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First Generation Long-Reach Manipulator for Retrieval of Waste from Hanford Single-Shell Tanks

P. W. Gibbons
L. B. McDaniel

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FIRST GENERATION LONG-REACH MANIPULATOR FOR RETRIEVAL OF WASTE FROM HANFORD SINGLE-SHELL TANKS

P. W. Gibbons
Westinghouse Hanford Company
P. O. Box 1970, S4-58
Richland, WA 99352
(509) 372-0095

L. B. McDaniel
Westinghouse Hanford Company
P. O. Box 1970, S6-12
Richland, WA 99352
(509)372-0305

ABSTRACT

The U.S. Department of Energy, Richland Operations Office, has established the Tank Waste Remediation System to resolve environmental and safety issues related to underground waste-storage tanks at the Hanford Site. The Tank Waste Remediation System has identified the use of an advanced-technology, long-reach manipulator system as a low-water-addition retrieval alternative to past-practice sluicing.

INTRODUCTION

The U.S. Department of Energy, Richland Operations Office, has established the Tank Waste Remediation System to resolve environmental and safety issues related to underground waste-storage tanks at the Hanford Site. Retrieval of the waste from single-shell tanks (SSTs) is a key part of the Tank Waste Remediation System's strategy for resolving underground storage tank issues by transferring waste from aging SSTs into sound double-shell tanks for temporary storage pending final treatment for disposal. The strategy for attaining a viable retrieval system is rigorous study followed by feasibility testing, a hot demonstration, and finally production.

The Tank Waste Remediation System has identified the use of an advanced-technology, long-reach manipulator system (see Figure 1) as a low-water-addition alternative to past-practice sluicing, the baseline SST retrieval system. Past-practice sluicing was used in the 1950's and 1960's to remove waste from SSTs as part of routine Site operations. It is a simple process in which a stream of water, similar to the stream from a fire hose, is directed onto the waste surface, breaking the waste into a slurry. The slurry is then pumped out of the tank. This method generates about one-third meter of liquid slurry on the top surface, water which could increase the tank's leakage potential. Historically, sluicing has been less effective in tanks with interior obstructions that prevent the jet from reaching some areas. A long-reach manipulator is a mechanical deployment system mounted above the tank that reaches down into the tank to position waste retrieval tools. These tools are used to break up the waste and convey it out of the tank. This versatile technology allows deployment of retrieval tools (end effectors) that are matched to conditions in each tank and that can be changed if new conditions are identified. In tanks of questionable structural integrity, tools can be used that satisfy safety requirements without affecting the tank's leakage potential; for example, they can be used to immediately recover any water used to dislodge waste.

LONG-REACH MANIPULATOR SELECTION

The long-reach manipulator was chosen as an alternative retrieval system after an extensive review of prospective alternatives to past-practice sluicing, conducted over several years. A wide variety of options were considered, from large-scale commercial mining equipment to small, in-tank, mobile platforms. Waste mobilization techniques from simple mechanical digging to exotic high-energy laser ablation were looked at. The criteria for the selection were as follows.

- The system must be suitable for retrieval of waste from any of the large SSTs.
- The tank's integrity after retrieval must be sufficient to confine any remaining waste (based on the

