ALARA tools: Source Term Control at CNE Cernavoda

NUCLEARELECTRICA
Puterea Viitorului

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INTRODUCTION

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- Individual and collective dose reduction is one important objective of Cernavoda NPP radiological safety policy. Radiological risks associated with operation and maintenance activities performed in a nuclear power plant must be controlled in a such manner 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.

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

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We continuously monitor external and internal radiation sources mainly by using automated systems, but also through radiation control technicians monitoring routines, and the 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.

SOURCE TERM CONTROL

Radiation Monitoring System (RMS)

Remote monitoring technology can expand the list of RP protective barriers being 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)

- **connect** the on-line radiation monitoring equipment to a computerized interface allowing remote monitoring, remote control capability and maintaining integrated short and long-term database.

- **interface** with RP systems: Fixed Gamma Area Monitoring, Fixed Contamination Monitoring, Portable/ Semi-portable Radiation Monitors, Fixed Tritium in Air Monitoring, Liquid Effluent Monitor, Gaseous Effluent Monitor, 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. All the RMS components are located in accessible areas or in mild environmental conditions.

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Radiation Monitoring System (RMS) functions

- **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**; to configure the network database;
- **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.

Among CANDU stations, Cernavoda TAM system distinguishes by the accuracy of measurement results. To achieve this goal a long term monitoring of noble gases activity concentrations have been performed to provide the most appropriate correction factor for noble gases compensation.

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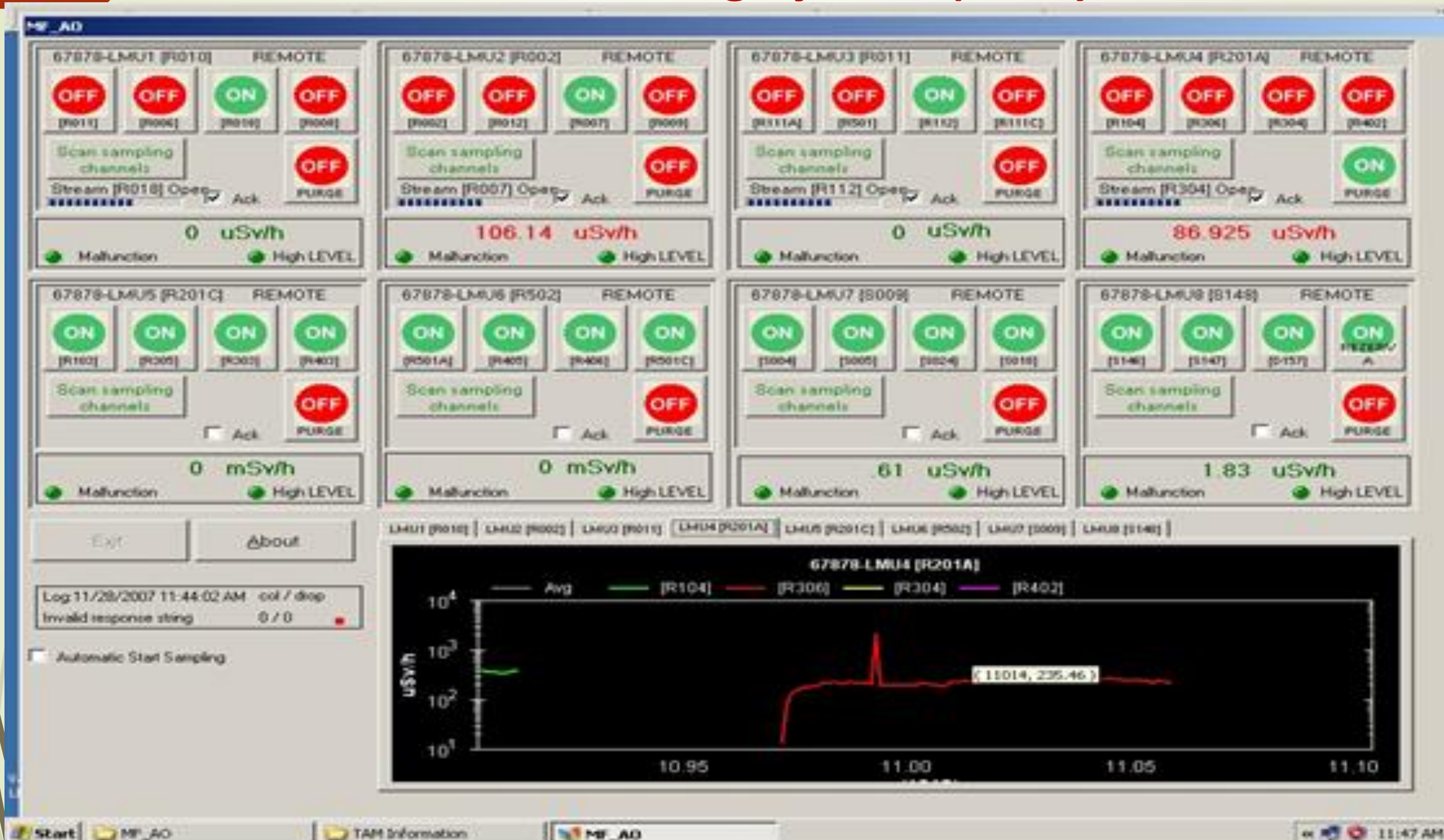
Tritium in Air Monitoring System (TAM)



