

Resin Liner Recovery and Over-Packing at Ontario Power Generation's Western Waste Management Facility – 8237

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ABSTRACT

Spent resins generated from Ontario Power Generation (OPG)'s and Bruce Power's CANDU reactor operations are stored at OPG's Western Waste Management Facility in Kincardine, Ontario, Canada. The older resins are contained in 3 m³ epoxy-coated cylindrical carbon steel containers known as resin liners. The liners are stored in a stacked configuration within cylindrical in-ground containers.

Previous studies indicated evidence of unacceptable liner wall corrosion and the potential for eventual leakage of resin from the liners. Based on this, OPG elected to re-package the majority of the resin liners into stainless steel over-packs. A contract for this work was awarded to a project team consisting of Duratek of Canada, Kinectrics, Inc. and E.S. Fox.

This paper provides an overall summary of project activities focusing on the effectiveness of the equipment utilized and the soundness of the developed programs, plans and procedures. Specific information is provided on key aspects of the project and the overall achievement of project goals.

INTRODUCTION AND BACKGROUND

Spent resins generated from Ontario Power Generation (OPG)'s and Bruce Power's CANDU reactor operations are stored at OPG's Western Waste Management Facility (WWMF) in Kincardine, Ontario. The resins arise from moderator and primary heat transport clean-up systems, from other clean-up systems, and from applications of the CAN-DECON and CAN-DEREM decontamination processes. The older resins are contained in approximately five hundred and eighty five 3 m³ epoxy-coated cylindrical carbon steel containers known as resin liners¹ (recently, the carbon steel liner has been replaced by a stainless design). The carbon steel liners are stored in a total of twenty 12 m³ and eighty nine 18 m³ in-ground containers² (IC-12s and IC-18s); the liners are stored in a stacked configuration with an IC-12 containing four and an IC-18 containing six stacked resin liners.

Because of imperfections in their inner epoxy coating, the carbon steel resin liners are susceptible to localized corrosion. Over a number of years, starting in about 2002, OPG commissioned studies to determine the condition of the stored resin liners. Visual and ultrasonic inspections by Kinectrics were performed on a limited number of resin liners. Although their outer surfaces did not show any sign of damage or leakage of contents, the ultrasonic inspection indicated localized wall damage with observed pits

¹ The resin liner is a right circular cylinder with a diameter of 1.63 m and a height of 1.80 m. It has a wall thickness of 6.3 mm. The top head is equipped with a leg-in grapple ring and a single lifting attachment located at the center. There are several variations of the basic design; they relate primarily to the size and configuration of the lifting attachment and the design of the head. The maximum loaded weight of a resin liner is less than 4,545 kg.

² The IC-12's have an inside diameter of 1.73 m and are 8.38 m deep. The corresponding dimensions for an IC-18 are, respectively, 1.73 m and 11.76 m.

varying in depth up to 90% of the liner wall. Liners containing CAN-DECON cation resins were determined to have the greatest potential for internal wall damage. It was concluded that pitting corrosion could eventually lead to through wall penetration and thus limit the life of the liners.

The structural integrity of resin liners subjected to various degrees of corrosion was further investigated. Gas formation, as a result of corrosion primarily, has resulted in pressurization of some of the liners (they are designed to be water but not necessarily gas tight) over their storage duration and hence in release of C-14 and tritium contaminated gases into the IC cavity. Examination of the impact of internal gas pressure on structural integrity indicated that the point of highest stress during a lift was around the central lifting lug. The combined impact of internal gas pressure and corrosion of internal tie rods could overstress the top shell around the lifting lug during a lift.

To prevent any possibility of resin leakage into the IC's, OPG established in 2006 a resin liner remediation project (RLRP) to re-package designated carbon steel resin liners into stainless steel over-packs³. The over-pack design conforms to the requirements for long-term storage and future disposal in OPG's planned Deep Geologic Repository. The RLRP was planned in two stages. Stage 1 included all design, planning, program development, procedure development, training, equipment fabrication, mobilization, rehearsals, trial runs and over-packing of 50 resin liners. Stage 2 included incorporation of lessons learned in Stage 1 and the over-packing of an additional 350 resin liners. As a result of the concern with overstressing the top shell during a lift, all liners were required to be vented in-situ prior to being lifted.

