# STORED LIQUID WASTE REMEDIATION PROGRAM, PHASE 1, AT CHALK RIVER LABORATORIES

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## ABSTRACT

Liquid intermediate- and high-level radioactive wastes presently stored in 21 tanks at the Chalk River Laboratories are being retrieved, conditioned and consolidated into a new storage system. The Liquid Waste Transfer and Storage project is responsible for designing, constructing and commissioning the storage system, specifying and procuring retrieval and transfer equipment and developing operating, maintenance and training procedures and materials. The project has characterized the existing wastes and completed an inspection of the present storage tanks and vaults. The conceptual design has progressed to include a criticality safety assessment, a safeguards analysis, selection of retrieval and transfer technologies and conceptual design of the new storage system. The transfer and collection of wastes from these 21 tanks will be a step forward in the goal of achieving a long-term management solution for the wastes.

This paper provides an overview of the development of the conceptual design, including the new storage system, the retrieval system and the transfer systems, the laboratory program that supports the blending sequence and waste conditioning and the tank and vault inspection.

## INTRODUCTION

Atomic Energy of Canada Limited (AECL) is a Federal Crown Corporation charged with leading the development of peaceful applications of nuclear technology in Canada. AECL is headquartered in Mississauga, Ontario with research and development facilities located at the Chalk River Laboratories (CRL), approximately 300 kilometres northeast of Toronto. The CRL site includes the NRU research reactor, the MAPLE reactors for isotope production, and is the technology base for AECL’s reactor designs.

CRL was developed in the mid-1940s. It was home to the first sustained nuclear reaction outside the United States, the Zero Energy Experimental Pile (ZEEP) in September 1945. Over the past 50+ years, the CRL research, operation and isotope production activities have generated a substantial amount of liquid waste presently stored in the site’s waste management areas. These

Stored Liquid Wastes (SLW) are in 21 underground tanks, in two separate locations; some of the tanks date back to the 1950s (Figure 1). Several tanks are in a deteriorated condition and are therefore a health, safety and environmental (HSE) concern.


**Fig. 1. Chalk River SLW Storage Sites.**

The SLW are considered legacy wastes. Under the Canadian Government "Program Integrity Funding Allocation – Capital Rust Out," a one-time special appropriation to augment AECL's Decommissioning Fund, monies were provided to address the SLW. A phased approach was put forward and approved by management.

Phase 1 is to design, procure and construct large consolidation tanks in a shielded concrete vault at the Chalk River site (Figure 1) and to procure equipment to transfer the waste into the new tanks, where the waste would remain pending completion of Phase 2. The infrastructure will be turned over to an operations entity to perform the waste transfer and storage monitoring. The waste transfer from the current tanks into the new tanks will address immediate health, safety and environmental concerns relating to the stored liquid waste. The tanks to be built during Phase 1 will allow for safe storage of the liquid waste for a minimum period of 25 years and will reduce current annual monitoring costs relating to the current tanks.

Phase 2, comprising the design and construction of a processing facility to convert the liquid waste into a solid form and an interim dry storage facility for the solid waste product, will be implemented within the design life of the new storage system.

## PHASE 1. LIQUID WASTE TRANSFER & STORAGE CONCEPT

The Stored Liquid Wastes (SLW), presently in five storage locations with an inventory of approximately 300 $m^3$ of intermediate- and high-level wastes, are primarily the result of a diverse nuclear research and development program, operation of associated facilities and radioisotope production. The Liquid Waste Transfer & Storage (LWTS) Project, the initial phase to remediate the wastes, has three main objectives:

1. *Health, Safety and Environmental Risk Reduction*
   The consolidation of the wastes presently stored in tanks constructed before 1980, with several known to have defects, into a new storage system meeting current standards for design, construction and operations will provide a substantial HSE risk reduction.
2. *Regulatory Commitment*
   The CNSC has expressed concern over the storage of the SLW, and in particular, the storage of medical isotope production waste material. AECL has committed to the CNSC to treat/condition these wastes by 2010 to reduce the criticality safety constraints and monitoring requirements during storage.
3. *Operating Costs and Future Liabilities Minimization*
   The new storage system and the conditioning of the wastes will reduce monitoring, maintenance and surveillance activities, and will position the wastes for a long-term waste management solution.