Typical display of TAM monitoring results (instantaneous and historical values) on remote PC

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Tritium in Air Monitoring System (TAM)

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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: in horizontal feeders cabinet at Unit 1, from July to November 2016, and on September 18th, 2019, on spare impulse line connected to 1-3310-P4 discharge.

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Tritium in Air Monitoring System (TAM)

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Evolution of tritium level (mSv/h) in 1R-501 and horizontal feeders cabinets, Unit 1, 2016 – TAM historical log file

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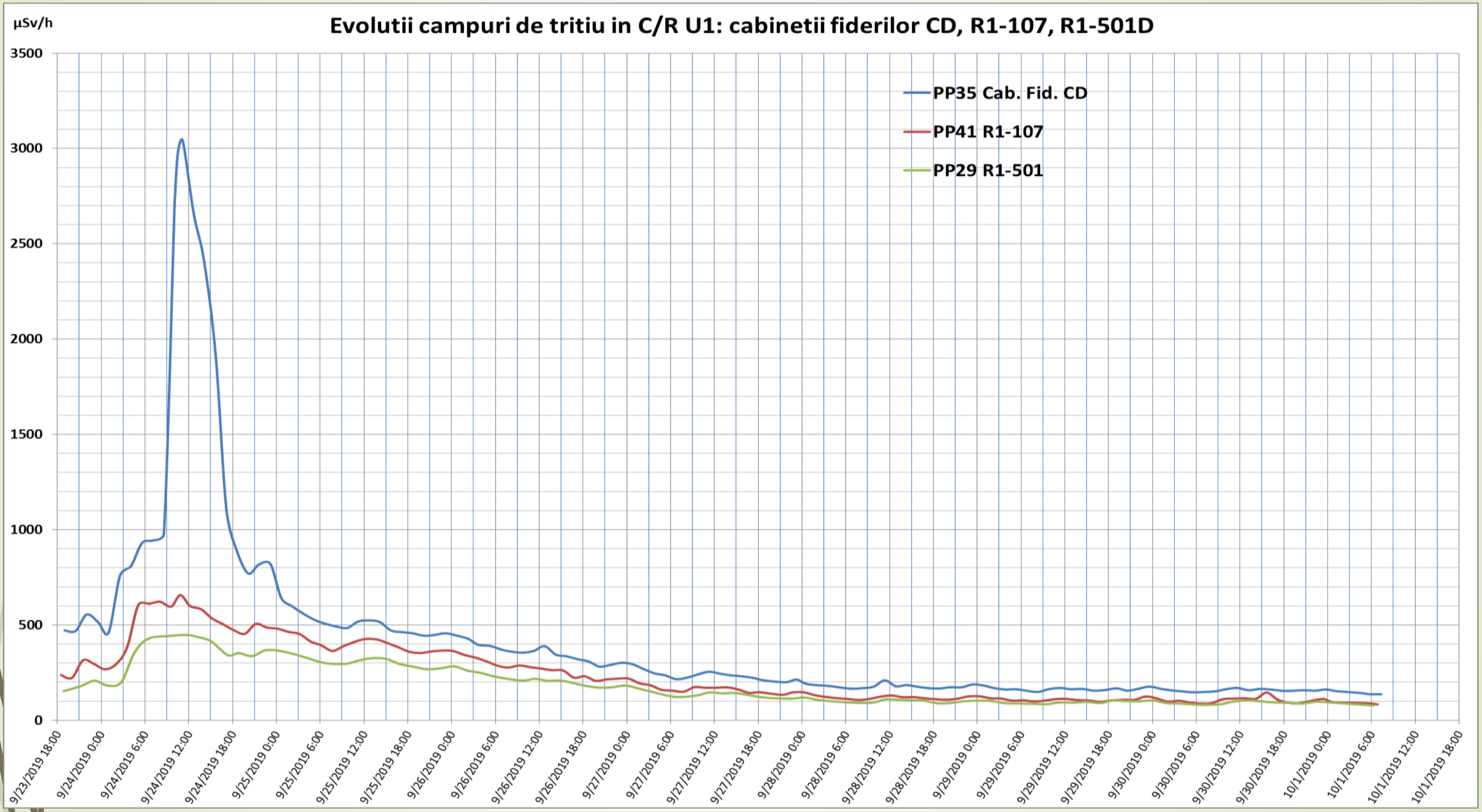
Tritium in Air Monitoring System (TAM)