A team consisting of Duratek of Canada (Duratek), an EnergySolutions company, Kinectrics Inc. and E.S. Fox was awarded the contract for the RLRP on July 3, 2006. As prime contractor, Duratek has overall responsibility for managing the project over a designated construction island (CI) and for the supply of engineered systems to recover and over-pack the resin liners. Kinectrics⁴ has responsibility for safety (conventional and radiation protection), health and environmental management on the CI, for supply of liner venting and gas scrubbing systems and for radiological characterization of the liners. E.S. Fox⁵ has responsibility for the supply of the stainless steel over-packs, providing craft labor, site support facilities, and support equipment for handling and transporting resin liners and over-packs.

Field work in Stage 1 commenced in April 2007 and was successfully completed by end of June 2007. Following approval by OPG, Stage 2 started in Aug 2007 and is currently ongoing. Renegotiation of the Stage 2 work scope led to the inclusion of twenty-six resin liners which were stored in trenches⁶. To date, over 250 liners have been successfully retrieved and over-packed. Based on the current schedule, Stage 2 is expected to conclude in March 2008.

This paper presents a description of the RLRP. The scope of work, the strategic approach employed and details of the project execution are covered.

³ The 316-L stainless steel over-pack is a right circular cylinder with an outside diameter of approximately 1.66 m and an overall height of approximately 1.92 m. Walls and bottom are 11.1 mm thick and the lid is 9.5 mm thick. The lid is held in place with 12 M22 imperial size high strength stainless steel side mounted bolts. It is equipped with a top ring to permit handling of the over-pack using a remote-operated grapple. Empty and loaded weights of the over-pack are approximately 1,450 kg and 6,000 kg, respectively.

⁴ Kinectrics was involved in much of the preliminary work conducted by OPG to assess the condition of the resin liners.

⁵ E.S. Fox has several years of experience as a contractor at the WWMF and was on OPG's Approved Vendor's List. Its Fabrication Division, the supplier of carbon steel and stainless steel resin liners to OPG, provided one of the two prototype over-packs for preliminary testing by OPG. Most importantly, E.S. Fox has the fabrication shop facilities and work force to meet the demanding over-pack fabrication schedule for the project.

⁶ The trenches are segmented concrete-lined structures. Each segment is 3.05 m wide, 13.03 m long and 3.05 m deep. Each segment is covered by a concrete lid with covers placed over the segment joints.

SCOPE OF WORK

As discussed, the overall objective of the RLRP is to safely over-pack 400 resin liners and return them into their original and other available IC structures. To achieve the objectives of the RLRP, the overall work scope included planning, engineering, procurement, provision and set-up of field facilities, staffing, training, equipment set-up, preparation of procedures, commissioning trials including rehearsals, field activities, project site housekeeping, post-work clean-up, records preparation and assistance to OPG with licensing/regulatory issues associated with the work. Major specific tasks included the following:

- Design and fabrication of an enclosed work platform to permit year round over-packing operations,
- Design and fabrication of lifting and shielding systems
- Procurement of stainless steel stock and setting up fabrication and just in time delivery of over-packs to the project site,
- Mobilization of the CI,
- Preparation of safety (radiation protection and conventional safety), health and environmental (SHE) management plans, programs and procedures – this included the identification of and definition of actions required to minimize and control potential abnormal and accident events, and development of processes to contain and clean-up radioactive resin in the event of a resin liner failure,
- Design and fabrication of equipment to vent the resin liners in-situ prior to lifting them,
- Design and fabrication of scrubbers for a) cleaning the IC structures prior to opening them, b) cleaning emissions from vented liners and c) environmental monitoring of C-14 and H-3 released at the project site, and
- Radiological characterization of resin liner contents

Work on the project site, a construction island set-up within the WWMF facility, would be conducted under the control of Duratek. It would be responsible for ingress and egress from the CI and for the radiation protection, safety, health and environmental management programs over the boundaries of the CI. The footprint of the CI would vary as work progresses to minimize interference with OPG's day to day operations.

