WORLD CLASS ALARA PERFORMANCE AT DARLINGTON NUCLEAR

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Abstract In January 2008, Darlington Nuclear was selected by Information System on Occupational Exposure (ISOE) North American Technical Center to receive the 2007 World Class ALARA Performance Award for setting and achieving high standards in radiation protection. The purpose of this presentation is to share some of the station's successes and challenges in reducing dose to operation and maintenance personnel. In particular, the following dose reduction initiatives will be discussed:

- Innovative shielding design including the use of water shielding walls for on-line airlock maintenance, tungsten shielding blocks for feeder replacement, and exposure reduction for horizontal flux detectors
- Use of remote monitoring array to scan reactor face for hot spots to reduce dose and save critical path time
- Tritium reduction through improvements in human performance, outage scheduling and introduction of new technology

With increasing work scope associated with maintenance, refurbishment and retro-fit activities, there is an upward pressure on collective dose making it a critical resource for many inspection and maintenance work groups. There is a need to reduce radiation source terms as a lasting solution to address ever-increasing collective dose. Darlington's long term strategic goals to reduce tritium and gamma source terms and a bold vision for the future will be discussed.

1. Introduction

Over the past 8 years, there was an upward pressure on collective dose due to increased workload associated with refurbishment or plant life extension projects. For example, station outage work activities increased from 6000 tasks in 2000 to over 12,000 tasks in 2007 (see Figure 1). With increased workload, there is a corresponding increase in collective radiation exposure (CRE), the number of exposured workers and the maximum dose they received. For example, the CRE as an average for all CANDU reactors has increased by more than 60% from 2000 to 2006 (Figure 2). A similar rate of increase in CRE and maximum individual dose was observed at Darlington. With the number of refurbishment project either on-going or planned, there is a risk that the limited person-rem resources available from the skilled labor pool may not be sufficient to complete the required work. Dose reduction and careful management of person-rem resources become a strategic business requirement.

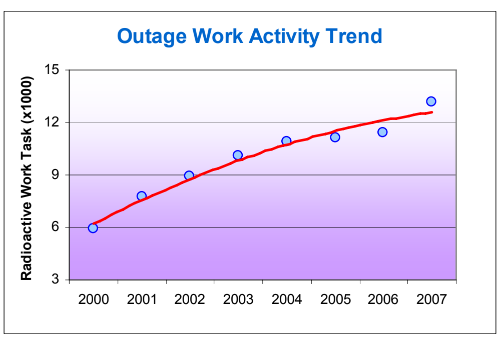


Figure 1. Upward Trend in Workload

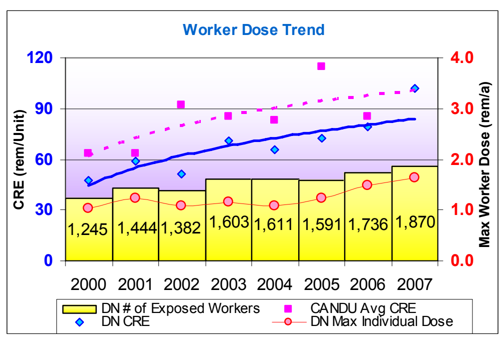


Figure 2. Upward Trend in CRE and Individual Dose

In January 2008, Darlington Nuclear was selected by the Information System on Occupational Exposure (ISOE) North American Technical Center to receive the 2007 World Class ALARA Performance Award for achieving high standards in radiation protection. The purpose of this presentation is to share some of the station's successes and challenges in reducing dose to its workforce.

2. Dose Reduction Initiatives

a) Installation of Submicron Filtration

There is a need to reduce radiation source terms as a lasting solution to ever-increasing collective dose. Perhaps one of the most cost-effective solutions is to improve the effectiveness of the filtration system. Working with Station Engineering, the ALARA group at Darlington was able to initiate a planned reduction of HT and Moderator filter pore size in steps from 2 uM to 0.45 uM and then 0.1 uM. Significant dose rate reduction was observed in both Fixed Area Alarming Gamma Monitors (FAAGM) and routine manual surveys. For example, containment dose rates decreased from 18.6 mrem/h in 2002 to 12.5 mrem/h in 2008. Based on the number of person-hours spent inside containment, a total dose saving of 130 rem for Unit 1 was estimated (Figure 3)

