OVER-PACKING OF SPENT ION EXCHANGE RESIN CARBON STEEL LINERS AT ONTARIO POWER GENERATION'S WESTERN WASTE MANAGEMENT FACILITY

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ABSTRACT

Spent resins 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. The older resins are contained in 3 m^3 epoxy-coated cylindrical carbon steel containers known as resin liners. The liners are stored in a stacked configuration within cylindrical in-ground containers.

Based on previous studies which indicated evidence for unacceptable liner wall corrosion and the potential for eventual leakage of resin from the liners, OPG elected to repackage the majority of the carbon steel liners into stainless steel over-packs. A contract for this work was awarded in mid-2006 to a project team consisting of Duratek of Canada, Kinectrics, Inc. and E.S. Fox. The project was successfully completed in March 2008.

This paper presents a summary of the overall project and achievements.

1. Introduction and Background

Spent resins generated from CANDU reactor operations in Ontario are stored at Ontario Power Generation (OPG)'s Western Waste Management Facility (WWMF) in Kincardine. Stored intermediate activity level resins arise primarily from moderator and primary heat transport clean-up systems and from applications of CAN-DECON and CAN-DEREM decontamination processes. The older resins are contained in approximately five hundred and eighty five 3 m^3 epoxy-coated cylindrical carbon steel containers known as resin liners[1] (recently, the carbon steel liner has been replaced by a stainless design). The carbon steel liners are stored in a total of twenty 12 m^3 and eighty nine 18 m^3 in-ground containers[2] (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

[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 1.73 m and 11.76 m, respectively.

liners. Figure 1 is a schematic of the IC structure showing, for simplicity, only two stacked resin liners.

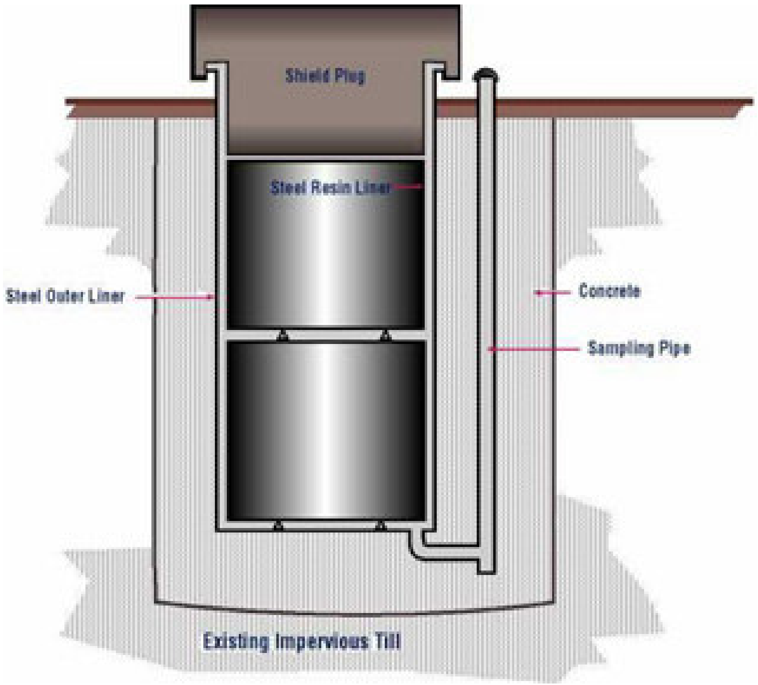


Figure 1: Schematic of an In-Ground Container

Because of imperfections in their inner epoxy coating, the carbon steel resin liners are susceptible to localized corrosion. 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-packs[3]. 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 involved 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 (an Energy*Solutions* company), Kinectrics Inc. and E.S. Fox was awarded the contract for the RLRP on July 3, 2006. As prime contractor, Duratek had overall responsibility for managing the project over a designated construction island and for the supply of engineered systems to recover and over-pack the resin liners. Kinectrics had responsibility for safety (conventional and radiation protection), health and environmental management on the Construction Island, for supply of liner venting and gas scrubbing systems and for radiological characterization of the

[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.

liners. E.S. Fox had responsibility for the supply of the stainless steel over-packs, craft labor, site support facilities, and support equipment for handling and transporting resin liners and over-packs.

Stage 1 field work commenced in April 2007 and was successfully completed by end of June 2007. Following approval by OPG, Stage 2 started in Aug 2007 and has recently been completed. The project site was vacated by end of 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.

2.0 Technical Basis for Over-Packing of the Carbon Steel Resin Liners

Over a number of years, starting in about 2000, Kinectrics performed a number of investigations to assess the condition of stored carbon steel resin liners. These investigations eventually led to OPG's decision to over-pack the resin liners and significantly influenced the scope of the RLRP. This section provides a brief account of the outcomes of these investigations to provide an overall context for the RLRP.

