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Remote Handling Equipment for Removal of Waste from Single-Shell Tanks at the Hanford Site

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REMOTE HANDLING EQUIPMENT FOR REMOVAL OF WASTE FROM SINGLE-SHELL TANKS AT THE HANFORD SITE

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ABSTRACT

Mechanical retrieval equipment concepts are being developed for remote 'mining' of the radioactive waste in underground storage tanks at the Hanford Site in Washington State. This paper presents a description of the tanks, the waste, the key design considerations, and some of the more promising concepts for mechanical waste retrieval.

INTRODUCTION

Radioactive waste has been stored in underground tanks at the Hanford Site in Washington State for more than 40 yr. These wastes were produced as a byproduct from plutonium production and separation operations that began as part of the World War II defense effort.

The U.S. Department of Energy, in agreement with the U.S. Environmental Protection Agency and the State of Washington Department of Ecology[1] is preparing to demonstrate the ability to retrieve waste from one of the underground tanks. This activity is part of an overall program of environmental restoration that has been initiated at the Hanford Site.

One method of retrieving the waste is to use remotely operated mechanical equipment. Another alternative is hydraulic sluicing. This paper describes the efforts completed to date to design remotely operated mechanical equipment to demonstrate this method of waste retrieval.

DESCRIPTION OF SINGLE-SHELL TANKS

There are 149 single-shell tanks (SST) at the Hanford Site. They are underground tanks ranging in size from 208,000 to 3,800,000 L (55,000 to 1,000,000 gal). The tanks are circular, constructed with reinforced concrete, and lined with carbon steel. The 208,000 L tanks (there are 16 total) have flat tops and are 6 m (20 ft) in diameter. The larger tanks have domed tops and are 23 m (75 ft) in diameter. Tank heights vary depending on tank capacity. There is considerable variation in the number, location, and type of openings in the tops of the tanks with the majority having at least one 107-cm (42-in.) diameter opening in the center. The top on a typical tank is ~2.5 m (8 ft) below grade.

WASTE DESCRIPTION

The original waste consisted of liquids from the plutonium separation process that were strong acids. The acids were neutralized before they were stored in the tanks. The neutralization process caused a complex mixture of solids to precipitate and form a layer of sludge in the bottom of the tanks. To reduce the volume of liquids, as well as remove the radioactive isotopes of cesium and strontium, a waste reduction program was initiated in the 1960s. This program significantly reduced the amount of water (using evaporation) and reduced the concentration of cesium and strontium. This program resulted in a concentrated salt slurry, which was returned to the underground tanks. This salt slurry is now salt cake. Although not fully characterized, it is estimated that the radiation levels near the surface of the salt cake in a typical tank are less than 100 rads/h. A photograph of the interior of a typical tank is shown in Figure 1.