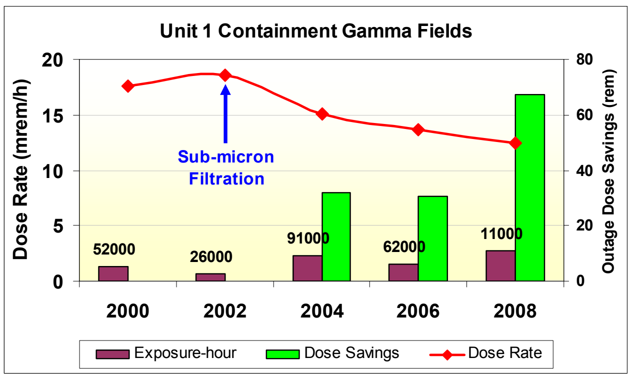


Figure 3. Unit 1 Exposure Trend and Estimated Dose Saving

b) Remote Monitoring

With advances in monitoring and wireless communication technology, remote monitoring such as teledosimsetry, becomes an important tool to reduce worker dose. Some of our current and future applications are described below:

(i) Reactor face Scan - Teledosimetry is routinely used for reactor face scan to minimize the need for manual surveys. Twenty four EPDs are installed on two 12 ft scaffold tubes attached to the RAB platform. The EPDs are spaced approximately 1 foot apart to align with the channels and cover the full width of the reactor face. Fuel Handling operators working with RP drive the bridge upwards pausing briefly at each row to allow time for RP to record readings transmitted by the teledosimetry (Figure 4). This method was developed by Darlington ALARA and adopted by many CANDU utilities. The benefits are estimated to be 0.5 rem dose and 1 shift critical path savings per outage.

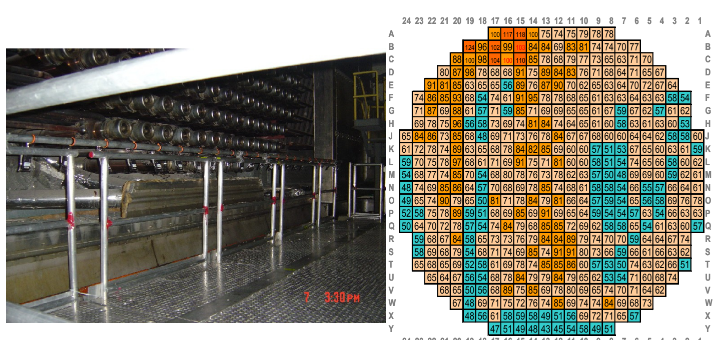


Figure 4. Reactor Face Scan using Teledosimetry

(ii) Airlock and waste depot monitoring - Other examples of remote monitoring are remote readout of gamma and tritium levels at airlocks and monitoring of waste depot dose rate to prevent unposted hazards (Figure 5)

Figure 6. Remote Monitoring at the Airlocks and Waste Depot

c) Shielding Applications

Temporary shielding is used extensively during IPG and outage work activities and credited with large dose savings. Some of the more unique applications of shielding are described below.

(i) Water wall for on-power airlock EQ work - Each wall section consists of 2 units with a combined height of 9 feet. Typically, several sections are installed and fill with water to provide excellent shielding (Figure 7). Three sections of the water wall were installed at our main airlock to allow on-power EQ work to proceed. With a water thickness of 20 inches, our experience showed that the dose rate reduction was 6 times for gamma and 11 times for neutron. The estimated dose savings were 8 rem for 3 outages in 2007 and 2008. In addition, a total critical path savings of 2 weeks were realized.

Figure 7. Application of Water Shield Wall for Dose Reduction

(ii) Water bag for ECI hot spot shielding - High dose rate hot spots of up to 50 rem/h contact and 2 rem/h working distance were encountered at ECI pipes due to crud accumulation. Shielding using conventional method will incur high personnel dose. A flexible water bag complete with straps and hose was installed at a low dose section of the ECI and moved to the hot spot location. Once it was at the designated location, a small pump was used to fill the bag with water (Figure 8). A dose rate reduction of 9x were achieved with 1/10 of installation dose using lead blankets.