The LWTS Project objectives will be met by completing the design, construction and cold commissioning of facilities to enable the retrieval and transfer of the wastes, the consolidation and storage of the wastes and the conditioning and storage of isotope production waste.

During the project development process, AECL has determined that new on-site facilities are required. A thorough evaluation of treatment technologies has identified vitrification as the best method for solidifying the collective SLW. Vitrification is consistent with present world practices dealing with high-level waste (HLW). AECL has previously demonstrated acceptable waste glass from these wastes. The consolidation and conditioning of the wastes into two new storage tanks, one intermediate-level and one high-level, will provide an appropriate feed for the solidification process.

### Phase 1 Concept Development

Concept development required that the project fully understand the nature of the wastes and their present surroundings, previous studies performed at CRL, and worldwide experience with similar wastes. Results of these investigations are presented below, as well as the conclusions and decisions taken to advance the concept.

**Waste Characteristics and Waste Conditioning**

The SLW main characteristics are shown in Table I. There are five major waste streams:

1. *Loop decontamination waste (LDW):* waste generated from the decontamination of test loops associated with research reactors; solvents include organic acids and permanganate solutions;
2. *Ion exchange regeneration waste (IXRW):* waste generated from regeneration of mixed bed ion exchange resins used to maintain water quality in spent fuel pools;
3. *Cobalt production waste (CPW):* waste arising from the aluminum de-cladding of Cobalt-60 targets in sodium hydroxide solution;
4. *Historic fuel reprocessing waste (HFRW):* waste generated from early (1950s) fuel reprocessing program experiments; and
5. *Isotope production wastes (IPW):* waste resulting from the dissolution of irradiated Molybdenum-99 targets in nitric acid and the Mo-99 extraction process.

**Table I. Waste Characteristics**

| Waste Description | Waste Type | Chemical Nature | Volume $m^3$ (est) | Maximum Activity Range B/γ (TBq) |
|---|---|---|---|---|
| LDW | ILLW* | Alkaline | 12 | 0.2 |
| IXRW | ILLW* | Alkaline and Acidic | 153 | 80 |
| CPW | ILLW* | Alkaline | 60 | 1 |
| HFRW | HLLW** | Acidic | 17 | 1000 |
| IPW | HLLW** | Acidic | 45 | 5000 |

*ILLW - intermediate-level liquid waste
**HLLW- high-level liquid waste

A thorough sampling and analysis program was undertaken to characterize both the liquid and solid wastes in the tanks. Both chemical and radiochemical analyses were performed on all wastes. This data was used to develop a blending and conditioning strategy for the consolidation of the waste.

The waste characterization data was also used to perform preliminary calculations and literature searches to evaluate the suitability of a glass matrix as a final waste form. The project's conclusion is that the wastes can be treated in a glass melter and that a glass, suitable for long-term storage and disposal, can be produced.

An extensive laboratory program was undertaken to evaluate various blending and conditioning strategies and to identify physical and chemical issues. Several blending strategies were evaluated based on waste type, waste chemistry, radionuclide content and pH. The proposed blending strategies were tested in a laboratory setting, first with surrogate solutions and then with actual waste. The laboratory program led the project to three important design considerations:

- High shear mixing is required during the intermediate-level waste consolidation.
- Acidic chemistry is preferable for consolidation and long-term storage to reduce the potential for precipitation.

- Heat rejection is required during consolidation of some wastes to remove heat of neutralization.

Further, the project concluded that separate storage tanks are required for intermediate- and high-level wastes based on:

- Only the high-level wastes are likely subject to IAEA safeguard measurements during storage.
- The high-level wastes contain 99% of the mercury inventory.
- The high-level wastes are more chemically compatible than a mixture of high- and intermediate-level waste.
- Conditioning of the fissile component of the high-level wastes is more easily accomplished.
- Blending of two waste streams during the solidification process is easily accomplished.

