



ECC-SMART PROJECT

Joint European Canadian Chinese development of Small Modular Reactor Technology

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<u>Abstract:</u>	This deliverable outlines the results of the Workshop on Post-Irradiation Examination (PIE), held from August 26 to 30, 2024, at the CVR research center in the Czech Republic. The workshop focused on the critical role of post-irradiation examination in the nuclear industry, emphasizing its importance for the safe operation of current nuclear power plants and the development of next-generation nuclear technologies. Through a combination of theoretical courses and practical sessions, the event provided young researchers and students with insights into the behaviour of materials under irradiation, practical PIE techniques, and hands-on experiences in hot cell laboratories. Additionally, participants were given access to exclusive lab tours and research reactor visits, enhancing their understanding of PIE's application in real-world scenarios.

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Executive Summary

This deliverable D6.5, *Training Material - Booklet & Presentations*, was produced to document the creation of educational resources developed for the Workshop on Post-Irradiation Examination (PIE), held from August 26 to 30, 2024, at the CVR research centre in the Czech Republic.

The workshop was organized to address the objectives of Task 6.3 and 6.4 of Work Package 6 of the ECC-SMART project.

In its first part, the Deliverable briefly introduces the ECC-SMART project through its initially defined objectives. The purpose of the Deliverable follows with a focus on a slight deviation from the Grant Agreement and its proper justification. In the second part of the document, the programme of the event is stated together with the abstracts of the presentations. The Deliverable concludes with an overview of the students' involvement expressed via the data obtained from the questionnaire.

The booklet and presentation materials developed as part of this deliverable encapsulate the content and learning outcomes of the workshop. The booklet offers detailed explanations of PIE techniques, methodologies, and recent research developments, making it a valuable reference for students and professionals. The presentation slides serve as a visual aid, designed for use in future training sessions, workshops, and dissemination activities.

This deliverable supports the ECC-SMART project's broader goals by fulfilling several key functions:

- **Knowledge Dissemination:** The booklet and presentations translate complex PIE concepts into accessible materials, ensuring that the workshop's insights reach a broader audience within the nuclear research and education communities. The material serves as an educational resource that can be utilized in academic settings and professional development.
- **Promoting Research Opportunities:** Highlighting the contributions of the ECC-SMART project, the materials provide participants with knowledge of ongoing research avenues and potential career paths in the nuclear field. The focus on cutting-edge SMR development and PIE techniques encourages young researchers to engage with contemporary challenges in nuclear safety and materials science.
- **Strengthening Project Visibility:** As an integral part of the project's dissemination strategy, this deliverable ensures that the workshop's findings and methodologies have a lasting impact beyond the event itself. By converting the workshop content into a formal, reusable format, it ensures that the ECC-SMART project's contributions continue to inform future research and educational initiatives.

The training material is a key asset in the dissemination process, bridging the gap between advanced nuclear research and practical, application-based learning. By capturing the essence of the workshop, this deliverable contributes to building a knowledgeable and skilled future workforce for the nuclear industry. It ensures that the insights and advancements achieved through the ECC-SMART project are made available to the wider scientific community, fostering a culture of continuous learning and innovation.

In conclusion, this deliverable not only preserves the educational value of the Workshop on Post-Irradiation Examination but it also amplifies its impact. It transforms the workshop experience into

a lasting resource, supporting the broader objectives of the ECC-SMART project to enhance nuclear safety, drive innovation, and develop the next generation of nuclear technology experts.

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List of acronyms and abbreviations

Acronym/Abbreviation Definition

CBS	Concrete Biological Shield
CVR	Research Centre Řež
DBS	Doppler Broadening Spectra
EC	European Commission
ECC-Smart	(Joint) European Canadian Chinese development of Small Modular Reactor Technology
ENEN	European Nuclear Education Network
GEN-III	Generation III nuclear reactors
GEN-IV	Generation IV nuclear reactors
LTO	Long-Term Operation
LVR-15	Research Reactor LVR-15
MCNP	Monte Carlo N-Particle (Transport Code)
NPP	Nuclear Power Plant
ODS	Oxide Dispersion Strengthened (Steel)
PALS	Positron Annihilation Lifetime Spectroscopy
PIE	Post Irradiation Examination
PIIP	Post-Irradiation Inspection Program
R&D	Research and Development
RIVE	Radiation-Induced Volumetric Expansion
SEM	Scanning Electron Microscopy
SMRs	Small Modular Reactors
TEM	Transmission Electron Microscopy
VRABEC	VVER-type Reactor for Advanced Basic Education and Curriculum
VVER	Water-Water Energetic Reactor (Russian nuclear reactor type)
WP	Work Package
XRD	X-ray Diffraction

List of Annexes

Annex 1: Workshop Program

Annex 2: Presentations

Annex 3: Feedback from students

1 Introduction

1.1 Project summary

The Joint European Canadian Chinese development of Small Modular Reactor Technology (ECC-SMART) is a multinational project focused on the development and licensing of the future Supercritical Water-cooled Small Modular Reactor (SCW-SMR).

The ECC-SMART project main objectives are:

- to provide science-based recommendations and methodologies for performing safety evaluations and safety improvements fostering the safety standards, including the experimental validation of essential items for safety demonstrations related to the SCW-SMR,
- to derive the most economical safety-driven SCW-SMR design requirements by identifying adequate solutions to key technical issues which drive cost and safety and their influence to the future licensing process,
- to increase the level of knowledge as well as the interest of the industrial partners and demonstrate the benefits of the SCW-SMR concept.

1.1.1 Purpose of this document

This document is a deliverable of the Work Package 6 “Dissemination and communication” lead by ENEN. Training material -booklet & presentations - Designing and compiling the information developed for training in the format of a booklet and presentation materials. This document is important in the dissemination process. This deliverable is fully focus on the Post-Irradiation Examination Workshop held in Czech Republic, in August 2024. The deliverable aims at the following objectives:

- Designing and compiling the information developed for training in the format of a booklet and presentation materials.
- to share insights, methodologies and best practices on PIE with students and young specialists.

