ISOE European Symposium

Rotterdam, 4 – 6 June 2024

Programme & Book of Abstracts

Supported by

ISOE European Symposium

Rotterdam, 4-6 June 2024

The European Technical Centre of the Information System on Occupational Exposure (ISOE) is pleased to organize, in collaboration with and the support of Elektriciteits Produktiemaatschappij Zuid-Nederland (EPZ) and Authority for Nuclear Safety and Radiation Protection (ANVS), the 2024 ISOE European Symposium on Occupational Exposure Management at Nuclear Facilities.

The Symposium will be held in Rotterdam, Netherlands, from the 4th to the 6th of June 2024. It is co-sponsored by the OECD Nuclear Energy Agency (NEA) and the International Atomic Energy Agency (IAEA).

The Symposium is targeted at all those concerned with radiological protection at nuclear power plants: radiation protection managers and staff members, maintenance and operation planners, contractors, exposed workers, regulatory body representatives and international organisations. It is also opened to research reactors and professionals from other nuclear fuel cycle installations sharing common radiological protection issues.

Dealing with occupational radiation protection at the design, operation and decommissioning stages of installations, as well as accident situations, this new meeting point of radiation protection professionals under the heading of ISOE will be a great opportunity to share, at the international level, experiences and practices favouring a continuous improvement of radiation protection.

Furthermore, the accompanying Technical Exhibition will give participants the opportunity to see the latest developments from industrial and commercial companies active in fields of radiation protection.

Prior to the Symposium, on Monday 3 June 2024, two meetings devoted to specific audiences have been organised:
- A Radiation Protection Managers meeting
- A Regulatory Body Representatives meeting

We are looking forward to welcoming you in Rotterdam,

Caroline SCHIEBER
Head of ISOE-ETC
On behalf of the Programme Committee

PROGRAMME COMMITTEE MEMBERS

Patrick ARENDS	ANVS – Netherlands
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Caroline SCHIEBER	ISOE ETC, CEPN – France
Thorsten STAHL	GRS – Germany
Philippe WEICKERT	EDF UNIE-GPEX – France

CONFERENCE LANGUAGE

The conference language will be English.

SYMPOSIUM VENUE

The Symposium will take place at:

Van Nelle Fabriek
Van Nelleweg 1
3044 BC Rotterdam (Netherlands)

The Symposium will take place in the Koffiefabriek building (Entrance 3).

Dedicated Meetings – Monday 3 June 2024

The ISOE Symposium will be preceded by two dedicated meetings devoted to specific audience.

If you wish to participate to one of those meetings, please contact the relevant person as indicated below in order to register to one of these meetings.

The registration to these meetings is free of cost.

Radiation Protection Managers Meeting	
10:00 - 18:00	Location: Van Nelle Fabriek *Contact-person:* **Hans MEIJER**, Borssele NPP – j.meijer@epz.nl

Regulatory Body Representatives Meeting	
10:00 - 18:00	Location: Van Nelle Fabriek *Contact-person:* **Patrick ARENDS**, ANVS – patrick.arends@anvs.nl

ISOE European Symposium

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PROGRAMME

TUESDAY 4 JUNE 2024

08:30 - 09:00	*Registration*

09:00 - 09:20	Opening Ceremony (ETC, EPZ, ANVS)

Session 1.	RP Management
Chairpersons	**Monika Fárníková (Temelin NPP, Czechia), Ignacio Calavia (CSN, Spain)**
09:20 - 09:40	Highlights on RP Activities at OECD NEA Ye Zhang (NEA)
09:40 - 10:00	ALARA Planning for the Opening and Closing Activity of Angra 1 Reactor during Maintenance Shutdown and Refuelling at Angra 1 Fernando Mendonça Soares Filho (Angra NPP, Brazil)
10:00 - 10:20	RP Highlights from Vogtle 3 Startup Victoria Messenger (Vogtle NPP, USA)

10:20 - 11:05	*Coffee-break, Visit of Exhibition, Posters*

Session 2.	RP at Design Stage of NPPs
Chairpersons	**Richard Parlone (Sizewell B NPP, UK), Liisa Salminen (Loviisa NPP, Finland)**
11:05 - 11:25	Lessons Learned from UK Generic Design Assessment of New Reactors, Past and Present Stuart Johnson (ONR, UK)
11:25 - 11:45	Radiation Protection Aspects for Advanced Reactors David Perkins, Rodolfo Vaghetto (EPRI, USA)
11:45 - 12:05	Designer/Operator Work Program for the Radiation Protection Design of EPR2 Sébastien Poirrier, Matthieu Longeot (Edvance, France)
12:05 - 12:25	Radiological Protection Considerations of SMRs Rahil Mashhadi (ONR, UK)
12:25 - 12:45	Decision-Making Method for the Installation of Valves Remote Controls at the Design Stage of a NPP Sébastien Poirrier (Edvance), Caroline Schieber, Eymeric Lafranque (CEPN), France

12:45 - 14:00	*Lunch Break*

Session 3. Chairpersons	**Update on Health Effects associated with Occupational Exposure** Patrick Arends (ANVS, Netherlands), C. Schieber (ISOE ETC – CEPN, France)
14:00 - 14:40	Results of the Epidemiological Study “INWORKS” David Richardson (University of California, Irvine, USA)

Session 4. Chairpersons	**Use of Gamma Camera/CZT** Annika Ljungberg (Ringhals NPP, Sweden), Charles Peretti (EDF DIPDE, France)
14:40 - 15:00	An Efficient Bayesian Algorithm for Localizing Contaminants in Nuclear Waste: Application on 3D Imaging of Waste Drums Nhan Le, Hichem Snoussi (Troyes University of Technology), Alain Iltis (Damavan Imaging), France
15:00 - 15:20	Gamma-camera: An Innovative Tool for Limiting Dosimetry and Contribute to the Operational Performance of Radiation Protection Rémi Bourdeloie, Marc Lestang (EDF UNIE-GPEX, France)
15:20 - 15:40	Pixelated CZT Spectra Real-Time Monitoring during PWR CRUD Burst & Operation Failed Fuel Episode Brian Eick (Point Beach NPP), David Nestle (H3D), USA

15:40 - 16:25	*Coffee-break, Visit of Exhibition, Posters*

Session 5. Chairpersons	**Exposure Management** Veli Riihiluoma (STUK, Finland), Charlotte Guenault (ASN, France)
16:25 - 16:45	The UAE Nuclear Legislation Framework and Oversight for Internal and External Dose Management in Nuclear Facilities Edward Deogracias, Mariam Alzaabi (FANR, UAE)
16:45 - 17:05	Digital Radiological Passbook Application Ignacio Calavia (CSN, Spain)
17:05 - 17:25	Dose Registration System in The Netherlands and Europe Govert de With (NRG, The Netherlands)
17:25 - 17:45	Electronic Dosimetry Management System Replacement at Temelín NPP - Challenges and Solutions Ondřej Kvasnička (Temelín NPP, Czechia)

WEDNESDAY 5 JUNE 2024

Session 6. Chairpersons	**Job Experiences** **Stuart Johnson (ONR, UK), Hans Meijer (Borssele NPP, Netherlands)**
09:00 - 09:20	Repair of Welds with Degradation due to Stress Corrosion in Primary Circuit Piping: Operational Insights from 2023 Charles Peretti (EDF DIPDE, France)
09:20 - 09:40	Krško NPP Slovenia 2023 Projects Maja Kozole, Jan Jamnik Srpčič (Krško NPP, Slovenia) *NATC Young Health Physicists Distinguished Paper Award*
09:40 - 10:00	Watts Bar Unit 2 SGR Outage ALARA Experience Brad Boyer (Watts Bar NPP, USA)