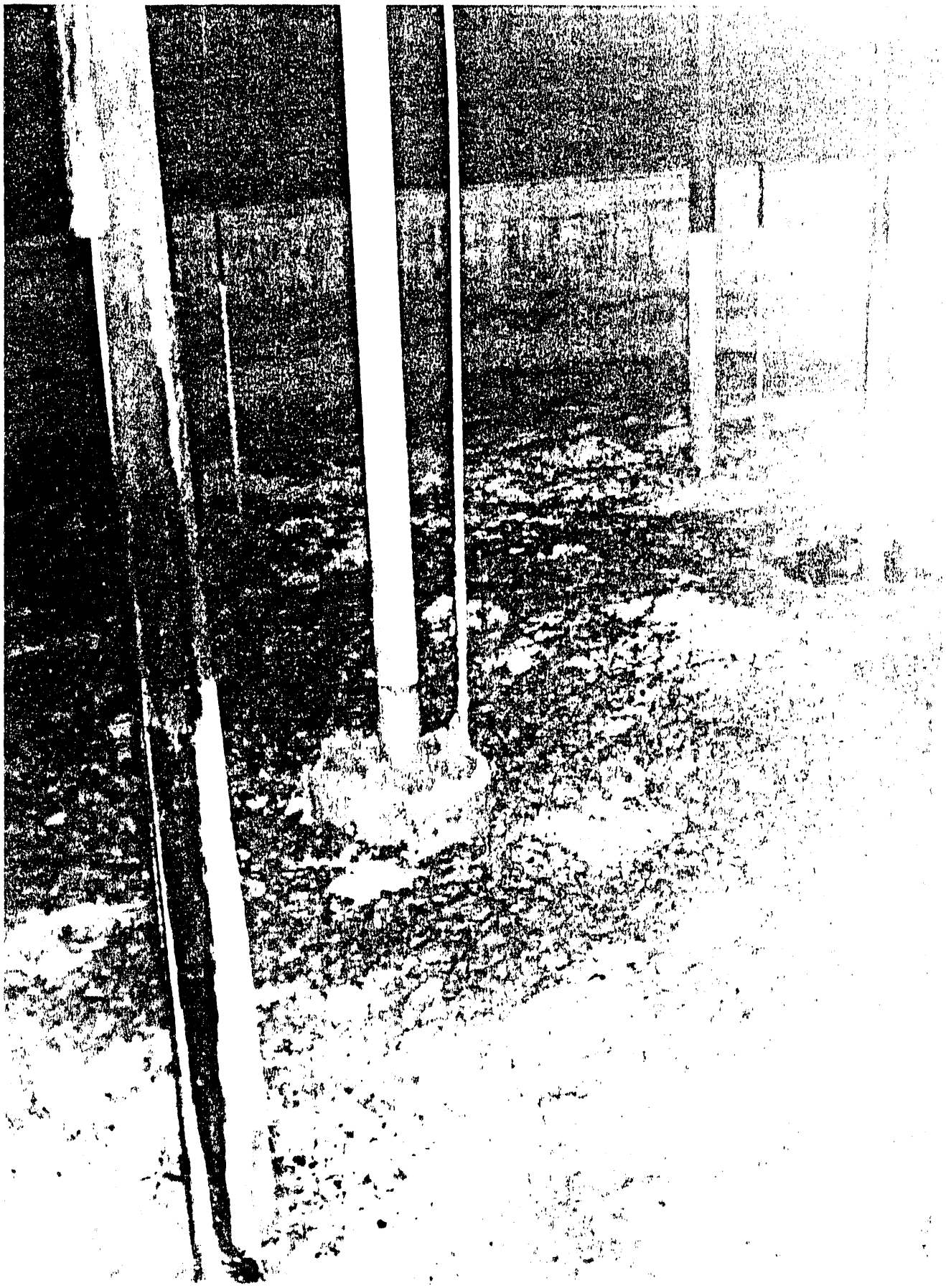

Figure 1. Single Shell Tank Interior Tank AX 101

The sludge is expected to vary in consistency from liquid to dry and hard. The salt cake is expected to vary in consistency from a dry, hard crystalline material to a wet, mushy solid that has no structural strength.

Although not classified as a chemical waste, there are other items in the tank that may need to be removed. These items consist of vertical obstructions such as piping and tubing, which penetrate various openings in the top of the tank and extend into the waste. These obstructions may need to be removed, using remotely operated equipment, to gain access to the waste in the tank. In addition to the vertical obstructions, miscellaneous metallic debris is mixed with the waste. This debris, whether removed or not, will complicate the design and operation of the waste retrieval equipment.

PREVIOUS WASTE RETRIEVAL EQUIPMENT STUDIES

Equipment concepts for retrieving waste from the SSTs have been the subject of previous studies, the first being completed in 1975;[2] other studies [3,4,5,6] have followed.

DESIGN INFORMATION

Design information is currently being formulated parallel to the effort to develop the most viable mechanical equipment concepts for waste retrieval. Some key design assumptions are identified below.

- Waste consists of hard and soft sludge and salt cake. Sludge and salt cake may exist separately or may be in an intermixed state.
- Waste can be removed from the tank in any form possible (i.e., no preconditioning of the waste will be required by the retrieval equipment before delivery outside the tank to other systems for transport).
- If the tank requires special preparation before waste removal (e.g., partial top removal or removal of vertical obstructions within the tank), equipment must be included in the design to accomplish this function.
- The final configuration of the tank and its surroundings, except for the top and the piping systems and earth above the top, must remain undisturbed.

KEY DESIGN CHALLENGES

Some of the key design objectives include the following.

