TANK WASTE RETRIEVAL ISSUES AND OPTIONS FOR THEIR RESOLUTION

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ABSTRACT

The U.S. Department of Energy has undertaken the significant challenge of remediating the high-level wastes currently being stored underground in tanks located at the Hanford Site in Washington State. A key element of the remediation process is the recovery of these defense production wastes in preparation for downstream processing and disposal. A number of technical and programmatic issues have been identified with the waste recovery process, referred to as retrieval. In response to these issues, a retrieval strategy was developed that addresses the need to meet legal obligations and balances the technology development needs. This strategy has been embodied into a retrieval plan, which looks at numerous retrieval system approaches and establishes a basis for development of the selected systems. The strategy and plan are evolutionary in approach, with the ability to change when waste properties are better understood, key decisions are negotiated, and lessons learned are available from initial retrieval efforts.

INTRODUCTION

This paper discusses the issues associated with and the options for retrieval of high-level radioactive wastes stored in underground single-shell tanks (SSTs) at the Hanford Site in Washington State. Wastes are also stored in other types of tanks constructed as double-shell tanks (DSTs). However, the retrieval of wastes from these tanks will not be discussed because the characteristics of these waste types are relatively well understood and there is a high level of confidence in the successful use of mixer pump technology for the retrieval of these waste types. On the other hand, recovery of wastes residing inside the SSTs presents a significant number of unknowns and the sheer number of tanks to be addressed poses a major challenge.

THE CHALLENGE

High-level radioactive waste has been produced at the Hanford Site since 1944 as a byproduct of processing spent nuclear fuel for the recovery of plutonium and uranium. Approximately 140 million L (37 million gal) of waste are stored in 149 SSTs. These underground storage tanks were constructed and placed in operation between 1943 and 1964. The SSTs are located in 12 tank farms. Each tank farm contains between 4 and 18 tanks and is located in the 200 West or 200 East Area of the Hanford Site. No wastes have been added to any of the SSTs since November 1980. A total of 67 SSTs are now known or suspected leakers. Pumpable interstitial liquid and supernate wastes have been removed from 105 SSTs and transferred to DSTs through a jet-pumping program. A total of 48 SSTs have been identified by the U.S. Department of Energy (DOE) as having potential for release of high-level waste due to uncontrolled increases in temperature or pressure. These tanks are designated as "Watch List" tanks by DOE.

The sides and bottoms of the tanks are reinforced concrete with a carbon-steel liner, which varies in thickness from 0.63 to 0.95 cm (1/4 to 3/8 in.). The domed top is 38.1-cm (15-in.)-thick reinforced concrete, with no steel liner. There are four tank sizes: 208,000-L (55,000-gal) tanks, which have a diameter of 6.1 m (20 ft) and a height of about 7.6 m (25 ft); 2.0 M-, 2.8 M-, and 3.8 M-liter (533,000-, 750,000- and 1,000,000-gal) tanks, which have diameters of 22.9 m (75 ft) and wall heights of about 5.5, 7.3, and 9.7 m (18, 24, and 32 ft), respectively. Figure 1 is a typical configuration of a 22.9-m (75-ft)-diameter SST. The tanks are buried 1.5 to 3.6 m (5 to 12 ft) underground to provide radiation shielding. The internal tank environment is complicated by internal tank structures (e.g., vertical pipes called risers and air lift circulators), hardware from previous processes (e.g., ion exchange resin), and the disposal of miscellaneous components and radioactive materials (e.g., 30.5-m [100-ft] steel tapes, concrete blocks, fuel elements, shroud tubes, and samarium "poison" balls).