A major effort was carried out to determine the best option for dealing with the fissile waste. Our investigation of glasses containing uranium had shown that the US Department of Energy (DOE) had developed stable 6-10 wt% uranium formulations. Previous vitrification experiments at CRL have produced glasses with up to 30% uranium. The majority of the sodium is contained in the ILLW which is required to control viscosity during glass making, while the HLLW contains the bulk of the uranium, a glass former. Our calculations indicated that a blend of both, the maxi-blend approach, would generate a stable glass with less volume than vitrifying each separately. Analysis showed that the sodium content of the maxi-blend was driving the formulation and additional glass formers were required. This information provided input to the conditioning solution for the fissile waste.

The targets used in Molybdenum-99 production are irradiated for a relatively short period. A significant inventory of High Enrichment Uranium (HEU) remains in the radioactive waste stream. Recovery of the HEU material for reuse is possible but not economical. Downblending of the HEU with isotopic depleted uranium to Low Enrichment Uranium (LEU) was determined to be best practice to improve criticality safety margins.

The uranium added for downblending provides another source of glass formers. The depleted uranium, added to achieve the optimum glass waste volume when all wastes were blended, provides a final $U^{235}$ concentration of 1.4 wt%. Coincidentally, this concentration has been shown to be critically safe under all known storage conditions and allows conventional and commercial vitrification technology to be used to solidify the liquid wastes.

## Waste Retrieval and Transfer

The retrieval and transfer of the wastes requires three main steps: (1) accessing the tanks to permit retrieval equipment installation; (2) mobilizing and homogenizing the wastes, including sludges; and (3) transferring the waste to the new storage system.

The tanks are all subsurface; all but two in concrete vaults, some with overburden (Figure 2) and some with a roof structure over the vault. Tank access involves one or more of the following activities, depending on specific conditions and design features: removing soil/overburden or opening existing roof hatches, opening existing vault penetrations or creating (drilling) new penetrations, and opening existing tank penetrations or drilling new ones.

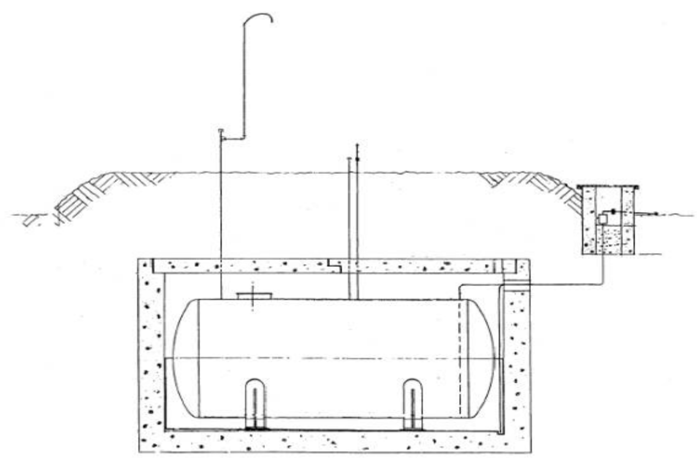

**Fig. 2. Typical CRL Buried Tank.**

To support the transfer activity and to develop a better understanding of the vault structures and tanks, a camera inspection program was undertaken[(a)]. A total of 16 tanks and 11 vaults were inspected to determine variations from as-built drawings, confirm liquid and sludge levels and characterize the sludge consistency/hardness. Some tank and vault configurations were found to be different from the available drawings; tank waste inventories were consistent with recorded data and the sludges, when present, were easily dispersed.

Retrieval of the waste from the existing storage tanks requires mobilization of sludges, where present. AECL has looked at international experience and best practices with similar structures and waste forms. Much of the review focused on DOE experience, in particular those sites having experienced similar challenges. The DOE has conducted a thorough evaluation of a large number of retrieval technologies. Many have been shown to be suitable for the type of wastes at CRL. One retrieval technology stood out as being particularly well suited for the retrieval of sludges known to be in some of the tanks. This is the skid-mounted pulse-jet system developed in both the United Kingdom and Russia [1,2].

