Cernavoda NPP: Source term control improvement & optimization of individual and collective doses

NUCLEARELECTRICA
Puterea Viitorului

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ISOE 2024

Kyoto, 01 – 03 October, 2024

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INTRODUCTION

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- Individual and collective doses reduction is one important objective of Cernavoda NPP radiological safety policy. Radiological risks associated with operation and maintenance activities must be controlled so that radiation exposure of personnel be kept **ALARA**.

- **Identifying, reducing, and controlling** radiation sources are important for both optimizing workers exposure and preventing unplanned exposures.

- Accurate and effective **communication** of radiological risk is important for source term and personnel exposure control.

SOURCE TERM CONTROL

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Potential **external and internal radiation hazards** have been **identified** based on the project design characteristics and operating experience of CANDU nuclear power plants.

During the approval and installation phases, RP specialists conduct reviews to ensure that dose reduction and radwaste minimization techniques have been incorporated into installation, operation, and maintenance activities.

Radiological protection team has been integrated into station activities: work planning, outage planning and scheduling, plant modification reviews, and plant strategic decision-making processes.

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We continuously monitor external and internal radiation sources by:

- using automated systems,
- radiation control technicians monitoring routines, and
- measurements performed by properly qualified workers before, during, and after performing radiation jobs.

Monitoring results are used to establish protective measures (barriers) to various phases in the ALARA Planning, Radiation Work Permit (RWP), and work process.

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Radiation Monitoring System (RMS)

Remote monitoring technology can expand the list of RP protective barriers used for worker protection. Cernavoda NPP Radiation Monitoring System (RMS) integrates several systems continuously measuring radiation levels in selected areas and processes.

This aids RP personnel in assessing plant conditions and provide alarms for operation and maintenance personnel, to take appropriate actions in two situations:

- mitigating the consequences by preventing the inadvertent release of radiation in case of a plant event and,

- unexpected exposure to radiation of plant personnel.

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Radiation Monitoring System (RMS)

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- **connect** the on-line radiation monitoring equipment to a computerized interface allowing remote monitoring, remote control capability.

- **interface** with RP systems: Fixed Gamma Area Monitoring, Fixed Contamination Monitoring, Portable/ Semi-portable Radiation Monitors, Fixed Tritium in Air Monitoring, Liquid & Gaseous Effluent Monitors, and Post Accident Air Sampling and Monitoring. Information is transferred in real time.

- is only having a **support function** for the radiation monitoring equipment, which are stand-alone devices being able to operate independently.

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Radiation Monitoring System (RMS) functions

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- **Monitoring** – allows operator to **survey the radiation hazards and annunciate high levels** in Radiation Control Service (RCS) room and Main Control Room (MCR); **survey** the **working status** of the measuring loops;
- **Control** – to establish the **set-up parameters** for the automatic operation of the channel; to operate manually the measuring loop for **non-routine measurements / calibrations;**
- **Maintainability** – annunciate **equipment and system failures;**
- **Data storage** – every event is **stored in a data file** that can be read and backed up or printed; **integrated short and long term databases** can be kept;
- **Operator interface** – provide customer reports, detailed display of historical events, remote interactive control functions for the field radiation monitoring equipment.

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Fixed Area Gamma Monitors System (FAGM)

This system is intended for the protection of personnel working in those areas of the Reactor Building and Service Building where high gamma radiation fields are expected.

The system consists of 35 loops connected to a Central panel through redundant network line.

Between 2009 and 2016 extension with one loop (from 34 to 35) and improvement (replacement of silicium detectors with ionization chamber) were performed in both units.

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Tritium in Air Monitoring System (TAM)

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The specificity of Cernavoda RMS not existing in other CANDU stations consists in integration of a "state of the art" remote Tritium in Air Monitoring – TAM System, designed to allows:

- quick detection and monitoring of tritiated water leaks,

- systematic and reproducible monitoring data for source control and

- personal exposure assessment.