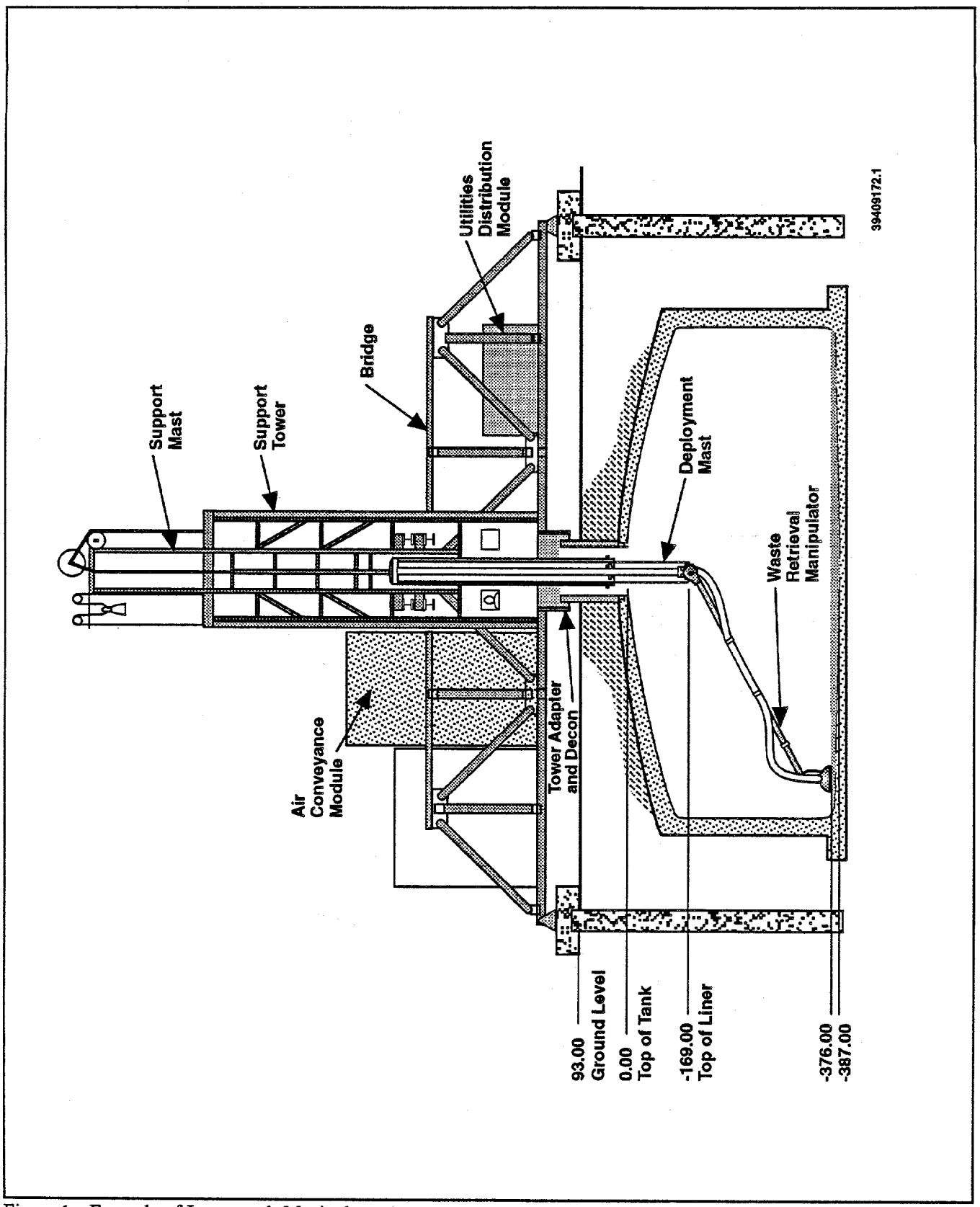

Figure 1. Example of Long-reach Manipulator Arrangement.

assumption that the tank and some residual waste will remain in the ground as part of a landfill closure).

- The technology must be sufficiently mature that a technology break-through would not be needed for a successful program.

- The system must be adaptable to changing retrieval requirements and to handling unknown tank conditions, as the final closure requirements are not defined and the tank contents are not 100% known.

A series of engineering decision analyses[1,2,3,4] were conducted to select the most viable retrieval alternative to past-practice sluicing. The three finalists were long-reach manipulator waste-retrieval systems capable of using a nominally sized 1.1-m (42-in.) center riser, an enlarged center riser, and a bridge-mounted excavator mounted over a tank with the dome removed and a temporary enclosure to provide confinement.[5] Further evaluation showed that the radiation and contamination problems within the confinement structure would cause excessive exposure of the personnel operating and maintaining the open-dome system. Hence, the large manipulator using either the 1.1-m or the enlarged riser was found to be the most feasible and most likely to succeed.

DESIGN DEVELOPMENT STRATEGY

In the process of developing the functions and requirements for the manipulator system, several feasibility studies were conducted to verify that certain activities were within reach and would not require a technological breakthrough. For example, the U.S. Department of Energy Office of Technology Development conducted a large manipulator test[6] in which a large industrial arm was combined with a smaller dexterous arm and a selection of tools to show that such an integrated system was both feasible and controllable. Testing was also done by the Underground Storage Tank Integrated Demonstration program with a high-pressure water-jet scarifier that showed a waste-dislodging rate consistent with the overall retrieval schedule.[7]

The development of the final technology configuration will be accomplished by the selected equipment vendor. A procurement specification, based on the functions and requirements, provides a description of the information in sufficient detail to ensure that the legal requirements and Site interfaces are clear while not presupposing a configuration or arrangement. Thus the full creative ability of industry can be brought to bear on the solution.

SST RETRIEVAL SYSTEM DEMONSTRATIONS

The SST waste retrieval program within the Tank Waste Retrieval System includes hot retrieval demonstrations of both past-practice sluicing and long-reach manipulator-based retrieval to validate those technologies for use in retrieval of waste in the remaining SSTs. Demonstration of SST retrieval technology is required by the Hanford Federal Facility Agreement and Consent Order,[8] known as the Tri-Party Agreement. This milestone requires the removal of at least 99% of the radioactive chemical-waste inventory (based on the average waste volume in all 133 of the 22.8-m- [75-ft-] diameter SSTs). Tank 241-C-106 has been selected for demonstration of both technologies.