10:00 - 10:20	Synthesis of RPM and RB Meeting days

10:20 - 11:05	*Coffee-break, Visit of Exhibition, Posters*

Session 7. Chairpersons	**Waste Management** **Laure-Anne Beltrami (ISOE ETC, France), Jan Jamnik Srpčič (Krško NPP, Slovenia)**
11:05 - 11:25	The UAE Regulatory Framework and Oversight for Radiation Protection and Waste Management Edward Deogracias, Mariam Alzaabi (FANR, UAE)
11:25 - 11:45	High Activity Radioactive Waste Disposal in the Netherlands Michiel de Nood, Ewoud Verhoef (COVRA, Netherlands)
11:45 - 12:05	NPP Krško – Spent Fuel Dry Storage Project (SFDS) Daniel Novak, Marjan Pavlin (Krško NPP, Slovenia)
12:05 - 12:25	Use of a Robot for the Treatment of High Dose Rate Waste at the Tihange NPP Benoit Lance (Tihange NPP, Belgium)

12:30 - 14:00	*Lunch Break*

Session 8. Chairpersons	RP at Decommissioning Stage Thorsten Stahl (GRS, Germany), Johannes Isokivelä (Forsmark NPP, Sweden)
14:00 - 14:30	Radiation Protection Issues in the Decommissioning of Nuclear Facilities: Lessons Learned from the ISOE WGDECOM Laure-Anne Beltrami (ISOE European Technical Centre – CEPN, France)
14:30 - 14:50	Measures to Prevent Internal Contamination by Alpha Emitting Aerosols during Decommissioning and Dismantling NPP with Highly Contaminated Internals Martin Listjak, Pavol Pajersky, Jana Vajdova, David Bednar (VUJE, Slovak Republic)
14:50 - 15:10	ALARA Approach for Decommissioning of Components Outside of Reactor Vessel of Saint-Laurent A2 Graphite-Gas Reactor Pierre Dumontier (EDF DP2D - Structure Déconstruction SLA)
15:10 - 15:30	Radiation Related Event Associated with Dismantling of a Reactor Pressure Vessel Ünal Ören (Barsebäck NPP), Nikola Markovic (European Spallation Source ERIC), Erik Pärsen (Barsebäck NPP), Sweden

15:30 - 16:15	*Coffee-break, Visit of Exhibition, Posters*

Session 9. Chairpersons	Source-Term Management David Perkins (EPRI, USA), Rémi Bourdeloie (EDF UNIE-GPEX, France)
16:15 - 16:35	Radiological Consequences of Accelerated BWR Fuel Spacer Corrosion Mattias Olsson (Forsmark NPP, Sweden)
16:35 - 16:55	Ag-110m: An Improved Shutdown Strategy to Optimize Radiation Fields on Low Temperature Primary Systems Edgar Moleiro (EDF UNIE-GPEX, France)
16:55 - 17:15	Combined Non-Aggressive Technology Utilization for Source Term Management of Ag-110m, Co-60, Co-58 that Results in Substantial Decline in Plant Dose Rates and Refueling Outage Collective Radiation Exposure Derek Hultquist (Cook NPP), Phil Mora (Salem NPP), Patricia Robinson ((n,p) Energy), Paul Skinner (Consulting NPP Chemist), Dave Nestle (H3D), USA

19:30	**Symposium Dinner at Wereldmuseum Rotterdam** Address: Willemskade 25 3016 DM Rotterdam	

Thursday 6 June 2024

Session 10. Chairpersons	Events Timo Kontio (Loviisa NPP, Finland), Benoit Lance (Tihange NPP, Belgium)
09:00 - 09:20	At the Interface of the Healthcare System and a Nuclear Power Plant – Reflections following a Local Event Stephanie Nyström, Dick Skattberg (Forsmark NPP, Sweden)
09:20 - 09:40	Near Miss Event of an Almost Unnoticed FME Event during Scaffolding Works above Reactor Parts Liisa Salminen (Loviisa NPP, Finland)

Session 11. Chairpersons	Education and Training Timo Kontio (Loviisa NPP, Finland), Benoit Lance (Tihange NPP, Belgium)
09:40 - 10:00	Opportunities and Challenges in Integrating AI for Radiation Protection Education and Training Lily Ranjbar (Oregon State University, USA)
10:00 - 10:20	The Benefit of Practical RP Simulation Training to Improve Safety Performance Richard Parlone, Josh Say (Sizewell B NPP, UK)

10:20 - 11:05	*Coffee-break, Visit of Exhibition, Posters*

Session 12. Chairpersons	Monitoring Devices Philippe Weickert (EDF, France), Fernando Mendonça Soares Filho (Angra NPP, Brazil)
11:05 - 11:25	Roadways Controls: A New Device that guarantees Measurements and Contamination Detection Marc Lestang, Charlotte Dabat-Blondeau, Maxime Karst (EDF UNIE-GPEX), Adrien Sponem (Bugey NPP), France
11:25 - 11:45	Application of New Techniques (such as Robots or Drones) used at the Fukushima Daiichi Nuclear Power Station to ALARA Toshikazu Suzuki (Fukushima Daiichi NPP, Japan)
11:45 - 12:05	Innovative Alpha-Detection System based on Dadiochromic Diacetylenic Monomer Valentina Desgranges, Catherine Monier, Adrien Guimet (EDF R&D, France)

12:05 - 12:30	Distinguished Papers and Closure of the Symposium

FRIDAY 7 JUNE 2024

Technical Visit

A visit to the research reactor from Delft Technical University is arranged from 09:30 to 14:00. Registration needed, using the registration form (limited to 25 participants).

NB: The visit to the Borssele NPP, which was originally on the programme, has been cancelled.

HOW TO GET TO ROTTERDAM?

By Plane

- Rotterdam The Hague Airport (no intercontinental flights available)
  Bus 33 departs every 10 minutes towards Rotterdam Centraal

- Amsterdam Schiphol Airport
  Direct train service to Rotterdam Centraal (approximately 30 min)

By Train

- Rotterdam Centraal railways station

HOW TO GET TO VAN NELLE FABRIEK?

The Symposium will take place in the Koffiefabriek building (Entrance 3) of Van Nelle Fabriek.

By Bus

- Bus 38 (every 10 min): from Rotterdam Centraal to "Beukelsbrug/Van Nelle Fabriek".
  Travel time: 8 minutes. From the bus stop, go down the stairs and stay on the left.
  About 7-minute walk to Entrance 3.

By Tram from Downtown Rotterdam City

- Tram 8 towards Spangen and get off at "Spartastraat". About a 15-minute walk to Entrance 3.

REGISTRATION TO THE SYMPOSIUM

	Registration Fees	Online Registration
Participant	470 € (VAT Reverse charge)	Registration form
Commercial Booth	1700 € (VAT Reverse charge)	Booth Registration form

Payment of the fees must be done after online registration and receipt of the invoice.

Registration deadline: 17 May 2024

Information can also be found on ISOE website: **www.isoe-network.net**

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BOOK OF ABSTRACTS

ISOE European Symposium

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Table of Contents

ORAL PRESENTATIONS

Session 2. Lessons Learned from UK Generic Design Assessment of New Reactors, Past and Present

Stuart Johnson
ONR, United Kingdom
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- A brief overview of what Generic Design Assessment entails in the UK.
- Learning from the radiological protection assessment of new reactor designs.

Session 2. Radiation Protection Aspects for Advanced Reactors

David Perkins*, Rodolfo Vaghetto

Electric Power Research Institute, 3420 Hillview Ave, Palo Alto, CA 94304 U.S.A

*Corresponding Author, E-mail: dperkins@epri.gov

Advancements in nuclear technologies since the 1950's allowed for the development and implementation of commercial light and heavy water reactors in use globally today. Technology advancements over the years have led to the evolution of the Generation III/III+ reactors to the Generation IV reactors. These advanced reactors include water-cooled small modular reactors (SMR) and non-light water reactors. Deployment of these advanced reactors have the potential to generate clean, carbon-free electricity and heat, but will also be competing with natural gas, solar, wind, and the existing commercial nuclear fleet. In many cases, the proposed advanced reactors are based on technologies that have already been researched, developed, and deployed over the past six-plus decades. Some of these technologies were operated in demonstration modes as far back as the late 1950's, with few advanced to commercial operations. The operations of these technologies and the data from these technologies is currently very limited, and mostly based on the operation of past research, test, and prototype reactors, and a limited number of commercial reactors.