A long term monitoring of noble gases activity concentrations have been performed in order to provide the most appropriate correction factor for noble gases compensation, and, as a result, a highest accuracy of measurement results.

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Tritium in Air Monitoring System (TAM)

The use of the system improves safety performance by providing:

- ✓ **rapid and accurate identification of leak location;**
- ✓ **dynamic of tritium field (influence on other areas of interest);**
- ✓ **reliable estimation and prediction of leak rate evolution;**
- ✓ **assessment of personnel exposure involved in corrective maintenance activities,**

as it have been proven for management of PHT heavy water leaks.

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Outage Activity Transport Monitoring

The deposition of activity and fission products on the out-core surfaces of a CANDU reactor leads to the formation of gamma radiation fields around the primary heat transport – PHT – and moderator system components: the reactor face, feeder cabinets, steam generators and moderator heat exchangers.

Outage Activity Transport Monitoring (OATM) surveys permit component radionuclide activities and their radiation field contributions to be trended with reactor operation.

These data are required to:

- **assess the effects of chemistry changes on radiation fields,**
- **evaluate the source term reduction technologies and**
- **decontamination planning.**

SOURCE TERM CONTROL

Outage Activity Transport Monitoring

An understanding of radioactivity distributions on reactor components is crucial for:

- Assessment and analysis of occupational doses;
- Source term monitoring;
- Radiation shielding design and optimization of work procedures.

Gamma fields characterization for reactor faces, horizontal and vertical feeders' cabinets, steam generators and PHT heat exchangers) - started in 2010 and was performed every planned outage in both units.

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Outage Activity Transport Monitoring

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2023 WANO Peer Review mission identified as a strength for RS.1 area: "Radiation protection and chemistry personnel collaborated to reduce radiological source term and improve ALARA planning for refueling outages. As a result, radiation fields on primary system surfaces and steam generator general areas were reduced by 18 and 50 percent, respectively. This was accomplished through a collective review of surveys and adjustments of operational chemistry parameters that effectively dispersed the radionuclides with the highest contributions to outage radiation fields."

Using the results of surveys performed during planned outages, from 2010 till 2023, a theoretical model for predicting radiological condition (first of a kind in industry) was created and validated.

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Characterization of alpha source term

The primary source of alpha emitters is irradiated fuel leaking from fuel pin cladding defects.

Alpha contamination is associated with systems and components related with fuel (the reactor coolant system, spent fuel pool, spent resins, and the associated radioactive waste systems).

First step in designing a program for the control of alpha contamination was the characterization of gross alpha activity levels in the areas where TRU may be present, in order to assign a proper Area Action Level.

Representative samples were analyzed by radiochemical and spectrometric methods to determine alpha nuclide composition.

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Characterization of alpha source term

The alpha source term characterization was performed initially by assuming that all gross alpha activity is generated by the most restrictive nuclide in the mixture: ^{241}Am.

In the second stage, the alpha nuclide distribution for specific areas of the plant was determined by radiochemical analysis, for areas where significant levels of “old/aged” alpha contamination could be present: spent fuel bay, fuel handling working areas, temporary and interim radioactive waste storage, decontamination facilities.

The up-to-date understanding of the facility TRU presence has been obtained through a detailed characterization of plant contamination and by the evaluation of historical events related to fuel defects.

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Characterization of alpha source term

The monitoring results indicate that accessible contaminated areas are classified in present as Level 2 and 3 Areas (significant and, low alpha contamination). For these areas the alpha emitters' exposure is not likely to exceed 10% of the total internal dose in case of an internal contamination.

The surveillance will be continued for the areas identified with potential for TRU contamination, depending on fuel failure incidence and major activities performed on component of PHT and auxiliaries generating contaminated particulates.

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Management of defective fuel

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Defective fuel is identified by continuous monitoring of radioactivity in fuel channels and it is promptly discharged to spent fuel bay.

There are two systems working together:

Gross Fission Products (GFP) system continuously monitors the bulk coolant: detect the presence of failed fuel, monitor the 131-I activity and monitor noble gas activity (eg. 133-Xe)

Delayed Neutron (DN) system, locates low power defects below GFP threshold.

