Remediation of the Active Liquid Waste Tanks at Chalk River Laboratories, AECL-14339

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ABSTRACT

AECL has implemented the Nuclear Legacy Liabilities Program (NLLP), funded by Natural Resources Canada (NRCan), to strategically address legacy waste, decommission facilities, and restore lands affected by AECL early operations. As part of the initiative, two Active Liquid Waste Tanks, located at the Chalk River Laboratories (CRL) in Ontario Canada, had been identified as requiring remediation.

Characterization and assessment activities performed by AECL had determined the tanks to be an environmental liability as such the recoverable liquid inventory within the tanks must be removed and dispositioned. Perma-Fix was awarded a contract from AECL for the development of a Remedial Action Plan (RAP), design and construct a mobile liquid waste extraction and processing facility, package, transport and dispose of approximately 3500-gallons (13,250 liters) of liquid Mixed Low-Level Waste (MLLW). It was determined that the waste would require thermal treatment at a Resources Conservation and Recovery Act (RCRA) permitted facility and the resulting ash would be returned to AECL, in accordance with the approved import license agreements.

The basic elements of this project necessary to retrieve, process, transport and disposition the liquid waste include the following:

- Prepare the Remedial Action Plan.
- Develop the plans and documents necessary to work on the CRL site.
- Design and construct of the mobile liquid waste extraction and processing enclosure.
- Prepare the ALWTs for liquid waste extraction.
- Deploy the process enclosure.
- Extract, process, package and transport the waste for final treatment.
- Demobilize from the CRL site

Each of these activities had to be performed in an efficient and timely manner to ensure completion within the limited outdoor working period in Canada.

The main purpose of this project was to remove radioactive liquid waste from the underground storage tanks as the first step to environmental remediation of the waste storage area. Completion of this project will allow AECL to place the waste management area in a stable configuration and reduce the risk of leakage from these aging tanks.

This project demonstrated the capability of deploying a mobile processing system that could safely extract liquid waste from underground storage facilities and process the waste so that it could be compliantly transported for final disposition. In addition, the international obstacles associated with dual regulation of waste management, transportation and customs all proved to be manageable.

INTRODUCTION

The Nuclear Legacy Liabilities Program (NLLP), funded by Natural Resources Canada (NRCan), strategically retrieves legacy waste and restores lands affected by Atomic Energy of Canada Limited's (AECL) early operations [1]. The Environmental Remediation and Technical Support (ERTS) Branch at Chalk River Laboratories (CRL) is responsible for facilitating many of the initiatives of the NLLP at CRL. As part of this initiative, Active Liquid Waste Tank 1 (ALWT-1) and Active Liquid Waste Tank 2 (ALWT-2), located in one of CRL's earliest waste management areas, were identified as requiring remediation.

Perma-Fix Environmental entered into a contract with AECL, to extract, package, transport and disposition the liquid waste from the ALWT-1 and ALWT-2. The project was to be performed in two phases that consisted of: the development of a Remedial Action Plan (RAP) to identify the requirements for performing on-site management of the liquid waste removal; and the implementation of the RAP by removal of the liquid waste in ALWT-1 and ALWT-2. A unique approach was required taken to extract the liquids on this project due to the configuration of the waste.

Background

Two engineered structures, commonly referred to as "tanks", for active liquid waste disposal were constructed in the 1950s. These facilities received waste from the various laboratories and production plants at CRL. When each of the facilities was filled, they were covered with sand. Following a historical records review, characterization of the two legacy tanks was completed in a phased approach; first assessing the structures non-intrusively and then intrusively sampling the inventory.

ALWT-1 is a concrete tank 3.5 m by 3.7 m and 3.0 m in height, buried 1.2 m below the ground surface. The tank has a central concrete dividing wall and originally had a partial concrete cap on the northern half only. Both halves of the tank were filled with sandy backfill and completely full of liquid. Based on the intrusive sampling of the tank it was estimated that ALWT-1 contained approximately 2,200 to 2,800-gallons (8,300 to 10,600 litres) of retrievable liquid waste depending on the surface retention of liquid on the sand. In Fig. 1 the top surface of ALWT is exposed revealing the partial concrete cap on the northern portion while the southern portion has at least three red clay funnel shaped pipes and has been backfilled with sand. A newly fabricated concrete lid was grouted in place on the southern half of the tank following the discovery of the tank being partially open.