The EPRI Advanced Nuclear Technology Program (ANT), in collaboration with the Nuclear Energy Institute (NEI) has developed the advanced reactor roadmap, identifying key enablers and actions to enhance the deployment of these technologies. Further efforts require EPRI to identify the technology gaps and key activities and areas for radiation protection personnel to consider for these future designs. This paper provides an overview of the technology map moving forward and radiation protection considerations.

KEYWORDS: Advanced Reactors, Radiation Protection

Session 2. Designer/Operator work program for the radiation protection design of EPR2

Sébastien POIRRIER, Matthieu LONGEOT (Edvance)

As part of the radiation protection design work for the EPR2 project, a designer / operator work program has been initiated to develop and strengthen interactions between the radiation protection design teams and the operator representatives.

The main intent is to facilitate the collection of operating experience and feedback, one challenge being the identification and availability of the expert entities / key actors able to share their knowledge on very specific topics.

Information from operating nuclear power plants is key at design stage for various purposes:

- to support the decision-making process in design phases (optimization, best practices, etc.),
- to serve as input data for studies such as radiation exposure assessments (e.g. dose rate measurements, radiation shielding solutions),
- to allow comparisons between design data and operating plant data (e.g. radiation source terms, radiological zoning and contamination levels in rooms of the plant).

Another goal of the designer / operator work program is to discuss various transverse topics (decontamination means, main outage activities, etc.) and document a clear status on such topics as a way of developing knowledge for all design stakeholders.

The work program also includes the planning of workshops to interview representatives of operating plants on a wide range of RP topics, and on-site workshops to benefit from a site walkthrough focusing on several aspects of interest (e.g. EVEREST mode, radiation shielding equipment).

Session 2. Radiological Protection Considerations of SMRs

Rahil Mashhadi
ONR, United Kingdom
Rahil.Mashhadi@onr.gov.uk

- Radiological protection considerations for SMRs currently undergoing Generic Design Assessment in the UK.
- To include some findings from the CRPPH Task Force on SMRs.
- To include a brief overview of emergency planning zones and the implications on SMR siting in the UK.

Session 2. Decision-making method for the installation of valves remote controls at design stage of a NPP

Sébastien Poirrier[1], Caroline Schieber[2], Eymeric Lafranque[2]

[1]EDF/DIPNN/EDVANCE
[2]CEPN

When designing nuclear facilities, the decision to install valves remote controls (VRCs) or “remote drives” shall be based on a set of design rules with various criteria described in reference documentation:

- Radiation protection (room’s dose rate, risk of contamination, valves’ maintenance doses…),
- Room and equipment accessibility,
- Frequency of valves’ operation,
- Investment costs,
- etc.

Since the latest power plant designs, such as EPR, include a significant increase in the number of VRCs compared with previous designs, EDVANCE asked CEPN to propose a method to optimize VRCs installation beyond the already existing criteria.

The proposed method is based on a successive evaluation of 8 criteria. These criteria can be assessed independently of each other, but the proposed method recommends considering all of them when making the final decision.

This presentation will summarize the methodology proposed by CEPN and considered by EDVANCE for the ongoing design phases of Nuclear New Builds, which integrates quantitative radiation protection criteria (compliance with individual dose constraints, net dosimetric gain, cost-effectiveness analysis) and qualitative criteria related to the impact on contamination levels, worker safety, intervention times, material constraints and technical feasibility. A short example will also be shared along the presentation to illustrate an application of the method and how results can be used.

Session 4. An Efficient Bayesian Algorithm for Localizing Contaminants in Nuclear Waste: Application on 3D Imaging of Waste Drums

Nhan Le[a,*], Hichem Snoussi[a], and Alain Iltis[b]
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[b]Damavan Imaging, 2 rue Gustave Eiffel, 10430 Rosières-Près-Troyes, France

Abstract

Accurate localization of the spatial distribution of radioactive contaminants within an object is an essential task for a wide range of nuclear engineering applications, particularly in the domains of treatment, conditioning, storage, and disposal of radioactive waste. Using compact Compton cameras for localizing contaminants through 3D radioactive source imaging is a cost-effective way, but poses a major, yet interesting, challenge for 3D imaging convergence. A potential solution is combining Compton data from multi-view angles simultaneously to improve the parallax, and then adopting an iterative statistical algorithm to reconstruct radioactive source images. The conventional maximum likelihood expectation maximization (MLEM) algorithm for 3D reconstruction using list-mode multi-view Compton data is often stuck with slow convergence and require a large number of Compton events data for noise reduction. In order to overcome those limitations, we exploit the inherent smoothness of images as prior knowledge by modelling the expected image as a convex Markov random field (MRF), and take advantage of the Bayesian framework to develop a maximum a posteriori reconstruction algorithm under the assumption of the Poisson data model. The main originality resides in a novel maximization scheme with line-search strategy that allows not only to break directly the correlation inherent in MRF prior but also to update all voxels simultaneously during iterative maximization process. In the context of the *DreamScanner* project, we experiment the developed 3D reconstruction algorithm to localize the radioactive sources on real 3-view data conducted with a hand-held CeBr3 Compton camera developed by Damavan Imaging and a 220l nuclear waste drum containing punctual 0.2 MBq ^{22}Na and an extended cylindrical sources. Various comparative studies with more classical statistical reconstruction algorithms (i.e., MLEM and MAP-EM algorithms) confirm that our algorithm converges more quickly to an accurate image of radioactive sources with a much smaller number of Compton events data.

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Session 4. Gamma-camera: An innovative tool for limiting dosimetry and contribute to the operational performance of radiation protection

Rémi BOURDELOIE, Marc LESTANG
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KEYWORDS: gamma-camera, source term, characterization, operating principle, use cases, prospects

Electricité de France's (EDF) main objective in terms of radiation protection is to reduce the exposure of workers at EDF's nuclear power plants.
The analysis and monitoring of the source term in nuclear units requires the implementation of state-of-the-art tools.

In order to achieve these objectives, EDF-UNIE-GPEX has carried out studies to improve working practices in the field of radiation protection.
This includes the research and development of innovative materials.

Following initial experiments on the subject since 2015, EDF-UNIE-GPEX has put in place a market at the end of 2022, to enable each nuclear power plants to equip itself with a gamma camera.

The aim of this talk is to present the technology implemented and the results of the first ex-periments through several use cases, as well as future prospects.

Session 5. The UAE Nuclear Legislation Framework and Oversight for Internal and External Dose Management in Nuclear Facilities

DEOGRACIAS, Edward (Federal Authority for Nuclear Regulation, United Arab Emirates);
ABDULLA, Mariam (Federal Authority for Nuclear Regulation)

Content

The infrastructure of the UAE Nuclear Program has been established with the Policy of the State on the Evaluation and Potential Development of Peaceful Nuclear Energy issued in 2008, which aims to develop and regulate the nuclear sector towards peaceful purposes of nuclear energy, as well as the Federal Law by Decree No. 6 of 2009 Concerning the Peaceful Uses of Nuclear Energy that had established the Federal Authority for Nuclear Regulation (FANR) as the independent safety, security and non-proliferation regulator.

The paper will present the regulatory framework including the licensing processes and oversight activities of licensees and facilities, especially those related to internal and external dose management. The regulations published by FANR provide the requirements for the licensing of nuclear facilities, radiation protection, and establishment of workplace monitoring and individual monitoring.

The paper will reflect the regulatory inspection processes providing oversight for internal and external dose management programme. FANR uses specific focused inspections as strategy to review all aspects of licensee external and internal exposure with respect to regulatory requirements. FANR also assign Resident Inspectors at the Licensee's facility to oversight the compliance of the licensee in the area of the Radiation Protection Programme, including external and internal exposure, through observations, attending meetings, review of licensee documentation and plant tours. FANR Resident Inspectors also maintains open communications with the Licensee and are made aware of any issues requiring FANR follow-up.

Topic: Internal/External Dose Management

Session 5. Digital radiological passbook application

Ignacio Calavia
CSN Spain

The CSN has developed a digital radiological passbook intended to be deployed during 2024. This digital application will be beneficial for all parties involved: contractors, external workers and nuclear power plants. The data produced by the use of the application will provide new opportunities for risk informed regulations as well as for analyzing data that were not available before. During 2023 and start of 2024 the application has been tested by NPPs and a reduced number of contractors, providing feedback for the development team.