The Delayed Neutron monitor is used to locate the particular channel that contains the defect. The location of failed fuel bundle is determined by measuring the amount of delayed neutron activity in coolant.

SOURCE TERM REDUCTION STRATEGY

Contamination control

We obtained long term personnel **contamination risk reduction**, and a significant **reduction of radioactive waste** volume by reducing the surface of contaminated areas in Zone 1 and eliminating some permanent Rubber Areas.

Contributing to this has been the permanent rigorous control of installing, using, and uninstalling of Rubber Areas and ventilated tents.

SOURCE TERM REDUCTION STRATEGY

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Chemistry control of radioactive circuits

Plant strategy:

- **To maintain in service at full capacity all the purification systems:**
- **COG research and development project recommendation: Planning of PHT ion exchange resin replacement no later than 6 month before the planned outages to increase the filtering capacity of dissolved species.**
- **The replacement program of moderator purification system resins was optimized in order to make the replacement before the retention capacity for carbonates is exhausted.**

SOURCE TERM REDUCTION STRATEGY

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Chemistry control of radioactive circuits

Plant strategy:

- **To manage the ion exchange and mechanical filters replacing in order to provide high efficiency retaining of the activated corrosion products and to contribute to the reduction of gamma radiation fields, and of radiation doses.**
- **Decrease filtering capacity from 5 to 2 microns, for cartridges on PHT purification and Fueling Machine circuits.**
- **Project started in 2015, and for PHT purification systems the action is in progress.**
- **2024: all the cartridges of fueling machine have 2 microns filters.**

SOURCE TERM REDUCTION STRATEGY

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Tritium source term control and reduction

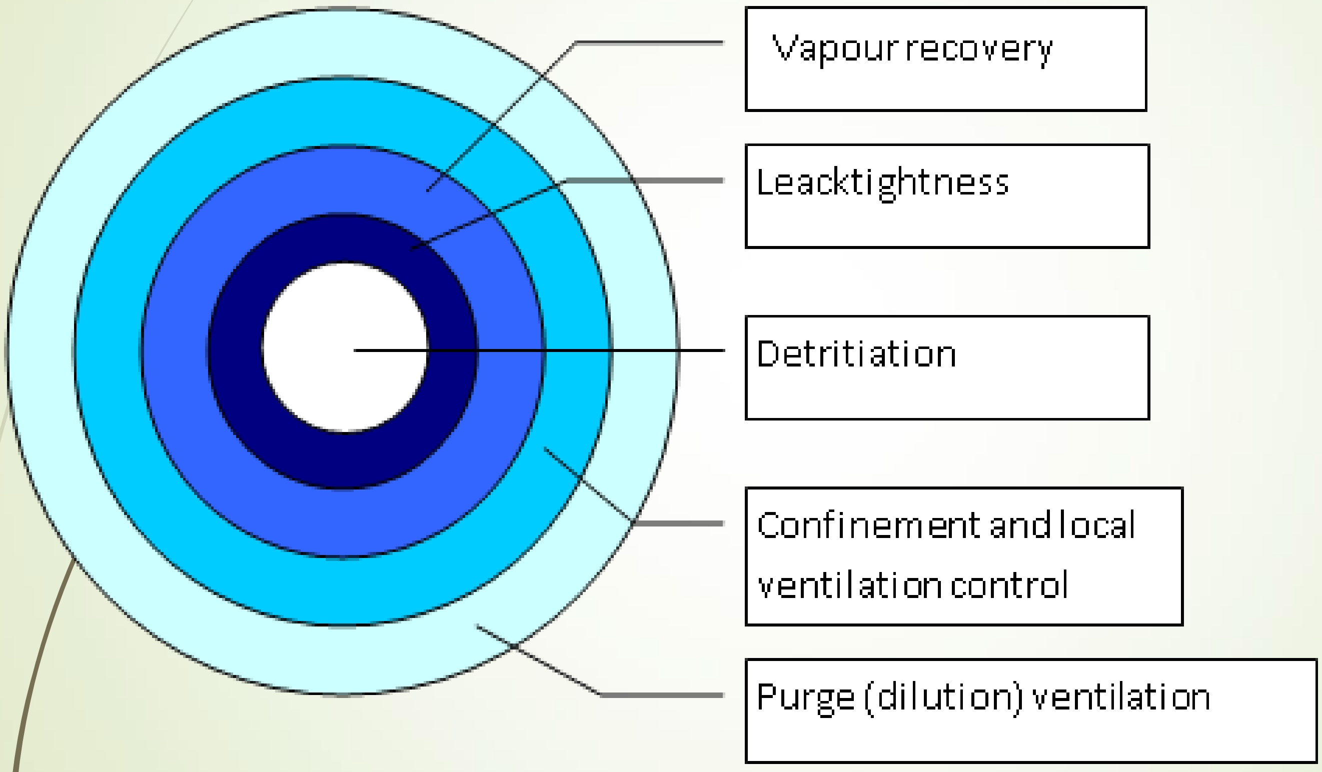
Tritium is the main contributor to internal exposure in a CANDU plants. Tritium is continuously produced in the heavy-water systems by neutron activation reactions, most of it in Moderator circuit.

