



**N.I.N.E.** NUCLEAR AND INDUSTRIAL  
ENGINEERING



**NC STATE UNIVERSITY**

Department of Nuclear Engineering

# **Fourth OECD/NEA Multi-Physics Pellet Cladding Mechanical Interaction Validation Benchmark (MPCMIV- 4) Workshop**

**Bologna, Italy  
May 22, 2023 (track 1 morning)**

**Hosted by ENEA, Italy**

## **Announcement and Proposed Program**

## **Sponsorship**

The third OECD/NEA Multi-Physics Pellet Cladding Mechanical Interaction Validation Benchmark (MPCMIV-3) workshop will be held on May 22, 2023 (track 1 morning), in Bologna, Italy in conjunction with fourteen other 2023 OECD/Nuclear Energy Agency (NEA), Nuclear Science Committee (NSC) Working Party on scientific issues and uncertainty of Reactor Systems (WPRS) workshops, meetings, school and CTF User Group meeting, in order to facilitate co-ordination and share work, to combine efforts in common areas such as neutronics, thermal-hydraulics, multi-physics modelling and uncertainty analysis, and to make the participation more efficient. The meetings/workshops concerned are:

- *May 22, 2023 (track 2 morning)* – Ninth COBRA-TF (CTF) User’s Group (UG) Meeting (CTF-9) followed by a hands-on CTF training sessions which will be conducted on Monday afternoon, May 22, 2023 and Tuesday morning, May 23, 2023 (track 2);
- *May 22, 2023 (track 1 afternoon)* – First Burst-Fission-Gas Release Benchmark (BFGR-1) workshop;
- *May 23, 2023 (track 1)* - Sixteen OECD/NEA Light Water Reactor (LWR) Uncertainty Analysis in Modelling (UAM) Benchmark (LWR-UAM-16) workshop;
- *May 23, 2023 (track 2)* – OECD/NEA HTGR-TH Benchmark introductory presentation and discussions;
- *May 22-23 (track 3), 2023* – OECD/NEA International School on Simulation of Nuclear Reactor Systems (SINUS);
- *May 24, 2023 (track 1 morning)* - OECD/NEA Task Force on Doppler Effective Fuel Temperature meeting;
- *May 24, 2023 (track 2 morning)* – Fourth OECD/NEA McMaster Core Thermal-Hydraulics (CTH) Benchmark (CTH-4) workshop;
- *May 24, 2023 (track 1 afternoon)* – OECD/NEA Task Force Artificial Intelligence & Machine Learning meeting;
- *May 24, 2023 (track 2 afternoon – LFR neutronics) – May 25, 2023 (track 2 morning – LFR Thermal-hydraulics) – Second OECD/NEA Lead Fast Reactor (LFR) Benchmark (LFR-2) workshop;*
- *May 24, 2023 (track 1 afternoon) – May 25, 2023 (track 1 morning)* - Eight OECD/NEA Time-Dependent Neutron Transport (C5G7-TD) Benchmark (C5G7-TD-8) workshop;
- *May 25, 2023 (track 2 afternoon)* – Second Liquid Metal Fast Reactor (LMFR) Thermal-Hydraulics (T/H) Benchmark workshop (LMFR T/H-2);
- *May 25, 2023 (track 1 afternoon) – May 26, 2023 (track 1 morning)* - Third meeting on OECD/NEA TVA Watts Bar 1 (WB1) Multi-Physics Multi-Cycle Depletion Benchmark (TVA-WB1-3) workshop.
- *May 26, 2023 (track 2)* - Eight OECD/NEA Sodium Fast Reactor (SFR) UAM Benchmark workshop and First Liquid Metal Fast Reactor (LMFR) Thermal-Hydraulics (T/H) Benchmark workshop (SFR-UAM-8);
- *May 26, 2023 (track 1 afternoon)* – Fifth benchmark meeting on Rostov-2 VVER-1000 multi-physics transient benchmark (Rostov2-5).

Evaluation of transient multi-physics experimental data for Light Water Reactor (LWR) systems is a growing area of interest. Analyses of reactivity-initiated accidents (RIAs) such as design basis accidents (DBAs) as well as the slower and less severe anticipated operating occurrences (AOOs) are important in determining the overall safety of the current fleet and future nuclear power plants. Industry challenge problems, as the pellet cladding interaction (PCI) and the pellet cladding mechanical interaction (PCMI), are associated with those events. PCI and PCMI are based on multi-physics and multi-scale phenomena requiring accurate and realistic modelling and simulation (M&S). Possible PCI/PCMI fuel failures reduce reactor performance related to power uprates, higher burnup and fuel rod manufacturing quality. PCI and PCMI are possible in many fuel rods in each reactor core and are controlled by local effects but have a system-wide influence. Three-dimensional (3D) fuel performance models coupled with reactor physics and thermal-hydraulics models are needed to assess the complex coupled physics and the irregular geometries responsible for PCI/PCMI fuel failures. The Multi-physics Pellet Cladding Mechanical Interaction Validation (MPCMIV) benchmark addresses the need for adequate high-quality experimental data for PCI/PCMI industry challenge problem to properly validate both the existing (traditional) multi-physics tools and as well as the next generation (novel) high-fidelity multi-physics code systems being developed. The MPCMIV benchmark is based on experiments that require coupling between reactor physics, thermal-hydraulics, and fuel performance tools to achieve a multi-physics M&S and utilizes test reactor data from controlled experimentation to validate this M&S. The objectives of benchmark activities, which are supported by US Department of Energy (DOE) Nuclear Energy University Program (NEUP), also include the development of integral evaluation to be submitted to the NEA International Reactor Physics Benchmark Experiments (IRPhE) Project Handbook and multi-physics handbooks. The evaluation process includes an internal review, an independent peer review, and an OECD/NEA review.