ALWT-2 is buried 1 m below the ground surface. The physical dimensions of the tank are 3.7 m by 3.7 m and 2.9 m in height. In Fig. 2 the top surface of ALWT-2 has been exposed revealing the hatch access off-centered in the lid towards the north side of the tank and raised approximately 0.5 m from the top of the tank. A stainless steel hatch cover (about 180 lbs) was fabricated and installed to replace the original hatch cover. Intrusive sampling of the tank's contents verified the configuration of sand and liquid within the tank. Sand had also been backfilled into ALWT-2 creating a conical pile directly under the hatch with liquid above the sand in the southern portion. Based on the intrusive sampling of the tank it was determined ALWT-2 contains approximately 1,300 to 1,600- gallons (4,900 to 6,000 litres) of liquid waste, depending on the surface retention of liquid on the sand.

Fig.1 The top surface of ALWT-1 exposed.

Fig.2 The top surface of ALWT-2 exposed.

Inventory

The inventory of the two ALWTs included liquid wastes from various laboratories and chemical processes onsite from approximately 1950 until 1955. The assumed method of emplacement is based on historical recollections of “a large concrete tank” into which bottles of waste were smashed (presumably to save space) and liquid waste was dumped from steel drums. The suspected inventory includes liquid wastes from fuel reprocessing research and various other nuclear research activities and/or operations.

As previously mentioned intrusive sampling was performed on both tanks with the objective of verifying the contents. A large portion of the radioactivity has been adsorbed and/or precipitated on the solids in the tank (i.e. sand pile). This behaviour is consistent with the high ionic conductivity and neutral to basic pH conditions of the liquid which were also observed in the analysis results. The assessment of the analysis results also verifies that the non-radiological inventory is a mixture of waste streams with evident remnants of fuel reprocessing wastes. The laboratory analysis indicated the presence of complexing agents in the liquid. The elemental composition of the liquid samples show significant concentrations of calcium and sodium ions in comparison to potassium and magnesium ions, suggesting that salt and lime may have been added to the liquid for neutralization.

Remedial Options Evaluation

The available physical data suggested that the concrete tanks have retained their physical integrity and had not leaked their contents over time. However, the contained liquid wastes presented a continued risk of leakage into the environment which had the potential for ecological impacts. It was; therefore, decided to bring the tanks to a passive operating state until the final restoration of the waste management area is undertaken. Following a formal remedial options evaluation, with respective stakeholders, the selected remedial option was partial retrieval of ALWT-1 and ALWT-2 with the remedial objective to retrieve only the liquid MLLW within the two tanks and disposition this waste appropriately. During the options evaluation the identified preferred disposition pathway for the recovered liquid was offsite processing as the CRL site has no readily available treatment process for this inventory onsite. If the inventory characteristics were favourable, thermal treatment was the preferred treatment process in order to provide a significant volume reduction of the liquid waste.

The concrete structure of the tank, sand pile and sludge within will remain buried until final disposal is available and detailed remediation of the waste management area is developed and implemented. As such the remedial design of ALWT-1 and ALWT-2 must ensure precipitation does not infiltrate the tanks during ongoing in-situ management of the remaining inventory.

REMEDIATION PROJECT DESCRIPTION

Through a commercial bid process, AECL contracted Perma-Fix Environmental to extract, package, transport and disposition the liquid waste from the ALWT-1 and ALWT-2. The project was to be performed in two phases that consisted of: the development of a Remedial Action Plan (RAP) to identify the requirements for performing on-site management of the liquid waste removal, and the implementation of the RAP by removal of the liquid waste in ALWT-1 and ALWT-2. The scope of the RAP was to identify the parameters for the liquid waste removal, identify the hazards and controls during waste retrieval and processing, satisfying all of AECL's internal Nuclear Safety and Compliance Programs, as well as identifying a defined end state for the remediation activities. The scope of the field work for the project included the design and construction of a mobile liquid waste processing system, design and installation of reinforcing lids on the ALWTs, installation of the extraction wells, deployment of the mobile processing enclosure, extraction, processing and packaging the liquid waste, transporting and treatment of the liquid waste.

