Improvements in ALARA management at Cernavoda NPP

NUCLEARELECTRICA
Puterea Viitorului

Vasile Simionov, Ion Popescu

Health Physics Department,
CNE Cernavoda, ROMANIA

ISOE 2014

Bern 9 – 11 April, 2014

NUCLEARELECTRICA
Puterea Viitorului

CONTENTS

- Introduction
- Effective Management of the Source Term (Sources of Worker Dose)
- Increasing organizational and individual ownership and accountability for work processes to manage radiological risk effectively
- Reducing collective and individual radiation exposure
- Improvement initiatives
- Conclusions

ISOE 2014

Bern 9 – 11 April, 2014

INTRODUCTION

NUCLEARELECTRICA
Puterea Viitorului

Work efficiency is an area of high concern for nuclear power plant operators, and work management is often a key issue in job-related decisions that might affect worker exposures.

The control of the activities involving radiological risk is part of ALARA Process.

INTRODUCTION

NUCLEARELECTRICA
Puterea Viitorului

Following are the main results of Cernavoda NPP concerning the three key focus areas of Big RP, an industry initiative to drive excellence in radiological safety:

- Effective management of the source term (sources of worker dose);
- Increasing organizational and individual ownership and accountability for work processes to manage radiological risk effectively;
- Reducing collective and individual radiation exposure.

EFFECTIVE MANAGEMENT OF THE SOURCE TERM (sources of worker dose)

NUCLEARELECTRICA
Puterea Viitorului

Radiation Monitoring System - RMS

RMS connects the on-line radiation monitoring equipment to a computerized interface system that allows remote monitoring, limited remote control capability.

Remote monitoring improved the control of source term (real time radiation hazard information) and contributed to reducing the collective dose (avoid the entrance in high radiation hazard areas).

RMS integrates all fixed and portable radiation monitoring equipment, a local area network (LAN) and dedicated components and software to control the field equipment, stores and displays the measured or processed data, trends.

RMS interface with: Fixed Gamma Area Monitoring, Fixed Contamination Monitoring, Portable Radiation Monitors, Fixed Tritium in Air Monitoring, Liquid Effluent Monitor, Gaseous Effluent Monitor and Post Accident Air Sampling and Monitoring.

EFFECTIVE MANAGEMENT OF THE SOURCE TERM (sources of worker dose)

NUCLEARELECTRICA
Puterea Viitorului

Management of Internal Tritium Exposures

CANDU reactors are moderated and cooled by heavy water (D_2O).

Most of the tritium present in CANDU reactors is in the form of tritiated heavy water – DTO.

The leaks from tritiated heavy water systems or their auxiliaries are the main sources of tritium in the reactor building air atmosphere.

Vapor Recovery Systems are designed to control tritium in air concentration and to recover heavy water loss from PHT and Moderator Systems.

The operation of dryer systems is carefully optimized in order to maintain tritium in air concentration and gaseous tritium emissions below the limits.

Leakage control is provided by a regular maintenance activity included in the routine maintenance activities, with good results in heavy water loss reduction.

EFFECTIVE MANAGEMENT OF THE SOURCE TERM (sources of worker dose)