### **Background and Purpose of the Benchmark Workshop**

A four-tiered structure of fidelity has been pro-posed to accommodate as many participants and computational tools as possible:

- Tier 1 (for novel tools): A 3D heterogeneous model of the R2 reactor and fuel rodlet (3D deterministic core physics simulator of both R2 core domain and fuel rodlet domain).
- Tier 2 (for novel tools – simplified): The benchmark team will generate a cross-section data set for the R2 reactor and then perform a core physics calculation (e.g., with a nodal diffusion code) in order to obtain the boundary conditions (i.e., neutron and gamma fluxes) for the fuel rodlet domain. These boundary conditions will then be used by the participants to develop a high-fidelity model of the fuel rodlet domain.
- Tier 3 (for traditional tools): The procedure is similar to tier 2, but the modelling is conducted with traditional tools. In this case, the cross-section generation step is needed.
- Tier 4 (only Fuel Performance tools): The benchmark team will provide appropriate boundary conditions to allow the use of only fuel performance tools in the benchmark.

For each tier, the MPCMIV benchmark is structured into four main phases:

- the development phase;
- the pre-qualification phase (data based on calibration ramp – empty rodlet – and initial ramp with the boiling water reactor [BWR] rodlet);

- the blind simulation phase (data based on a repeated ramp with the BWR rodlet), including uncertainty analysis (the results will not be attributed to any particular organization in NEA reports – individual participants are free to publish their results openly);
- the open or post-test phase, including sensitivity analysis.

Validation requirements will be set in all the steps.

An updated version Revision 3 of the Specification along with updated support data has been developed by the benchmark team and distributed to the participants and will be discussed at the incoming third benchmark workshop. The benchmark team (consisting of NCSU, NINE, INL, University of Illinois and McMaster University) has performed benchmark support studies which will be presented and discussed at the workshop.

The information about the MPCMIV benchmark is provided at:

[Nuclear Energy Agency \(NEA\) - Multi-physics Pellet Cladding Mechanical Interaction Validation \(MPCMIV\) Benchmark \(oecd-nea.org\)](http://www.oecd-nea.org/mciv/)

### **Scope and Technical Content of the Benchmark Workshop**

The topics to be addressed at the workshop include:

- Review and discussion of the third revision of the Benchmark Specifications and updated support data;
- Discussion of templates for submitting participants’ results for different exercises from different tiers;
- Presentations on benchmark team support studies and results for different physics domains and calculation tiers (approaches to the R2 depletion; reactor physics, thermal-hydraulics, and fuel performance calculations to provide the missing Boundary and Initial Conditions (BICs); steady-state and transient thermal-hydraulic simulations at different R2 power levels to provide information on pressure drops and heat losses; calculations of Tier 4 exercises with provided BICs; etc.)
- Presentations on development and validation of simulation models against the provided Pre-Qualification data;
- Benchmark participants’ presentation on their models and results;
- Presentations on multi-physics modeling and simulation and analysis of PCI/PCMI phenomena and events;
- Defining a work plan and schedule for the MPCMIV benchmark activities.

The proposed meeting program is attached as Annex 1.

### **Organization of the Benchmark Workshop**

The meeting is organized around the discussion in depth of updated benchmark specifications and support data, templates for submission of participants’ results, reference solutions, and proposed work plan and time schedule for the OECD/NEA MPCMIV validation benchmark activities. The participants are requested to present their modelling and results as well as their experience and expertise in PCMI multi-physics analysis.

### **Participation in the Meeting**

Participation is restricted to individuals from OECD/NEA member country institutions who agree to the benchmark non-disclosure agreement (NDA). Participants are asked to sign and send the corresponding [NDA form](#) to [wprs@oecd-nea.org](mailto:wprs@oecd-nea.org).

