Internal exposure at Cernavoda NPP

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1.0 INTRODUCTION

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. An effective control suppose the implementation of a process to systematically identify jobs / activities performed in radiological risk areas, so that radiological conditions are evaluated and appropriate protective measures are identified and implemented.

CANDU reactors are both moderated and cooled by heavy water (D_2O). Tritium is produced in CANDU reactors by neutron reactions with deuterium, boron, and lithium and by ternary fission. Most of the tritium present in CANDU reactors is in the form of tritiated heavy water – DTO.

The moderator is the largest in volume and the most irradiated D_2O system. Most of the moderator is contained in the reactor vessel and about 90 percent of the moderator D_2O will permanently be in the neutron flux. Therefore, in a typical CANDU reactor, about 97% of total tritium is produced in the moderator system. The primary heat transport system – PHT – is the other major heavy water system. Only about 5% of the heat transport system heavy water is in the neutron flux at any moment and the tritium growth rate is much lower than for the moderator (about 3% of total). Being subject to a higher leakage rate PHT system contribution to both the tritium dose to professionally exposed workers and the tritium emissions to the environment is about 50%.

The leaks from tritiated heavy water systems or their auxiliaries are the main sources of tritium in the reactor building air atmosphere. Special dryers are designed and are used to remove moisture from different ventilation systems of a CANDU reactor in order to maintain tritium in air concentration and gaseous tritium emissions below the limits established by the national authorities. Vapor Recovery System is designed to control tritium in air concentration and to recover heavy water loss from PHT and Moderator Systems. Also the system controls the air circulation, providing atmosphere separation between different areas of the Reactor Building.

Outside the human body tritium contribution to radiological hazard is negligible however, when tritium enters the body either by inhalation or absorption through the skin the decay energy carried by the β^- particle is deposited in body tissue being an occupational radiation hazard in the CANDU plants.

Despite all protective measures (design, procedures and rules), operating experience to date of CANDU reactors has indicated that DTO is the major contributor to the internal dose of professionally exposed workers.

After three consecutive years (2004, 2005 and 2006) of major concern on individual and collective internal doses (Figure 1), due to the increase of tritiated water vapours concentration in the Reactor Building, corrective and preventive actions and recommendations, aiming both work planning (exposure control) and technical aspects, worked efficiently and at the end 2007 internal dose contribution to the total collective dose was reduced to 30.7%.

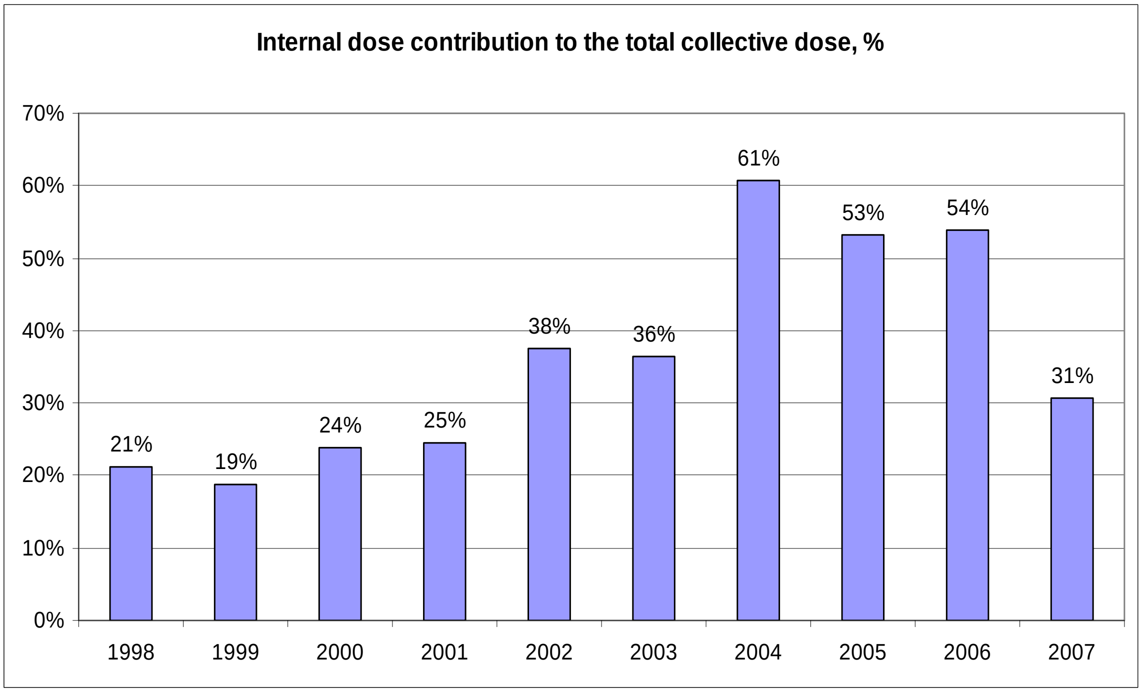

Figure 1 - Internal dose contribution

2.0 2004 – PROBLEMS AND SOLUTIONS

High tritium fields were identified in reactor building starting 2004, February 5th.
The most important findings and actions were as follow:

- Initiation of SOS procedure "D_2O leaks identification in the Reactor Building – PHT and F/H rooms – at full power"
- leak identification at rupture disk 33335-RD3 (Primary Heat Transport purification system);
- D_2O leak seen on surveillance camera in Moderator Enclosure Room at pump P1; P2 was put in service and the leak was reduced.
- samples taken from the moderator pump seals, revealed increased tritium concentrations; a damage at pump 32111-P1 hydro-cyclone was supposed.

Corrective actions to reduce the tritium fields in Boilers Room:

- ventilation hose installed as to aspirate from side B moderator pumps to dryer 3831-DR11;
- ventilation hoses installed at rupture disk 3335-RD-03;
- Dryers 1 to 4 adsorption / regeneration times changed to keep all the time three dryers in "adsorption".

As the tritium level in Boilers Room remained high, a Standard Operation Sequence (SOS) procedure was initiated for leak search on moderator system equipment, in accessible areas: leaks found on two valves.

During three days unplanned outage the leak search continued in rooms not accessible at full power (Moderator Enclosure, Emergency Core Cooling Valves Gallery, reactor vaults, boilers room); small deficiencies were fixed.

Components of Moderator System (pumps, circuits, valves and calandria rupture discs) were tested for leaks by wrapping in plastic bags. Leaks identified at two valves and RD2 rupture disk and those components were wrapped in plastic to be fixed during planned outage.

With reactor at full power the tritium dose rate in Boilers Room still stayed high. Following actions were intended to lower the doses:

- installing local ventilation for the equipment known as potential tritium sources;
- optimizing the adsorption / regeneration cycles for dryers servicing Boilers Room;
- optimizing the dryers efficiency Reactor Building: changing the supplier of molecular sieve.

During Planned Outage Calandria's rupture disk 3231-RD2 was replaced and it was considered the major contributor to tritium fields in Boilers Room.

The efficiency of remedial actions has been assessed using three methods:

- direct measurements of tritium fields around equipment that have been fixed;
- measurements of He leaks;
- pressure "hold test" on Moderator Cover Gas System.

We concluded that the main tritium source was Moderator Cover Gas (as He gas mixed with D2O vapor).

After the planned outage August – September 2004, till January 2005 the tritium dose rate in the reactor building and Boilers Room did not exceeded the normal values.

3.0 2005 – PROBLEMS AND SOLUTIONS

High tritium concentrations were identified in Boilers Room and in accessible areas in the Reactor Building starting January 2005.

In order to minimize the tritium fields in the Reactor Building started the actions to identify and eliminate the source. This is the line-up of events and actions:

- Bubblers installed in Boilers Room: PHT heavy water has been established as the tritium source;
- Initiation of Standard Operation Sequence (SOS) procedure "D_2O leaks identification in the Reactor Building – PHT and F/H rooms – at full power".

The search started at the Health Physics Department request, for the tritium dose rates lower than 0.1 mSv/h (administrative limit to be started the leak search).

- 12 valve from Moderator System were wrapped in plastic to be tested with He detector (to identify potential He leaks from Moderator Cover Gas valves); leak identified at 3231-CP1 compressor, 1000 times higher than normal operation values.
- During two days Unplanned outage, July 19th to 20th – Initiation of SOS procedures for D2O leaks identification in the Reactor Building – Emergency Core Cooling Valves Gallery and on Moderator system at <2% Reactor Power.
- Leak identification at moderator pump P2 hydro-cyclone; local ventilation installed.

3.1 Corrective and preventive actions and recommendations

Corrective and preventive actions and recommendations aimed both work planning and technical aspects:

- ALARA planning of routine and maintenance activities in Reactor Building / Boilers Room (respiratory protection, limiting the time spent in Reactor Building, postponing some activities, optimize the routine activities performed by the operators and radiation protection technicians in the Boilers Room);
- Mandatory use of respiratory protection for anticipated committed dose higher than 0.03 mSv (at Cernavoda NPP wearing respiratory protection is mandatory for tritium dose rates higher than 0.05 mSv/h);
- Acquisition of a semi-portable tritium monitors, with gamma and noble gases compensation;
- Design change, so dryers serving Reactor Vaults (R107, R108) and Boilers Room (R501) to "suck the air" direct from these rooms;
- Analyze the possibility of installing a drying unit on the entrance of the ventilation tubes serving reactor building in order to decrease the influence of the humidity of air on tritium fields;
- Re-routing moderator cover gas purge line, for both units.
- Modernize Tritium in Air Monitoring – TAM – system.