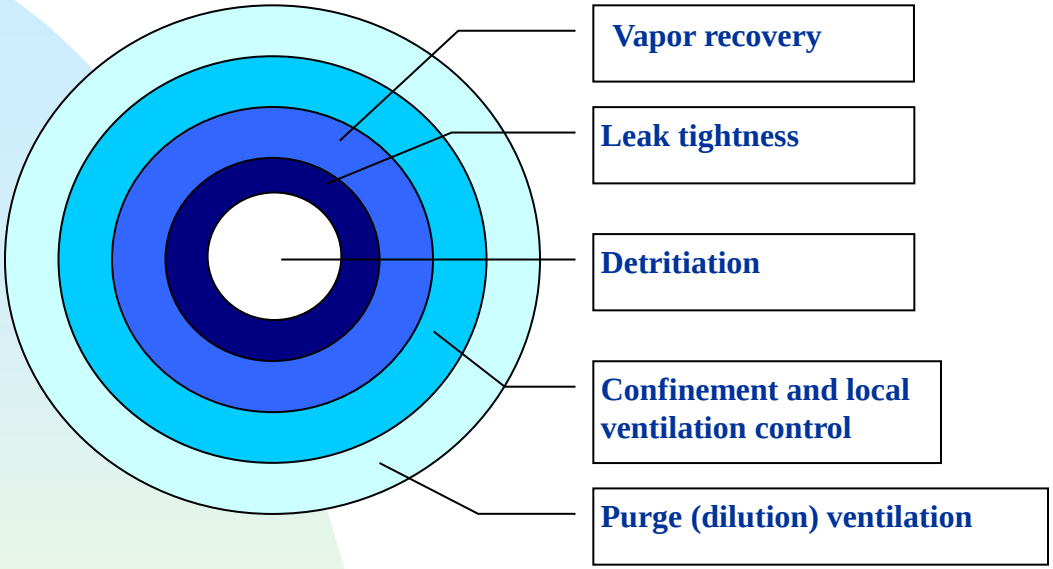


Fig. 1 Conceptual barriers for ^{3}H control in a CANDU power plant

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.

Figure 1 illustrates the succession of the necessary barriers for the control and the containment of the tritium inside the installation.

EFFECTIVE MANAGEMENT OF THE SOURCE TERM (sources of worker dose)

NUCLEARELECTRICA
Puterea Viitorului

Management of Internal Tritium Exposures

Before the commercial operation, in Unit 2 the "Tritium in Air Monitoring" (TAM) has been operational and integrated in the Radiation Monitoring System. By promptly detecting tritiated water vapor, TAM serves to:

- detect heavy water leakages;
- indicate levels of tritium in radiological area;
- decrease the exposure of plant personnel by preventing the entrance in those areas where tritium dose rates unexpectedly increased and reducing time spent by radiation control staff for air sampling.

Even the tritium concentration in Unit 2 systems is low the TAM system proved its efficiency by prompt detection of increased level of tritiated water vapor in the air of some rooms in the Reactor Building and Service Building since in service.

EFFECTIVE MANAGEMENT OF THE SOURCE TERM (sources of worker dose)

NUCLEARELECTRICA
Puterea Viitorului

Management of Internal Tritium Exposures

TAM system generates alarms for high level of tritium fields. Since its installation TAM system has early detected equipment leaks and prevented personnel internal exposure: on February 2012, a small heavy water leakage was discovered at one of the main PHT pumps in Unit 1. This leakage has been monitored until Planned Outage in order to quantify the leakage level.

Other heavy water leakages have been early detected and localized by TAM system, avoiding significant internal exposure and limiting heavy water losses.

DIRECT EXPOSURE CONTROL:
Outage Activity Transport Monitoring (OATM)

NUCLEARELECTRICA
Puterea Viitorului

The deposition of activity and fission products on the out-core surfaces of a CANDU reactor leads to the increasing gamma radiation fields around the various primary heat transport – PHT – and moderator system components.

Understanding the radioactivity distributions in various reactor components (reactor faces, feeder cabinets, steam generators and moderator heat exchangers) is crucial for the following purposes:

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

DIRECT EXPOSURE CONTROL:

Outage Activity Transport Monitoring (OATM)