STRATEGIC APPROACH

The basic approach adopted for recovering and over-packing the resin liners was to keep the process simple in terms of both the equipment employed and the steps required. Ideally, equipment selected and recovery techniques utilized would have been proven successful in similar applications earlier. Equipment design packages, for the most part, were based on designs previously proven in similar field applications.

The standard resin liner recovery process would utilize an all weather enclosure, a work platform and a crawler-type mobile crane for making a direct resin liner pick from an open IC (see Figure 1). This approach was judged to be the safest and fastest method. The use of a mobile crane permits the option to increase the work force by utilizing an additional crane and crew, if required to achieve schedule commitments. The crawler-type crane offered the additional benefit of 'walking' the work platform from position to position over the IC's, eliminating the need to relocate the work platform using a transport trailer.



Figure 1
Resin Liner Being Directly Picked from an Open IC

Resin liner recovery tools were planned to be simple manually operated tools. Duratek's experience indicated that variations of the basic designs used in previous fuel pool work could be employed to engage the resin liners. This approach was followed to develop several different resin liner recovery tools for engaging various designs of lifting lugs and links that were expected to be encountered.

The configuration of the IC storage area at the WWMF (the top of the ICs is up to 46 cm above the ground surface) necessitated the use of a work platform to perform the lifting operations. The work platform was designed to span two adjacent IC's to minimize the number of relocations. An enclosure around the work platform provided a degree of protection from the wind and the weather, primarily to prevent precipitation from entering an open IC. Finally, the work platform included design features to prevent or reduce the potential for spread of contamination from an open IC in the unlikely event of a spill from a resin liner. Figure 2 presents a view of the CI with the enclosed work platform installed over two ICs.

Venting the liners was a pre-requisite for lifting them and thus has to be accomplished while the liner is still in its storage location (up to several meters below grade) within the IC. A number of methods were considered including undoing existing plugs located on top of the resin liner. After considerable investigation, the solution of choice became an abrasive water jet tool which can easily be lowered down the IC and suitably placed on top of the resin liner. This tool offered the quickest, safest and ALARA compliant option for breaching the liner head.

Air/gas scrubbing equipment, needed to minimize C-14 and tritium releases, was selected based upon proven designs and the equipment was simply sized to the applications required for this project.



Figure 2
A View of the Construction Island Showing the Enclosed Work Platform, the Crawler Type Crane, the Over-Pack and IC-18s

Dose rate and gamma activity measurements required as part of the work scope were recorded in-situ by lowering radiological equipment down the 4-6 in sample pipe which runs along the full depth of the IC (the pipe connects to the IC at the bottom but otherwise is separated from the IC wall by several inches of concrete). In-situ measurements permitted a) dose rates at the surface of the stored liners to be projected prior to their lift, thus providing valuable information for planning the individual liner over-packing operations, and b) avoided the need for gamma activity measurements on the work platform following a resin liner lift, thus saving dose and process time.

A detailed analysis of the various process steps was undertaken to determine the dose budget for the project. This analysis provided valuable insight into the radiological dose impacts of the various process steps and guided the design of the shielding equipment used on the work platform. Wall thickness of the process shields was optimized to reduce the projected dose budget.

PROJECT EXECUTION

Project plans controlling various aspects of the project were required by OPG within sixteen weeks after award of contract. Work on these plans as well as on equipment design began immediately upon contract award. Discussions were initiated with OPG on limits of the CI, preferred access points to the work area, location of support facilities, electrical power feed locations and equipment lay-down area.

Several iterations were required to establish an agreeable boundary for the CI Island permitting the project team sufficient room to work and OPG sufficient access to the IC storage area for their routine operations. Upon resolution of this, OPG drafted a Memorandum of Understanding (MOU) that granted Duratek control of the CI over the project duration. By virtue of this MOU, Duratek's project site access control, radiation protection program, safety program and environmental management plan would govern activities on the CI over the life of the project.