2.1 Corrosion Assessment

Examination of the internal epoxy coating in three unused resin liners in 1999 [1] revealed the presence of extensive defects in the coating indicating the potential for severe corrosion damage to the carbon steel particularly from storage of cation bed decontamination resins. Subsequent laboratory investigations [2] confirmed these suspicions; based on measured corrosion rates, the estimated time for through wall penetration of cation bed resin liners with defective coating was estimated to be about 25 years.

2.2 Inspection of Stored Resin Liners Using Ultrasonics

The observed potential for significant corrosion damage led to visual and ultrasonic inspections on a limited number of stored resin liners [3]. Although their outer surfaces appeared to be intact, the ultrasonic inspection indicated localized wall damage with observed pits varying in depth up to 90% of the liner wall. Liners containing cation bed decontamination resins were determined to have the greatest potential for internal wall damage. Pitting corrosion could eventually lead to through wall penetration and thus limit the life of the liners.

2.3 Characterization of the Contents of Stored Resin Liners

As part of a continuing effort to assess liner integrity, contents of several resin liners (gas, resin and water phases) which had been in storage for up to 18 years were chemically and radiochemically characterised [4]. Two liners, one containing cation and the other mixed bed decontamination resins were observed to be pressurized; other mixed bed liners were either under a slight vacuum or at atmospheric pressure. The headspace oxygen was observed to be significantly depleted in all liners examined. Hydrogen, carbon dioxide, carbon monoxide and hydrogen sulfide were observed to varying extents in the headspace gas with one examined cation bed resin liner containing as much as 45% hydrogen. The latter along with the observed water phase pH (as low as 3) presented a compelling evidence for corrosion attack from stored cation decontamination resins. The headspace gas also contained varying levels of C-14 and tritium as a result of partitioning from degraded resin.

2.4 Characterization of the Air in IC Structures

Although the liners were initially subjected to a hydrostatic test at 22.5 psig, they are not necessarily gas tight. As a result of atmospheric pumping experienced by the IC storage structures, headspace contents of non-gas tight liners could potentially escape and contaminate the air within the IC structures. C-14 and tritium were observed in the air contained within several IC structures and confirmed the presence of leaking resin liners.

2.5 Assessment of Pressurization within Stored Resin Liners

The carbon steel liners were not intended for use at pressures exceeding 15 psig. As a result of gas formation from corrosion, as well as from radiolytic and biogenic processes, gas-tight liners may develop pressures exceeding 15 psig over their storage duration. Studies undertaken to assess gas pressurisation in leak-tight liners [5] indicated that pressures in cation bed resin liners could potentially exceed 15 psig. For mixed bed resin liners, pressures are, however, unlikely to exceed 5 psig even after 50 years of storage. Further assessment [6] confirmed the potential for significant over-pressures in cation bed resin liners even in the presence of various leak pathways. These liners, therefore, must not remain as sealed units if they are over-packed.

2.6 Assessment of Liner Integrity during Lifting

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.

The above assessments led OPG to specify the following requirements for the RLRP:

Because of uncertainty with respect to the type of resin stored in various liners, all resin liners should be vented in-situ prior to being over-packed. As a result of the C-14 and tritium contamination in the IC air, all ICs should be scrubbed prior to the start of over-packing operations. Scrubbing would also be required to clean up the IC air following the venting of each resin liner. Vented liners should be stored within non-gas tight stainless steel overpacks to prevent future over-pressurization.

3. Scope of Resin Liner Remediation Project

The RLRP scope included the following major tasks:

- Work would be conducted on a Construction Island within the WWMF facility with the contractor being responsible for ingress/egress, radiation protection, conventional health and safety, and environment.
- Procurement of stock and fabrication of over-packs for just in time delivery.
- Design/fabrication of an enclosed work platform to permit year round operations.
- Design and fabrication of lifting and shielding systems.
- Design and fabrication of equipment for in-situ venting of the resin liners.
- Design and fabrication of C-14/H-3 scrubbers.
- Monitoring of C-14 and H-3 at the project site.
- Radiological characterization of resin liner contents.
- Assistance to OPG with licensing/regulatory issues.
- Mobilization of the Construction Island and performing commissioning trials (including cold rehearsals).

4. Strategic Approach

The basic approach for over-packing resin liners was to select equipment and recovery techniques which had been proven successful in similar applications earlier. The standard liner recovery process utilized an all weather enclosure, a work platform and a crawler-type mobile crane for making a direct resin liner pick from an open IC. Resin liner recovery tools were planned to be simple manually operated tools. Variations of the basic designs used in previous fuel pool work were employed.