The program to remove pumpable interstitial liquids and supernate waste was started in 1968. Removal of the liquid leaves two types of waste: a sludge-type waste, which varies in consistency from that of a thin paste to peanut butter, and a salt cake, which varies from a jelly form to a hard material like weak concrete. These wastes have a high pH (approximately 12) and consist primarily of sodium hydroxide; sodium salts of nitrate, nitrite, carbonate, aluminate, and phosphate; and hydrous oxides of iron and manganese. The radioactive components consist primarily of fission product radionuclides, such as ^{90}Sr and ^{137}Cs, and small quantities of actinide elements, such as uranium, plutonium, and americium. A representative interior view of one SST is shown in Fig. 2.

The challenge that lies ahead for DOE is to retrieve the wastes from all 149 SSTs as part of an overall program that will recover, treat, and dispose of all wastes currently residing in underground storage tanks.

ISSUES ASSOCIATED WITH RETRIEVAL

The development of systems for waste retrieval from the SSTs is proceeding in an effort to support the process of waste remediation, to expedite the resolution of safety concerns related to the continued storage of high-level wastes, and to meet legal commitments to the Washington State Department of Ecology and the U.S. Environmental Protection Agency in the "Hanford Federal Facility Agreement and Consent Order" (Tri-Party Agreement) (1). However, numerous issues exist that will impact the selection of specific retrieval approaches. Some significant issues affecting retrieval and requiring

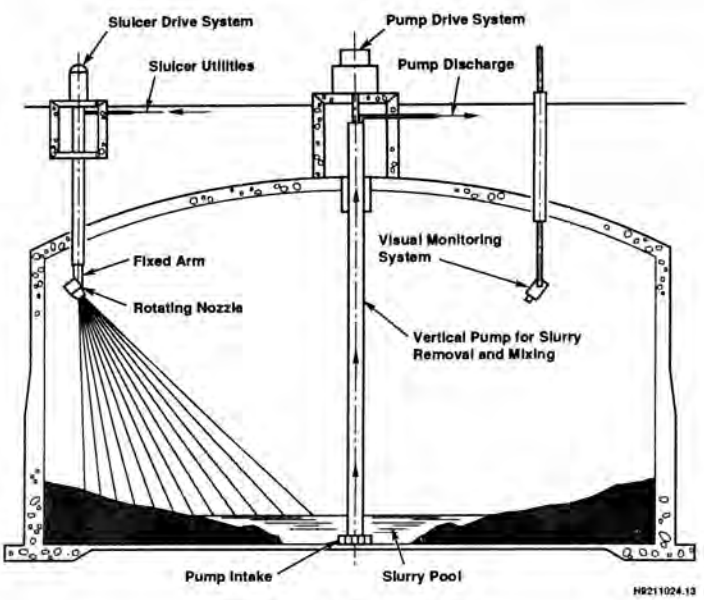

Fig. 1. Single-shell tank.

Fig. 2. Interior of Tank B-105.

resolution prior to retrieval system implementation are listed below.

- The current baseline is to retrieve the wastes from all 149 SSTs. At the *current time*, a significant number of tanks are not well characterized. This may result in a requirement for different retrieval systems to retrieve different waste types or enough flexibility in a single system to handle a variety of waste types. Technology development activities must remain broad in order to include flexibility to retrieve difficult waste types and must also account for tank conditions (i.e., tank configuration, structural integrity).
- The schedule for the development of retrieval systems with the capability to successfully recover SST wastes in compliance with environmental regulations is aggressive. Some yet-to-be-developed elements of retrieval systems may have to be pursued at a higher risk to support the current schedule.
- Uncertainty exists over the application of the environmental regulations to retrieval and the potential impacts that could result. The interpretation of the regulations are an important basis for the requirements to which the retrieval system must be designed.
- Safety issues associated with "Watch List" underground tanks at the Hanford Site are being addressed through other ongoing programs. Activities associated with the resolution of these safety issues could affect planned retrieval efforts (i.e., tank retrieval sequence, water removal, in-tank hardware additions).
- Closure planning (which includes definition of what constitutes an acceptable tank cleanout) must be developed prior to pursuing waste retrieval efforts. Closure criteria will establish the performance requirements of retrieval systems.
- The costs associated with retrieval of wastes are substantial, and alternatives must be identified and developed in a manner to establish a cost-conscious retrieval program.
- Acceptable risk to the environment during waste recovery operations is another uncertainty. Without resolution to this uncertainty, the design criteria for the development of retrieval systems may be overly conservative. Examples include the need to employ double confinement systems to monitor leakage during waste recovery operations. Conservative design requirements lead to extended design and development programs, which conflict with a need to meet an aggressive schedule.

