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PROGRAM OF THE
HANFORD HIGH-LEVEL WASTE
RETRIEVAL TASK

A NARRATIVE DESCRIPTION

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ABSTRACT

The objective of this task is to develop and demonstrate the equipment and methods for the retrieval of high-level radioactive wastes from underground storage tanks at Hanford. The approach will be to continue with engineering studies and the conceptual design in progress and follow on with the engineering design, construction, testing and demonstration of a Prototype Retrieval System. This system will consist of a large, mobile platform providing the support and control of an articulated arm used to remotely position waste recovery/removal tools. Other major components include the equipment needed to bring the material up to the platform for packaging and subsequent transport to a processing facility, and the television viewing and lighting subsystem. This prototype system will be functionally complete and will contain items such as a control center, tool change and maintenance/repair capability, etc. The program includes a complete non-radioactive demonstration of the system in a mock waste tank as well as a radioactive demonstration involving one or more waste tanks.

1.0 INTRODUCTION

The accumulation of radioactive wastes at the Hanford site began in 1944 with the generation of liquid wastes from nuclear reactor fuel processing. As part of the Manhattan Project, reactor and chemical separation facilities were constructed for the production and purification of plutonium for possible use in nuclear weapons. A total of eight graphite-moderated reactors and one dual purpose reactor producing both plutonium and steam, were eventually built at Hanford. At this time, however, only the dual purpose N Reactor remains in operation, with one fuel processing plant (Purex) being maintained in standby condition for intermittent operation as required by N Reactor plutonium production. The history and detailed description of the Hanford Site is presented in reference 1.

These radioactive wastes, referred to as high-level wastes, have been stored as liquids in underground tanks ranging in size from 55,000 to 1,000,000 gallons located on the Hanford 200 Areas plateau. As the result of deterioration and subsequent leakage from some of the storage tanks, these high-level liquid wastes are currently being processed for conversion to less mobile forms which can be safely stored for at least decades. This current waste solidification program will:

- Remove, solidify and store in double-wall metal capsules most of the ^{90}Sr and ^{137}Cs (the major heat generators),
- Concentrate the liquid wastes via evaporation to produce salt crystals which are then stored as salt cake in existing single-shell tanks,
- Continue to store the insoluble chemical fraction (sludge), which precipitated from the original liquid waste, in existing single-shell tanks, and
- Store the residual liquor (previously called terminal liquor) in double-shell tanks.

Under this program, projected to the end of calendar year 1980, the underground storage tanks (total 168) will contain approximately:

- o 3,000,000 gallons of liquid wastes awaiting solidification,
- o 10,000,000 gallons* of residual liquor,
- o 36,000,000 gallons* of solids, and
- o 3,500 capsules of ^{90}Sr and ^{137}Cs (~ 100 cubic feet).

*The quantity of residual liquor may be reduced and that of solids increased pending the application of waste treatment techniques currently under study.

The objective of the Hanford Long-Term High-Level Waste Management Program (reference 2) is to develop, evaluate, and demonstrate the technology for long-term storage or final disposition of the high-level waste existing at the end of the current waste solidification program. The plan of this program includes three basic alternatives. First is the continuation of existing or improved tank storage, with assurance of waste isolation from man through continuing maintenance and surveillance. The second approach involves the retrieval of the wastes from the storage tanks, the processing of these wastes to a less mobile form, and storage in a deep geologic site (e.g., basalt) which has potentially zero surveillance requirements. The third alternative includes retrieval and processing (immobilization), but with storage in a surface facility requiring minimum surveillance. Before an alternative can be selected and put into operation, the various technologies must be developed and demonstrated, the alternatives assessed (cost and risk), and one or more environmental statements prepared and evaluated. This program is being carried forward under the direction of the

Energy Research and Development Administration as an integral part of the expanded national program leading to safe, terminal storage of nuclear wastes (reference 3).

The program discussed herein addresses the retrieval of solidified wastes from underground storage for subsequent processing - a task common to two of the three alternatives presented in the plan for the disposition of Hanford high-level wastes. This document represents a general plan of action for the technology development phase of the waste retrieval task. The Waste Retrieval Task will include conceptual designs and engineering studies leading to the design, construction, and testing of a functionally complete Prototype Retrieval System. Under current plans the capability of this system will be demonstrated first with non-radioactive tests in a Prototype Test Facility and, second, by retrieving wastes from one or more of the Hanford waste tanks. Items specifically excluded from consideration in this task are packaging of waste for offsite transportation, processing (including blending of waste types) which may be necessary to provide suitable feed to the processing facility, and specific procedures for handling residual liquor and the stored capsules of concentrated ^{90}Sr and ^{137}Cs . Residual liquor, for example, can be handled using existing techniques of pumping and transport via underground piping.