Figure 8. ECI Hot Spot Water Bag Shielding

(iii) Reactor Face Shield Block: A second generation shield block was used to reduce gamma fields originate from the reactor face. Unlike the original shield blocks (also developed by Darlington ALARA), the improved version is made of flexible polymer containing tungsten. The blocks measured about 1 foot square with a 7 inch hole cut out to reduce weight. The decision to cut out the center was based on our assessment and actual measurements that the end fittings contribute very little to the radiation fields due to the combined shielding effects of water, shield plug and closure plug. Detailed shielding information is provided below:

- Each block weighs 22 lbs with a 7" hole cut out
- 15 min and 14 mrem to install 35 blocks
- Dose rate reduction of more than 2x (90 mrem/h before shielding and 42 rem/h after shielding)

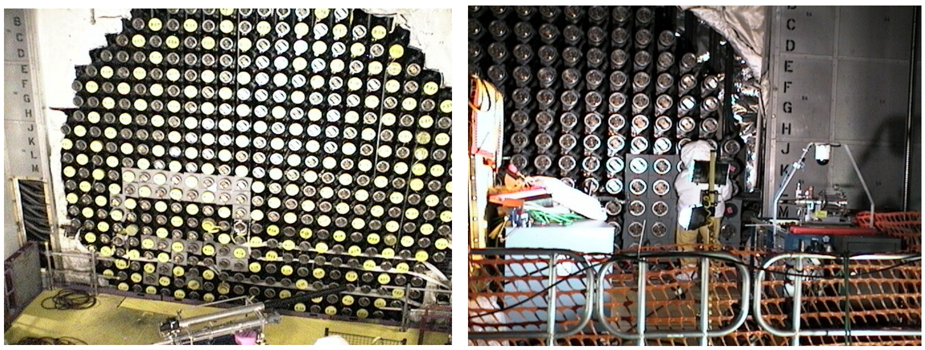


Figure 9. Reactor Face Shielding Blocks

d) Decontamination

Strippable Decon Gel paint has been used successfully to decontaminate floor and other surfaces. In one recent application, the floor of HX1 room floor was coated with the material and peel the next day (figure 10). Result of decontamination is provided below:

- Before – 5000 cpm
- After - 0 cpm
- Peeling - 4.5 mrem/h C

Figure 10. Decontamination Using Strippable Paint

e) Characterization of Dose and Dose Rates

A great deal of efforts was made to understand and characterized radiation fields in a number of exposure environments. Results of the study were use to develop better shielding strategies and techniques:

(i) Reactor face field characterization – At the reactor bridge platform, workers conduction feeder inspection or channel reconfiguration work are exposed to two roughly equal sources of radiation - one from the reactor face and other from the overhead feeder cabinet. This knowledge allowed us to develop a shielding strategy to protect workers at the reactor face. It consists of a combination of shielding blocks and overhead shielding structure to provide a complete protection for worker working at the reactor face. Figure 11 shows the configuration of fuel channels and feeders, and the variation of dose rates when moving up and down the reactor face.

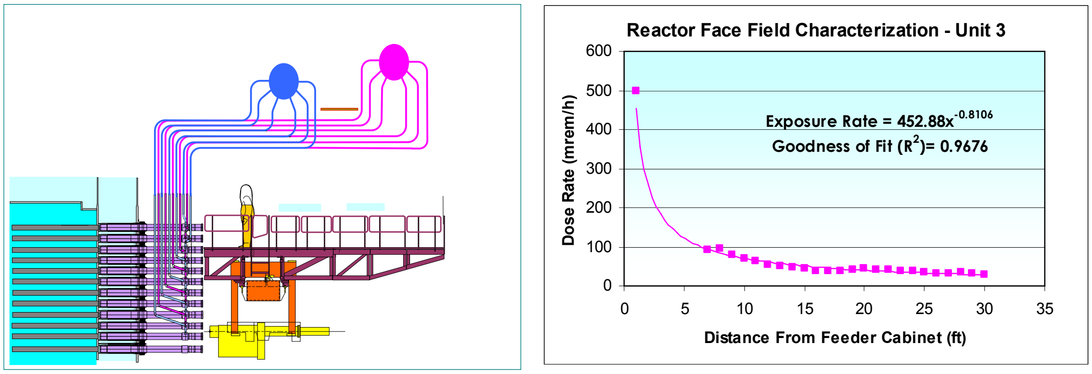
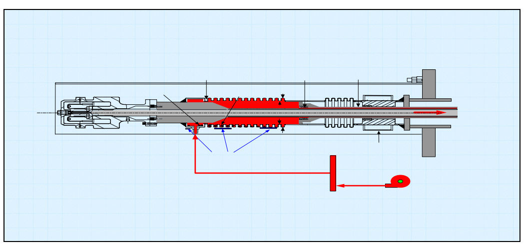