Until the issues, as typified above, are resolved, assumptions will be established to provide a basis for the technical and performance requirements, which, in turn, will allow the design and technology development process to proceed.

THE RETRIEVAL STRATEGY

The interim resolution of the issues discussed above are embodied into a retrieval strategy. This strategy, whose development began during a national retrieval workshop of technical experts from across the country, forms the basis for evaluating the options for the retrieval of wastes from the SSTs. The strategy addresses the need to resolve tank safety issues, complies with regulations and regulatory commitments, proceeds with Hanford Site waste disposal objectives, and works within the constraints of available tank space. These drivers interact and will change over time as safety issues are resolved; new storage tank space becomes available through waste management, waste disposal, and new tank construction; and decisions are made on waste treatment processes. This strategy is being implemented as the Hanford Site SST waste retrieval strategy and includes the following key elements.

- Start with known technology to resolve near-term drivers (tank safety, Tri-Party Agreement commitments, etc.).

- Continue with technology development to enhance the capabilities of current technologies and to bring on line technologies that improve personnel safety and environmental safeguards performance and/or cost effectiveness of waste retrieval systems.
- Implement enhanced technologies as they become available, if they provide significant improvements, over the systems currently being used or being developed.
- Continue with the development of more advanced concepts and implement these concepts, if they represent significant improvements, over systems currently being used or being developed.
- Continue evaluation and validation of the strategy and adjust as necessary.

The retrieval strategy includes the development of multiple technologies to achieve a high probability for successfully completing the retrieval mission. The multiple technology approach is required to address the great diversity of waste types, tank geometries, tank safety issues, and environmental concerns over retrieval of waste from leaking tanks. The strategy will also incorporate the lessons learned from early retrieval campaigns through implementation of advanced systems in later retrieval actions (SST retrieval is anticipated to require 20 to 30 years to complete).

DEVELOPMENT OF THE RETRIEVAL OPTIONS

To understand the potential options for waste retrieval from the SSTs, the retrieval process must be broken down into the major functions. These functions are the bases for the identification and evaluation of the potential technology solutions to fulfill these functions. Finally, a recommendation on the technologies and/or systems to be used must be completed.

RETRIEVAL FUNCTIONS

The task of retrieval is broken down into a series of subtasks or functions necessary to removing waste from underground storage tanks. Figure 3 encompass the functions that must be accomplished, in some form, for any retrieval system concept. These functions are laid out in a fashion that illustrates the sequence and the relative duration over which these functions would be needed.

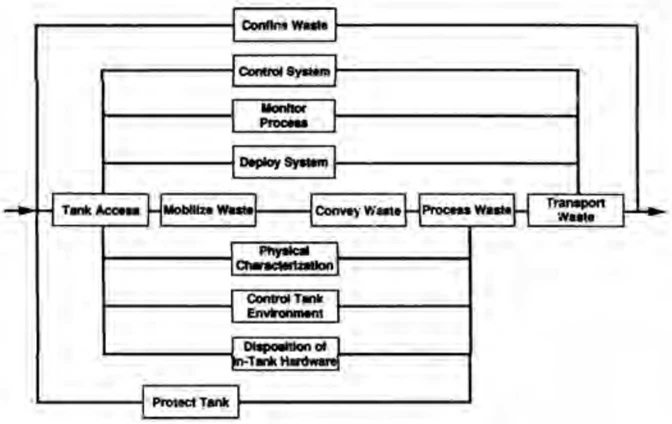

Fig. 3. Retrieval functions.