The pulse-jet system uses an air-driven jet pump device to alternately remove and re-inject a portion of the waste from the tank, cycling in a "suck and blow" manner until the waste is homogenized. At that point, the system valves are positioned to allow the waste to be directed to a transfer system. An optional steerable nozzle is used to remove residual material.

Transfer of the waste will be performed in two ways. For those tanks in close proximity to the new storage system, a temporary pipeline will be used for transfer. The pipeline will have secondary confinement to contain any leaks. Shielding will be used where appropriate. Approximately 75% of the wastes will be transferred by pipeline directly to the WSS. The balance of waste, stored in a remote waste management area, will be transferred by truck in a shielded transport container. The container, consisting of an outer flask with an inner stainless steel liner, has a capacity for approximately 5 $m^3$ of waste. All waste transfers, except for the fissile waste, will enter the WSS through a receiving tank. The fissile material will be transferred directly into the appropriate storage tank containing an inventory of depleted uranium.

## Waste Storage

The WSS consolidates the SLW, presently in five locations into two waste storage tanks, one for HLLW and one for ILLW wastes. By consolidating the wastes into storage tanks designed to today's standards, with suitable sampling, retrieval and secondary confinement systems, the wastes are well positioned for further treatment in a solidification facility when the source of funds for the next phase is appropriated.

The storage system is comprised of an underground L-shaped vault containing the storage tanks, each anchored to bedrock, and a second underground rectangular vault containing the process tanks. An above-grade steel structure covers the vaults. The building has two operating levels. The lower level consists of a truck bay, a chemical storage area and the main entrance. The main level consists of the control room, the electrical room, the change room, the process room and the pump room. The main level is at the same level as the top of the vaults. Figure 3 provides an illustration of the facility.

**Fig. 3. Waste Storage System.**

The large vault houses two 350 $m^3$ tanks and one 200 $m^3$ tank. The smaller tank, the Slightly Enriched Uranium (SEU) Tank, will contain the HLLW, including the isotopically downblended IPW and the HFRW. One of the larger tanks, the Consolidation Tank, will be used to blend the remaining ILLW wastes (LDW, IXRW, CPW). The third tank will remain empty and is intended as a leak management tank.

The small vault contains two process tanks, the receiving tank and the holding tank. The vault is located under the process room. All wastes but one received at the WSS will enter through the receiving tank. The fissile waste will be added directly to the SEU Tank containing a heel of depleted uranium solution. The receiving tank will be used for sampling and pH conditioning. It will have high-sheer mixing capability. The holding tank will serve as a backup to the receiving tank and will also be used during pH adjustments. The process room allows access to the process tanks. The pump room will be shielded and accessible. All piping will have secondary containment.

The vaults, constructed of ordinary concrete, are lined with stainless steel to provide secondary confinement for the storage tanks and prevent concrete contamination. The vault roof is also concrete with removable sections to allow access to the tanks.

The WSS design incorporates the following design elements:

- Minimal moving parts in vaults and tanks;
- Materials selected to minimize damage by radiation;
- Risers in tanks to install and remove equipment;
- Shield plugs in vault roof for maintenance and inspection;
- Piping systems designed for drainage back to tanks;
- Flushing system to reduce radiation in pipes and tanks;
- Secondary confinement for all pipes and tanks;
- Low point leak detection;
- Spare tank available for leak management;
- Stainless steel vault liners;
- Leaks collected in liners are pumped to tank; and
- Leak overflow in process vault to main vault.

The WSS has an active ventilation system, including particulate and charcoal filters. The storage tanks will be ventilated. The truck bay consisting of a reinforced concrete pad will have a lightweight roof and a leak collection system. Tie-downs will be used to fix the trailer and flask to prevent movement during a seismic event. A PLC-based control system will allow the operator to control pumps and valves and monitor conditions. Remote monitoring will be installed.

A graphical overview of the various activities to be performed during tank access, retrieval, transfer and storage processes is presented in Figure 4.