Mobilization

Prior to operations at the CRL site, several activities were performed including, design and construction of a mobile waste processing facility, development of work control and waste management documents and obtaining approvals and training for US contractors to work at the CRL site.

The processing enclosure contained the pumps, valves, and piping to allow for the liquid waste extraction, waste filtration, chemical additions and packaging. The enclosure was maintained at a negative pressure using a HEPA filtration system and powered by a portable diesel generator. There were several constraints during the design of the processing enclosure including:

- As there is no existing infrastructure support in the vicinity of ALWT-1 and ALWT2, the processing enclosure must be self-sufficient and include all required temporary facilities and controls (i.e. temporary utilities, barriers and enclosures, and controls).
- Following any intrusion into the tank the top slab must be able to support all foreseen loads (i.e. cover soil and snow).
- All materials or equipment brought to CRL must also be compliant with the National Building Code of Canada with regards to fire or electrical safety [2].
- If the design of the process enclosure proposed to use any pressurized systems greater than 15 psig, it would require registration with the Technical Standards and Safety Authority in Ontario under CSA N285 [3].

Due to the radiological activity of the liquid waste, Type-A shipping containers were required for transporting the retrieved wastes. Based on the volume, it was decided to use 375-gallon Intermediate Bulk Containers (IBC) totes. These totes are double wall carbon steel and internationally certified for transporting liquids including passing a 30-foot drop test. AECL was responsible for applying for a Canadian export permit and licence for the retrieved waste to be shipped to US based Perma-Fix facilities, as well as the Canadian import licence to facilitate the return of the residue to AECL for long term management.

AECL's engineering change control process engaged applicable Nuclear Safety and Compliance Program to identify the relevant process required for the remediation activity. Required internal AECL approvals included: a waste management plan, an environmental evaluation matrix and a radiological work assessment. An independent safety assessment was also performed following a hazards and operability (HAZOP) evaluation of the detailed design. The work plan prepared by Perma-Fix identified the detailed work activities along with applicable procedures and/or checklists for the operation of the equipment.

Implementation

The on-site operations were performed in five basic activities, installation of new reinforcing lids on the ALWTs, installation of the extraction wells and installation, operations of the process enclosure, waste transportation and demobilization. The first two activities were performed to prepare the ALWTs for liquid waste extraction. The third activity was the actual retrieval of the liquid waste from the ALWT and processing the waste for off-site transport. Finally, the liquid waste was transported to the pre-determined RCRA permitted facility, the DSSI facility in Tennessee, and the equipment was demobilized from the CRL site.

ALWT Lid Installation

The data obtained from the historical records, and assessed against National Building Code of Canada requirements, indicated that the ALWT lids would not support the weight of the cover soil plus the design snow load for the area. Therefore, the lids would require reinforcement prior to beginning the liquid waste extraction. New lids were designed to meet the loading requirements and preparations were made to install the lids. Each tank was excavated to expose the original lid and a riser was installed on the existing lid to allow for access after the new lids were fabricated in-situ and the excavation was backfilled. The rebar was then installed and the concrete was poured using a fast set recipe to allow for obtaining adequate strength for backfilling within three days. Fig. 3 illustrates the installation of both the risers and rebar on ALWT-1 prior to the concrete pour.

Fig.3 The installed risers and rebar on ALWT-1 prior to the concrete pour to provide adequate reinforcing of the tank lid.