Still, during 2005 planned outage we confront again the tritium problem (meaning relatively high internal collective and individual doses).

4.0 2006 PROBLEMS AND MORE CORRECTIVE ACTIONS

During 2006 internal exposures due to tritium intakes remained high, mainly due to DTO leakages form the moderator and primary heat transport systems. Besides, an unexpected major leak of tritiated water from primary heat transport system occurred during planned outage. There were not detectable effects on the environment. The individual internal doses received by the employees involved in the recovery of the spilled water did not exceed the investigation limit of 1 mSv committed dose.

Corrective and preventive actions and recommendations were as follows:

- we issued two procedures (“ALARA Program for CNE Cernavoda” and “Radiation Work Permit System”) regarding ALARA planning of routine and maintenance activities in Reactor Building;
- Adsorption / regeneration time for dryers of D_2O vapor recovery system, versus air humidity was optimized;
- We acquired a performant installation to detect and measure the He leaks in order to accurately locate the defective equipments;
- In order to increase the RP awareness in the plant and dose reduction ownership:
    - ❖ We placed specific radiation protection information: charts, RP bulletin, newsletter on RP stations goals, ALARA initiatives, RP policies and procedures in key high traffic areas of the plant;
    - ❖ we provide twice a month collective doses for station working groups;
    - ❖ we established monthly collective dose targets for station and work groups;
    - ❖ we established performance indicators to improve station / work group performance
    - ❖ we established more challenging internal dose reduction targets to lower the ratio internal dose / total dose;
    - ❖ The threshold for the use of respiratory protection equipment was lowered to 0.03 mSv anticipated committed dose;
    - ❖ we implemented a lower level for follow-up of internal exposure to tritium of 0.3 mSv committed dose (the investigation and removal level is 1 mSv committed dose).

5.0 2007 – RESULTS AT UNIT 1 AND PREVENTIVE ACTIONS IMPLEMENTED IN UNIT 2

During 2007 the implementation of corrective and preventive actions continued. Internal individual and collective doses were reduced through:

- heavy water leaks removal:
    - ❖ Sight Glass related to Moderator Primary Heat Transport and heavy water collection systems were repaired;
    - ❖ leakages from Fuel Handling Machine related equipment were remediate;
    - ❖ leakages from Moderator Cover Gas system compressor’s were eliminated.
- When expected committed dose exceeded 0.03 mSv, using respiratory protection became mandatory for entering Reactor Building.

Corrective and preventive actions and recommendations were efficient and, at the end 2007, without planned outage in Unit 1, the internal dose contribution to the total collective dose was reduced to 30.7%.

Also, during 2007 a major issue was the first criticality and commercial operation for Unit #2 (also CANDU 6 project).

At Cernavoda NPP Unit #2, in commercial operation since November 2007, was implemented the Radiation Monitoring System (RMS). At Unit #1 is under way modernization of radiation protection systems: liquid effluent monitor, gaseous effluent monitor, inter-zonal contamination monitors, area alarming gamma monitors) which will be integrated under a common, Unit #1 &Unit #2, RMS.

Before the commercial operation, in Unit #2 the “Tritium in Air Monitoring” was operational and integrated in the Radiation Monitoring System.

Modernization of the “Tritium in Air Monitoring” system in Unit 1 will be finished at the end of 2008.

In order to prevent the extension of the problems related with tritium dose rates in the Reactor Building, in Unit #2 a drying unit was installed on the admission of the ventilation tubes in reactor building in order to decrease the influence of the humidity of air on tritium fields.

For long term a heavy water de-tritiation facility project is in progress. A pilot-plant is under commissioning to test the technology to be applied to reduce tritium concentration in our CANDU reactor moderator system.

6.0 2008 - NEW RADIATION PROTECTION PERFORMANCE INDICATORS

Since in 2008 we are operating two units and taking into account a 45 days planned outage at Unit 1, ALARA Technical Committee approved in its first meeting challenging values for collective dose and internal dose contribution.

In order to further improve plant performance related with exposure of radiation worker for 2008 ALARA committee approved the implementation of some new performance indicators for the major work groups and for the plant:

- Unexpected acute individual external exposures
- Unexpected acute individual internal exposures
- Maximum individual dose
- Skin and clothes contaminations of workers
- Internal contaminations with radio-nuclides other than tritium
- Unexpected contamination of surfaces

7.0 CONCLUSIONS

The need to manage worker exposure is universal, but the approaches taken and the results achieved will depend upon the case under consideration. CANDU reactors design incorporated several ALARA solutions to improve radiological performances.

Performance indicators are necessary in order to improve radiation protection performances. While worker exposure results can be one indicator of the effectiveness of a plant's dose management program, these cannot be the only criteria used to judge program effectiveness. Keeping exposures ALARA is first a way of thinking, rather than a formula.

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

Improving operation practices is necessary to reduce radiation exposure.

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

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