Session 5. Electronic dosimetry management system replacement at Temelin NPP - challenges and solutions

Ondrej Kvasnicka
Temelin NPP, Czechia

For several years solutions for the obsolete electronic dosimetry management system were considered at Temelin NPP. As the plant already employs DMC family EPDs (Electronic Personal Dosimeter), in 2021 a decision was finally made to replace the system totally with a complete solution from company MIRION.

In the Czech NPPs EPDs are dosimeters of legal record, thus all reports to regulator are based on data from the system. Also, due to its crucial role in the workers RCA entry/exit control procedure, high availability of the system is required. These facts together with the cyber security requirements made the system transfer a very delicate process. The migration strategy and data transfer process will be described. The chosen sw/hw architecture and its future expandability will be presented.

Session 6. Repair of welds with degradation due to stress corrosion in primary circuit piping: operational insights from 2023

Charles PERETTI
EDF/DIPDE

Stress corrosion cracking (SCC) is a complex phenomenon of metal degradation caused by a combination of mechanical stress and chemical corrosion. The process leads to the formation of micro-cracks in the material, which can propagate, compromising its structural integrity. Notably, SCC involves the continuous crack propagation under ongoing mechanical stress, even at relatively low corrosion levels.

At the end of 2021, indications of stress corrosion were revealed by non-destructive examinations in several French nuclear power plants, leading EDF to temporarily shut down those with the most significant damage and to initiate a major repair program.

French standards and regulations mandate the complete replacement of degraded sections of piping within nuclear installations rather than partial repairs. This approach guarantees operational reliability and safety in compliance with the strict safety standards of the French nuclear industry but has a significant cost in terms of dosimetry.

Session 7. The UAE Regulatory Framework and Oversight for Radiation Protection and Waste Management

DEOGRACIAS, Edward (Federal Authority for Nuclear Regulation, United Arab Emirates);
ABDULLA, Mariam (Federal Authority for Nuclear Regulation)

Content

In 2008, the UAE published a comprehensive policy on the Evaluation and Potential Development of Peaceful Nuclear Energy. The policy projected escalating electricity capacity requirements to meet future demand, while emphasizing its commitment to the highest standards of safety, security non-proliferation, and operational transparency.

Accordingly, The UAE's Federal Authority for Nuclear Regulation (FANR), the independent regulatory body in the UAE was established by the Federal Law by Decree No. 6 of 2009 Concerning the Peaceful Uses of Nuclear Energy, to be the authority responsible for the oversight of nuclear safety, security, radiation protection and safeguards.

The paper will highlight FANR's main responsibilities in developing a regulatory framework including licensing and oversight of radiation protection programme and radioactive waste management in accordance with IAEA Safety Standards and the best international practices for the construction, operation, and decommissioning of nuclear facilities.

The paper will also focus on the regulatory inspection processes providing oversight for radioactive waste management programme. FANR uses specific focused inspections to review all aspects of licensee radioactive waste management programme with respect to regulatory requirements. FANR also assign Resident Inspectors at the Licensee's facility to maintain awareness of the Radiation Protection Programme, including the radioactive waste management programme, through observations, review of licensee documentation and maintaining open communications with the Licensee of any issues requiring FANR follow-up.

Topic: RP and Waste Management

Session 7. NPP Krsko – Spent Fuel Dry Storage Project (SFDS)

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After the Fukushima accident, Nuclear Power Plant Krsko decided to increase safety through the safety upgrade project. To increase safety and storage capabilities for spent fuel assemblies and storage capabilities the Spent Fuel Dry Storage project began in 2012. To store all spent fuel elements outside of the spent fuel pool, the Dry Storage Building (DSB) has been constructed within the NPP Krsko yard. Construction of the Dry Storage Building was finished at the beginning of the year 2023. The basic function of the DSB is to protect the casks from environmental conditions and to reduce the dose rate outside the DSB. The design of the cask and DSB walls assures the dose rate at the exterior of the DSB walls does not exceed 3 µSv/h, and the dose rate at the site boundary does not exceed 0.05 mSv/yr. Impact of the dry storage on the radiation parameters on plant fence is monitored with passive dosimeters. Monitoring with passive dosimeters is also established inside the Dry Storage Building.

The DSB has a capacity of 2590 spent fuel elements which will be removed from the spent fuel pool in three phases. During phase one (March – August 2023) NPP Krsko moved 592 (16 casks with 37 elements) spent fuel elements to the dry storage.

In preparation for the dry storage project, several trainings and presentations were held. Before beginning work on the project, a procedure for conducting radiological control during the transfer of spent fuel was written. In addition to the RP workers from NPP Krsko, radiological control was also carried out by subcontractors.

According to the initial ALARA plan, the estimated collective dose for the project was 92 man mSv. The project was finished with the 53 man mSv collective dose. The highest individual dose on the dry storage project was 2.8 mSv. The main contributors to the lower doses were effective ALARA communication of the project manager by the contractor and the effective work of decontaminators and radiological protection personnel. In the various phases of filling the casks several different shielding approaches were established, such as the use of a snake shield, neutron shields, temperature-resistant shields, etc.

Workers wore electronic and passive dosimeters (gamma + neutrons) provided by the plant. To compare the received neutron doses workers also wore additional passive neutron dosimeters, supplied by an additional provider. The workers most exposed to neutron radiation also wore neutron electronic dosimeters.

Session 7. Use of a robot for the treatment of high dose rate waste at the Tihange NPP

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Introduction

At the Tihange NPP, part of the high dose rate waste are treated with a robot during periodic campaigns, in order to condition the waste into 400 L drums ready for disposal. This paper describes the facilities, the equipment and the work arrangements, based upon the latest campaign held between mid November 2022 and end September 2023. The robot and associated equipment belongs to Equans Belux SNS (Specialized Nuclear Services).

Waste sorting, packaging and conditioning

Waste sorting is primarily performed according to two criteria: (i) the combustible nature of the waste and (ii) the contact dose rate, with a considered threshold of 2 mSv/h. Waste of contact dose rate less than 2 mSv/h are packaged as non-conditioned waste, for further conditioning processing at the waste facilities of Belgoprocess. For such low dose rate waste, there is a sorting, according to the combustible nature of the raw waste and according to the waste sorting rules (waste flux separation) from the national waste management authority, ONDRAF-NIRAS. Waste higher of dose rate than 2 mSv/h can be prepared as conditioned waste; i.e. fully prepared and blocked with a mortar of specific dosage, meeting the disposal acceptance criteria from ONDRAF-NIRAS. The complete process is reported in the Table 1.

< 2 mSv/h rad waste
1st sorting of raw waste on the work post
Short term storage
2nd sorting, pre-treatment and packaging with the operators
Radiological characterization
Short term storage
Acceptance
Transport to Belgoprocess
Treatment
Conditioning
Storage before disposal
Disposal process

> 2 mSv/h rad waste
1st sorting of raw waste on the work post
Short term storage
2nd sorting, pre-treatment and packaging with the robot
Conditioning
Radiological characterization
Short term storage
Acceptance
Transport to Belgoprocess
Storage before disposal
Disposal process

Table 1: Waste cycle of life. Distinction is made between waste of contact dose rate higher or lower than 2 mSv/h. Shaded cells represent the tasks performed by the Tihange NPP

Typically 3 types of high activity waste are handled by the robot: (i) the NPP water filters (e.g. primary coolant purification) – higher than 2 mSv/h but lower than 300 mSv/h, (ii) raw waste coming from the various maintenance works and (iii) the sludges (e.g. coming from the decantation of substances inside tanks filled with effluents). The robot is installed approximately every 3 years in a specific building (FY1) of the plant, in order to treat the dedicated HB drums containing the to be treated raw waste.

The robot and the facilities

The robot is remote controlled from outside of the radiologically controlled area, but some operators stay in the FY1 building for the associated work logistics, protected by appropriate biological shielding. The robot is hanged from a crane and performs the sorting work with various tools (dose rate probe, pincers, cutting tools) on a customized table. The workspace is also geared with a 100-ton press. All this equipment is under a scaffolding surrounded by a thermo-retracted skin, in order to assure the confinement of the radioactive contaminants. The confinement is connected to mobile filtration units. The FY1 building is itself connected to the RCA ventilation system. Additional RP arrangements are foreseen for the FY1 operators, as ambient dose rate surveillance, measurement of the atmosphere activity, hands and feet contamination control at the building exit and of course wearing of individual protection for dedicated work.