Benchmark NDA form:

[https://www.oecd-nea.org/upload/docs/application/pdf/2022-03/nda-mpcmiv-benchmark-23\\_04\\_2018.pdf](https://www.oecd-nea.org/upload/docs/application/pdf/2022-03/nda-mpcmiv-benchmark-23_04_2018.pdf)

### **Organization and Program Committee of the Meeting**

An Organization and Program Committee has been nominated to make the necessary arrangements for the MPCMIV-3 benchmark workshop and to draw up the final program, etc. The members of the Program Committee are:

**Giacomo Grasso** – *Co-Chair, and Local Host*  
ENEA, Italy

**Alessandro Petruzzi** – *Co-Chair*  
NINE S.r.l., Italy

**Domenico De Luca**  
NINE S.r.l., Italy

**Maria Avramova**  
North Carolina State University, USA

**Gregory Delipei**  
North Carolina State University, USA

Secretariat: **Oliver Buss**  
OECD/Nuclear Energy Agency, France

### **Proposed Program of the Meeting**

The proposed program for the fourth OECD/NEA MPCMIV Benchmark Workshop (MPCMIV-4) was drawn-up by the Program Committee and is enclosed as Annex 1.

### **Language of the Benchmark Workshop**

The official language of the MPCMIV-4 Benchmark workshop is English.

### **Proceedings of the Meeting**

A summary of the workshop will be published by the OECD/NEA after the meeting. The summary will be distributed free of charge to the benchmark participants and to Delegates of the EGMUP, WPRS, and NSC. The program committee and the session Chairmen will prepare a summary report on the main results of the meeting for presentation to the EGMUP, WPRS, and NSC. Presentations will be available free of charge to the benchmark participants to download from participants' restricted area of the benchmark website after the workshop.

### **Contacts and Registrations**

The annual benchmark workshops/meetings of the [Working Party on Scientific Issues and Uncertainty Analysis of Reactor Systems](#) (WPRS) and CTF UG Meeting and Training will be hosted by ENEA in Bologna (Italy). The meetings will take place in three tracks in parallel

during the week of May 22<sup>nd</sup> to May 26<sup>th</sup>, 2023 to exchange our results and lessons-learned for the different WPRS benchmark activities and to discuss future activities.

The link to registration page for the WPRS-related workshops/meetings, overall program, and local information for transportation and hotels is:

[https://www.oecd-nea.org/jcms/pl\\_71612/wprs-benchmarks-workshop-2023](https://www.oecd-nea.org/jcms/pl_71612/wprs-benchmarks-workshop-2023)

The link to registration page for the CTF-9 UG Meeting and Training is:

<https://www.ne.ncsu.edu/rdfmg/cobra-tf/ninth-ctf-user-group-ug-meeting-and-training/>

### **Workshops' Location**

The meeting place for the ten meetings/workshops during the week of May 22<sup>nd</sup> to May 26<sup>th</sup>, 2023 in three tracks at the Zanhotel Europa, Via Cesare Boldini 11, Bologna, Italy (in-person meeting). As mentioned above the local information for transportation and hotels is given at:

[https://www.oecd-nea.org/jcms/pl\\_71612/wprs-benchmarks-workshop-2023](https://www.oecd-nea.org/jcms/pl_71612/wprs-benchmarks-workshop-2023)

The schedule for the incoming WPRS Workshops, SINUS school and CTF UG Meeting and Training is given in the table below:

Day	Track 1	Track 2	Track 3
Monday, 22 May 2023	MPCMIV	CTF User Group	OECD NEA International School on Simulation of Nuclear Reactor Systems (SINUS)
	Burst-Fission-Gas Release (EGRFP)	CTF Training	
Tuesday, 23 May 2023	LWR UAM	CTF Training	
		HTGR-TH	
Wednesday, 24 May 2023	EGMUP Task Force on Doppler effective fuel temperature	CTH	
	EGMUP Task Force Artificial Intelligence & Machine Learning C5G7-TD	LFR Neutronics	
Thursday, 25	C5G7-TD	LFR Thermal-	

May 2023	TVA-WB1	Hydraulics	
		LMFR T/H	
Friday, 26 May 2023	TVA-WB1	SFR-UAM	
	Rostov-2	SFR-UAM	

## ANNEX 1

### OECD/NEA Multi-Physics Pellet Cladding Mechanical Interaction Validation (MPCMIV) - Fourth Workshop (MPCMIV-4)

#### Host Organization

Hosted by ENEA  
Bologna (Italy)

**Morning of May 22, 2023**  
**Track 1**

#### PROPOSED PROGRAM

M1-11: Session code

- M1. Introduction and opening remarks
- M2. Overview of benchmark activities since the last MPCMIV workshop.
- M3. Presentations on related activities and PCMI multi-physics analysis
- M4. Discussion of the updated Specifications
- M5. Presentation of updated support data
- M6. Presentation and discussion of benchmark team's support studies and results
- M7. Presentations on development and validation of simulation models against the provided Pre-Qualification data.
- M8. Participants' presentations on their modelling and results of the MPCMIV benchmark.
- M9. Integral benchmark evaluation and development of validation protocol and guidelines for multi-physics transient applications.
- M10. Action items and schedule of benchmark activities - next workshop (MPCMIV-5) and plans
- M11. Conclusions and closing remarks.