Within the project execution, various types of education and training activities aimed at students and young researchers have been witnessed and periodically reported. These are (1) the participation in the research tasks (2) participation at the events organized by the consortium and (3) student internships organized by the consortium members.

Throughout this deliverable, the focus lies in the Chapter 3.4.2 of the Grant Agreement (point 3). The student internships organized by the consortium members: a) Special training related to the PIE in CVR is planned (spring 2023) to use the unique opportunity for the students to participate at the evaluation of the irradiated specimens. b) Ad hoc actions - the internships up on request. In the Grant Agreement, it was mentioned that there would be special training on PIE. Later on, it was decided that the training would be organized in the form of a workshop with a duration corresponding to the summer school. The reason for this deviation was that more students and young researchers could have been reached and participated in this event. Also, it was decided that the PIE workshop would become the subject of the current deliverable D6.5 which was approved by the project officer.

2 PIE Workshop

2.1 Programme of the Workshop

The Workshop on post-irradiation examination (PIE) held at the CVR research centre in the Czech Republic, in August 2024, focused on the vital role of PIE for the safe operation of current nuclear power plants and important for the development of new generation nuclear reactors and technologies. The 5-day event featured a blend of theoretical courses and practical performances of PIE techniques. The official programme was accompanied by social activities and a tour around the Prague city center.

The theoretical courses introduced the behavior of materials under neutronic and proton irradiation, methods used for PIE, and provided an interesting perspective on real applications such as the surveillance program, LTO, and fuel inspection. Lectures were delivered by invited nuclear experts. The practical part included work performed in hot cells, with a special focus on new opportunities and challenges.

The first day began with an introduction to the program and host institution, CVR from Michaela Krydova, European Project Coordinator, and Ondřej Srba, Director of the Materials Research and Diagnostics Section, at Research Centre Řež. Some highlights of the day include the importance of irradiation experiments for safety and reliability by Jan Klouzal – Director of Safety and Reliability Division at UJV Řež a.s., insights into the regulatory framework for new nuclear reactors in the Czech Republic by the Director of the Nuclear Safety Section at the State Office for Nuclear Safety in Czech Republic, Stepan Kochanek and engaging sessions on Neutron Irradiation by experts from CVR and ČVUT.

The second day delved into Proton Irradiation and Advanced Material Testing, covering proton irradiation techniques as a surrogate for early neutron radiation damage and exploring topics like Hot Cells and mechanical properties of irradiated materials and the introduction to TANDETRON and its role in proton irradiation.

The third day, the excursions and Examination of Irradiated Materials took place. Participants explored some of the most advanced facilities: The LVR15 and TANDETRON. These excursions provided valuable practical insights into the reactor and particle acceleration for applications in nuclear physics, materials science, and medical research. The complementary lectures allowed the participants to dive into the analysis of the Irradiated Microstructure and insights into accelerated

irradiation and mechanical testing. Additionally, the participants got to explore Material Research with a focus on Future Nuclear Technologies and a dive into Surveillance Programs with the lectures of experts from CVR and ÚJV Řež, a. s.

The fourth day was dedicated to the application of Post Irradiation Examination in nuclear fuel and the long-term operation of nuclear power plants. The sessions included: PIE of nuclear fuel, The current state of nuclear fuel inspection and digital image processing presented by experts from CVR and Discussion on the long-term operation of NPPs. The day wrapped up with a deep dive into the Concrete Biological Shield and its examination techniques, crucial for both new builds and life extension of NPPs.

The last day of the PIE Workshop took participants on an excursion to the VRABEC University reactor at ČVUT. Providing hands-on experience for participants in nuclear engineering and reactor physics.

The Program of the workshop is provided in Annex 1.

Below is the detailed description of the contributions of the Workshop, outlining the key topics addressed, the insights shared by various experts and a summary of the significant discussions and outcomes that emerged from the sessions.

All presentations are provided in Annex 2.

2.2 Abstracts

The workshop featured a series of lectures from renowned experts in their respective fields. Each lecturer brought unique insights and cutting-edge knowledge, enriching the participants' learning experience. Below are the abstracts of the lectures, summarizing the key takeaways and focus areas of each session.

1. **Title:** *Welcome – Programme of the Workshop*

Author: Michaela Krýdová

Abstract:

This presentation discusses the ECC-SMART project, an international collaboration focused on advancing Small Modular Reactor (SMR) technology, with an emphasis on supercritical water-cooled reactors (SCW-SMR). Funded under the Horizon 2020 program, the project involves partners from Europe, Canada, China, and Ukraine, with a total budget of €8.9 million. Key objectives include defining design requirements, addressing licensing challenges, and establishing safety guidelines for SCW-SMRs. The project dedicates 20% of its budget to education and training (E&T), engaging young researchers through internships, training, and event participation.

2. **Title:** *CVR Introduction*

Author: Ondřej Srba

Abstract:

This presentation highlights the history, mission, and operations of the Research Centre Řež, a leading R&D organization in the Czech Republic specializing in energy and nuclear technology. Established in 2002, with roots back to 1955, the center operates two research reactors and extensive experimental infrastructure supporting nuclear power, GEN IV reactors, SMRs, and fusion technologies. Key activities include materials research, reactor safety, waste processing, and energy storage. The center also collaborates internationally and advances education in nuclear energy and cutting-edge technology development.