The CI and support facilities were set up during March 2007. Equipment deliveries commenced in April and continued until the first week of May. As equipment arrived, it was set up and hands-on training in the use of the equipment was conducted. Cold rehearsals were subsequently performed to ensure resin liners could be recovered and over-packed safely and efficiently utilizing the procured equipment and operating procedures developed. As a result of the cold rehearsals, minor modifications were made to several operating procedures and additional liner grappling tools were designed and fabricated to allow recovery of liners with smaller lifting lug holes. Authorization to proceed with recovery operations was subsequently granted by OPG and recovery of resin liners commenced on June 1, 2007.

To date, recovery and over-packing operations have proceeded according to plan and have been incident free.

Key aspects of the project are briefly discussed below.

Equipment Design

Design of resin liner recovery equipment was performed at Duratek's Columbia, South Carolina office. An outline of the steps required to recover and over-pack a resin liner was developed. This outline provided guidance for identifying suitable equipment required to permit safe and efficient recovery/over-packing of the resin liners. The design objective was to work, as far as possible, to basic equipment designs used in similar applications on past projects. Innovative designs for engaging various sized lifting links/lugs encountered on a variety of resin liner top head designs were developed based on Duratek's considerable experience in retrieval of fuel pool equipment.

Similarly, steel and concrete shield designs routinely employed in Duratek's operations were modified for use on this project. A concrete/steel process shield is utilized to stage the empty over-pack for receiving the recovered resin liner. Its design permits the over-pack lid bolts to be inserted horizontally just above the shield wall. Rotating steel shields, mounted on a frame and casters, are additionally provided to further reduce dose pick-up during the over-packing operations. Together, these design features provide an optimal degree of shielding to the working personnel.

The process shield is located on a work platform that spans two IC's. The work platform has a movable work station that can be positioned to permit access to either of the two ICs spanned. The work platform is equipped with a gantry crane to aid in handling equipment (such as lighting, electrical connections, television camera and monitor, hydraulic units and weather cover) when working inside the IC. The work platform is also equipped with wind anchors.

Provision was also made for a shielded transfer bell which is handled by an overhead crane to recover high activity resin liners (up to 10 rem/h) and transfer them to the over-pack staged within the process shield. To date, it has not been necessary to utilize the transfer bell; preliminary assessment indicated that except for the highest dose rate liners, use of the transfer bell with its associated complexity would not be consistent with ALARA.

As noted earlier, in-situ venting of each resin liner was a key process requirement. A commercially available water jet system was appropriately adapted to permit the cutting head to be lowered on top of the liner head; activating the jet (water at 50,000 psi containing entrained garnet) leads to perforation of the head within a few seconds. After significant testing and assessment at Kinectrics, the tool was deployed in the field and has to date performed flawlessly. A view of the cutting head being deployed within an IC is shown in Figure 3.

Scrubbers were required to clean the IC air in preparation for work over the IC and also to capture the contaminants released from perforated resin liners. Two dedicated scrubber systems, one for each application, were designed and built at Kinectrics. Both systems employed an absorbent bed to capture moisture and associated tritium and a second bed to trap C-14 in the form of carbon dioxide. Operation of the vent scrubber was integrated with that of the water jet system, allowing safe evacuation of released gases immediately after the liner head was breached. In addition to these scrubber systems, compact

suitcase mounted environmental scrubbers were also designed and built to permit monitoring of C-14 and tritium releases at the work platform and along the site boundary; in these instances, the absorbents employed, following a pre-determined exposure period, are processed on-site and analyzed using a liquid scintillation counter to obtain emissions data. Figure 4 shows views of the liner vent scrubber and the environmental scrubber.