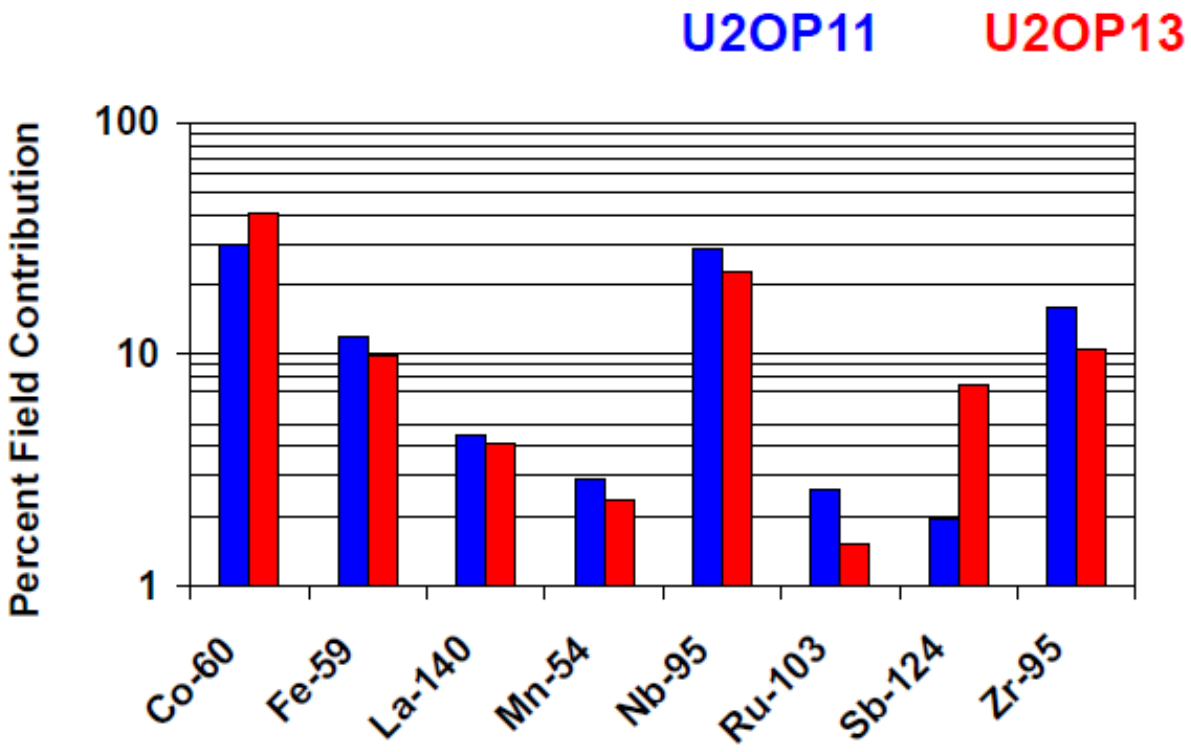
NUCLEARELECTRICA
Puterea Viitorului

Dose rate and gamma spectra surveys have been performed at Cernavoda NPP Unit 1 during Planned Outages in May 2010 and May 2012 and at Cernavoda Unit 2 in May 2011 and May 2013, during planned outages.

The up to date results indicate that the deposits of activation and fission products are significantly lower than other CANDU plants. This is due to a good chemistry control and a proper operation of primary heat transport and moderator circuits.

Hot spots management program (identification, characterization, removal or shielding) is in place.

DIRECT EXPOSURE CONTROL:
Outage Activity Transport Monitoring (OATM)

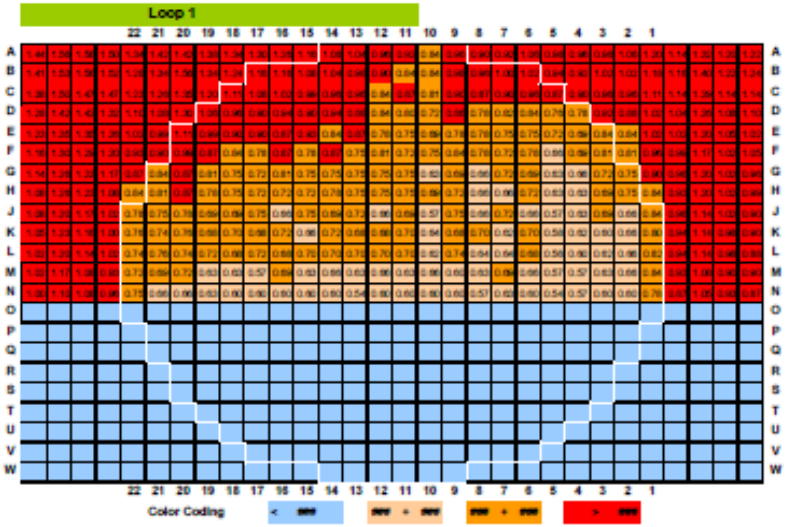


Changes in Radionuclides Field Contribution on reactor faces at Cernavoda Unit 2

DIRECT EXPOSURE CONTROL:
Outage Activity Transport Monitoring (OATM)