Evolution of tritium level (mSv/h) in 1R-501 and horizontal feeders cabinets, Unit 1, 2019 – TAM historical log file

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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 various 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 perform various assessments such as the effects of chemistry changes on radiation fields, evaluation of the source term reduction technologies and decontamination planning.

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Outage Activity Transport Monitoring

Dose rate and gamma spectra surveys were performed by Kinectrics for the first time at Cernavoda NPP Unit 1 during Planned Outage in May 2010, 19 days after reactor shutdown; at Cernavoda Unit 2 in May 2011, also during planned outage, and every outage since for both Unit#1 and Unit#2.

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.

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Characterization of alpha source term

The primary source of alpha emitters is irradiated fuel leaking from fuel pin cladding defects and, to a lesser extent, irradiated tramp fuel materials.

Alpha contamination is most commonly associated with systems and components associated with fuel such as the reactor coolant system, spent fuel pool, spent resins, and the associated radioactive waste systems.

First step in designing a program addressing 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

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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 appropriate radiochemical analysis, mainly 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

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

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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,**
- **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.**

The status of these systems is periodically monitored by station System / Component Health Monitoring process.

SOURCE TERM REDUCTION STRATEGY

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Chemistry control of radioactive circuits

Improvements for 2019 – 2023 period:

- Continuing the reduction strategy of filtering dimension for mechanical filters in nuclear systems by implementing an important project modification in both Unit 1 and Unit 2. In Unit 1 the first reduction of filtering dimensions from 5 to 2 microns was implemented in august 2015 for PHT purification system, continued during the 2016 planned outage with PHT pumps sealing system. Unit 2 PHT purification system filters were replaced with 2 microns filters in December 2015.

SOURCE TERM REDUCTION STRATEGY

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Chemistry control of radioactive circuits

Improvements for 2019 – 2023 period:

- Planning of PHT ion exchange resin replacement no later than 6 month before the planned outages to increase the filtering capacity of dissolved species. This recommendation is the result of a COG research and development project. For moderator purification system resins the replacement program was optimized in order to make the replacement before the retention capacity for carbonates is exhausted.