3. **Title:** *Importance of the irradiation experiments for safety and reliability assessment*

Author: Jan Klouzal

Abstract:

This opening presentation gives an overview of the importance of understanding the impact of irradiation on systems, structures, and components of nuclear installations. It explains the difference between design, safety, and defense-in-depth approaches, discussing radiation impacts on nuclear fuel, reactor internal components, the pressure vessel, and supporting concrete

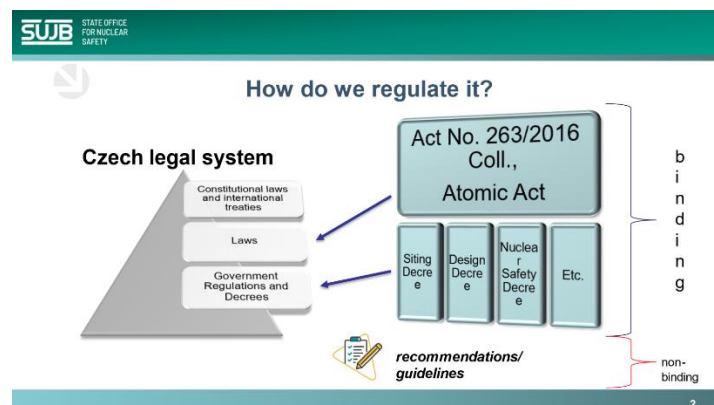
structures. Each field is treated in more depth in specialized presentations during the workshop.

4. **Title:** *Regulatory framework for new nuclear reactors in the Czech Republic*

Author: Stepan Kochánek

Abstract:

The presentation provides an overview of the Czech nuclear regulatory framework, focusing on aspects such as licensing, assessment, and enforcement, particularly concerning small modular reactors (SMRs) and new technologies. It highlights the challenges these technologies pose to existing regulatory frameworks, as they often lack comprehensive safety measures. The presentation will also discuss potential gaps in national systems and legislation and propose solutions for regulatory bodies to adapt to these new technologies. This presentation will explain challenges related to new technologies in the nuclear sector and explore how regulatory bodies may respond. The information aims to highlight gaps in national legislation and suggest possible solutions.

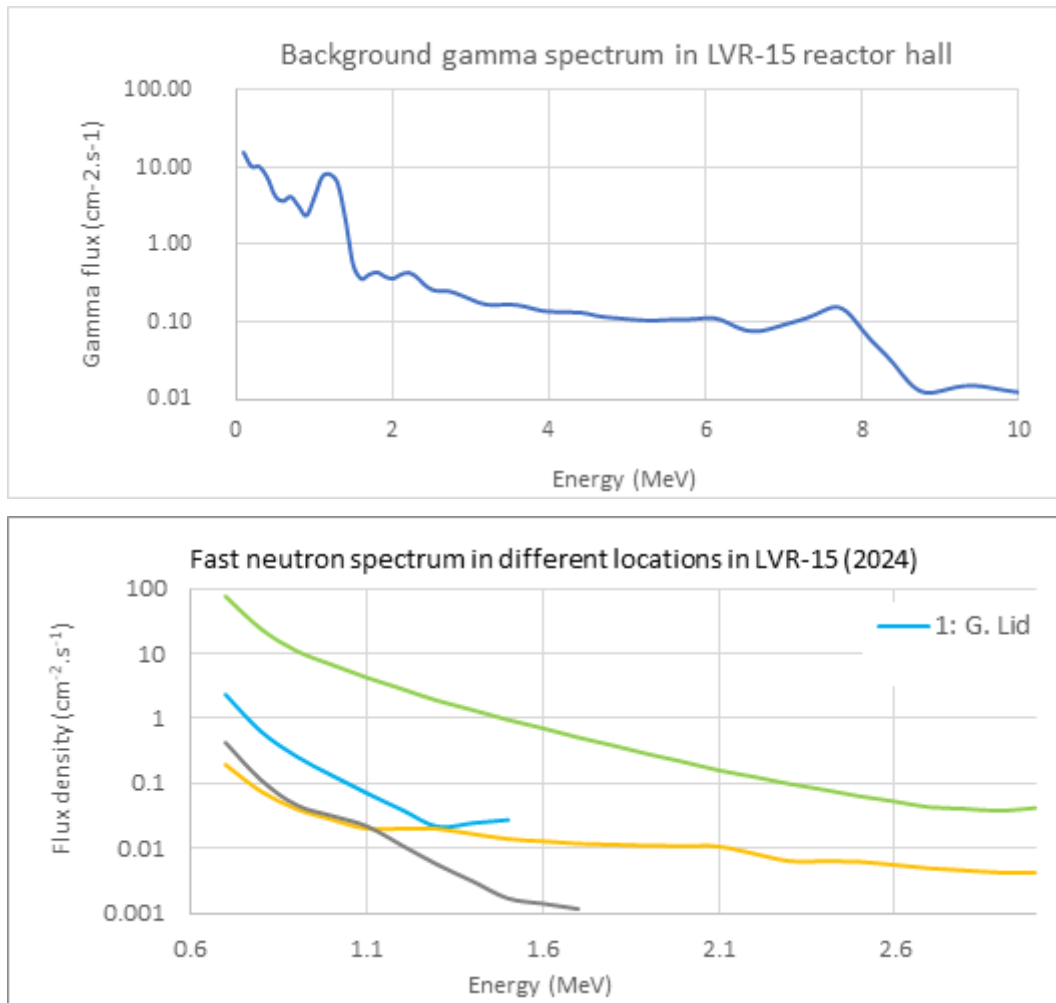


5. **Title:** *Dosimetry*

Author: Jakub Beinstein

Abstract:

The presentation discusses dosimetry in radiation protection, covering basic methods such as protection by time, distance, shielding, and source control. It introduces the online dosimetry system of the LVR-15 research reactor and highlights neutron dosimetry challenges, including detection, biological effects, and monitoring. The final section focuses on radiation protection measurements during and after irradiation experiments, including radioactive waste disposal.