Figure 2: Left: master slave arms used by the operator inside the shelter (outside of the RCA). Right: pictures of the robot ready for use in its confinement

Figure 3: Left: table for the waste treatment. Right: confinement made of a scaffolding covered by a thermo-retracted skin

Examples of treatment with the robot

The process for the treatment of used filters consist to compact and put them into a specific 400 L drum, with a maximum of 20 compressed pellets. This specific drum, geared with a centering basket, is the final drum ready for disposal. For the sorting of raw waste, the robot opens the bags and searches for the raw waste with a dose rate higher than 2 mSv/h. Those are loaded into a metallic box of 30 L volume. Once the

box is full, it is compacted in the 100-ton press and once again put into the same type of final drum. For each pellet, the size, the weight, the dose rate and information about the original nature of the waste is fulfilled in the production file of the final waste drum.
Raw waste with a dose rate lower than 2 mSv/h are gathered in bags, going back towards the non conditioned waste management lines. This sorting evidences that some shortcomings occur, during the waste sorting on the work post. For instance, some overclothes are thrown as such in waste bags, instead of separating the most contaminated parts, often located at the feet level, from the rest.
At the last stage of the robot campaign, the sludges are treated, mixing them with cement into 30 L boxes before drying, compression and loading of the pellets inside the basket.

Figure 4: from left to right, view of a final waste drum at 3 main stages: (i) empty final waste drum, (ii) fulfilled final waste drum, (iii) conditioned final waste drum with a certified mortar

Results and conclusions

As a result of the 9 months of the last campaign (mid Nov 2022 – end Sept 2023), 148 HB drums have been treated and a total of 62 final drums have been produced, for a coming and final cementation. This represents a volume reduction factor higher than 2. This reduction comes from the compaction process on the one hand and from the waste < 2 mSv/h oriented back towards the non-conditioned waste treatment.
No significant incident occurred during the considered 9-month period. One can nevertheless mention:

- One face contamination, but without any internal contamination
- One surveillance dose rate probe surrounding the site (TELERAD dose rate probe) has exceeded the alarm threshold (set at 5 x natural background), while handling a high dose rate filter
- Few non respects of the safety marking.

Several improvements have been identified at the outcome of the campaign, that are considered for implementation for the next campaign:

- Additional electricity and compressed air connections
- Additional gamma dose rate probes and associated cables
- Improvement to be brought to the air lock connected to the confinement
- Renewal of the air activity monitoring device.

The collective radiation exposure was 1.7 and 3.5 man.mSv, respectively for the internal and external personnel, with maximum individual dose of 0.28 and 1.6 mSv for the same personnel categories. This collective dosimetry is low as compared to the site annual radiation exposure, what highlights that the use of the robot meets the ALARA approach at the Tihange NPP.

Acknowledgment

Equans Belux SNS (Specialized Nuclear Services) is acknowledged for allowing the use of pictures of the robot and related equipment

Glossary

HB : Haut blindage
NPP: Nuclear power plant
ONDRAF – NIRAS : Organisme National de gestion des Déchets Radioactif et Matières Fissiles / Nationale instelling voor radioactief afval en verrijkte splijtstoffen
RCA : Radiologically Controled Area

Session 8. Radiation Protection Issues in the Decommissioning of Nuclear Facilities: Lessons Learned from the ISOE Working Group on Radiological Protection Aspects of Decommissioning Activities at Nuclear Power Plants (WGDECOM)

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Decommissioning of nuclear power plants is a subject of growing importance for the nuclear industry. During decommissioning of NPPs, economics, technical and organizational challenges are encountered and only few feedbacks are collected and shared at the international level to deal with these challenges.

In November 2014, ISOE (Information System on Occupational Exposure, www.isoe-network.net) decided to establish a new working group dealing with occupational radiological protection during decommissioning activities at NPPs, the WGDECOM. The objective of this working group is to improve the sharing of operational RP data and experience for NPPs in all stages of decommissioning. The WGDECOM focuses on the following items:

- Areas which are the most relevant for effective management of occupational exposure;
- Collection of operational data, in particular collective doses;
- Creation of a network of operational RP experts for decommissioning activities;
- Factors and aspects that play key roles in achieving good RP practices in decommissioning.

Visits have been organized in USA (Illinois and California) and Europe (Sweden, Switzerland, Spain, France, Germany and Belgium). The following topics have been addressed during these meetings and will be presented:

- Regulatory context and strategy of decommissioning,
- Characterization,
- Collective doses analyses for high doses works,
- Management of risk of internal exposure,
- Radioactive waste management,
- Integrated risk management,
- Use of robotics.

The outcomes of the last period of WGDECOM from 2020 to 2023 will also be presented.

Some technical topics discussed during the last meetings will also be addressed.

Session 8. Measures to prevent internal contamination by alpha emitting aerosols during decommissioning and dismantling NPP with highly contaminated internals

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The first operated NPP A1 in Slovakia was a gas-cooled heavy water moderated reactor that used natural uranium fuel. The reactor was operated from 1972 to 1977. It was shut down after severe accident classified as INES 4. The fuel partially melted and spread to the primary circuit. Later, due to several incidents and leakages, also to secondary one.

Currently, the 4th stage of the decommissioning project is ongoing, which is focused on dismantling the primary circuit piping and technology. The internal surfaces are heavily contaminated with alpha emitting radionuclides (transuranic). During dismantling activities, aerosols contaminated by radionuclides emitting alpha radiation are produced. Volume activity in working environment is non-negligible from radiological point of view. There is a potential risk for internal contamination leading to annual committed effective doses of several sieverts without a proper protection of workers. Along with the fact that there was a limited experience with labor in such radiological working environment, it was a huge challenge from the radiation protection point of view. This paper presents examples of good and bad practice identified during routine inspections of workplaces. It also highlight various measures with their justification and effectiveness to reduce creation of aerosols during dismantling activities and to minimize their spread into the surrounding and other service areas and corridors. Conclusion describes the radiation situation before and after the implementation of corrective measures, analyzes the effectiveness of individual approaches and presents different recommendations for similar situations during D&D projects around the world.

Session 8. ALARA approach for decommissioning of components outside of reactor vessel of Saint Laurent A2 Graphite-Gas reactor

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The presentation will address a specific worksite realized outside of reactor vessel of Saint Laurent A2 (SLA2) reactor: cutting out contaminated piping under SLA2 reactor vessel.

One of the dismantling stages outside the Saint Laurent A2 reactor vessel consists of removing all the contaminated piping connected under the reactor vessel.
The scenario initially adopted considered the alpha risk from the removal of the first pipe to the last. This implied heavy intervention conditions with all that is involved in carrying out works with presence of alpha contamination (airlocks containment, protective clothing, etc.).
A characterization strategy was put in place during the first phases of the worksite to enable us to relax the conditions of intervention during the worksite.

The presentation will cover the worksite, the initial radiological conditions, cutting processes (selection and feedback), radiological characterization approach for piping already cut in the lower part. Finally, the operating conditions planned for cutting pipes in the upper part.

Session 8. Radiation related event associated with dismantling of a reactor pressure vessel

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Abstract: A radiation related event occurred at the Barsebäck Nuclear Power Plant in August 2022. The event was associated with the dismantling of the reactor pressure vessel at Unit 2 and resulted in spread of contamination in the reactor building (in the reactor hall the contamination levels were about 3500 – 10 000 kBq/m^2 with local elevations up to 50 000 kBq/m^2) and in releases of Co-60 to the atmosphere from the ventilation stack where the source term was approximately 3E8 Bq. The HotSpot Health Physics Code was applied to estimate the radiological impact in terms of the effective dose and ground deposition. The highest effective dose value of 8E-6 mSv and maximum ground deposition value of 8E-4 kBq/m^2 occurred at approximately 2 km from the facility. An environmental radiological characterization was performed and the Co-60 concentration values were below the detection limits. Also, internal contamination due to inhalation of Co-60 was quantified in six workers which were engaged in the reactor pressure vessel dismantling operations. Whole-body measurements where conducted with a HPGe-detector and the intakes were estimated to be in the range of 4 – 21 kBq. For the dose assessment, the software CADORmed was applied. The corresponding committed effective doses were 0.3 – 1.5 mSv including the contribution from difficult-to-measure nuclides.