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Fuel Handling Machine purification system

Some components of Fuel Handling Machine are made of stellite, a cobalt-chromium alloy which could generate a significant quantity of ^{60}Co. In order to ensure a good filtering capacity for heavy water entering Fuel Handling Machine circuits, the project provides mechanical and ion exchange columns filters. Heavy water supply circuit mechanical filters have been upgraded to 2 microns, improving also the operation of the machine.

In order to reduce gamma radiation doses two project modifications started to reduce filtration dimensions for the remaining filters, the first stage was finalized in 2017.

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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 dose: about 80% from a representative person dose;

– professional exposure between 10% up to 60% of the total collective dose.

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

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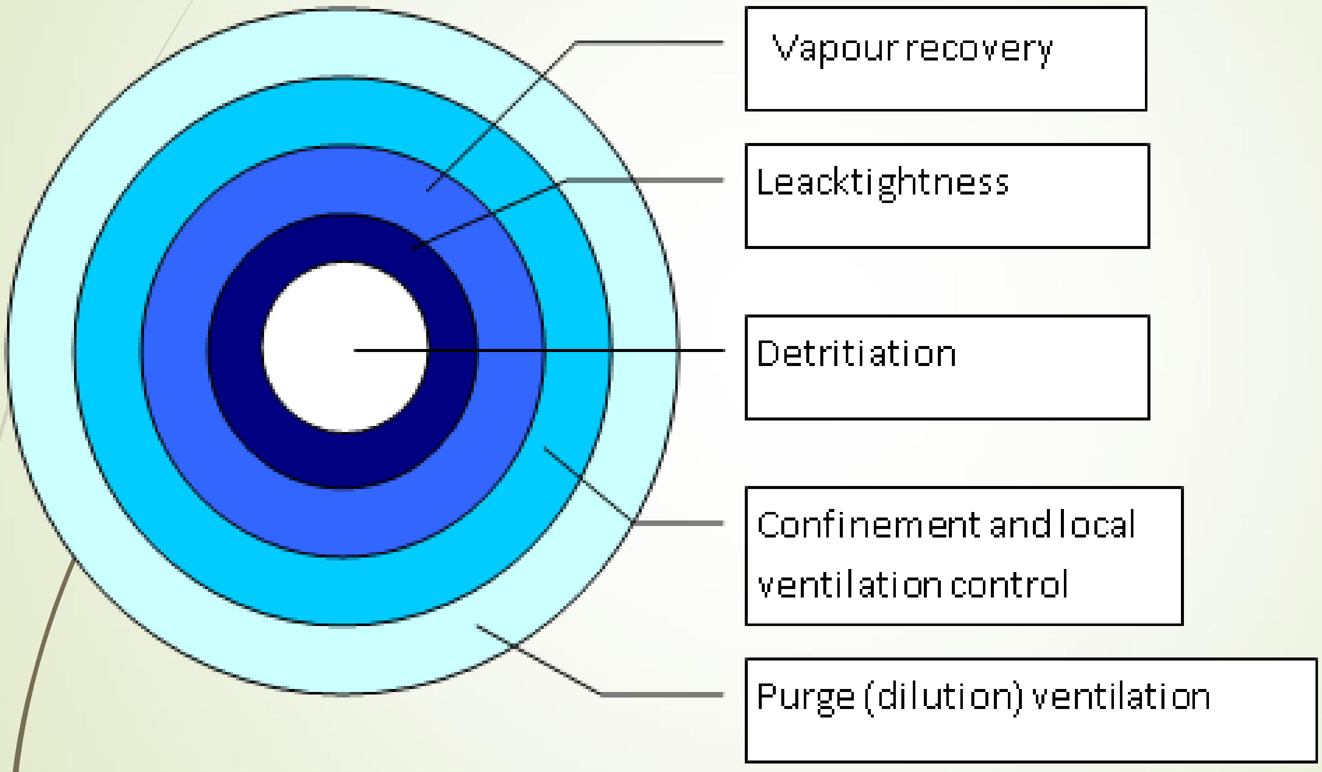
Tritium source term control and reduction



Conceptual barriers for tritium reduction in a CANDU reactor

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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. The purified heavy water then is returned to the storage tanks for further use.

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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.

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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 contributing to 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?