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Kick-Off Workshop for the TVA-WB1 Reactor Pressure Vessel Fluence Exercise (TVA-WB1-RPVF)

1 July 2025

Department of Engineering of the University of Cambridge, Trumpington Street, CB2 1PZ, Cambridge, United Kingdom

The workshop will be held in Cambridge, UK, as part of the Benchmarks Workshops of the Working Party on Scientific Issues and Uncertainty of Reactor Systems (WPRS). The WPRS Benchmarks Workshops event with three parallel tracks combines benchmarking efforts in common areas such as neutronics, thermal-hydraulics, and multi-physics modelling and uncertainty analysis.

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Sponsorship

The Kick-Off Workshop for the TVA-WB1 Reactor Pressure Vessel Fluence Exercise (TVA-WB1-RPVF) will be held on 1 July 2025 in Cambridge, UK, as part of the Benchmarks Workshops Event of the Working Party on Scientific Issues and Uncertainty of Reactor Systems (WPRS). This event with three parallel tracks combines benchmarking efforts in common areas such as neutronics, thermal-hydraulics, and multi-physics modelling and uncertainty analysis. The full schedule for the incoming WPRS Workshops, SINUS-3 school and CTF-11 Meeting and Training is given on the public meeting web page: https://www.oecd-nea.org/jcms/pl_98752/wprs-benchmarks-workshops-2025

Executive Summary

Ex-core transport calculations for reactor pressure vessel (RPV) neutron fluence evaluation are an addition as a new exercise to the OECD/NEA Tennessee Valley Authority (TVA) Watts Bar nuclear power plant Unit 1 (WB1) multi-physics cycle depletion benchmark (Exercise 8). The specifications for the first seven exercises have been concluded. Comparative analyses for exercises under the Expert Group on Physics of Reactor Systems (EGPRS) have been performed. Currently, the comparative analysis of exercises (with thermal-hydraulic feedback) under the Expert Group on Multi-Physics of Reactor Systems (EGMUP) is being conducted.

Plant life extensions and power uprates have expanded the reactor pressure vessel (RPV) area of concern regarding neutron damage. However, guidance on RPV fluence analyses only addresses the traditional beltline region (directly surrounding the effective height of the active core) while an accurate prediction of neutron fluence and displacements per atom (dpa) beyond that region is required. Multiple physical parameters that are not being addressed and many approximations that have been traditionally applied should be reconsidered.

The traditional computational approach to calculating the RPV fluence is based on two consecutive steps: an in-core criticality transport calculation (aiming to determine the neutron source) and an ex-core fixed-source transport calculation (aiming to propagate neutrons to the ex-core structures). An advanced high-fidelity approach is being developed with the DOE CASL activities, through an internal coupling of the pin-by-pin fission source computed by VERA with the Monte Carlo Shift code to provide both in-core and ex-core quantities in a single simulation. This approach has been applied by ORNL to TVA-WB1 and can be considered as a reference solution, but it substantially increases the complexity of the coupled computational system. This, along with the fact that utilities routinely perform in-core calculations for all operational cycles, makes the two-step approach the practical methodology applied worldwide in the industry. Therefore, investing effort in enhancing this approach is justified.

There are two major difficulties in calculating the RPV fluence: a) the strong attenuation of the flux between the core and the vessel, which results in a very strong sensitivity of the calculated fluence to the ex-core transport modelling and methods (geometry, nuclear data, reduction variance techniques, …); b) the complexity of the neutron source calculation, that must be provided by fuel pin and depends on the operating conditions. Traditionally, the latter aspect has received less attention.

The motivation for introducing Exercise 8 is to improve the two-step computational approach for RPV neutron fluence evaluation by assessing the impact of the neutron source calculation on the

ex-core quantities of interest (QoI).
Considering the well-established TVA-WB1 benchmark, and taking into account the availability of ex-core reference solutions for this reactor to be provided by ORNL (which is very valuable, since the RPV experimental measurements are proprietary), the addition of this new exercise would allow the analysis sought to be carried out with a relatively low additional effort, maximizing the benchmark benefits.
This activity fits within the scope of WPRS, which studies, among others, the uncertainties associated with the modelling in reactor physics and radiation transport, phenomena involved in this proposal. And more in particular, it fits within the scope of EGPRS as it mainly focuses on the approximations adopted for the evaluation of the neutron fission source.