Figure 11. Reactor Face Field Characterization

(ii) Ion Chamber and HFD cable replacement shielding strategy – very high radiation fields of up to 60 rem/h contact dose rates were observed at the SDS2 bunker during EQ cable replacement work. Detailed analysis of system configuration was made to identify the source and location of high dose rates. Our analysis identified that the D2O supply line is responsible for crud deposition at the D2O bellows of the flux detectors. This was confirmed by field measurements and allowed the formulation of shielding strategies to reduce installation dose and improve overall shielding effectiveness. The result is a major reduction in job dose from 37.7 rem in 2007 to 18.1 rem in 2008 (Figure 12).



EQ Cable	As Found	Shielded	Job Dose
D721	271 mR/h	165 mR/h	37.7 rem
D811	280 mR/h	68 mR/h	18.1 rem

Figure 12. Ion Chamber and HFD Shielding

f) Internal Dose Reduction

(i) Source Term Characterization – Similar to external dose reduction discussed above, our initial efforts were focused to understand and characterize factors influencing tritium levels inside containment. Results of our study indicate that higher tritium occurred when PHT is full and depressurized or refilled to gravity fill state (GFS). This created a pressure window where closure plugs are leaking the most. Further study indicated that the closure plugs started to leak at 2.3 MPa and stop when the PHT is at the very low level drain state (VLLDS). Vault tritium is also elevated during ice-plug work when the vault vapor recovery system is reconfigured in N2 purge mode. Analysis of tritium uptake pattern showed that 70% of station annual internal dose was received during outage with the balance of 30% during normal operations. In a typical outage (e.g. D631) a staggering 90% of outage tritium dose was received during a 12 day period when PHT is either full or in GFS (Figure 13). Detailed information of tritium concentration and uptake pattern allows us to focus our efforts and resources to minimize internal dose.

108.587 SOFT
SHIELD TANK
107.477
ROW 'A'

CA

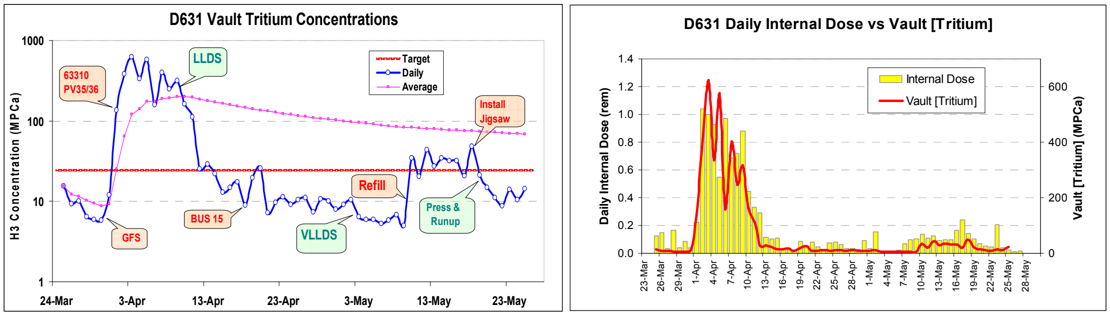


Figure 13. Vault MPCa and Tritium Uptake

(ii) Tritium Reduction ALARA Plan – A comprehensive outage ALARA plan was prepared to control tritium exposure. Key program elements include:

- Action levels established with pre-determined corrective actions
- Closure plug leakage mitigation (CP tightening, PHT low level drain state to reduce static pressure)
- Portable dryers installation and maintenance (D811 result: achieved a 96% capacity factor, 24 drums and 1200 Ci extracted from vault air)
- Tritium reduction and control @ airlocks (Figure 14).