NUCLEARELECTRICA
Puterea Viitorului

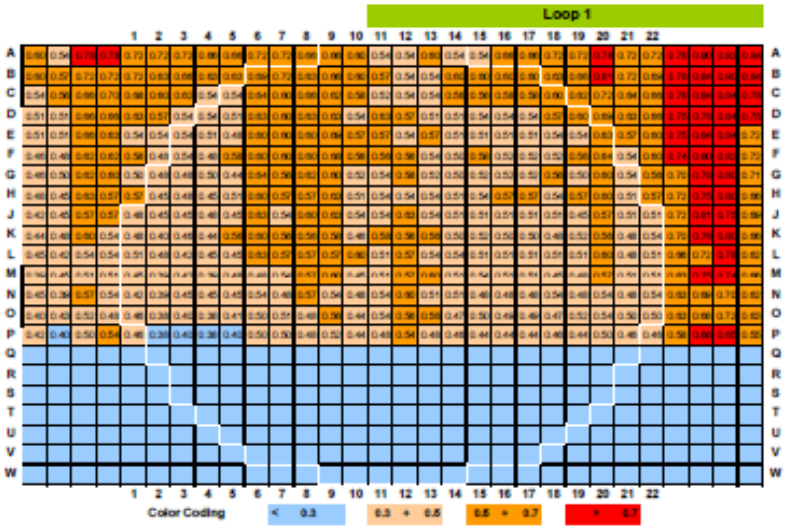
"A" Face



U2OP13 Outage

Pale Blue	$r_i < R-3\sigma$
Tan	$R-3\sigma \le r_i \le R$
Orange	$R < r_i \le R+3\sigma$
Red	$r_i > R+3\sigma$

"C" Face



Face/Loop	Loop 1	Loop 2	L1/L2
"A" Face	0.97 ±0.2	0.84 ±0.2	1.15
"C" Face	0.61 ±0.1	0.55 ±0.1	1.11
"A" / "C"	1.6	1.5	

Dose rate maps at close proximity to the reactor faces and vertical feeders cabinets (~30 cm) at Cernavoda Unit 2

FAILED FUEL AND ALPHA CONTAMINATION CONTROL

NUCLEARELECTRICA
Puterea Viitorului

Neutron activation of ^{238}U is the principal mode of transuranic radionuclides – TRU - production in nuclear power plant.

The presence of alpha emitting radionuclides in nuclear reactors working areas is related to fuel cladding defects, allowing the fission products to migrate into the primary heat transfer – PHT circuit.

The presence of TRU includes primarily longer-lived radionuclides, such as: ^{238}Pu, ^{239}Pu, ^{240}Pu, ^{241}Pu, ^{241}Am, ^{243}Cm, ^{244}Cm. The mere presence of these radionuclides within a facility does not require substantial radiation protection program changes.

FAILED FUEL AND ALPHA CONTAMINATION CONTROL

NUCLEARELECTRICA
Puterea Viitorului

Because alpha-emitting nuclides have high internal dose conversion factors, they result in significantly lower limits and action levels, compared to beta/gamma nuclides.

Alpha-emitting nuclides are generally more difficult to measure, and often must be inferred from the presence of surrogate radionuclides, or quantified using relatively expensive and time-consuming analytical methods. We must consider quantifying the presence of alpha-emitting radionuclides, to ensure effective protection of workers and compliance with regulatory requirements.

There was a technically comprehensive response to the site's failed fuel problems, including alpha contamination identification and control.

FAILED FUEL AND ALPHA CONTAMINATION CONTROL

NUCLEARELECTRICA
Puterea Vitorului

Radiation protection programs have being revised to address aspects related with the control of TRU contamination:

- Procedures for alpha internal exposure management (air sampling, reference levels for alpha contamination, alpha contamination monitoring, etc.);
- Representative samples from systems, equipment and areas susceptible to present alpha contamination - measured to determine qualitatively and quantitatively alpha nuclides;
- Internal dosimetry procedures - developed for alpha nuclides dose calculation;
- Radioactive waste management process has been improved to characterize solid waste for transuranics content.
- Radiation protection technicians - trained for alpha radionuclides risk management.

No alpha internal contamination events have been registered and the levels of alpha contamination in working areas related to fuel handling are quite low in present.

INCREASING ORGANIZATIONAL AND INDIVIDUAL OWNERSHIP AND ACCOUNTABILITY

NUCLEARELECTRICA
Puterea Viitorului

Management commitment and support to ALARA

ALARA is an important element of the global approach to radiological protection and plant management commitment to ALARA is clearly stated by the "Radiation Protection Principles, Policy and Regulations".

ALARA program relies on Radiation Protection staff which provide technical support, supervision, doses and contamination control, data bases.

Department managers are encouraged to promote the ALARA concept in current activities and documents in use.

Daily planning meetings and other routine assessments address radiation protection problems for current operation and maintenance activities, equipment, and facilities.

INCREASING ORGANIZATIONAL AND INDIVIDUAL OWNERSHIP AND ACCOUNTABILITY

NUCLEARELECTRICA
Puterea Viitorului

ALARA Committees

Station ALARA Committee insures that the provisions of ALARA Program are respected.