6. **Title:** Basic Terms - *Introduction to Neutron Irradiation & Research Reactors Utilisation*

Author: Sebastian Nyvlt

Abstract:

This introductory presentation provides a foundational understanding of nuclear interactions, particularly focusing on neutron- and photon-induced interactions. It examines the classification and applications of research reactors, emphasizing neutron activation analysis for sample composition determination and the production of radioisotopes like ⁹⁹Mo for medical diagnostics. Other applications, including neutron-induced gemstone coloring and boron neutron capture therapy for cancer treatment, are also discussed. The presentation concludes by highlighting the need for innovative methods to improve the utilization of neutron irradiation in various fields.

7. **Title:** *Irradiation in Research Reactors (Opportunities, Procedures, Construction of irradiation rigs – Experiences, etc)*

Author: Miroslav Vinš, Jaroslav Šoltés

Abstract:

This presentation gives an overview of the LVR-15 research reactor, including its characteristics, utilization, and opportunities for material irradiation. It describes the process of experiment preparation and evaluation. The LVR-15 is a light water tank-type reactor with 10 MW power, used for neutron material testing, isotope production, and other purposes. The presentation also introduces the MCNP transport code used for neutron spectra and fluence calculations, safety analysis, and more.

8. **Title:** *Degradation mechanisms (and integrity testing during the NPP lifetime)*

Author: Radim Kopřiva

Abstract:

This presentation covers degradation mechanisms and the integrity testing necessary for ensuring the long-term safe operation of nuclear components. It also discusses surveillance programs for reactor pressure vessels, focusing on radiation embrittlement caused by fast neutron flux. Surveillance programs for VVER reactors are described, highlighting their role in extending nuclear power plant lifespans.

9. **Title:** *Proton Irradiation as a Surrogate for Early Neutron Radiation Damage*

Author: Jarmila Degmova et al.

Abstract:

Positron annihilation spectroscopy was used to investigate early stages of radiation-induced damage in Chinese ferritic/martensitic steel SIMP and strengthened variant ODS EUROFER. Materials were irradiated by neutrons at the LVR-15 research reactor and by protons at the 6 MV Tandetron Accelerator. The potential of proton irradiation as a surrogate for neutron radiation damage was explored, using positron lifetime (PALS) and Doppler broadening spectra (DBS) to characterize vacancy-type defects. The results suggest a promising potential for using proton irradiation to assess early neutron damage.

10. **Title:** *Tandetron: Introduction (Proton Irradiation)*

Author: Vladimír Havránek

Abstract:

In this presentation, Vladimír Havránek outlined research at the Tandetron 4130MC accelerator at Řež, part of the Czech Academy of Sciences' Nuclear Physics Institute. The facility uses versatile MeV ion sources for materials irradiation and analysis, with techniques like PIXE, RBS, PIGE, and NRA. Applications include ion microbeam systems, high-energy implantation, and ion beam

writing for precise material modification and characterization. The accelerator also supports biological research and detector testing, contributing to advancements in nuclear materials and nanostructure research

11. **Title:** *Hot Cells Newly developed methods*

Author: Alica Fedoriková

Abstract:

The presentation is aimed at introducing the concept of Hot-cell laboratories. During the presentation it is explained why, how and where the post-irradiation examination takes place, under what conditions, what is the motivation for this experimental activity. The way of planning the experiment, its realization, evaluation and implementation of the results into practice with the aim of increasing the safety and reliability of NPPs is explained in more detail.

The infrastructure of Hot cells in CVR is presented, what types of tests are implemented and the work with active material is presented. The specifics of this work and what is needed for proper analysis are mentioned. In the end of the presentation the concept of ATF (accident tolerant fuel) cladding and its advantages vs. disadvantages is explained. The presentation was then complemented by an excursion in the hot cells laboratory, where all mentioned methodologies were presented in practice.

12. **Title:** *Mechanical properties of irradiated structural materials and their testing*

Author: Mariia Zimina

Abstract:

Nuclear industry has very strict requirements for the materials used in the power plants due to the higher components replacement and repair costs compared to other industries. This leads to various regulations and restrictions when it comes to materials testing. The conditions, such as temperature, pressure and environmental factors, should be taken into account for the materials qualification. Simulation of these conditions is usually conducted in the certified laboratories using standardized testing methods. However, this can be challenging when the material is neutron irradiated. The handling of neutron irradiated materials should be done safely following IAEA guidelines, rules and standards. Laboratories specialized in neutron irradiated materials studies are the hot cells facilities. There are 53 post irradiation examination facilities [1] in the world providing surveillance programs and research for 440 nuclear power reactors operation in 32 countries plus Taiwan, with a combined capacity of about 390 GWe.

This talk will be focused on the research experience of neutron irradiated materials mechanical testing in Europe and the UK. It will cover the challenges in transport of neutron irradiated materials from the power plant to the hot cells, designing the experiments and procedures to perform the testing including mechanical and microstructural analysis as well as the testing in environments simulating light water reactors (PWR/BWR/SCW) and liquid metals and salt environments for GENIV nuclear reactors. Most importantly, it would focus on a power of collaborative research, which plays an important role for the scientific and industrial success. The examples of international collaborative projects and programs which had significant impact in industry will be discussed.

Reference:

[1] Post irradiation examination facilities database, International Atomic Energy Agency, <https://infcis.iaea.org/PIEDB/facilities>

13. **Title:** *LVR-15 research reactor irradiation capabilities*

Author: Jan Vít

Abstract:

The LVR-15 experimental reactor in the Czech Republic is introduced, focusing on its irradiation capabilities. The presentation covers the reactor's parameters and its use in materials research and isotope production. It also details the various irradiation rigs, including the CHOUC A rig and rigs used for high dpa irradiation and cladding materials testing.