Figure 14. Use of Munter Dryer and Plastic Curtain to Reduce and Contain Tritium

Significant dose reduction was achieved during our spring outage in 2008 (D811) in which tritium concentrations were reduced from 500 MPCa to less than 10 MPCa and tritium dose accounts for only 6% of total dose (Figure 15).

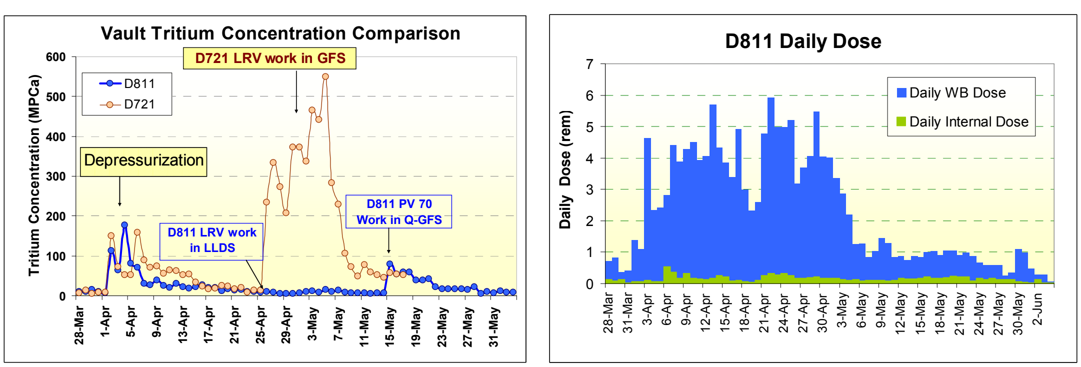


Figure 15. D811 Outage Tritium Results

On-going improvements in controlling tritium source term have contributed to continual downward trend in internal dose per task as well as the ratio of internal to total dose (Figure 16).

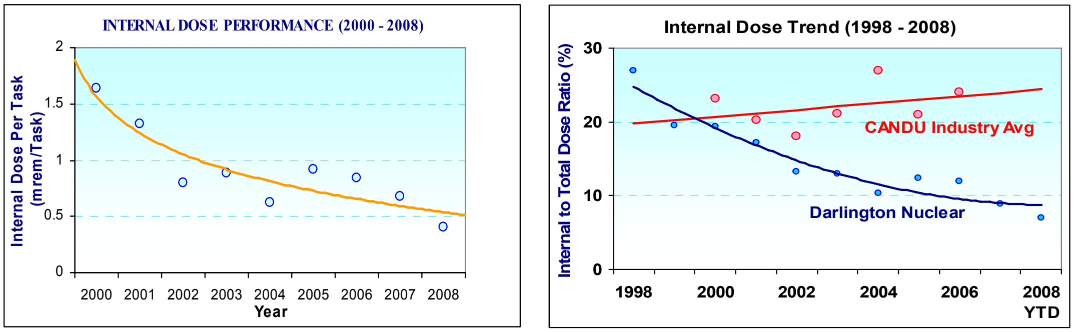


Figure 16. Internal Dose Performance Trend

3. Human Performance Improvement

a) Impact of Worker Practice

Human performance has a large impact on the effectiveness of radiation protective equipment (RPPE). Our experience indicates that after a very focused communication campaign which included the use of video, poster and presentations at safety meeting topics, to increase worker awareness about the importance of maintain plugged in to air headers, the plastic suit protection factor (PF) increased by a factor of 2. The same study also showed that the impact could decrease over time unless a new communication campaign is implemented. Obviously, there is a need to re-invent the message to maintain its effectiveness.

