workshop

A summary of the Workshop will be published by the OECD as soon as possible after the meeting. The summary will be distributed free of charge to the participants in the Workshop and to delegates of the NSC and CSNI. The programme committee and the session chairmen will prepare a Summary Report on the main results of the meeting for presentation to the NSC and CSNI. In addition, copies of presentations will be distributed free of charge to all participants at the meeting.

Workshop Location

Hotel "Kopito, National Park Vitosha, Sofia, Bulgaria

Local Arrangements

The **hotel information** is as follows:

1. "KOPITO": recommended by the organisers: Double room: 65 EUR - incl. breakfast and use of different facilities. Reservations must be made through INRNE hotel registration
2. "ROTASAR": downtown: Double room: 35-40 EUR - bed and breakfast. Microbus transportation to the conference place is provided by the organisers.
3. "RAI": downtown: Double room: 35-40 EUR - bed and breakfast next to ROTASAR. Microbus transportation to the conference place is provided.

Transportation

1. From/to Airport Sofia
   - Microbus by the organisers or taxi to Hotel Kopito (~30 km).
   - Microbus by the organisers or taxi to hotel Rotasar or Rai (~6 km).
2. Transportation from the city to the conference place
   - Microbus by the organisers every morning and evening from/to Hotel Rotasar,
   - Hotel microbus transport of Hotel Kopito,
   - A shuttle microbus provided by the organisers.

Additional information will be distributed as necessary before the workshop.

Annex

OECD/DOE/CEA VVER-1000 Coolant Transient Benchmark - Second Workshop (V1000-CT2)

Sofia, Bulgaria
5-6 April 2004

Hosted by: INRNE/KNPP

PROPOSED PROGRAMME [01]

April 5th

Session 1 – Session Chair – Nikola Kolev

09:00-09:30 Introduction and Welcome
INRNE – *Jordan Stamenov, INRNE*
KNPP – *Vasil Hadjiev, KNPP*
OECD-NEA – *Francesco D'Auria, representing CSNI-GAMA*
José maría Aragonés, representing NSC
Enrico Sartori, representing NEA Secretariat
Introduction of Participants [02]
09:30-10:00 Overview and status of V1000CT-1 (Phase 1) Benchmark - *Kostadin Ivanov [03]*
10:00-10:30 Overview and status of V1000CT-2 benchmark - *Eric Royer[04]*

10:30-10:45 Coffee Break

Session 2 – Session Chair – Grady Yoder

10:45-11:15 Comments and Modifications of V1000CT-1 Specifications – *Boyan Ivanov, Kostadin Ivanov [05]*
11:15-11:45 Discussion of Exercise 1 of V1000CT-1 – *Pavlin Groudev, Malinka Pavlova, Antoaneta Stefanova, Rositsa Gencheva [06]*

11:45-13:15 Lunch

Session 3 – Session Chair – Pavlin Groudev

13:15-13:45 Comparative Analysis of Exercise 1 of the V1000CT-1 Benchmark - *Boyan Ivanov, Kostadin Ivanov* [07]
13:45-14:15 Discussion of Exercise 2 of V1000CT-1 Benchmark - *Kostadin Ivanov, Boyan Ivanov [08]*
14:15-14:45 Comparative Analysis of Exercise 2 of V1000CT-1 Benchmark - *Boyan Ivanov, Kostadin Ivanov [09]*

14:45-15:00 Coffee Break

Session 4 – Session Chair – Soeren Kliem

15:00-15:30 Comparative Analysis of Exercise 3 of the V1000CT-1 Benchmark – *Boyan Ivanov, Kostadin Ivanov [10]*

15:30-17:00 Participants' presentations on Phase 1 – V1000CT-1

- V1000CT-1 Exercise 2, HZP Neutronic Comparisons: *S. Aniel-Buchheit, B. Ivanov, K. Ivanov, J. Hadek[11]*
- Joint Participation of University of Pisa and PSU to the VVER1000 CT Benchmark, *Juswald Vedovi, Giorgio M.Galassi, Francesco D'Auria, and Kostadin Ivanov [12]*
- VVER-1000 Kozloduy Benchmark Analysis Performed by KU with RELAP5-3D: *Alexander Shkarupa* [13]
- FZK Investigations for the V1000-CT Benchmark Phase1: V*ictor H. Sanchez Espinoza [14]*

17:00-18:00 Reception

April 6th

Session 5 – Session Chair – Eric Royer

9:00-10:00 Discussion of V1000CT-1 Modelling Issues and Obtained Results - *Kostadin Ivanov [15]*

10:00-10:30 Participants' presentations on Phase 1 – V1000CT-1

- Preliminary Results for Exercise 1 of V1000-CT Benchmark by GRS Applying ATHLET code: *S. Langenbuch, K.D. Schmidt, K. Velkov [16]*
- Simulation of Exercise 3 scenarios of V1000CT-1 using DYN3D-ATHLET coupled code system, *Y.Kozmenkov Soeren Kliem, [17]*
- Solution of V1000CT-1 Benchmark – Exercise 1 and 2 : *Jan Hádek, Radim Meca [18]*

10:30-11:00 Discussion of the schedule for Phase 1 activities – *Enrico Sartori*

11:00-11:15 Coffee Break

Session 6 – Session Chair – Pertti Siltanen

11:15-11:45 Overview of the Mixing Tests – *Dimitar Popov, Csvetan Tupalov KNPP [19]*

11:45-12:15 Discussion of the Specifications of Exercise 1 of the V1000CT-2 Benchmark – *Nikola Kolev, Dimitar Popov, Sylvie Aniel, Eric Royer [20]*

12:15-12:45 Preparation of the thermalhydraulic benchmark V1000CT –2 – *Ulrich Bieder, Sylvie Bétin, Gauthier Fauchet, Nikola Kolev. [21]*

12:45-14:00 Lunch

Session 7 – Session Chair – Jan Hadek

14:00-14:30 Description of VVER-1000 MSLB Scenario - *Nikola Kolev and Eric Royer [22]*

14:30-15:30 Participants experience on VVER analysis and vessel CFD modelling

- Thermohydraulic and Stress Model of Pressurized Thermal Shock of VVER 1000 Reactor Vessel: *Hana Hauerova, Petr Kodl, Eva Pechmannova*: [22]

15:30-15:45 Coffee Break

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15:45-16:15 Discussion of the schedule on Phase 2 and next workshops - *Enrico Sartori*

16:15-16:45 Discussion of the impact of the benchmark activities involving coupled 3-D neutron kinetics and thermal-hydraulics on the Nuclear Reactor Safety, Design and Operation - *Francesco D'Auria and K. Ivanov*

16:45-17:00 Conclusion and closing remarks – *Francesco D'Auria*