The next step was well installation. The drilling company used a carbide cutter bit to cut through the original lid and then an auger bit was used to drill to the bottom of the tank. With the drilling complete, a fifteen-foot long, six-inch diameter standpipe was pushed to the bottom of the tank. The standpipe was designed with a screened section at the bottom to allow liquid waste flow into the pipe and keep the sand out. As shown in Fig. 4, extraction pipes were placed inside the standpipe for transferring the liquid waste from the tank to the process enclosure.

Fig.4. A view down the riser of ALWT-2 showing the extraction pipes installed within the standpipe.

Waste Extraction and Processing

The modifications to tank lids and installation of the standpipes were performed consecutively such that the subcontractors (e.g. drillers) only had to be mobilized once. However the bulk removal and processing for ALWT-1 and ALWT-2 happened sequentially. The retrieval and processing of ALWT-1 occurred first as the radioactivity of the inventory is less significant but the complexity of the retrieval was assumed to be more challenging due to the soil fill level in the tank.

The process enclosure was deployed to the CRL site and placed adjacent to ALWT-1, as shown in Fig. 5. A formal start-up process was performed to ensure that the system worked as designed and that no damage occurred during transport from Tennessee. The processing activities included liquid waste extraction, pH adjustment, internal tank transfer, a second pH adjustment, sampling and finally transfer to the 375-gallon (1,420 litres) totes. The bulk extraction, processing and packaging was completed in approximately one week. At this point, the process enclosure was relocated to ALWT-2 and the liquid waste "sipping" began on ALWT-1. The sipping process was retrieval of the final few inches of free liquid from the bottom of the tank. The sipping activities were performed using a small peristaltic pump connected to a 3/8-inch extraction pipe. The liquid waste was pumped into a 55-gallon (208 liters) drum and then transferred into the process enclosure for processing and packaging. The sipping operations were performed until the end state criteria, <100 litres (26-gallons) of liquid waste, obtained in a five-day period, was achieved.

Fig.5 The process enclosure staged beside ALWT-1.

Process Enclosure Operations

As seen in Fig. 6 the process enclosure had a series of pumps, tanks, valves, filters and instrumentation used to prepare the liquid waste for packaging and off-site treatment. The liquid waste was extracted using a high volume peristaltic pump and transferred through a 50 micron filter to the first one thousand gallon holding tank. The liquid waste was processed in batches of 650-gallons (2,460 litres). After this level was reached, the pH was raised to between 9 and 12 using triethanolamine and then the waste was transferred to the second holding tank through a 10 micron filter. At this point, a second adjustment was made to bring the pH down to between 5 and 7 using acetic acid. These pH adjustments were performed to provide a consistent and neutral waste form and to ensure the Total Organic Carbon (TOC) levels were appropriate for the waste treatment requirements. The chemicals were added using a metering pump that injected the chemicals into a static mixer as the tank contents were being recirculated. An in-line pH meter was used to determine when the appropriate levels were reached. When the pH adjustment was completed, samples were taken and sent to the DSSI facility for analysis. This analytical data was used to verify the preliminary data obtained during the intrusive characterization sampling events and to prepare the shipping papers for waste transport.