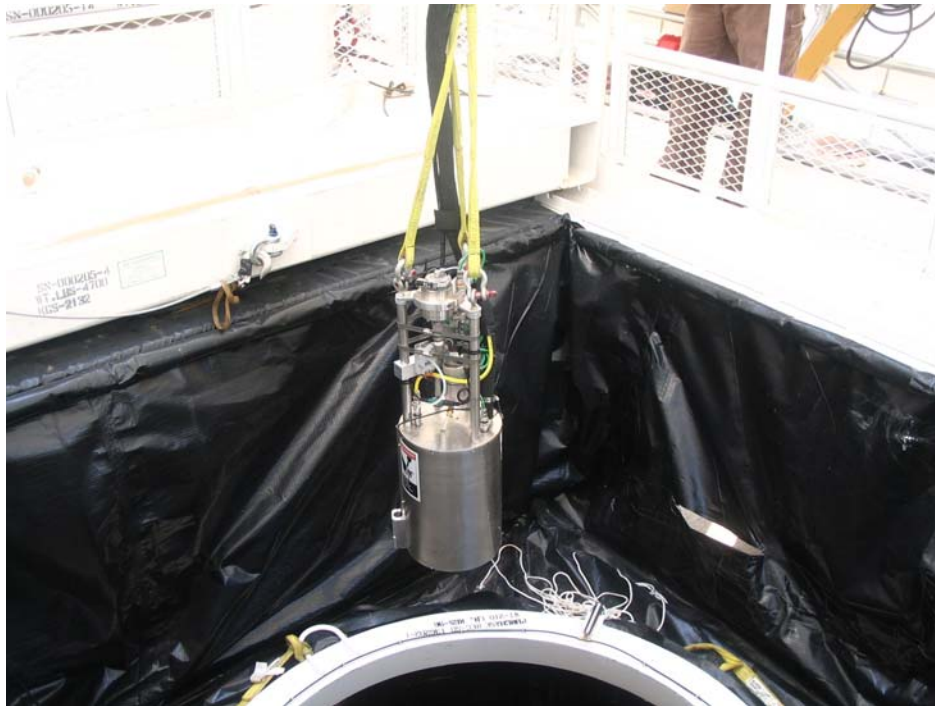


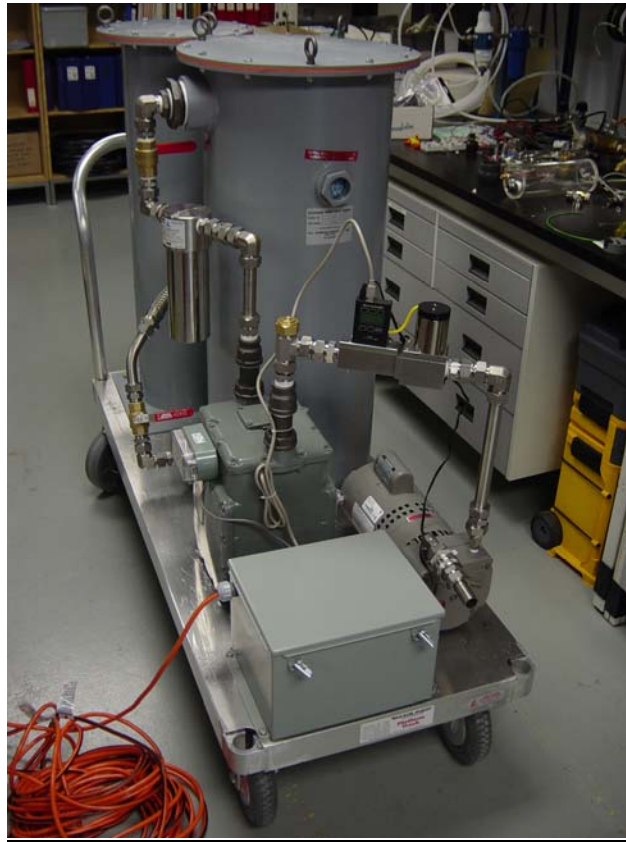
Figure 3
The Water Jet Cutting Head Being Lowered in to an IC

Fabrication of Over-Packs

Over-packs were fabricated at E.S. Fox's Fabrication Division located in Niagara Falls, Ontario.