Session 9. Radiological Consequences of Accelerated BWR Fuel Spacer Corrosion

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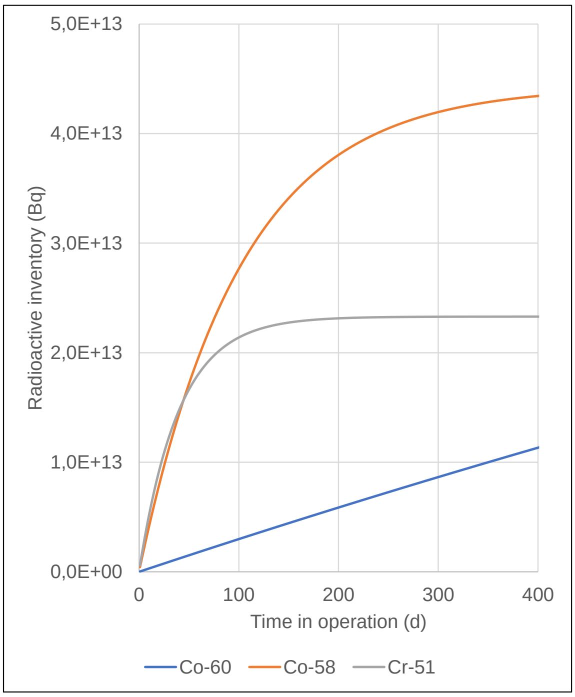
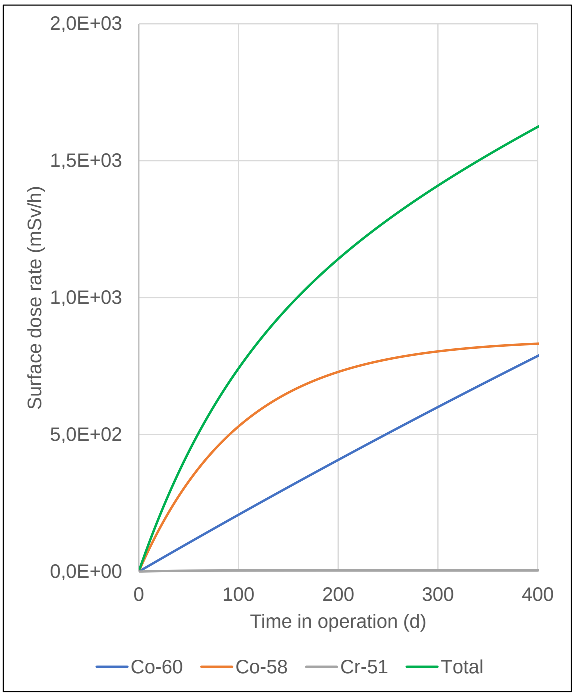
In recent BWR fuel models, nickel base alloys have been used for fuel spacers to a greater extent than before. Meanwhile, zircaloy has been phased out as a spacer material. The nickel base alloys consist mainly of nickel, chromium and iron but also of a small cobalt impurity. In a BWR environment they tend to corrode faster than for example stainless steel. Due to the position of the spacers in the neutron flux of the reactor core, accelerated spacer corrosion may thus become a radiological issue.

At Forsmark units 1 and 2 a few episodes of accelerated fuel spacer corrosion have been observed over time. This presentation will focus on observations done since 2020. At that time a new fuel model entered service at both units. High spacer corrosion is observer and has resulted in notable increases of activated corrosion products in the reactor water, especially Co-58 and Cr-51. Co-60 has not increased so far which suggests a low cobalt impurity of the spacer material.

One of the resulting radiological issues is increased dose rates in areas near the reactor water clean-up (RWCU) filters. Unless actively addressed, this will lead to increased dose to workers as necessary tasks are carried out. The figures below show the calculated build-up of the radioactive inventory and surface dose rate of a deep bed RWCU filter as a function of time, based on chemistry and process data from unit 2 2022–2023. After a year of operation the calculated surface dose rate is 1.6 Sv/h.

Other radiological consequences include more loose contamination in systems, contaminations, releases of radioactivity to the environment and limitations in waste handling.





Examples of build-up of important radionuclides and surface dose rate contributions in/on a reactor water deep bed clean-up filter vessel at Forsmark 2, 2022–2023 annual cycle.

Session 9. Ag-110m: An improved shutdown strategy to optimize radiation fields on low temperature primary systems

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KEYWORDS: Ag-110m, Silver, Radiation field, Shutdown, Radiochemistry

Introduction

Primary coolant silver impurities can be a major problem for PWR plants as Ag-109 (48,2 atom%) from elemental silver can be activated in Ag-110m which specific behavior presents difficult challenges for power plant staff. In fact, this radioelement is difficult to manage during shutdown and in certain circumstances its specific behavior can lead to massive increases in radiation fields and outages total exposures. A classic shutdown strategy is not well suited for this radioelement and a specific shutdown strategy must be defined and applied.

Ag-110m: An improved shutdown strategy to optimize radiation fields on low temperature primary systems

For EDF plants affected by silver contamination this element can be an important contributor to shutdown radiation fields, up to 90% or more for some components, and represents roughly 10 to 15% of outages total exposure1),2). Through the years, EDF have gathered an important operating experience, the analysis of which supported by R&D studies4) has allowed some mitigation strategies to be implemented. Despite this effort, at the middle of the last decade the situation was not totally satisfactory as silver contamination events were still difficult to predict and to prevent. In 2018, an innovative experiment carried out on Civaux nuclear power plant4) provided interesting results that paved the way for an improved shutdown strategy in:

- Reaching and maintaining a high level of oxygen immediately after forced oxygenation.
- Limiting the cooling gradient between the loop and RHR and CVCS circuits after forced oxygenation.
- Maintaining as long as possible an efficient circulation on CVCS circuit as solubilization of silver and thus dose rate decrease can occur several days after forced oxygenation.

This improved strategy was implemented more particularly during two shutdowns in 2021 for Bugey and Chinon B, with very good results as for Bugey an estimated gain of 20% of outage's total exposure was estimated.

Conclusion

EDF have faced, since the commissioning of their fleet, different issues with the management of Ag-110m. In recent years some important breakthroughs on understanding silver behavior have occurred that lead to improved shutdown strategies. These strategies were successfully implemented in the Bugey's and Chinon B's shutdowns in 2021.

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Session 9. Combined Non-Aggressive Technology Utilization for Source Term Management of Ag-110m, Co-60, Co-58 that Results in Substantial Decline in Plant Dose Rates and Refueling Outage Collective Radiation Exposure

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Abstract

Contemporary management of US nuclear power plant operations compels us to reduce costs and improve radiation safety through continuous examination of those processes which impede maximizing the economic operation of nuclear power reactors. Outage duration, fuel duty and performance, worker productivity, and radioactive source term are critical elements of that process.

As plants age, Rx components and Rx Vessel Internal modifications and repairs are driving new source term management challenges. Several plants now US NPP have experienced failed components that have generated high level of deposited Ag-110m which accounted for 80% of the outage dose rates.

A collaborative workshop process was engaged through ISOE/NATC with EdF to gain knowledge with Ag-110m transport and deposition behavior. Subsequentially, non-aggressive technology changes were implemented to reduce Ag-110m dose rates by factors of ten times to one hundred times at Palisades. Aggressive methods of ultrasonic fuel cleaning and chemical decontamination of RHR/CVCS circuits were not determined to be economical or produce a sustainable result.

H3D CZT technology was employed to gain the data set for determination of locations for significant deposit occurred throughout the Rx coolant circuit. Revisions to shutdown sequence, use of PRC-01M technology, resulted in mitigation of both Ag-110m and Co-60 deposition and consequently dose rates. The combining of non-aggressive technology successfully delivered substantial dose rate reduction.