- Tank Access--Access to the tank for the retrieval equipment will be through the existing tank risers or through new risers that will be installed in the tanks.
- Mobilize Waste--All retrieval concepts require the waste to be broken up and separated from the main body prior to removal from the tank. Example processes include pulverization, water cutting, pneumatic cutting, etc.
- Protect Tank--During the retrieval process, the integrity of the tank must be protected from overstresses, thermal stresses, and chemical damage.
- Confine Waste--The waste must be excluded from the environment during retrieval, preparation for transport, and transport to pretreatment or storage.
- Control System--During initial setup and retrieval operations, control systems are required to perform the retrieval functions.
- Monitor Process--Monitoring of the retrieval process is necessary to provide input to the system controls, ensure the safe operation of the system, allow operator interaction, and prevent damage to the tank and/or retrieval equipment.
- Deploy System--All retrieval systems require some method to install, remove, and/or move the retrieval equipment inside the SST.
- Physical Characterization--The recovery of wastes from the SSTs requires knowledge of their physical and chemical properties.
- Control Tank Environment--The tank environment must be controlled during the retrieval operations.
- Disposition of In-Tank Hardware--In-tank hardware refers to any of a number of components installed in the tank, such as air lift circulators or thermocouple trees or components thrown into the tank for disposal (e.g., measuring tapes).
- Convey Waste--A primary function of waste retrieval is the process of moving the wastes from inside the tank to outside the tank.
- Process Waste--To be able to transport the waste to downstream processes, the waste must be processed by mixing, slurrying, de-lumping, dissolving, or diluting.
- Transport Waste- Once retrieved, the waste must be moved to the downstream process location.

TECHNOLOGY EVALUATION PROCESS

The process of evaluating technologies and systems applicable to the retrieval of wastes from SSTs has spanned several decades. Most recently, a series of systematic engineering studies (2) and national technology working groups identified and examined the technologies applicable to the retrieval process and then recommended specific approaches. Based on these studies, component screening and feature tests were conducted in fiscal year 1990.

In the second phase of the evaluation and selection process, engineering teams were identified to develop and select SST retrieval system concepts. The concepts incorporated the technologies previously identified. These concepts were developed to a point where the physical arrangements of the concepts were defined, issues were identified, and solutions were developed.

The results from the work completed above were reviewed as part of a "clean sheet" evaluation by a national working group, with members including other national laboratories, private consultants, and government agencies (e.g., the Bureau of Mines). This national working group, in a series of meetings conducted over the course of a year, defined the retrieval functions (discussed previously), identified constraints and requirements, identified potential technologies applicable to the specific retrieval functions, and recommended system concepts.

Currently, the long-range plans for retrieval are being updated to include the recommendations from the efforts described above and to outline future activities that identify and evaluate new potential solutions. This long-range plan is the basis for implementing developing retrieval systems.

SYSTEM APPROACHES

A number of system approaches or concepts were identified both in the studies and in the retrieval workshops. The approaches identified span a wide range:

- Hydraulic-based systems--These systems use low- to high-pressure water jets to dislodge or mobilize the wastes, which are subsequently removed by traditional pumping methods. Many of the systems in this grouping rely on proven approaches that have been employed in the past for similar applications. Aside from concerns over the addition/control of water during retrieval operations and limitations in the recovery of some waste forms, this type of technology was considered to be the most mature and the most promising for recovery of selected waste types. Past-practice sluicing, as used on SSTs at the Hanford Site since the 1960's, is an example of this type of system (refer to Fig. 4).
- Traditional mechanical mining approaches--Mining systems have been used for many years to recover salt, coal, etc., from underground mines. The systems that have been considered are adaptations from this type of technology. Continuous mining systems, such as long- wall miners, and batch mining systems were examined and later dropped from further consideration. In general, these types of systems were judged to be difficult to maintain in hazardous environments, lacked the flexibility needed to operate within a tank environment, and might present considerable challenges to maintaining worker and environmental safety.
- Pumping technologies--Pumping systems used to mobilize and mix wastes within the tanks were examined for applicability for retrieval of wastes from SSTs. This type of technology uses water jets placed within the waste to mobilize and mix the waste in preparation for removal. The mixer pump systems currently being employed by DOE, at Savannah River and West Valley, are examples of the technology being considered. A concern over the structural integrity of the tanks and uncertainty associated with the ability of pumping systems to mobilize many of the SST wastes forms caused this technology to rank low for future consideration.
- Manipulator-based approaches--Long-reach manipulator systems used to deploy specialized end effectors are the basis for this approach (refer to Fig. 5). The range of options span from using human operators to plan and execute all recovery of wastes, to using computer systems to implement automated recovery operations. Though this approach suffers from greater complexity when compared to other concepts, it is also one of the most flexible in being able to address concerns with protection of the tank, ability to recover a wide variety of waste types, and protection of the worker and the environment.