14. **Title:** *Irradiated Microstructure as Seen Through an Electron Microscope*

Author: P. Zháňal

Abstract:

This presentation explores the effects of radiation on materials, focusing on irradiated microstructures. Using electron microscopy techniques like scanning electron microscopy (SEM) and transmission electron microscopy (TEM), the presentation visualizes and analyzes changes at the atomic level, including defect formation, phase transformations, and microstructural features. Insights gained from studying defects, new phase formations, and the evolution of grain boundaries help understand the material properties and their performance in radiation-rich environments. The presentation includes case studies across various materials used in nuclear reactors, emphasizing the importance of advanced characterization techniques in materials science.

15. Title: *Accelerated Irradiation and Mechanical Testing of Advanced Reactor Cladding Materials*

Author: Hygreeva Namburi

Abstract:

Presented by H. Namburi and team from Canadian Nuclear Laboratories (CNL), this presentation focuses on cladding materials essential for advanced reactors such as CANDU, molten salt, and high-temperature reactors. It includes findings on material degradation under high neutron doses, elevated temperatures, and corrosive environments. The study partners with TRIUMF for accelerated irradiation testing and presents data on materials like Alloy 800H and stainless steel 310S. Small punch tests are used to assess irradiation impacts on material performance, aiming to ensure the materials' viability for next-generation reactors.

16. Title: *Material Research for Advanced Nuclear Technologies*

Authors: Monika Šípová, Leoš Křivský

Abstract:

This presentation covered research on materials developed to withstand the extreme conditions of next-generation reactors, including high radiation, temperature, and corrosive environments. Focused on cladding and structural materials essential for reactor safety, the team presented findings on HEA (High Entropy Alloy) and advanced structural materials such as 310S and 800H. Research addresses radiation-induced damage affecting mechanical and corrosion properties, a critical step toward safer and more resilient nuclear systems capable of long-term operation in challenging environments.

17. Title: *Surveillance Programs for Nuclear Power Reactor Pressure Vessels*

Author: Radim Kopřiva

Abstract:

This presentation covers surveillance programs essential for monitoring radiation embrittlement in reactor pressure vessels, particularly in VVER reactors. Radiation embrittlement due to fast neutron flux is the primary degradation mechanism affecting vessel longevity. Surveillance programs provide critical insights into the embrittlement state and enable predictions for long-term performance, essential for extending nuclear power plant operational life and safety.

18. Title: *Examination of Irradiated Nuclear Fuel*

Author: Václav Tyrpek

Abstract:

This presentation addresses the structural changes in nuclear fuel during its lifetime in a reactor, encompassing phenomena such as fission, recrystallization, and chemical reactions. Post irradiation examination (PIE) utilizes solid-state analysis techniques to provide insights into the microstructure and fission product behavior in uranium dioxide fuel. The contribution highlights past PIE campaigns, focusing on the microstructural and fission product nature and their implications for fuel properties and manufacturing.

19. **Title:** *The current state of nuclear fuel and its inspection possibilities*

Author: Marcin Kopec

Abstract:

Nuclear fuel is the first safety barrier in nuclear power plant operations. The presentation covers current R&D activities and technologies for both GEN-III and GEN-IV fuel systems. It also discusses the Post-Irradiation Inspection Programme (PIIP) and the development of technologies to assess fuel properties that reflect safe operation. CVR has been developing such technologies, which provide new information during fuel inspections.

20. **Title:** *Digital Image Processing for Fuel Inspection*

Author: Jan Blažek

Abstract:

This presentation demonstrates how video recordings from fuel inspections can be processed. The concept of a "one image overview," which forms the basis for subsequent photometry, is introduced. This innovative approach, developed over six years, has the potential to significantly change the inspection process and increase the volume of inspected files within the same time unit.

21. **Title:** *Long-term Operation of Current Operated NPPs*

Author: Vladimír Služen

Abstract:

This presentation discusses the current state of nuclear reactors globally, emphasizing the need for sustainable nuclear energy use. Key considerations include extending existing plant lifetimes, improvements within Generation III+ projects, and the integration of small modular reactors. The talk will also cover experiences from Slovakia's VVER-440 fleet, focusing on the evaluation of selected components' lifetime and the results from the EC project DELISA-LTO, aimed at ensuring reliable safety margins for long-term operations.

22. Title: *Concrete biological shield in new build and service life extension of NPPS*

Author: Petr Štemberk

Abstract:

The concrete biological shield (CBS) in conventional nuclear power plants typically serves as both biological protection and a load-bearing structure. The presentation discusses how neutrons and gamma rays emitted from the reactor impact CBS, with neutrons causing radiation-induced volumetric expansion (RIVE) in aggregates, leading to cracks and reduced mechanical properties. Gamma rays shrink the cement paste, exacerbating these issues. Due to physical inaccessibility and strict legislation, numerical simulations are employed alongside experimental irradiation tests on small samples to validate developed numerical codes for assessing the residual service life of CBS.

23. Title: *Precharacterization and Post-Irradiation Examination of Components of Concrete Biological Shield at CVR*

Author: Kamil Sobek

Abstract:

This study assesses the structural integrity and radiation-induced changes in components of the concrete biological shield (CBS) subjected to prolonged exposure in a nuclear environment. The characterization phase includes detailed material analysis and baseline measurements of CBS components before neutron irradiation at the LVR-15 research reactor. Critical reference points for comparing pre- and post-irradiation properties are established. The study emphasizes aggregates, which comprise the majority of shielding concrete and can undergo significant changes under high radiation. Analytical methods like X-ray diffraction (XRD), scanning electron microscopy-energy dispersive X-ray analysis (SEM-EDX), and Raman spectroscopy are utilized to map data, allowing predictions about material behavior and contributions to efficient decommissioning after operation.