Availability of 316L stainless steel was a problem during the last half of 2006 and extended into the first half of 2007. The quantities and sizes of the material specified (316L) resulted in late deliveries requiring E.S. Fox to accelerate the fabrication schedule and maintain over-pack fabrication in accord with resin liner recovery schedules throughout Stage 1. Once the material pipeline was full, over-pack fabrication progressed in good fashion.

Initial over-pack testing was conducted at E.S. Fox's Port Robinson facility over the period May 8-9, 2007. This testing included lifting, stacking and standing water tests. Additionally, the initially fabricated over-pack was subjected to radiography of selected welds and a complete dimensional check.



(a)



(b)

Figure 4
Views of (a) the IC Air Scrubber and (b) the Environmental Scrubber

Process for Resin Liner Recovery and Overpacking

Utilizing the equipment noted above along with a crawler crane and miscellaneous hand tools mounted on reach rods, the steps in a resin liner recovery (direct pick) and over-packing iteration are as follows:

- The IC-18 shield plug⁷ is lifted slightly and spacers inserted between the plug and the IC to create a flow path. In the case of an IC-12, the weather cover is first removed and the underlying steel plate is then unbolted from the IC (the shield plugs⁸ remain in place) to achieve the same.
- The IC vent scrubber is attached to the IC sample pipe to remove any C-14 and tritium contamination present in the IC air. Upon completion of scrubbing, the spacers are removed and shield plug is positioned back in the case of an IC-18.
- The work platform is located over the IC, leveled, and wind anchors attached.
- IC shield plug is visually inspected and lifted a few inches using the crawler crane and held for ten minutes to ensure that it can be safely lifted; the shield plug is then removed to the designated lay-down location.
- The top most resin liner is visually examined and radiological checks are performed. If satisfactory, the liner head is further probed using a blunt-head tool mounted on a reach rod.
- Following satisfactory probing, the liner venting tool is lowered into position utilizing the gantry crane mounted on the work platform. The tool is activated and a vent hole is cut in the resin liner head. The scrubber associated with the liner venting tool is activated to relieve any over-pressure in the resin liner and to scrub the vented gas prior to its discharge outside the work enclosure.
- Depending upon the configuration of the liner lifting lug, the appropriate liner engagement tool is lowered into the IC using the crawler crane. Manipulating tools mounted on reach rods are used to guide the tool into position and engage the liner. Visual examination of the liner engagement is performed to ensure proper engagement.
- Using the crawler crane, the liner is lifted a few inches and held in place for five minutes during which the top head of the liner and the lifting lug are visually examined for signs of deformation. If none is observed, the liner is lifted from the IC and placed into the over-pack (previously staged inside the process shield on the work platform). Using the gantry crane, the over-pack lid is placed and bolted on the over-pack.
- Utilizing the remote-operated over-pack grapple tool and the crawler crane, the over-pack is lifted and placed into the designated IC for storage. As an alternate, the over-pack may be placed into a shield on a transfer cart and transferred for storage to a different area of the IC farm.
- Serial number of the liner and over-pack are recorded along with identification number of the storage IC and the stack location within it.

⁷ Each IC-18 has a concrete shield plug that provides IC closure, shielding and weather cover. During over-packing operations, six resin liners are removed from each IC-18 but only four over-packed liners can be accommodated. There is, however, sufficient room within the IC-18 to store a newer design, stainless steel resin liner (this will not require an over-pack) at a later date.

⁸ Each IC-12 has two concrete shield plugs placed on top of the stack of resin liners, a steel cover plate bolted to the top of the IC and finally a concrete weather cover. During recovery operations the weather cover, cover plate and both shield plugs are removed. A modified concrete shield plug is used to replace the two existing shield plugs after the over-packed resin liners are returned to the IC-12. The modified shield plug permits four over-packed resin liners (same as before) to be accommodated within each IC-12.