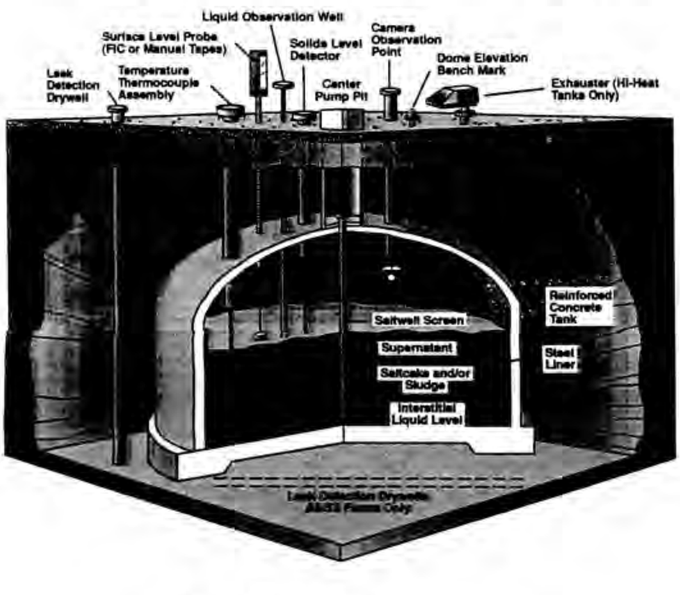

Fig. 4. Past-practice sluicing.

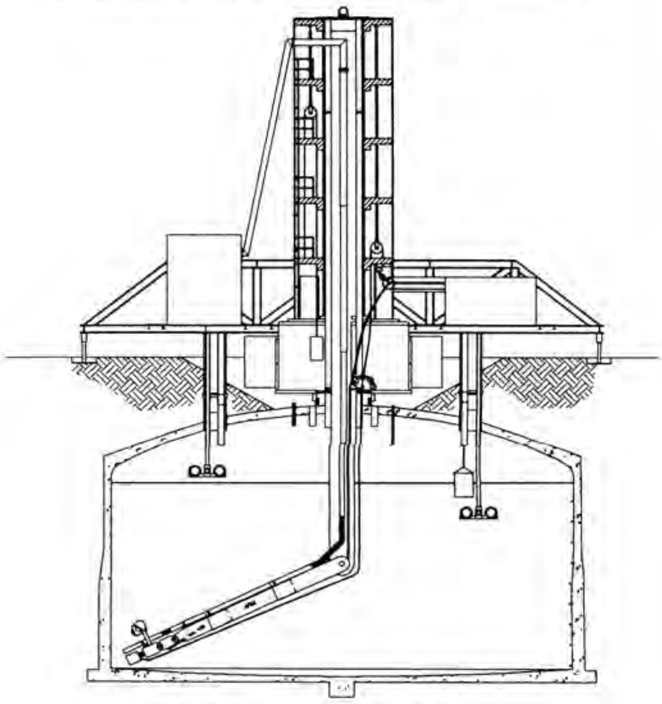

Fig. 5. Arm based concept.