DC Cook-1 and Salem-1 have activated reactor vessel internal structural materials that required repair or replacement, e.g., baffle bolts, Flexure Modifications. Westinghouse repairs DC Cook-1 and Salem-1 uses two methods for cutting: 1) mechanical cutting and 2) Electrical Discharge Machining. Both methods can impact source term if not managed. Electrical Discharge Machining (EDM) for cutting RVI flexures. This method of cutting alloys essentially vaporizes and condenses highly activated metals. Capture of this variable debris is very difficult and has resulted in elevated source term from small ingress into RCS and deposition to fuel. This paper will summarize the technology used to mitigate these emergent source term issues.

Session 10. At the Interface of the Healthcare System and a Nuclear Power Plant – reflections following a local event

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In October 2023 a worker at Forsmark experienced symptoms of a heart attack at the bottom of a reactor pool during outage work proceedings. As for many other tasks and situations, in the event of a medical emergency, the radiation protection (RP) group at Forsmark have an instruction on how to handle the radiological aspects of the transfer of an affected person that needs to leave the premises to be taken care of at the hospital. All the way from the controlled area at the Nuclear Power Plant and during transport to the hospital.

Experienced RP personnel were available both on the controlled area and outside at the offices that very skillfully made sure that this worker safely and swiftly could be transported outside to meet the paramedics and receive the care they needed at that time. 30 minutes later, the worker could converse with the paramedics. There had been no spread of radioactive contamination in connection to the event. The outcome was as good as one could have hoped, given the circumstances. But was that written instruction enough? Were those printed pages enough support to help any RP personnel do a good job if a similar situation arises again? What if there would have been significant spread of contamination in that same event? These were some of the reflections that rose following the event.

The RP personnel realized that in addition to the instruction, at every plant unit there should be a prepared RP-emergency case available, containing: Basic material like a scintillation detector, protection gloves and smear test patches. It should also contain plastic bags and tape for transportation of used smear test patches, any contaminated material or material belonging to the plant back to the site. For the RP staff there should be included e.g. an energy bar and drink in case the person needs to come along to the hospital for a long time, and a charged cell phone to stay in contact with colleagues. The case should also include the printed relevant instruction on a clipboard in case reading is required during a high velocity ambulance ride, logbook to take notes of the sequence of events or for example detected contamination levels or questions or suggestions to bring to health staff at the suitable time.

In addition to the practical materials, the group identified the need to develop stronger communication with health care workers and similar institutional workers through simulation exercises, and through this also improve the understanding of each profession's work at their interfaces. This, to improve efficiency by not interrupting one another, but also by deciding in advance what situation an RP control is prioritized to be performed before a health control - whenever they cannot be performed simultaneously. Insight to each other's work might relieve any potential unmotivated personal fear of radiation from health care personnel, rather than a reasonable respect for it, backed by facts. Additionally, practical exercise through simulations help prevent any individual becoming passive when put in a real critical situation that rather calls for quick action.

As a part of the Forsmark NPP emergency preparedness for medical events, a table top training exercise was already in the planning phase at the time of the event. Planning and participation also includes the regional hospital, rescue services and paramedics. At the scheduled time of the ISOE-conference, the simulation exercise would have taken place and reflections from that can be included in the presentation as well.

Session 10. Near miss event of an almost unnoticed FME event during scaffolding works above reactor parts

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During the annual outage of Loviisa 2 the transport protectors of the neutron flux de-tectors were damaged. Because of that damage the usual platform for removing said protectors was not able to be used. Because of that it was decided that a new platform will be built out of scaffolding materials above the reactor parts that were located in a storage well.

During the scaffolding works a battery of a respiratory mask fell into the well on top of the reactor parts. The missing of the battery was noticed by coincidence when the respirators were returned to radiation protection staff and it was later confirmed that it had dropped into the well. After a few days of fishing with a camera, the battery was found and removed in one piece.

The battery was a commonly used LCO type Li Ion battery, which may have caused a significant increase in the source term if it would not have been noticed before plac-ing the reactor parts back to the reactor. LCO batteries contain a considerable amount of cobalt.

In the presentation there will be some more discussion about the event and about the possible effects of the irradiated cobalt.

Session 11. Opportunities and Challenges in Integrating AI for Radiation Protection Education and Training

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This paper explores the dynamic landscape of radiation protection education and training, with an emphasis on incorporating artificial intelligence (AI). It provides a comprehensive examination of the potential benefits and inherent challenges in incorporating AI into the educational realm of radiation protection. By shedding light on both the promises and complexities, the research aims to guide educators, practitioners, and policymakers in navigating the integration of AI to advance radiation protection education.

The advancing capabilities of AI offer exceptional opportunities to enhance the educational landscape and optimize training methodologies in the field of radiation protection. Simultaneously, this integration introduces a spectrum of challenges related to data privacy, ethical considerations, and the imperative to align AI algorithms with established radiation safety standards.

The discussion begins by highlighting the transformative potential of AI in radiation protection education. The paper explores how AI-driven simulations, personalized learning experiences, and adaptive training modules can revolutionize how radiation protection professionals are trained, fostering a more proficient and resilient workforce.

Simultaneously, the integration of AI in radiation protection education and training presents challenges that demand careful consideration. The paper examines the ethical implications of utilizing AI in decision-making processes, emphasizing the need for transparency, accountability, and measures to prevent biases in educational content. Additionally, the discussion navigates the complexities of managing sensitive data, underscoring the importance of robust frameworks to protect the privacy and security of trainees.

The paper also addresses the crucial task of ensuring that AI algorithms align seamlessly with established radiation safety standards. Striking a balance between innovation and adherence to regulatory requirements is essential to guarantee the effectiveness and reliability of AI-driven educational tools in radiation protection.

Session 11. The benefit of practical RP simulation training to improve safety performance

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Josh Say (Radiation Protection Engineer, EDF Sizewell B

Abstract:
Radiological safety performance improves when personnel who perform radiological protection activities or who perform significant radiological risk tasks have realistic training to help them acquire and maintain their essential knowledge and skills.

The Radiation Protection and Training teams at Sizewell B jointly develop and deliver practical training programmes using simulated contamination and radiation sources at an off-site 'Excellence Centre', aiming to improve RP performance across many teams and reduce radiation exposure and contamination risks. The practical training uses contamination simulators, radiation field simulators and specially adapted contamination and radiation instruments and dosimeters. Training is performed in a realistic 'flow loop simulator' with operable pumps, tanks, pipes and fluid systems and is supported by RP personnel with feedback to the trainees.

This paper presents an overview of the practical training sessions include venting and draining active systems in areas with simulated hot spots, maintenance and decontamination of primary circuit or emergency boration system valves, emergency response team 'pathfinder' surveys and stay-time calculations for plant area with very high dose rates, and pre-outage training for barrier monitors. The paper also covers the feedback from the trainees and the positive improvements in contamination control and RP behaviours observed in the field following the training sessions.

Session12. Roadways controls: A new device that guarantees measurements and contamination detection

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For several years now, Electricité de France (EDF) has had a significant number of contamination points found on NPP's roadways, ranging from 70 to 125 points above 800 Bq. In 2021 and 2022, EDF even had up to 7 contamination points above 100 kBq and 4 above 1MBq.

Historically, measurements have been carried out on NPP's roadways, annually and after each shutdown. Since 2019, roadways are inspected following the transfer of big equipment, and quarterly at the exits of RCA. Several nuclear power plants have set up action plans to reclaim areas exiting RCA, which are helping to reduce the number of roadway contamination points.