Tritium is responsible for an important fraction of population (80%) and radiological workers doses (up to 60% of the total collective dose.

The design features can be considered as conceptual barriers which prevent or minimize occupational exposure to and/or environmental emissions of tritium.

SOURCE TERM REDUCTION STRATEGY

Tritium source term control and reduction



Conceptual barriers for tritium reduction in a CANDU reactor

SOURCE TERM REDUCTION STRATEGY

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Tritium source term control and reduction

Tritium source term control :

- **strict heavy water leak control,**
- **liquid collection systems and**
- **water vapor recovery through containment air drying.**

Operational limits for tritium in air concentration were established in order to early detection of tritiated heavy water leaks.

Water leaks from the PHT system and Moderator system are managed separately, because the moderator water contains much higher tritium levels.

The station design incorporates a distillation column to separate the light water (D2O Upgrading tower). The purified heavy water then is returned to the storage tanks for further use.

SOURCE TERM REDUCTION STRATEGY

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Tritium source term control and reduction

Vapor Recovery Systems have been designed to control tritium in air concentration and to recover heavy water loss from PHT and Moderator Systems. The system controls air circulation providing atmosphere separation between different areas of Reactor Building.

The **reactor building** itself offers a secondary, and final, barrier to tritium emissions to the environment. Reactor building air is passed through an exhaust dryer, limiting the heavy water vapor losses through the contaminated stack.

The most efficient method to control tritium source term is **detritiation**. SNN started a complex project to design, construct and operate a detritiation facility on Cernavoda NPP site.

SOURCE TERM REDUCTION STRATEGY

Hot spots control

Small radiation sources (hot spots) are identified and tracked into an electronic data base available for work planners.

Hot spots in accessible areas are posted, shielded or, if possible eliminated by system or component flushes to reduce general area dose rates prior to work.

CONCLUSIONS

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Controlling source term at Cernavoda NPP is a real challenge for our organization due to the complex aspects of generation and potential spreading ways.

By controlling systems modifications the integrity of protection barriers has been maintained in order to maintain radiation fields at levels as low as reasonable achievable.

Significant improvements of main radioactive circuits chemistry control which are in process of implementation will contribute to reducing activation products deposition and, as a result, to gamma radiation fields reduction.

CONCLUSIONS

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A sophisticated **RMS** has been successfully used to **continuously monitor radiological hazards** in accessible areas and in some other zones in order to early detect significant changes or abnormal trends of radiation fields.

Heavy water leaks have been promptly identified by using TAM – tritium in air monitoring system - and treated with high priority, resulting in significant reduction of personnel internal exposure and environmental emissions.

Good collective dose performances confirmed the efficiency of source term control policy of Cernavoda NPP.

Thank you for your attention!

Questions?