- Self-powered devices--Self-powered devices, such as crawlers, walkers, etc., are largely self-contained units that have the ability to move to the waste recovery location and deploy waste recovery equipment. Many of these types of devices were developed to operate in extremely hazardous environments, such as undersea and on other planets. All of these systems rely on the ability of the surface on which they are traveling to provide adequate support, which may not be the case with the wastes within the SSTs. It has been pointed out that although the waste surface may be structurally sound in many areas, in instances, pockets of sludge or liquid may exist just under the hard surface layer. A self-supporting system will have difficulties reliably moving about inside the tank.

In the realm of radically different approaches, self-sealing gels, waste vaporization, localized melting, and in situ vitrification were identified as potential concepts. In general, these types of approaches exist as extremely speculative concepts and will require considerable development before their strengths and weaknesses are actually understood. The concept of the self-sealing gel, by example, is based on the principle of using chemical additives that mix with the waste. Once mixed, the waste will form a gel when no physical energy is being added to the waste, such as agitation by pumping. This gel will tend to seal leak paths to the outside of the tank. If this approach proves viable, a significantly simpler and more cost-effective SST retrieval concept might use the sealing gel in conjunction with a mixer pump to recover wastes from the SSTs. However, at this point, little is known about the behavior and properties of the gel in combination with the wastes or about the behavior of the mixture in the presence of a radiation field. Considerable analysis and testing will be required before it can be determined that this is a viable technology to be used for waste retrieval. The example of sealing gel is typical of most of these advanced concepts; they appear promising, but not enough is known about them to make a decision to adopt them as part of a retrieval baseline.

THE PLAN FOR RETRIEVAL

The system concepts discussed above are grouped into three categories of technology development, based on the level of understanding associated with the technologies. This categorization is in concert with the implementation of the retrieval strategy discussed earlier.

The best understood system concepts are grouped into the reference technologies category. Past-practice sluicing and arm-based systems are placed in this category. Concepts that improve and/or build on these reference concepts are designated as enhanced concepts. Finally, concepts that represent totally different retrieval approaches that might even simplify downstream processing systems are grouped into the classification referred to as alternative concepts.

The retrieval plan is based on the development and implementation of the two reference retrieval approaches: past-practice sluicing and arm-based retrieval. The reference systems will be deployed to recover the wastes from the first hot demonstration tank spelled out by Tri-Party Agreement milestones. The lessons learned from this hot demonstration will be factored into the design of the enhanced systems, which will be deployed as needed to recover wastes from other SSTs. In parallel with these activities, the alternative technologies will be selectively developed and evaluated to determine if they hold sufficient promise to replace any of the reference or enhanced system approaches. For an enhanced or alternative technology to replace another approach, it must be able to demonstrate that it is significantly more cost effective, reduces environmental or safety risk, and/or provides schedule incentive.

CONCLUSIONS

In developing the waste retrieval strategy and plan, a comprehensive process was used to ensure that technologies applicable to retrieval were identified and evaluated. Engineering studies ranging back to the 1960's were examined, new studies were completed, and a series of national workshops was conducted to capture the viable concept ideas. Within this body of investigation, a common conclusion was found; past-practice sluicing was recommended if environmental protection constraints are satisfied or if solutions are found to address the constraints. Arm-based systems, in conjunction with specialized end effectors and conveyance systems, were identified as the best backup to sluicing in meeting the known requirements associated with retrieval.

Though many outstanding issues remain to be resolved within and outside of the retrieval program, a flexible strategy and plan have been established to allow retrieval to proceed with the development of technically viable systems. This is an evolutionary approach, which has the ability to change when waste properties are better understood, key decisions are negotiated, and lessons learned are available from initial retrieval efforts. The continuing search for and the development of improved methods of waste recovery offer the vehicle for uncovering and successfully developing system approaches that can do the job faster, better, safer, and cheaper.

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