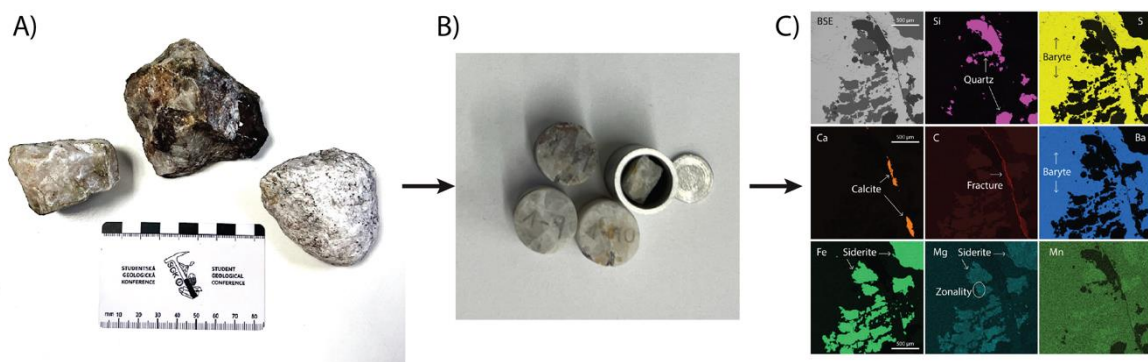


Fig. 1: Schematic of the sample processing and pre-characterization process, where A) samples of different aggregates of barite sampled at the deposit; B) processed barite into cylinders with dimensions of 1x1 cm, intended for analysis and irradiation and C) BSE and EDX imaging of a selected area indicating the presence of impurities and inclusions contained in the otherwise pure barite.

3 Involvement of the students

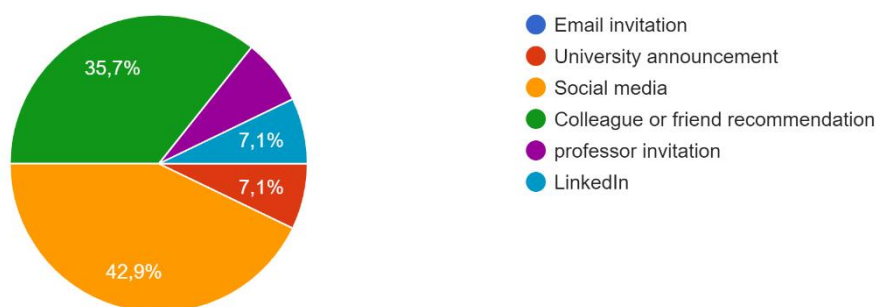
The workshop underscored the dedication of the project to education and training. Partnership with the ENEN2plus project encouraged enhancing student education and career growth by providing support for students.

The workshop attracted a dynamic group of 21 early-career researchers and students, aged between 18 and 30, from across the globe, all eager to enhance their research skills and academic expertise. Active participation by the students was a cornerstone of this workshop's success. Their engagement, from asking insightful questions to contributing to group discussions, was integral to the dynamic atmosphere. The following section presents data gathered through a participant questionnaire, illustrating their involvement and feedback throughout the event. Attending the Workshop provided the students with an excellent opportunity to share their experience, improve their soft skills and enlarge their professional network all of which they might benefit from in their future careers. The report on the selection process and feedback reports from the students, demonstrate a deep interest and significant knowledge improvement of the involved students. All the materials are provided in Annex 3.

As per the questionnaire, more than half of the participants heard about the event through social media - Facebook/Instagram/Twitter (42.9%) or LinkedIn (7.1%).

How did you hear about this event?

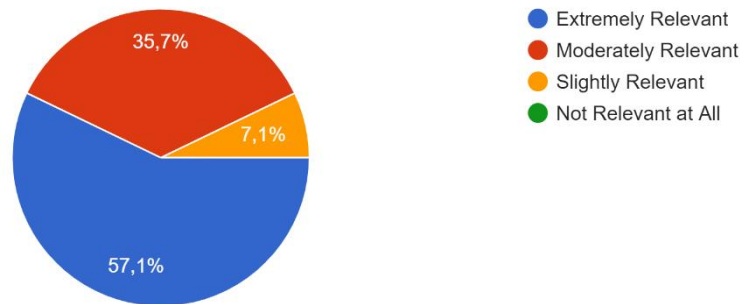
14 respuestas



- Graph 1

The feedback on how relevant they considered the workshop's content was highly positive. With 57.1% considering it extremely relevant to their work or study, 35.7% moderately relevant and 7.1% slightly relevant.

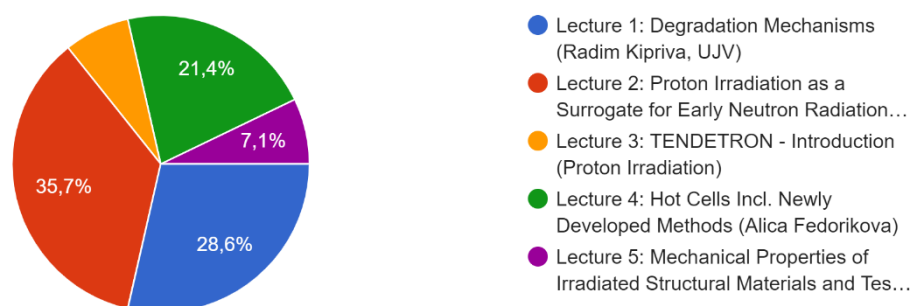
How relevant and useful was the workshop content to your field of work or study?
14 respuestas



- Graph 2

The participants were asked to vote for the most interesting presentation and it was a huge surprise that due to the diversity of interest and topics, the answers were extremely heterogeneous. There were 5 lectures voted as the “most interesting”. The topics included: “Degradation Mechanisms”, “Proton Irradiation as a Surrogate for Early Neutron Radiation Damage”, “TENDETRON - Introduction”, “Hot Cells Incl. Newly Developed Methods” and “Mechanical Properties of Irradiated Structural Materials and Tests”. It's important to highlight that out of the 5, 2 of them were strictly related to the theoretical content of excursions to TENDETRON and Hot Cells.