The configuration of the IC storage area at the WWMF necessitated the use of a work platform to perform the lifting operations. The work platform was designed to span two adjacent IC's to reduce the number of relocations. An enclosure around the work platform provided a degree of protection from the weather and prevented precipitation from entering an open IC. Figure 2 presents a view of the Construction Island with the enclosed work platform installed over two ICs.

A number of methods, including the undoing of existing plugs located on top of the resin liner, were considered for the in-situ venting of the liners at depths of up to several meters below grade. An abrasive water jet tool, which could easily be lowered down the IC and placed on top of a resin liner, was selected. It offered a rapid, safe and ALARA compliant technique for breaching the liner head.

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

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 inch sample pipe which runs along the full depth of the IC (see Figure 1). In-situ measurements permitted a) dose rates at the surface of the stored liners to be projected prior to their lift, providing valuable data for planning liner recoveries, and b) avoided the need for gamma activity measurements on the work platform, thus saving dose and process time.

A detailed analysis of the various process steps was undertaken to determine the dose budget for the project. The analysis provided valuable insight into the radiological dose impacts of the various process steps and resulted in an optimal design of the required shielding equipment.

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

5. PROJECT EXECUTION

Work on project plans and equipment design began immediately upon contract award. A Memorandum of Understanding (MOU) was negotiated with OPG specifying limits of the Construction Island and granting Duratek control over it for 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 Construction Island during the project.

The Construction Island and support facilities were set up during March 2007. Equipment deliveries commenced in April and continued until the first week of May. Hands-on training in the use of the equipment was conducted. Cold rehearsals were subsequently performed to ensure resin liners could be safely over-packed. Following authorization by OPG to proceed, recovery of resin liners commenced on June 1, 2007.

Key aspects of the project are briefly discussed below.

5.1 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.

Steel and concrete shield designs routinely employed in Duratek's operations were modified for use on this project. A concrete/steel process shield was utilized to stage the empty over-pack for receiving the recovered resin liner (see Figure 3). Its design permitted the over-pack lid bolts to be inserted horizontally just above the shield wall. Rotating steel shields, mounted on a frame and casters, further reduced dose pick-up during the over-packing operations. Together, these design features provide an optimal degree of shielding to the working personnel.

Figure 3: Resin Liner being Lowered into Overpack Pre-Staged in Process Shield

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 when working inside the IC.

Provision was also made for a shielded transfer bell to recover high activity resin liners (up to 10 rem/h) and over-pack them. This was, however, not utilized because of its complexity.

As noted earlier, in-situ venting of each resin liner was a key process requirement. A commercially available water jet system was 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) resulted in perforation of the head within a few seconds. After testing and assessment, the tool was deployed in the field and performed flawlessly. A view of the cutting head being deployed within an IC is shown in Figure 4.