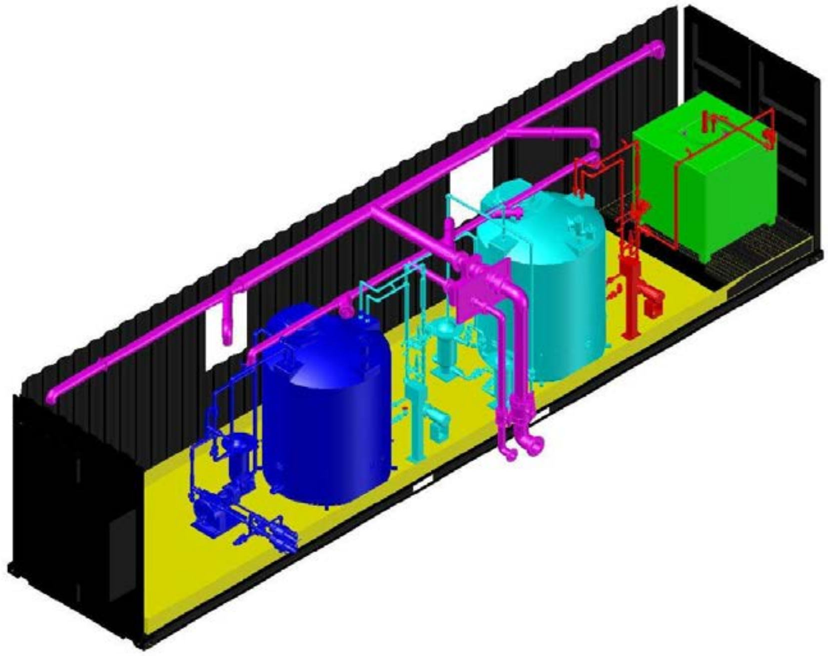

Fig.6 The internals of the process enclosure.

The final step was to transfer the liquid waste from holding tank two to the 375-gallon (1,420 litres) Type A totes. During the filling operations the following connections were made; the tote fill line was connected to the tote inlet, the tote vent was connected to the HEPA exhaust and a high level switch was installed in the tote lid. During filling operations, the control panel was set to transfer 325-gallons (1,230 litres) of waste and after this quantity was transferred, the transfer pump would de-energize and solenoid isolation valve would shut. If the automatic controls failed, the level switch would secure the transfer at 340 gallons (1,287 litres). The final fail-safe to prevent over filling a tote was a manual emergency stop switch.

Additional maintenance activities included routine bag filter change-out and periodic component replacement. The sludge and sand that was extracted during waste extraction was captured in the bag filters and required changing based on high pump discharge pressure or high filter differential pressure. The change out activities required additional PPE due to the potential for personnel contamination and radioactive material releases. There were approximately 30 filter change-outs performed with no incidents. After each change-out, the containment trays were wiped out and radiological surveys were performed to ensure that there was no loose contamination in the enclosure.

The reliability of the system components was excellent. However, due to the sand in the liquid waste, one flow meter failed. There was also an electronic failure that occurred on one of the tote level switches. These components were replaced and there was no effect the work schedule or the overall performance of the system.

Off-site Waste Management Facility Operations

The liquid waste was shipped to the Perma-Fix DSSI facility for thermal treatment (as shown in Fig. 7). A total of 3,117-gallons (11,800 litres) of liquid waste was shipped for treatment. The waste was batched and mixed with diesel to create and combustible mixture. The residual ash resulting from the thermal treatment was packaged and returned to the CRL site for long term storage.

The Dry Active Waste (DAW) and the process enclosure were shipped to the Perma-Fix Northwest facility for thermal treatment and decontamination. The process enclosure piping, valves and filters were constructed from plastic materials and were removed and incinerated. The remaining metal components that came in contact with the waste were decontaminated and released for recycle. The ash resulting from the thermal treatment was also packaged and returned to the CRL site for long term storage. The process enclosure structure was verified to be not contaminated and stored for use on future projects.

Fig.7 Loading of transport packages for off-site shipment.

Follow-up Monitoring

Following the demobilization activities, a final radiological survey was conducted, which included all areas impacted by the activities involved in the remediation project. At the time of the final survey, the general area reported background levels. It was highlighted in the remedial options evaluation that maintaining monitoring and sipping capabilities provides greater flexibility with regard to managing the ALWTs long term. Thus as part of the design requirements AECL required that the standpipes installed for accessing the tanks remain in-situ. The standpipes were designed such to restrict ingress of precipitation. At one year after the original liquid extraction activities, the tanks will again be 'sipped' to determine if substantial accumulation of free liquids has occurred.

DISCUSSION

In order to work at the CRL site, each contractor had to pass an AECL background investigation, complete the mandatory onsite safety training and obtain a Work Permit from the Canadian Customs and Immigration Office. These processes can be long-lead activities and should be planned well in advance. One of the difficulties with obtain the work permits was different immigration officials had different interpretations of the laws. This was an inconvenience but did not affect the project schedule. The scenario that caused the difficulty was the requirement for a Labor Market Opinion (LMO) if you are being hired by a Canadian company. Perma-Fix was working under contract for AECL and the operations personnel were not AECL employees. The solution turned out to be a North American Free Trade Agreement (NAFTA) exemption that allowed a work permit to be issued for personnel working under contract that had a specific skill not readily available in Canada or for the Benefit of Canada.