Tank C-106 is a 1.9-ML (500,000-gal) concrete tank with a steel liner at the sides and bottom. It is the only remaining Hanford Site SST that requires water addition for waste cooling. The tank has a useable depth of approximately 5 m (16 ft) at the side walls. The tank currently contains 1.5 m (5 ft) of soft, heat-generating sludge on top of 0.6 m (2 ft) of hard sludge. The hard sludge is believed to have the consistency of chalk. The tank is relatively unencumbered by dome-mounted in-tank hardware (ITH) (e.g., pumps, thermocouple trees), having only a few such items near the edge of the tank. It does, however, contain loose ITH consisting of pump parts and pipe sections laying in the waste and is expected to also contain stones and stainless steel measuring tapes as additional ITH that may interfere with retrieval tools.

Retrieval of the soft, high-heat sludge from C-106 is scheduled to be accomplished by past-practice sluicing. Sluicing is a logical choice for C-106 as it is a wet tank, requiring regular water additions for evaporative cooling of the sludge. Unlike most Hanford SSTs, this tank cannot be dried out until the heat-generating sludge is removed. It is anticipated that the long-reach manipulator-based retrieval system will retrieve the hard sludge layer at the bottom of Tank C-106 but will be prepared to also retrieve any soft sludge not recovered by sluicing. A requirement of the long-reach manipulator is that it be designed to operate with low amounts of water addition. This will allow it to be safely used if a leak in the tank is detected during the earlier sluicing operations.

LONG-REACH MANIPULATOR CAPABILITIES

The first-generation long-reach manipulator will have limited capabilities compared to those needed for the remaining SSTs. It will not be configured for use in all SSTs. It will be sized for 1.9-ML (500,000-gal) and possibly 3.4-ML (750,000-gal) tanks but not in 4.5-ML (1-Mgal) tanks, thus reducing the depth to which the system must reach. It will not have to be used in full tanks, where only 3.5 m (12 ft) of clear head space above the waste would be available to unfold the arm in the tank. Instead, the first-generation system will be used only in tanks with at least 5.5 m (18 ft) of clear head room. This simplifies the geometry of the system and eliminates the need to excavate a hole in the waste to make enough room to deploy the arm into the tank. No in-tank hardware or other materials, such as rocks or lead flashing, will be removed from the tank. In-tank hardware will be manipulated only to the extent necessary to access and retrieve the required amount of chemical waste. This reduces the number of end-effectors that initially need to be developed. It also allows slower, manual change-out of tools, precluding the need for a robotic or automatic tool-exchange system that would add considerably to the complexity of the system.

ADAPTABILITY AND EXTENSIBILITY

One of the primary risks in deploying a retrieval system in the SSTs is that the retrieval tools will prove inadequate because of design error, unexpected in-tank conditions, or emerging requirements. An advantage of the long-reach manipulator is its adaptability and extensibility. While the main system platform and arm remain the same, a variety of retrieval tools can be made up to handle situations ranging from the discovery of unexpected tank materials to evolving cleanout requirements. In addition, retrieval tools can be modified in relatively short order to respond to newly discovered conditions in the tank. This kind of adaptability and extensibility is inherent in the use of a manipulator and is one of its chief attractions in an arena where unknown conditions are certain.

The following areas of extensibility are not inherent but must be built in.

- Once work at C-106 is complete, the system could be moved to a tank farm, such as the TX Farm, and used as part of the project to retrieve tank waste at the first complete tank farm, a group of ten to sixteen tanks.
- In the event that sluicing is used to complete retrieval of C-106, the first-generation system demonstration itself could be done in an alternate tank.

This capability will be an additional expense. A cost estimate of the savings stemming from the addition of these features will be used to determine the cost effectiveness of providing this extensibility.

CONCLUSION

The strategy for attaining a viable retrieval system, consisting of rigorous study followed by feasibility testing, a hot demonstration, and finally production, has progressed to the beginnings of a project for a hot demonstration. Based on extensive study and feasibility testing, a long-reach manipulator system has been selected as an alternative to past-practice sluicing.

This type of system is within the state of the art as evidenced by the successful large-manipulator integrated testing.

This long-reach manipulator can be equipped with a wide variety of retrieval tools. It can be configured as a low water-addition retrieval method that could retrieve tank waste without increasing the tank's leakage potential. It can, therefore, provide the flexibility necessary to adapt to unknown in-tank conditions and to use improved retrieval tools and methods based on operational experience.

Initial testing of waste retrieval tools indicates that retrieval rates consistent with production retrieval are feasible.

The lessons learned in the development by private industry, deployment, and use of the long-reach manipulator system will guide the development of requirements for second-generation or enhanced systems. In the meantime, a system capable of successfully retrieving waste from an SST in spite of unknown conditions will have been made available to the Tank Waste Remediation System retrieval effort.

ACKNOWLEDGEMENTS

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