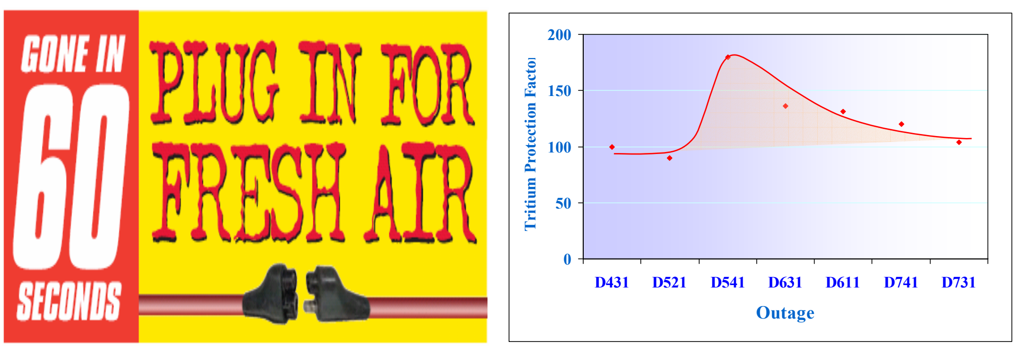


Figure 17. The Impact of Worker Communication Program on Protection Factor

b) Coaching, Monitoring & Follow-up

Daily worker EPD dose and tritium uptake are monitored and unusual occurrences are flagged for follow up. Action levels are established to ensure consistent approach:

- 3 uCi/l or 10 mrem EPD – follow-up with worker/supervisor
- 10 uCi/l above planned or EPD alarm – department EFDR, SCR
- 35 uCi/l above planned or 100 mrem above EPD alarm – root cause investigation

In conjunction with the action levels, focused observation and coaching (O&C) are used by RP staff to improve human performance. Performance management includes interview by RP management for significant RP infractions or repeat events.

4. Future Challenges

Two ambitious goals were established to reduce internal and total worker dose:

1) Reduce Tritium in containment to < 1 MPCa by 2011

Action plans:
- Redesign closure plugs to be leak tight through out the outage
- Create alternate venting path to preserve VVRS during ice plug work
- Install portable dryers to supplement VVRS

Benefits:
- Eliminate plastic suits for most outage work
- Reduce outage duration by 2-5 days
- Reduce worker dose (>40 rem/outage) and tritium emission

2) Reduce γ dose rate by 25% by 2011

Gamma scans identified Co-60 as the dominant source of radiation responsible for 75-80% of total exposure. Studies showed that more than 80% of Co-60 originates from FM stellite ram balls. Corrective action plans include both long term and short term actions:

- Long term plan: COG project to develop replacement strategy
- Short term plan: FM filtration improvement – submicron filters & IX

The following graph (Figure 18) shows that there is a gradual reduction of containment dose rates after installation of submicron filters. The same graph also shows that the reduction may be leveling off as the rate of source term removal is substantially equal to the rate of addition. Actions intended to reduce the addition of source term into PHT is necessary to continue the downward trend.

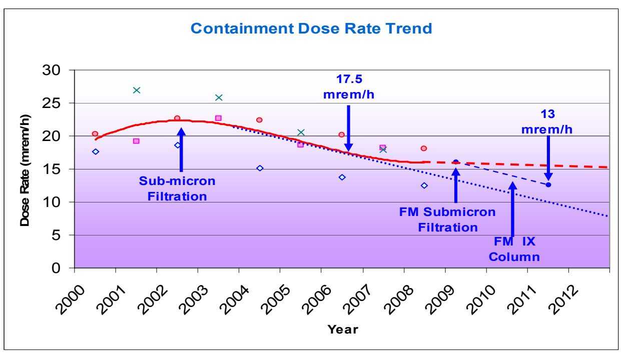


Figure 18. Containment Gamma Dose Rate Trend

5. ALARA Achievement and Recognition

The station's efforts in dose reduction were recognized by WANO. From 2001 to 2007, three consecutive WANO Strengths in ALARA were identified. For example, the most recent WANO evaluation (2007) identified areas of strengths in ALARA:

- High standards in RP have been set and achieved
- Robust controls prevent unplanned exposures
- Extensive ALARA planning, innovative shielding and aggressive tritium reduction

In 2007, Darlington was given an "A" rating in RP program implementation by the CNSC and was the proud recipient of ISOE 2007 World Class ALARA Performance Award.