Remediation of historic waste burials often reveals unanticipated situations or configurations which are difficult to plan for. Due to the thoroughness of previous characterization activities, there were few surprises during the remediation of ALWT-1 and ALWT-2. The two real-time discoveries experienced were both a direct result of the lack of engineer drawings for the two tanks. The first was during drilling activities on ALWT-2. It was realized that a full steel plate existed under the concrete lid of ALWT-2. This revelation resulted in longer than expected drilling times and caused frequent drill bit replacements. The other discovery was dimensional discrepancies for the lid dimensions on ALWT-1. Measurements taken during previous characterization activities on ALWT-1 had been less than accurate. Upon this discovery field changes were necessary in order to modify the new lid design to suit the actual conditions. Due to the responsiveness of Perma-Fix and their subcontractors, there was little impact to the project schedule because of this discrepancy.

Although the configuration of ALWT-1 and ALWT-2 posed some significant retrieval challenges, the process enclosure design was very close to actual performance and operating requirements. The exception was the design of the bag filters. The original design required removal of the entire filter housing in order to change out the bag filter. Very early into the operations it was obvious this was not feasible due to the build-up of sand around the top of the filter housing causing it to become lodged in place. The operation was modified to leave the housing in place and remove only the bag filter. This serendipitously reduced the time required to perform this activity thus reducing the overall radiological exposure of personnel. On the other hand, operational experience also identified the significant delay time for the absorbent used in the bag filters to activate. This had the potential to prolong exposure of any contamination within the filter housings to the rest of the inside of the processing skid or personnel in the area.

The largest uncertainty preceding the remediation of the ALWT-1 and ALWT-2 was the total volume of liquid that would be recoverable. The amount of liquids that is to be ultimately recovered from the tanks is governed by both the sand and liquid characteristics. The most probable recoverable liquid volume calculated, 3675-gallons (i.e. 13,900 litres) was based on tank dimensions reported from previous characterization activities, an interstitial sand void of 40% and a conservative surface retention factor of 12%. The actual volume of retrieved liquid recovered for offsite disposition was 2830-gallons (i.e. 10,700 litres). To achieve a calculated recoverable volume of this amount, with no changes in dimensional assumptions, the actual void volume and surface retention would be 37% and 14% respectively. Additionally prior to extraction operations, the sand level on the southern half of ALWT-1 was assumed to be one half a meter below the lid. During the remediation activities the actual conditions included that the sand was present to the top of the tank. Additionally drilling several intact bottles and solidified chemical precipitates were observed which would also result in small discrepancies between the calculated and actual recoverable volumes as well.

During the remediation activities the entire project team demonstrated an outstanding nuclear safety culture. The precision and accuracy of the checklists/procedures prepared for the work and operation of the equipment resulted in exemplary procedural use and adherence. Also noticeable, due to the operation physical separation of field crew within the processing enclosure and those operating the controls panel on the exterior was the consistent use of 3-way communication.

CONCLUSION

Perma-Fix and their sub-contractors successfully developed and implemented a RAP to address the liquid MLLW contained in ALWT-1 and ALWT-2 at the CRL site. This project required facility modifications; innovative uses of existing technology and the design, engineering and construction of equipment to be used in a foreign country. The success of the project was defined by completing the extraction and disposition of the liquid waste from ALWT-1 and ALWT-2 with no adverse effects on health, safety or the environment.

Approximately 2,830-gallons (i.e. 10,700 litres) of liquid MLLW was retrieved from two legacy tanks. The liability that this inventory represents has been significantly reduced by offsite thermal treatment which both stabilizes and reduces the volume of the original waste stream. Completion of this project progress AECL's efforts to ensure this waste management area in a stable configuration and reduce the risk of leakage from these legacy burials.

REFERENCES

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