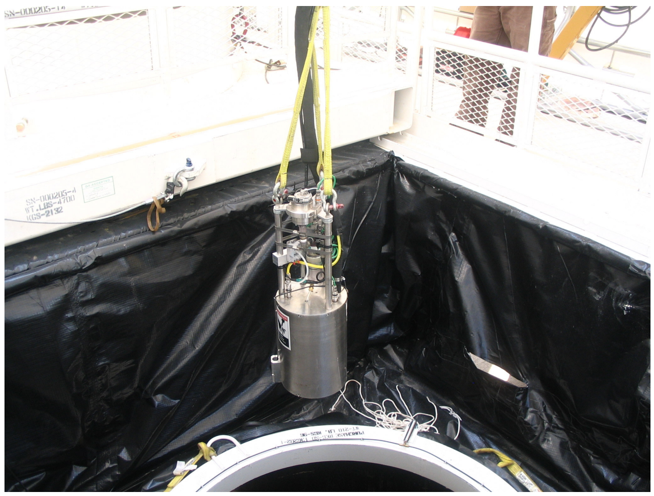


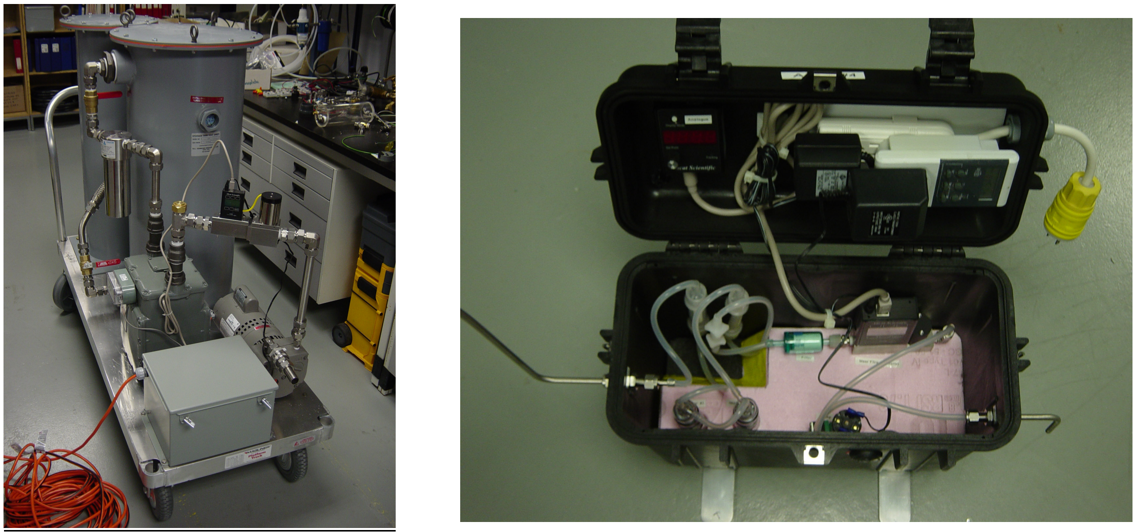
Figure 4: Water Jet Cutting Head Being Lowered in to an IC

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, were processed on-site and analyzed using a liquid scintillation counter to obtain emissions data. Figure 5 shows views of the liner vent scrubber and the environmental monitor.

5.2 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 well.

Initial over-pack testing was conducted 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 5: Views of (a) the IC Air Scrubber and (b) the Environmental Scrubber

5.3 Resin Liner Recovery and Over-packing

This section describes the main steps in the resin liner recovery and over-packing iteration:

- The IC-18 shield plug[4] was lifted slightly to insert spacers between the plug and the IC thus creating a flow path. For an IC-12, the weather cover was first removed and the underlying steel plate unbolted (the shield plugs[5] remained in place) to achieve the same outcome.

- The IC vent scrubber was attached to the IC sample pipe to remove any C-14 and tritium contamination present in the IC air.

[4] 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.

[5] 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.

- The work platform was located over the IC, leveled, and wind anchors attached.

- IC shield plug was visually inspected and lifted a few inches and held for ten minutes to ensure a safe lift; the plug was then removed.

- The top most resin liner was visually examined and radiological checks were performed. If satisfactory, the liner head was further probed using a blunt-head tool mounted on a reach rod.

- Following satisfactory probing, the vent tool was lowered into position and activated to breach the liner head. The vent scrubber was activated to relieve any over-pressure in the liner and to scrub the vented gas prior to discharging it.

- 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 were used to guide the tool into position and engage the liner. Visual examination was performed to ensure proper engagement.

- Using the crawler crane, the liner was lifted a few inches and held in place for five minutes during which the top head of the liner and the lifting lug were visually examined for any deformation. If none was observed, the liner was lifted out from the IC and placed into an over-pack (previously staged inside the process shield). Using the gantry crane, the over-pack lid was bolted on to the over-pack.

Utilizing the remote-operated over-pack grapple tool and the crawler crane, the over-pack was lifted and placed into the designated IC for storage. Alternately, the over-pack was placed into a shield on a transfer cart and transferred for storage to a different area of the IC farm.

5.4 Safety Health and Environmental Plan and Program

The transfer of SHE responsibilities for the Construction Island 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. SHE responsibilities were clearly specified and communicated to all workers prior to the commencement of the project. 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.

5.5 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. 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 [7] and aggregated for all the liners within the IC.

The overall dose for the RLRP was estimated to 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 actual dose incurred was 1750 person-millirem, or about 4.4 person-mrem per liner, substantially lower than projected. The low dose expenditure is attributed to

- Extensive rehearsals and training prior to commencement of radioactive work,
- On-going application of lessons learned as part of the job safety analysis process,
- Somewhat lower gamma dose rates than expected, and
- Significantly higher through-put than originally anticipated.

6. Conclusions

The original project schedule was based on two crews working simultaneously to recover and over-pack 12 liners per week. Stage 1 recovery operations demonstrated and Stage 2 work confirmed the capacity of a single crew to achieve and exceed this with the through-put averaging about 16 liners per week. As a result, the project was completed ahead of schedule with the overall dose expended being substantially lower than the projected dose budget. The success achieved is attributed to a number of factors:

- The project team worked cohesively and maintained focus on their respective areas of responsibility. The project field leadership and craft labor worked well while maintaining strong emphasis on conventional and radioactive safety practices.

- The equipment fabricated for the project 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, were successfully managed using the water jet cutting tool.

- OPG worked diligently to remove any potential barriers that would impede the recovery and over-packing operations.

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