- To remove the waste at an average continuous waste removal rate of 114 L/min (30 gal/min) or greater.
- To obtain an overall system inherent availability of at least 80%.
- To design waste retrieval equipment that will remove 95% of the waste in the tank.
- To design waste retrieval equipment having the capability to remove waste from tanks with diameters ranging up to 23 m (75 ft) and with capacities ranging up to 3,800,000 L (1,000,000 gal).

RETRIEVAL CONCEPTS UNDER CONSIDERATION

The general concept of a mechanical waste retrieval system consists of remotely operated equipment operating through at least one penetration in the top of the tank. The equipment is large because of the size of the tanks and the anticipated weight of the special tools (end effectors) that must dislodge and convey the waste from the tank. Most concepts developed to date consist of a long arm, supported above the tank, with telescoping and articulated arm segments. Attached to this arm may be a smaller, teleoperated arm with multiple degrees of freedom. Attached to the smaller arm are the end effectors used for removing the waste. Above the tank are the mechanical support systems such as arm deployment equipment, end effector storage and change out systems, waste conveyance equipment, arm washdown and maintenance equipment, camera and lighting deployment systems, and tank ventilation and waste confinement systems. Also located above the tank, and in most concepts located a fair distance from the tank, is the control station.

To ensure that the best overall concept is selected upon initiating the forthcoming advanced conceptual design phase, a number of alternative concepts are currently being evaluated. To conserve time and resources, only the best of these will continue to be developed to enable a more thorough evaluation during final concept selection. To accomplish the screening process, a decision analysis has been completed to rank eleven concepts from best to worst. Two of these were eliminated in the process because of a failure to meet all design requirements. Of the nine remaining, at least five are currently planned to be developed further. The two leading candidates, based on the decision analysis, are shown in Figures 2 and 3. The third leading candidate (not shown) is very similar to that shown in Figure 3, with the exception that the system is deployed through a smaller [107-cm (42-in.)] opening in the top.

The major feature of the concept shown in Figure 2 is accessibility to the waste. Accessibility provides design advantages such as reduced complexity of equipment and controls, ease of arm retrieval upon failure, maximum arm stability, ease of arm deployment, simplified hose and cable management, ease in working around debris in the waste, and minimum technical risk. The concept provides advantages with regard to equipment design; however, it has major disadvantages associated with removing a large portion of the tank top.

The concept shown in Figure 3 uses a teleoperated arm operating through an enlarged center opening in the top of the tank. The arm consists of a telescoping upper section and an articulated lower section with multi-degrees of freedom. The arm assembly is supported by an elevator system that will raise and lower the arm into the tank.

End effectors for all concepts under consideration include scarifiers that use high pressure air or water to dislodge the waste in combination with an air conveyance system to lift the waste from the tank. Abrasive water jets and grippers are being evaluated for removing metallic obstructions. All concepts to date are based on removing the end effectors from the tank for change out.

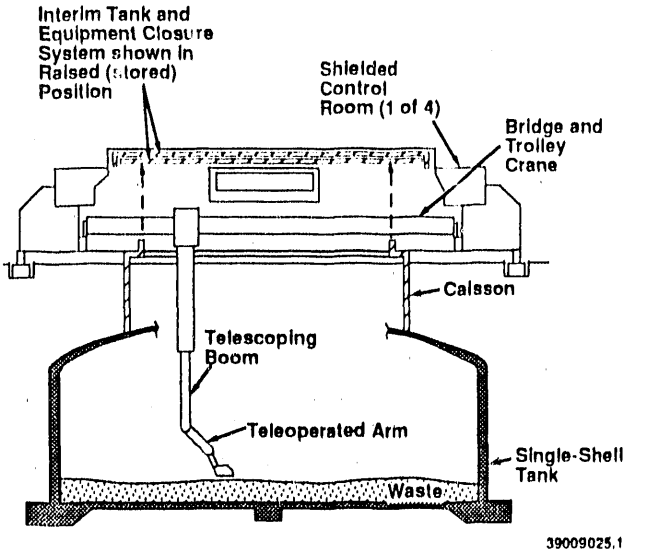

Figure 2. Large Tank Opening.