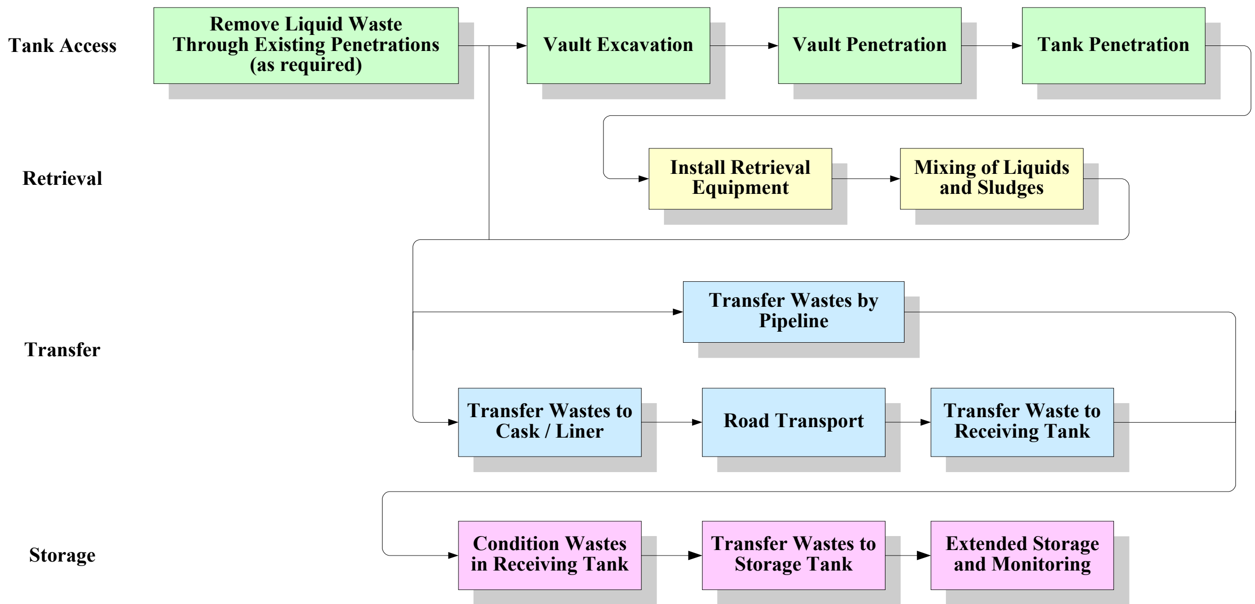


**Fig. 4. Tank Access, Retrieval, Transfer and Storage Processes.**

## PROJECT STATUS AND SCHEDULE

The WSS is expected to be operational in late 2008. Conceptual design is complete and specifications have been written to allow a design/build turnkey contract to be issued. A vendor will be selected in 2005 summer. Construction activities are expected to begin in 2006 spring. The waste retrieval and transfer operations are planned to begin in late spring or early summer 2009.

## SUMMARY

The Liquid Waste Transfer & Storage Project is one of the highest priority decommissioning-related activities at CRL because of health, safety and environmental risks associated with an aging storage tank complex and because of commitments made to the regulator related to wastes containing fissile material. This project is part of a long-term waste management solution for the Stored Liquid Wastes and is a step forward in minimizing the legacy liability that is passed on to future generations.

AECL has consulted extensively with others in developing the concept. In particular, experience with similar wastes and tanks within the DOE complex have identified proven methods and technologies to access, retrieve and transfer the wastes. The new storage system will ensure the wastes are stored safely in monitored tanks, as well as the future retrieval of the wastes to permit solidification.

The project has completed the conceptual design of the new facility and is presently issuing the Request for Proposal for a design-build work scope. The new facility will consolidate all SLW into two storage tanks, one for intermediate and one for high-level waste. This new tank system will be the feed system for a solidification process.

## REFERENCES

[1] AEA Fluidic Pulse Jet Mixer, DOE/EM-0447, Germantown, MD, US Department of Energy, Office of Science and Technology, 1999.
[2] Russian Pulsating Mixer Pump, DOE/EM-0622, Germantown, MD, US Department of Energy, Office of Science and Technology, 2002.

## FOOTNOTE

(a) Presented at WM'04 Poster Session, March 2004; P. Heeney, Atomic Energy of Canada Limited, In-Tank Inspections of Buried & Sub-surface HLW Tanks.