DAY 2: Proton Irradiation and Testing of Irradiated Materials Which was the most interesting lecture for you?
14 respuestas



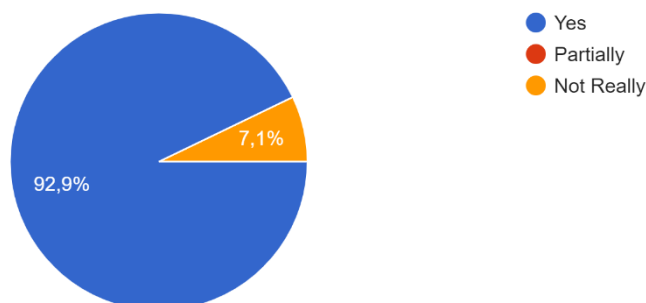
- Graph 3

A solid 92.9% of participants indicated in the questionnaire that the excursions to TANDETRON, VRABEC University Reactor, LVR15 and the Hot Cells significantly enhanced their understanding of the practical applications discussed during the workshop. These hands-on experiences provided valuable insights into the operational aspects of nuclear facilities, reinforcing the theoretical knowledge shared in the lectures on Post Irradiation Examination. The positive

feedback underscores the importance of integrating site visits into the learning process for a more immersive educational experience.

EXCURSIONS Did the excursions enhance your understanding?

14 respuestas



- Graph 4

Following the workshop, participants were asked to share feedback on their experience through a questionnaire, offering valuable insights into the impact and highlights of the event.

Many participants appreciated the relevance of the workshop to their professional development. Merell Lystra Recta expressed that *"the program was really interesting... useful for my research"* and shared gratitude for ENEN funding support, which enabled her attendance. For Lucas Autones, the workshop provided a practical connection to his work, noting, *"not only we had technical courses but also explored how it's applicable to the industry."*

The chance to visit specialized facilities, such as hot cells and research reactors, was a standout experience for several attendees. Ryan Oatley emphasized the unique opportunity, explaining, *"It was an amazing experience, something I hadn't had the opportunity to do yet in my university."* Selina Richter echoed this sentiment, highlighting the hands-on experience with manipulators in the hot cells as adding a valuable, practical dimension.

In addition to facility tours, specific lectures resonated with attendees. Ryan Oatley appreciated a lecture on nuclear power plant operations and future directions, describing it as offering *"a realistic overview of the nuclear fission landscape."* Similarly, Luiza Vlasenko Mischenko found value in the technical aspects that underscored safety and innovation in the nuclear industry.

The workshop effectively brought together academic knowledge, industry applications, and unique hands-on experience, fostering a deeper understanding of irradiation processes and material testing. This experience set the stage for future project activities as similar collaborations and educational initiatives are planned for the remaining phase of the project, continuing the momentum gained from the workshop.

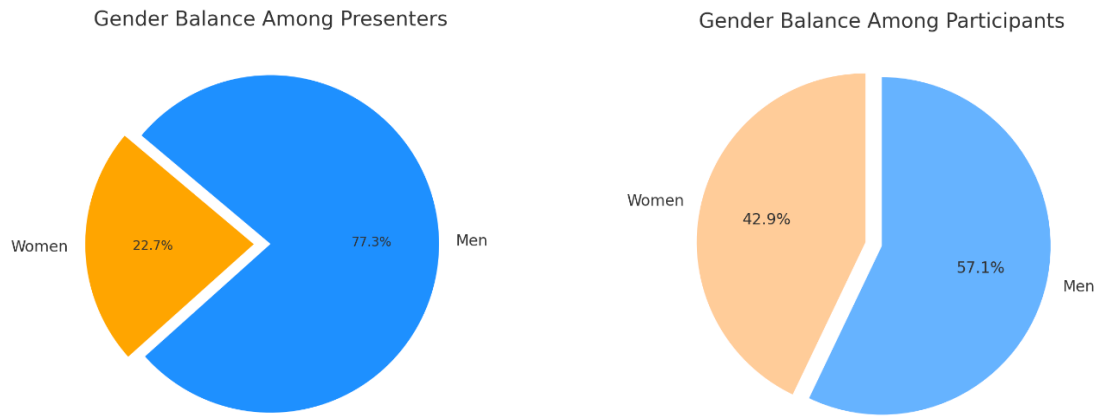
4 Conclusions

The Workshop on "Post-Irradiation Examination (PIE)" held in August 2024 in Řež, Czech Republic, was a notable achievement within the framework of the ECC-SMART project. **In comparison with previous workshops held by the ECC-SMART project, this one was particularly dedicated to education and knowledge-sharing with students and young professionals.** This event provided an invaluable platform for the exchange of knowledge and expertise in PIE, reinforcing the project's overarching goals while fostering education, engagement, and raising awareness of key project outcomes and innovations.

Unlike previous events that might have focused primarily on research dissemination and expert-level exchanges, this workshop placed a strong emphasis on fostering learning opportunities for the next generation of nuclear scientists. The program was designed with the aim of providing an immersive educational experience, where emerging professionals could engage directly with leading experts in the field.

This approach not only ensured that cutting-edge research and insights were accessible to younger participants but also allowed them to contribute to discussions, ask questions, and interact in a way that facilitated deeper understanding. Through hands-on sessions, presentations, and collaborative discussions, the workshop actively promoted the development of practical skills and critical thinking, essential for future leaders in the nuclear sector. By prioritizing education and mentorship, the workshop created a bridge between seasoned professionals and the students, facilitating a knowledge transfer that is crucial for ensuring continuity and innovation in reactor safety and related technologies.

An important element to consider for improvement in the workshop is the Gender distribution mostly among presenters. Among the presenters, 22.7% were women (5 out of 22), while men comprised 77.3%. In participant attendance, a greater gender balance was witnessed as 42.9% were women (9 out of 21)¹, with men making up 57.1%. The following charts illustrate these proportions, underscoring the need for continued efforts toward achieving greater gender diversity in future events mostly among the presenters.