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The above process is then repeated for each resin liner located in the IC. Similar steps are performed when a transfer bell is utilized.

Note that the work platform was not required for recovery of liners from the trenches; all other equipment was, however, utilized.

Safety Health and Environmental Plan and Program

The transfer of SHE responsibilities for the CI by OPG to Duratek represents a unique approach which contributed significantly to increased work efficiency. To administer these responsibilities, Kinectrics prepared detailed documentation on the SHE plan, program and procedures. Documentation relating to radiation protection was submitted to CNSC (the regulator) for approval.

SHE issues were integrated into all aspects of project activities, with commitment by all workers to meet relevant regulatory, OPG, and contractor requirements. Radiation safety issues were managed in a manner which ensured that exposures to ionizing radiation to the workers, public and the environment were kept as low as reasonably achievable (ALARA). Workers were involved in making decisions affecting their health and safety via participation in the daily job safety analysis process, in periodic safety meetings and in project joint health and safety committee meetings.

Project-related SHE hazards, risks, and barriers to reduce the risks were identified prior to the commencement of the project, and updated on an ongoing basis throughout the project. Relevant regulations, standards, guidelines and requirements were analyzed, interpreted and communicated to all affected parties. Project objectives, measures, and targets were established and suitable programs put in place to achieve them, consistent with changing conditions and emerging issues.

SHE responsibilities were clearly specified and communicated to all workers prior to the commencement of the project. In addition to defining individual shared responsibilities, the SHE structure included four positions to provide overall safety and environment as well as specific radiation safety support to field workers.

Development of Dose Budget and Dose Performance

Based on available 2004 data, the average contact dose rates for IC-12 and IC-18 resin liners were about 1300 and 670 mrem/h, respectively, with the maximum recorded dose rate being about 10.7 rem/h. Based on these data, a dose budget for the RLRP was developed considering direct liner pick-up below a threshold dose rate and use of the transfer bell above this value. For this purpose, a detailed breakdown of the tasks associated with recovery and over-packing operations was developed; placement of personnel on the work platform (with respect to the vertical centerline of the IC) and task durations were assigned. The total dose incurred in over-packing each liner was determined using the MicroShield code and aggregated for all the liners within the IC.

The analysis indicated that if liners with contact dose rates below 500 mrem/h (this applies to more than 50% of the liners) were directly processed (i.e. without a transfer bell), the overall dose for the RLRP would be about 18 person-rem or approximately 45 person- mrem per liner. No worker was expected to exceed his yearly administrative dose limit. The estimated dose budget was accepted by CNSC, the regulator.

The actual dose incurred to-date, despite not employing the transfer bell so far, has been substantially lower than projected. The collective dose received so far (total of 240 liners over-packed) is 1027 person-millirem, or about 4.3 person-mrem per liner. The low dose expenditure is attributed to

- Extensive rehearsals and training prior to commencement of radioactive work activities,
- On-going application of lessons learned as part of the job safety analysis process,

- Somewhat lower than anticipated external gamma dose rates, and
- Significantly higher through-put than originally anticipated.

CONCLUSION

The original project schedule was based on two crews working simultaneously to recover and over-pack twelve resin liners per week. Stage 1 recovery operations demonstrated and Stage 2 work to date has confirmed the capacity of a single crew to achieve and exceed this production rate. Currently, the through-put using a single crew is averaging about 16 resin liners per week. As a result, the project is projected to complete ahead of schedule. Also, the overall dose expended for the project is expected to be substantially below the projected dose budget. The success achieved is attributed to a number of factors:

- The project team has worked together cohesively and maintained focus on their respective areas of responsibility.
- The project field leadership and craft labor have worked well, emphasized conventional and radioactive safety practices and employed the equipment properly based on the operating procedures.
- The equipment fabricated for this project has performed in accordance with design objectives requiring little or no unplanned maintenance. In particular, liner venting operations, which were initially considered to be a rate limiting step, have been successfully managed using the water jet cutting tool.
- OPG has worked diligently to remove any potential barriers that would impede the recovery and over-packing operations.

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