ALARA Committee main responsibilities are:

- Reviewing and approving collective dose goals.
- Debating annual ALARA report and analyzing the opportunity for new ALARA actions.
- Analyzing and approving action plans to reduce radiation exposure; approving suggestions for Radiation Protection optimization.
- Long Term ALARA plan approval.

INCREASING ORGANIZATIONAL AND INDIVIDUAL OWNERSHIP AND ACCOUNTABILITY

NUCLEARELECTRICA
Puterea Viitorului

ALARA Committees

A periodic analysis of the radiation protection aspects, for on-line and outage activities, is provided by the ALARA Technical Committee which is responsible for:

- pre-job and post-job ALARA evaluation for activities / jobs with 5 man-mSv (or more) estimated collective dose;
- establishing ALARA specific objectives and targets;
- analysis of the evolution of dose related performance indicators;
- collect, analysis and evaluation of data for determining the efficiency of ALARA Process;
- Evaluation and approval of the action plans to decrease the exposure at the work groups' level.

INCREASING ORGANIZATIONAL AND INDIVIDUAL OWNERSHIP AND ACCOUNTABILITY

NUCLEARELECTRICA
Puterea Viitorului

ALARA Committees

Main departments and working groups assigned responsibilities for ALARA coordinators for the implementation of ALARA Program: Radiological Protection Department (Station ALARA coordinator), Operations, Maintenance, Fuel Handling and Nuclear Site Services.

ALARA Coordinators act as a link between the ALARA committees and personnel of the main working groups involved in operation and maintenance activities and:

- analyze monthly dose reports for their work groups);
- are involved in the issuing and following-up of the work group ALARA objectives and indicator, and the dose reduction plans.

INCREASING ORGANIZATIONAL AND INDIVIDUAL OWNERSHIP AND ACCOUNTABILITY

NUCLEARELECTRICA
Puterea Viitorului

Employee responsibilities

All personnel working in Radiological Controlled Area should posses ALARA awareness and be familiar with the common practical knowledge required to bring the dose levels lower.

All radiation workers must be aware of the radiation risk associated with work assignments.

Hazard Info is a computer application available on internal computer network, providing comprehensive up to date information regarding radiation conditions in Radiological Area.

On-line information is provided by Radiation Monitoring Systems.

INCREASING ORGANIZATIONAL AND INDIVIDUAL OWNERSHIP AND ACCOUNTABILITY

NUCLEARELECTRICA
Puterea Viitorului

Employee responsibilities

Workers are briefed prior to beginning work to prevent abnormal exposure.

RP staff and supervisors actively participate in pre-job briefing, mainly for high radiological risk activities.

Radiation accidents, incidents, and unsafe working conditions must be promptly reported to supervisors and notified to Radiation Control Services.

The awareness of Radiation Protection in the station and dose ownership have been increased by placing in key high traffic areas specific information: charts, bulletin, newsletter on RP stations goals, ALARA initiatives, RP policies and procedures.

INCREASING ORGANIZATIONAL AND INDIVIDUAL OWNERSHIP AND ACCOUNTABILITY

NUCLEARELECTRICA
Puterea Viitorului

Radiation Protection Fundamentals

Knowledge, skills, behaviors and practices that working personnel should apply for safety operation of the plant, are considered to be fundamentals.

Radiation protection events analysis revealed that deficiencies of RP Fundamentals created conditions for workers exposure above job estimated dose values.

Based on INPO guidelines Health Physics Department established “Radiation Protection Functional Area & Cross-Functional Fundamentals” and they are included in RP procedures.

Flyers have been distributed for fast promotion of most important of these fundamentals: radiological work management; radiological hazard recognition, minimization and communication; human error prevention.

INCREASING ORGANIZATIONAL AND INDIVIDUAL OWNERSHIP AND ACCOUNTABILITY

NUCLEARELECTRICA
Puterea Viitorului

Work Planning and Radiation Work Permit

The control of the activities involving radiological risk is part of ALARA Process. Radiation Control Service is involved in the planning of activities with significant exposures.

Radiation Work Permit – RWP procedure - issued in order to:

- identify jobs / activities performed in radiological risk areas, so that appropriate protective measures be identified and implemented;
- allow dose accounting for specific jobs.

RWP establishes all the radiation protection measures necessary for safe performing of a specific activity / job considered "radiation work" and for radioactive waste management.