In this context, EDF wanted to find a technical solution that would enable surface contamination measurements to be carried out autonomously over large areas. The measurements are carried out as part of inspections of roadways and adjoining areas at risk of contamination dispersion (at least in outdoor areas). As part of this research, EDF has teamed up with SOCOTEC to develop an autonomous robotized solution incorporating:
- A gamma measurement system based on two 3''x3'' NaI(Tl) probes.
- An algorithm integrating a screening system and a measurement system (ISO11929) capable of detecting 800 Bq equivalent 60Co over a surface area of the order of 2000 cm².
- A terrestrial drone (wheeled carrier) enabling measurements to be taken in remote-operated (via remote control), semi-autonomous or autonomous mode.
- A servocontrol system that automatically adapts the carrier's speed to take account of background noise and MDA (Minimum Detectable Activity).
- A servocontrol to slow down the wearer in the event of fluctuation or doubt about the measurement (clearance of a false positive).
- A LIDAR system enabling the carrier to move to safety if a vehicle approaches.
- Automatic correlation of site map and measurements.
- Spectrometry on detected points of contamination, with identification.

This system guarantees control with scrupulous respect for measurement conditions (probe/ground distance and speed), in all weather conditions (wet or dry ground) and measurement recording.

Session 12. Innovative alpha-detection system based on radiochromic diacetylenic monomer

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This contribution presents the recent works on alpha detection methods carried out by the R&D division of the French company EDF. In decommissioning nuclear power plant (NPP), the contaminated areas are frequently associated with a term source involving also alpha emitters. The behavior of alpha particles in matter is very well known; in an industrial environment as a NPP, their detection is complicated for their high stopping power in air. Biologically wise, they cause nearly no harm to humans unless they are inhaled, ingested, or got into the body through a cut. Therefore, the radioprotection for workers in alpha-contaminated sites must consider the risk of internal contamination by defining measures to ward it off: e.g, respiratory protectives gears and confinement airlocks. Nevertheless, the worker still needs to get close to the contaminated surface to assess its contamination or just to make a smear, thus potentially integrating a dose and risking of contaminating himself going through, for instance, the undress sequence. An important issue for EDF is to minimize the number of workers concerned with internal contamination. On these grounds, EDF R&D studies the feasibility of a new kind of passive tool for alpha particles detection based on radiochromic and radiation-sensitive material: the diacetylenic monomers. Diacetylene (DA) monomers are well known to polymerize topochemically in the solid state upon ultraviolet (UV) and gamma irradiation, resulting in colored polymers, but little literature is available concerning their behavior to alpha exposure. In this work, a new DA, named 6-BU, has been synthesized to enhance its reactivity to ionizing radiations.

A full characterization of its polymerization kinematics upon UV has been performed and it has been successfully studied upon alpha irradiation, using an ^{241}Am alpha source. An extensive campaign has been performed to analyze the reactivity of this monomer and its color change – from light blue to black, as a function of the exposition time, the alpha flux and the environmental conditions (temperature, radiative background, …). The polymerization rate has been estimated by means of two different analytical techniques, namely the UV-visible spectrometry and the differential scanning calorimetry. Also, an attempt to apply the gas chromatography-mass spectrometry for this kind of analysis has been made. Figure 1 shows the color change for an alpha-irradiated sample of 6-BU.

Figure 1. 6-BU sample before (left) and after (right) alpha irradiation

The characteristics of a tool embarking an active layer made of such a material are currently under evaluation with the concerned NPPs, for it shall allow to improve the radioprotection of workers in alpha-contaminated sites. For example, this device will provide a visual information on the presence of contamination or on its time-evolution by changing its color; this information which can be seen from afar, thus guiding the worker to a more efficient job and to a lesser integrated dose (smears closer to the contaminated area, earlier decontamination of contaminated area, …).

This presentation will discuss the experimental study and the analytical methods applied to analyse the obtained data. The results on the reactivity of the newly synthetised DA, the 6-BU, upon UV and alpha irradiation will be presented. Lastly, the foreseen use-cases and how such a tool will help in addressing the stake of a better management of alpha-contaminated worksite on decommissioning NPP for reducing the internal contamination risk will be dealt with.

Poster 1. Renewal of Nuclear Energy Legislation and Regulations in Finland

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The current Nuclear Energy Act in Finland was drafted in 1987 and contains several later amendments, making it complex and difficult to implement. Renewal of the nuclear energy legislation and regulations started 2022. Legislation and regulations will be renewed as a whole. The regulations considering radiation protection are also updated. In NPP sector at least four new regulations in the field of radiation protection or closely related to radiation protection will be issued. The aim is that the new law and regulations enter into force in 2028.

The Ministry of Economic Affairs and Employment of Finland (TEM) leads the preparation of the new legislation. STUK is closely involved in the preparation work. STUK is responsible for drafting nuclear safety regulations and providing necessary guidelines (project name SYTYKE). Stakeholders (e.g. Fortum, TVO) are kept constantly informed about progress of the project. The aim is a comprehensive renewal of nuclear energy legislation, in which the Nuclear Energy Act and the Government Decrees are harmonized considering the principles of the Constitution (Article 80). The renewal of nuclear safety legislation must also consider:

- Possible new energy or operating companies
- New nuclear power plant concepts (e.g. SMR)
- To create target-oriented requirements rather than detailed ones
- Consideration of technology neutrality international regulations (IAEA, WENRA)

SMRs will be considered in the renewal, however, no SMR specific regulations nor guidelines will be drafted. STUK has identified several questions that must be addressed, for example:

- Size of Emergency Planning Zone; (this will be changed already during 2024)
- Application of Defence-in-Depth;
- New business models and organisational arrangements in constructing, operating and decommissioning;
- Serial production of reactor modules and other components;
- New applications: process heat for industry, district heating, hydrogen production..;
- Marine-based reactors;
- Remote operation;
- Arrangements for spent fuel management.

One example concerning radiological consequences relates to emergency preparedness and the environment. New features and new ways of doing things should be enabled, as long as safety can be demonstrated. Current requirement states that for the Precautionary Action Zone (PAZ) 5 km, land restrictions in force and the Emergency Planning Zone (UPZ) 20 km, authorities shall draft an external rescue plan.

In Finland the operating NPPs are in sparsely populated areas. In this case, emergency preparedness and management measures (evacuation, sheltering inside, taking iodine tablets, etc.) target a smaller population group and are therefore easier to implement. Furthermore, the NPPs considered are large LWRs. Less than 100 people live less than 5 km from Olkiluoto and Loviisa. The current 5 km PAZ and the 20 km UPZ are problematic e.g. for district heating plants. Could they be smaller for SMR based on, e.g., risk-based review?

Poster 2. Real-time 3D Radiation Mapping Technologies Deployed on Robotic Platforms

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Combining advanced multi-sensor systems with robotic platforms to conduct remote or autonomous surveys maximizes dose reduction and efficiency improvements. Gamma Reality Inc. provides 3D radiation mapping, data fusion, and visualization technologies that are remotely deployable on various robotic platforms, including unmanned aerial systems and ground robots.

GRI's commercially available LAMP is a multi-sensor, compact system that includes a 3D laser scanner, visual camera, and radiation detector to provide real-time, fused 3D radiation maps and an augmented reality radiation overlay in the live video feed. Radiological data, including isotope identification and dose rate, as well as location and 3D laser scan data are automatically fused and visualized into an intuitive 3D radiation map that can be used for pre-job briefings, inform work planning, and also communicate the current radiological status of an area to management.

LAMP is currently deployed on the Spot quadruped robot for various nuclear power applications, including outage surveys, decontamination verification, radwaste shipment surveys, ISFSI mapping, spent fuel transfer monitoring, and more. GRI technologies enable faster, more efficient, and safer ways to conduct autonomous radiological surveys, identify hotspots, collect critical data to inform maintenance, or respond to an emergency for both the existing nuclear fleet, as well as next generation nuclear reactors.

Poster 3. Electronic dosimetry management system replacement at Temelin NPP - challenges and solutions

Ondrej Kvasnicka
Temelin NPP, Czechia

For several years solutions for the obsolete electronic dosimetry management system were considered at Temelin NPP. As the plant already employs DMC family EPDs (Electronic Personal Dosimeter), in 2021 a decision was finally made to replace the system totally with a complete solution from company MIRION.

In the Czech NPPs EPDs are dosimeters of legal record, thus all reports to regulator are based on data from the system. Also, due to its crucial role in the workers RCA entry/exit control procedure, high availability of the system is required. These facts together with the cyber security requirements made the system transfer a very delicate process. The migration strategy and data transfer process will be described. The chosen sw/hw architecture and its future expandability will be presented.

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