2.0 SUMMARY

Approximately 36,000,000 gallons of solidified high-level waste are contained in the underground storage tanks at Hanford. These solid wastes (salt cake and sludge, with nondrainable interstitial liquid) vary considerably in physical consistency as well as in chemical and radionuclide content, not only from tank to tank, but within a tank as

well. Nearly all of the solid wastes are contained in 75-foot diameter reinforced concrete tanks with single-shell steel liners which vary in capacity (533,000; 758,000; and 1,000,000 gallons), although many are only partially filled.

The objective of this task is to develop and demonstrate the performance of a retrieval system which has the functional capability to retrieve material from Hanford waste tanks in a safe, efficient, and cost-effective manner (Phase I: Technology Development). This Prototype Retrieval System would provide the basis for the construction of systems which could be required to perform the ultimate task of the removal of all Hanford high-level wastes for processing and terminal storage (Phase II: Operational) should the decision be made to do so.

Assumptions and conditions affecting the design of the retrieval system include the following:

- direct, additional loads shall not be imposed on the tank domes or risers,
- requirements for additional risers and site preparation shall be minimized,
- the uncontrolled addition of water may not be desirable,
- in-tank equipment (principally air-lift circulators) and debris must be separately removed,
- the design of waste material handling equipment will be affected by lack of specific knowledge of physical and chemical properties, and radionuclide content of the waste,
- uncertainties exist in the feed quantity and quality requirements of the Waste Processing Task, and
- environmental, safety and quality assurance considerations will be significant factors in the Waste Retrieval System design and transport mode selection.

With consideration of the above factors and the size, shape, and location of the larger of the dome penetrations, a retrieval system configuration based on a large mobile platform appears worthy of further engineering study. This platform, sized to the approximate 100-foot tank spacing, will support the waste handling apparatus and contain all auxiliary systems necessary for the safe, cost-effective, remote recovery, removal and containerization of the wastes. To gain entry through a central 42-inch riser, reach all points within the largest of the 75-foot diameter tanks and maneuver around in-tank obstacles, a hydraulically actuated, articulated arm will be used. This mechanical arm will serve to support and position a variety of waste handling tools. This Prototype Retrieval System will be completely equipped for retrieval operations and will require only electric power and water. "On-board" equipment and functions will include: a control and monitoring station, tool rack and tool change capability, a maintenance and repair hot cell with appropriate shielding and electromechanical manipulators, a waste packaging and handling section, the means for disposing of debris and obstacles removed from the tanks, equipment decontamination facilities, and a ventilation system coupled to the tank to control radioactive particulate emissions to the environment.

Subsystem and component design will emphasize simplicity and ruggedness, since low maintenance and high reliability are essential for cost-effective, long-term retrieval operations. Because safety and environmental considerations are of paramount importance, substantial effort will be devoted to designs and systems analyses to assure personnel safety and preservation of the environment from radioactive contamination.

Subsequent to development and testing of the various subsystems, the entire Prototype Retrieval System will be installed in a mock waste tank (Prototype Test Facility) as a means of testing component integration and control, and establishing performance and operational procedures. Demonstration of the Prototype Retrieval System will occur first under simulated conditions (nonradioactive) in the mock waste tank. Under current plans the retrieval system radioactive demonstration would involve operation of the complete Waste Retrieval System in one or more waste tanks. The Waste Retrieval Task final report will include a complete description of the Prototype Retrieval System as well as a discussion of potential operational procedures and problems.

3.0 BASIC PLAN

The basic plan of the Waste Retrieval Task is to design a Waste Retrieval System which can be easily and reliably configured to fit each of the several Hanford waste tank designs with a minimum of site preparation and penetration additions to the tank domes. It is intended, therefore, that the Prototype Retrieval System be configured to accommodate all large (75 foot diameter) single-shell tanks. It is expected that, at the time of retrieval operations, the double-shell tanks will be suitable for residual liquor recovery by pumping (and sluicing where necessary) using existing technology. The configuration of a Prototype Retrieval System will be arranged so that it will fit all tanks containing solids with the least possible alteration to the retrieval machinery and the lowest possible number of additional dome penetrations. This appears to be appropriate so that the Prototype Retrieval System will be representative of a system capable of safely and efficiently removing waste from all large Hanford waste tanks. The plan will be to

make the retrieval system as universal as possible without compromising performance and safety (or cost effectiveness).