It must be taken into account that, of the 442 reactors in operation in the world in 2021, 150 have obtained a license to operate beyond 40 years of their design life. Then, the identification of approximations that can or cannot be adopted for RPV fluence evaluation is of the utmost interest for the safety assessment in long-term operation.
The objective is to provide insight into the impact of the uncertainties in the neutron fission source (due to nuclear data, approximations, and physical parameters) on ex-core quantities of interest, such as RPV fluence or dosimeter responses (used to test the agreement against experimental data). Special attention will be paid to the extended beltline region that may be more sensitive to the operating conditions and physical and calculation parameters. The final goal will be the generation of relevant knowledge on the topic that can help the international community to adopt the best practices for safety analysis in long-term operation.
Draft specifications for Exercise 8 with two templates: one to collect the neutron fission source at periphery assemblies at different burnup steps, and one to collect the ex-core QoI that have been prepared by the benchmark team to be discussed at the kick-off workshop.

Scope and Technical Content of the Meeting

The work to be done can be summarized as follows:
1. In-core calculations to compute at periphery assemblies: the neutron fission source at pin-wise resolution and the fraction of fissions in main U and Pu isotopes (data required to completely define the spatial, angular, and energy distribution in the subsequent ex-core transport calculation).
2. Ex-core calculations to compute the QoI (an input for a Monte Carlo code could be provided if needed to promote the participation of institutions already involved in the TVA-WB1 benchmark in the new exercise).
3. Sensitivity Analysis and Uncertainty Quantification due to nuclear data, approximations, and physical and calculation parameters.
The topics to be addressed at the workshop include:

- Review and discussion of the draft specifications, including two templates: one to collect the neutron fission source at periphery assemblies at different burnup steps, and one to collect the ex-core QoI
- Presenting updated benchmark support data
- Presenting the experimental and measured data
- Discussing missing information, including uncertainty parameter information and needed clarifications
- Presenting and discussing the benchmark team’s support and related studies
- Participants’ presentations on their modelling and results for Exercise 8

- Presentations on other related activities in ex-core transport calculations for reactor pressure vessel (RPV) neutron fluence evaluation
- Defining a work plan and schedule for Exercise-8 activities

Participation in the Meeting

Meeting participation is not restricted.

Organization and Program Committee of the Meeting

An Organization and Program Committee has been nominated to make the necessary arrangements for the TVA-WB1-5 meeting and to draw up the final program, etc.
The members of the Program Committee are:

- **Nuria Garcia-Herranz** – Co-Chair and Co-Cordinator
  Universidad Politécnica de Madrid, Spain
- **Alireza Haghighat –** Co-Chair
  Virginia Tech, USA
- **Arzu Alpan** – Co-Chair
  Oak Ridge National Laboratory (ORNL)

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

Proposed Program of the Meeting

The proposed program was drawn up by the Program Committee and is enclosed as Annex 1.

Language of the Benchmark Workshop

The official language of the workshop is English.

Proceedings of the Meeting

The program committee and the session Chairs will prepare a summary report on the main results of the meeting. 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

Link to the registration page for the WPRS-related workshops and meetings and the overall program:
https://www.oecd-nea.org/jcms/pl_98752/wprs-benchmarks-workshops-2025

Workshop Location

The meeting place/venue for the meetings/workshops during the week of 30 June to 4 July 2025 is the Department of Engineering of the University of Cambridge:

Trumpington Street, CB2 1PZ, Cambridge, United Kingdom.

Annex 1:

Kick-Off Workshop for TVA-WB1 Reactor Pressure Vessel Fluence Exercise (TVA-WB1-RPVF)

Host Organization

Department of Engineering of the University of Cambridge, in collaboration with the Cambridge Nuclear Energy Centre, University of Cambridge, United Kingdom

1 July 2025

Track 1 (Afternoon)

PROPOSED PROGRAM

WB01. Introduction and opening remarks.

WB02. Review and discussion of the draft specifications, including two templates: one to collect the neutron fission source at periphery assemblies at different burnup steps, and one to collect the ex-core QoI.

WB03. Presenting and discussing updated benchmark support data.

WB04. Presenting and discussing experimental and measured data.

WB05. Discussing missing information, including uncertainty parameter information and needed clarifications.

Participants' presentations on their modelling and results for Exercise 8.

Presentations on other related activities in ex-core transport calculations for reactor pressure vessel (RPV) neutron fluence evaluation.

Defining a work plan and schedule for Exercise-8 activities.