The pre-job and post-job RWP analysis involve personnel performing work and, if necessary, the ALARA Technical Committee.

REDUCING COLLECTIVE AND INDIVIDUAL RADIATION EXPOSURE

NUCLEARELECTRICA
Puterea Viitorului

Plant Performance Indicators related to ionizing radiation exposure of the personnel have been established to improve station and work groups' performance. They are assessed and reported periodically to reflect the objectives and permanently mark out achievements and breakdowns.

Collective dose is a performance measure used to quantitatively assess the objectives of the radiation protection program and a management tool to improve the program for keeping worker doses ALARA.

Collective dose is assessed monthly, quarterly and annually for the entire plant and for each major work group: Operations, Mechanical Maintenance, Electrical Maintenance, Service Maintenance, Fuel Handling and Radiation protection.

REDUCING COLLECTIVE AND INDIVIDUAL RADIATION EXPOSURE

NUCLEARELECTRICA
Puterea Viitorului

Annual collective dose strongly depends on length and scope of annual planned outages. Over the 16 years run the four-year rolling average collective doses per unit at Cernavoda NPP shows a decreasing trend since 2003, which demonstrate the efficiency of ALARA policy at CNE Cernavoda.

Five years dose reduction plan has been developed and approved by senior management to provide oversight and resources for dose reduction initiatives.

Since 2009 to 2013 the collective dose per operating unit at CNE Cernavoda have values between 196 and 459 man•mSv performance which classified our plant in the top of CANDU plants.

REDUCING COLLECTIVE AND INDIVIDUAL RADIATION EXPOSURE

NUCLEARELECTRICA
Puterea Viitorului

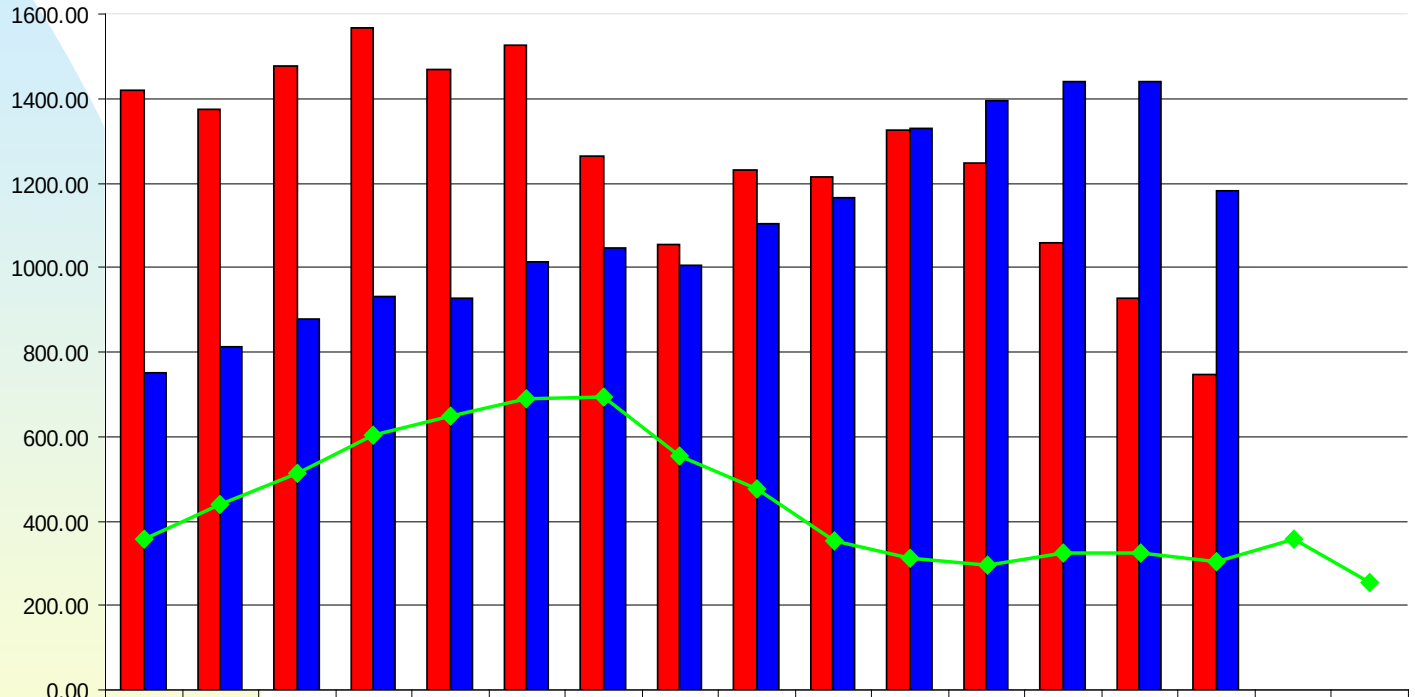
A comprehensive analysis was done in 2012 to identify collective dose reduction possibilities and an action plan was issued.