- Graph 5

Moreover, this dedication to educating young professionals reflects the ECC-SMART project's broader mission to not only advance scientific research but also to cultivate the next generation of experts who will drive the nuclear industry forward. The focus on international students and young professionals at this workshop, in particular, helped create an inclusive learning environment where participants could develop the expertise and confidence needed to tackle future challenges in the nuclear field.

In conclusion, the workshop represents a significant step toward sustaining the impact of the ECC-SMART project. Its thoughtful approach to knowledge sharing and data management will help ensure that the project's findings continue to be accessible, reusable, and impactful in shaping the future of reactor safety.

Annex 1



Workshop on Post Irradiation Examination (PIE)

26-30 August 2024

Conference Centre ÚJV

Centrum Výzkumu Řež, Hlavní 130, 250 68 Husinec-Řež

PROGRAMME			
Day 1 – Monday 26 th August 2024		Presenter/Institution	time
Introduction	Registration		09:00-10:00
	Welcome (Programme of the workshop; CVR introduction)	Michaela Krydová / CVŘ Ondřej Srba / CVŘ	10:00-10:30
	Importance of irradiation experiments for safety and reliability assessment	Jan Klouzal / ÚJV	10:30-12:00
Safety	Lunch		12:00-13:00
	Regulatory framework for new nuclear reactors in the Czech Republic	Štěpán Kochánek / SÚJB	13:00-13:40
	Dosimetry	Jakub Beinstain / CVŘ	13:40-14:10
Neutron Irradiation	Coffee break		14:10-14:30
	Basic terms, Introduction	Sebastian Nývlt / ČVUT	14:30-15:10
	Irradiation in Research Reactors (Opportunities, procedures, construction of irradiation rigs – experiences, etc)	Jaroslav Šoltés / CVŘ Miroslav Vins / CVŘ Jan Vít / CVŘ	15:10-16:10
Day 2 – Tuesday 27 th August 2024		Presenter/Institution	time
Proton Irradiation and testing of irradiated materials	Morning Coffee		08:00-09:00
	Degradation mechanisms	Radim Kopřiva / ÚJV	09:00-9:40
	Proton irradiation as a surrogate for early neutron radiation damage	Jarmila Degmová / STUBA	09:40-10:10
	TANDETRON: Introduction (proton irradiation)	UJF AV ČR	10:10-10:40
	Hot Cells incl. newly developed methods	Alica Fedoriková / CVŘ	10:40-11:10
	Mechanical properties of irradiated structural materials and tests (Inc. Testing in environments simulating PWR, SCW, etc.)	Mariia Zimina/Uni Bristol	11:10-12:00
Excursion	Lunch		12:00-13:00
	Hot Cells (SUSEN) Centre of Highly Sensitive Analytical Instruments		
	Dinner (the latest train from Řež at 17:23)		



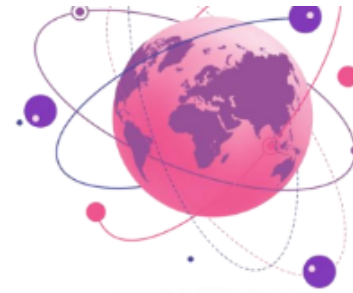
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Day 3 – Wednesday 28 th August 2024		Presenter/Institution	time
Excursion	Morning Coffee		08:00-09:00
	Excursion LVR15		
	Excursion TANDETRON		
Examination of materials damage	Lunch		12:00-13:00
	Analysis of the irradiated microstructure	Pavel Zháňal / CVŘ	13:00-13:40
	Accelerated Irradiation, Mechanical Testing and Microstructure Characterization of Advanced Reactor Candidate Cladding Materials	Hygreeva Namburi/CNL	13:40-14:10
PIE application	Coffee break		14:10-14:30
	Material research with a focus on advanced and future nuclear technologies (past, current and future projects → main points of interest)	Leoš Křivský / CVŘ Monika Šípová / CVŘ	14:30-15:10
	Surveillance programme	Radim Kopřiva / ÚJV	15:10-16:00
Day 4 – Thursday 29 th August 2024		Presenter/Institution	time
PIE application	Morning Coffee		08:00-09:00
	PIE of nuclear fuel.	Václav Tyrpekl / Faculty of Science Charles University	09:00-9:40
	The current state of nuclear fuel and its inspection possibilities.	Marcin Kopec / CVŘ	09:40-10:20
	Digital image processing for fuel inspection.	Jan Blažek / CVŘ	10:20-11:00
	Long-term operation of currently operated NPP.	Vladimír Slugeň / STUBA	11:00-12:00
	Lunch		12:00-13:00
	Concrete Biological Shield in New Build and Service Life Extension of NPPs	Petr Štemberk / CTU	13:00-14:00
Pre-characterization and Post-Irradiation Examination of Components of Concrete Biological Shield at CVŘ	Kamil Sobek / CVŘ	14:00-15:00	
Prague guided tour (the latest train from Řež at 15:23)			



Day 5 – Friday 30 th August 2024		Presenter/Institution	time
Excursion	<i>Bus at Holešovice nádraží Metro station (will be specified on Monday)</i>		8:30-9:00
	VRABEC University reactor	ČVUT	
	Final discussion		
	Wrap Up		
	<i>Lunch in the Prague centre</i>		12:00-14:00

* The time slots are indicative. The Programme can be slightly changed according to the needs.



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Annex 2

All workshop presentations are available for access through a dedicated SharePoint folder. This includes the complete set of slides and supplementary materials from each session. You can access them using the following link: [Annex 2 - D.6.5](#)

Annex 3

The complete Excel file with the Participants feedback can be find here: [Annex 3 – D.6.5](#)