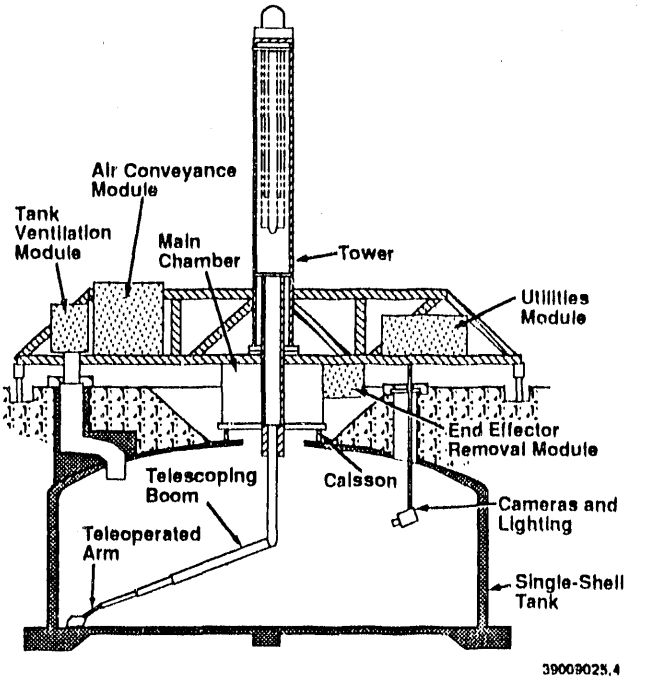

Figure 3. Slightly Enlarged Tank Opening.

The bottom of a 3,800,000-L (1,000,000-gal) tank is approximately 16 m (52 ft) below grade. Based on current concepts of end effectors, the arm must be capable of lifting at

least 450 kg (1,000 lb). This combination of arm length and payload will present new challenges in mechanical equipment and control system designs because the end effectors must be maneuvered with a relatively high degree of precision.

CONTROL SYSTEM

The Westinghouse Hanford Company is working with the Battelle Pacific Northwest Laboratory and the Sandia National Laboratory to develop a control system for maneuvering the end effectors within the tank. The Sandia National Laboratory's current development effort in the area of control system architecture is being extended to provide computer control. A simplified block diagram of the control system is shown in Figure 4. The Battelle Pacific Northwest Laboratory is evaluating the dynamic response of the overall system, which will use hydraulics as the power source. Future efforts are planned, with the assistance of Battelle Pacific Northwest Laboratory, in the area of sensor development for coping with the harsh environment in the tank during waste removal operations.

LONG RANGE PROGRAM AND SCHEDULE

The overall goal in the development of mechanical waste retrieval equipment is to initiate waste retrieval from a selected 'demonstration tank' by October 1997. Westinghouse Hanford Company is scheduled to complete an advanced conceptual design, suitable for incorporating into a request for bid package in early 1992. Offsite vendors will be requested to design, fabricate, and test the equipment before delivery for further testing and qualification at the Hanford Site starting in 1995.

The study of hydraulic sluicing is continuing parallel to the development of concepts for mechanical retrieval equipment. The feasibility of sluicing is largely dependent on developing a suitable method for preventing tank leakage during the sluicing operation. Until that can be accomplished, mechanical retrieval equipment (such as that described previously) will continue to be the front running method for waste retrieval.

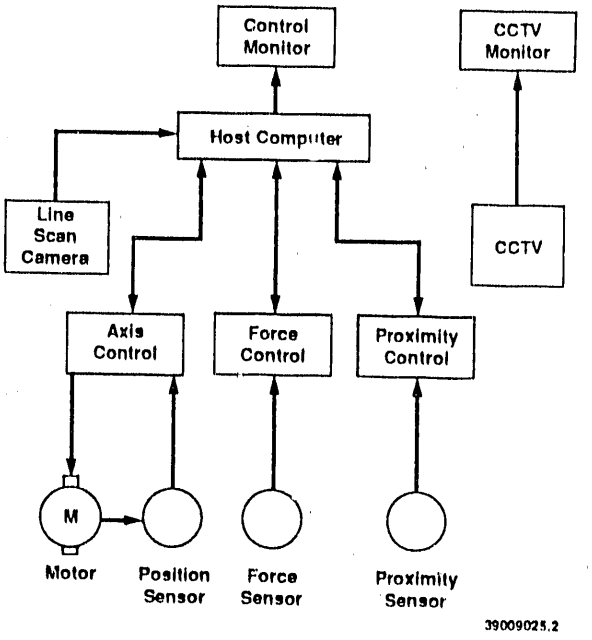

Figure 4. Control System Block Diagram.

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