- Reviewing planning /scheduling procedures to improve dose control for elevated / medium radiological risk activities;
- Review RWP procedure to introduce time limits for elevated / medium radiological risk activities;
- Reviewing work assessment procedure to incorporate RWP process improvements;
- Extensive use of teledosimetry system;
- Improving hot spot management process (identification, characterization, solutions for permanent / temporary shielding).

REDUCING COLLECTIVE AND INDIVIDUAL RADIATION EXPOSURE

NUCLEARELECTRICA
Puterea Viitorului

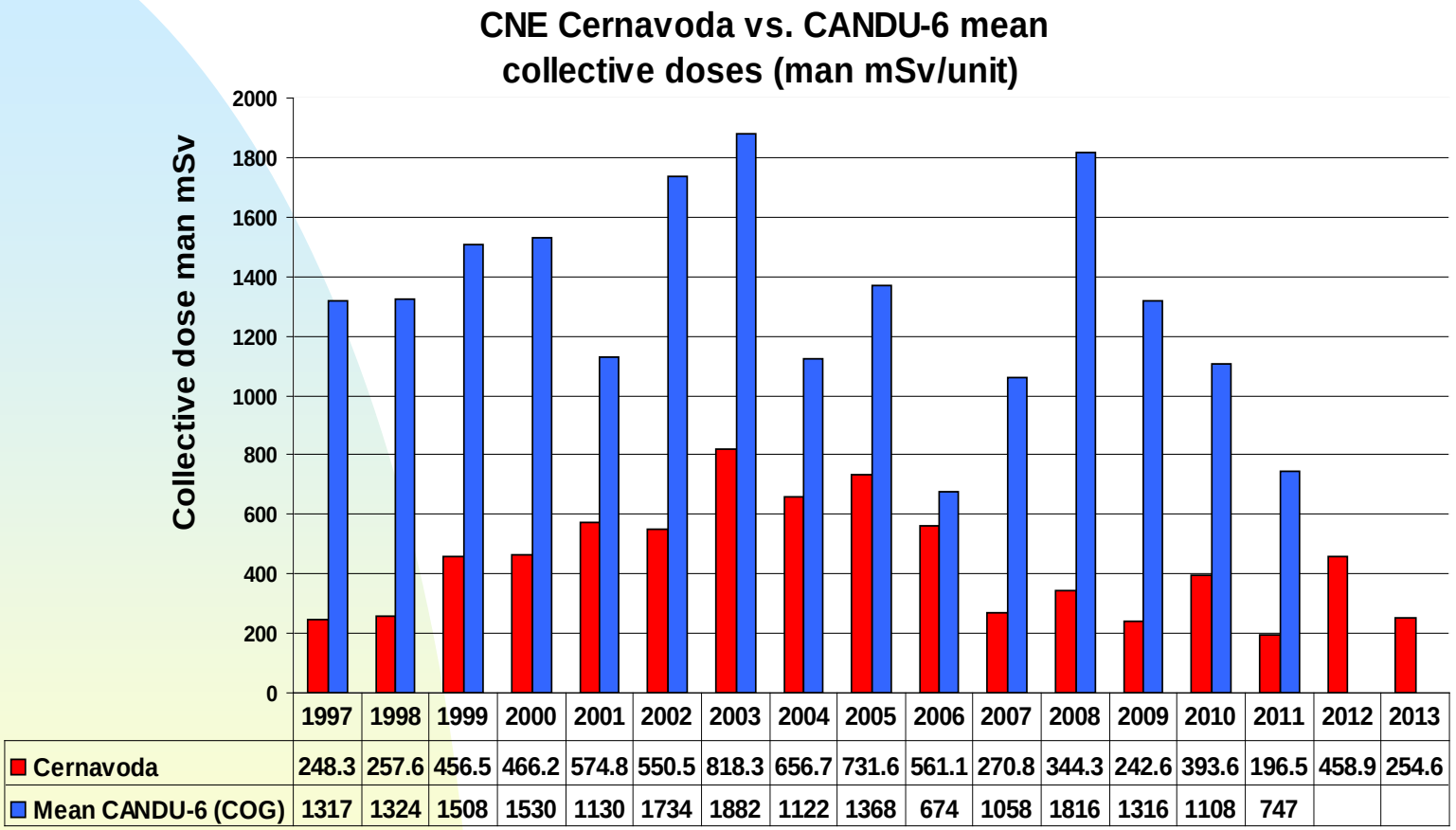
Four years rolling annual collective effective dose (man mSv) for CNE Cernavoda, vs. CANDU and CANDU 6 plants mean values



	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Mean CANDU-6 (COG)	1419.9	1373.1	1475.5	1569.0	1467.0	1526.5	1261.5	1055.5	1229.0	1216.0	1324.5	1246.7	1057.0	927.50	747.00		
Mean CANDU (ISOE)	751.91	810.41	877.45	931.22	928.53	1012.9	1045.8	1003.1	1103.8	1167.0	1331.2	1393.2	1441.7	1439.2	1182.8		
Cernavoda	357.15	438.78	512.00	602.45	650.08	689.27	691.91	555.04	476.95	354.71	312.86	294.27	322.93	325.91	303.33	356.74	254.55

REDUCING COLLECTIVE AND INDIVIDUAL RADIATION EXPOSURE

NUCLEARELECTRICA
Puterea Viitorului



	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Cernavoda	248.3	257.6	456.5	466.2	574.8	550.5	818.3	656.7	731.6	561.1	270.8	344.3	242.6	393.6	196.5	458.9	254.6
Mean CANDU-6 (COG)	1317	1324	1508	1530	1130	1734	1882	1122	1368	674	1058	1816	1316	1108	747		

REDUCING COLLECTIVE AND INDIVIDUAL RADIATION EXPOSURE

NUCLEARELECTRICA
Puterea Viitorului

In order to further improve plant performance related with exposure of radiation workers ALARA committee approved the implementation of new performance indicators:

- ☐ Unexpected acute individual external exposures
- ☐ Unexpected acute individual internal exposures
- ☐ Inadequate response to EPD's dose rate alarm
- ☐ Maximum individual dose
- ☐ Maximum individual internal dose
- ☐ Personnel Contamination Events (inside Radiation Controlled Area)
- ☐ Internal contaminations with radio-nuclides other than tritium
- ☐ Unexpected contamination of surfaces
- ☐ Personnel contamination identified at the exit of the RCA

All these indicators are followed and reported in monthly Radiation Protection Department report.

IMPROVEMENT INITIATIVES

NUCLEARELECTRICA
Puterea Viitorului

Five years ALARA plan (2014 – 2018) is aligned to management development strategy regarding the dose reduction through: source term reduction, shielding the hot-spots, controlling design changes and improving ALARA and RWP processes.

Radiation protection personnel is much more involved in work planning process (Plant Schedule, and Scheduling Improvements) for both on line and outage periods.

A new procedure for ALARA coordinators is being issued to extend their responsibilities for improving dose targets estimates, to capture lessons to learn from the department operational experience, and to help moving the ownership for dose reduction efforts to the individual departments.

IMPROVEMENT INITIATIVES

NUCLEARELECTRICA
Puterea Viitorului

RP Fundamentals for RP personnel and station workers will be reinforced with special attention to high radiological risk jobs, in particular radiography and high activity materials manipulation.

Specific remote monitoring improvements will be implemented: Unit #2 Tritium in Air Monitoring System extension and Electronic Personal Dosimetry system upgrade to accommodate Total Exposure module of Work Management System.

CONCLUSIONS

NUCLEARELECTRICA
Puterea Viitorului

Cernavoda NPP management recognizes the need to manage worker exposure as it is required by ALARA principle. The approaches taken are based on CANDU reactors design which incorporates several ALARA solutions to improve radiological performances and the results obtained are satisfactory.

Plant management commitment and worker alignment are important to achieve exposures that are ALARA.

Performance indicators are necessary in order to improve radiation protection performances.

Remote control of radiological risk and improved operation practices are both necessary to reduce radiation exposure.

The vital factor when working with nuclear power plant staff is to install ALARA ideology (or ALARA thinking).

Thank you for your attention!

Questions?