The following paragraphs outline the major steps which constitute the basic plan of the Waste Retrieval Task (details appear in later sections):

- Engineering studies, conceptual design and engineering design of the complete Prototype Retrieval System. Included in this step shall be concepts for retrieved waste packaging, handling, and onsite transport to a waste processing facility.
- Design, fabrication, testing and modification (if any) of the in-tank subsystems:
 - articulated arm,
 - lighting and television viewing,
 - material removal (elevator),and the mobile support platform equipped with control and maintenance features.
- Concurrent with the above, the design and construction of a Prototype Test Facility (mock waste tank) consisting of a below ground container simulating the size and shape of a large (1,000,000 gal.) waste tank. This facility will permit the following subsystem tests and integration work to be performed at full-scale to demonstrate and assure capability to remove all waste and in-tank obstructions and debris.
- In conjunction with the above and incorporating available information from a waste characterization program, the development, adaptation and testing of tools for the articulated arm
 - Mechanical (clamshell, auger, scraper, hammer, etc.)
 - Hydraulic (slurrying pump, displacement pump, etc.)
 - Pneumatic (vacuum equipment, sand blast, etc.).

- A full-scale demonstration of the complete Prototype Retrieval System in the mock waste tank with all systems and procedures operational (i.e., simulating the operational requirements of radioactive waste). Included at this step shall be the preparation of a draft of an Operational Procedures Manual.
- Concurrent with the above step, and prior to the following step, conduct appropriate studies and analyses relating to:
 - Tank site preparation requirements
 - Component failure modes and repair procedures (no contact maintenance)
 - Safety and shielding (Hazards Review)
 - Environmental impacts
 - Coordination with the Waste Processing Task requirements and capability to receive actual waste.
- As a final step in the presently envisioned program of the Waste Retrieval Task a radioactive demonstration is planned. This will entail the use of the Prototype Retrieval System (as modified and improved by full-scale component and total system tests) to retrieve high-level waste from a selected Hanford tank or tanks as a demonstration (proof-test) of procedures and system capability. Actual operational experience will be gained if the Prototype Retrieval System is used to supply the feed to pilot plant facilities of the Waste Processing Task.

In summary, the Waste Retrieval Task is a technology development program which will provide a technology base in the event a future decision is made to retrieve the solidified wastes from the Hanford storage tanks.

Reference 2 describes the relationship of the Waste Retrieval Task to other parts of the overall Hanford Long-Term High-Level Waste Management Program. The timetable and funding estimates for the technology development phase of the Waste Retrieval Task of the Waste Management Program Plan are shown in Appendix A.

4.0 WASTE STORAGE TANKS

The history and present status of high-level waste at Hanford is well documented (see, for example, reference 1, "FINAL ENVIRONMENTAL STATEMENT — WASTE MANAGEMENT OPERATIONS, HANFORD RESERVATION"). The purpose of this section is to characterize and categorize the waste tanks and their contents with emphasis on the fact that retrieval operations may not commence for many years. Consequently, use will be made of waste bulk volume projections based on current and planned waste management operations involving vacuum evaporator-crystallizers, salt well pumps, and new double-shell tanks for storage of terminal liquor. Note that residual liquid waste (residual liquor) is not to be considered since this material can be recovered and transported using existing technology of pumps and underground transfer lines. The storage tanks will be surveyed from the point of view of devising a Waste Retrieval System requiring the least possible alterations to the tank farm site or the structure of existing tanks.

4.1 TANK GEOMETRY AND ACCESS

The distribution of high-level waste storage tanks by area and size is as follows:

TABLE I

HANFORD HIGH-LEVEL WASTE STORAGE TANKS

		TANK CAPACITY IN GALLONS													
		DOUBLE SHELL ^c				SINGLE SHELL									
AREA		1,000,000				1,000,000		758,000		533,000		55,000		TOTAL	
200 EAST	BY FARM	AY 2	AZ 2	AW 6 ^a	AN 6 ^b	A 6	AX 4	BY 12		B 12	BX 12	C 12	B 4	C 4	
	SUBTOTAL	16				10		12		36		8		82	
200 WEST	BY FARM	SY 3				SX 15		S 12	TX 18	TY 6	T 12	U 12	T 4	U 4	
	SUBTOTAL	3				15		36		24		8		86	
TOTAL		19				25		48		60		16		168	

^a UNDER CONSTRUCTION^b PLANNED FY 1977^c ADDITIONAL TANKS ARE PLANNED FOR FY 1978

The basic shape of the tank interior and typical location relative to the ground level is shown in Figures 1 and 2 for each size (or type) of underground storage tank. Depths from ground level dimensions are approximate, since tanks are typically emplaced in farms in rows with 1-foot steps in elevation so that fluid will overflow (cascade) to a tank in the adjacent row.

Typically, tank domes contain a large number and variety of penetrations, not all of which are connected to the surface via risers. Following the ground rule that full use of existing penetrations will be made so that a minimum of risers need be added, the following illustrations (Figures 3 and 4) show all dome penetrations 30-inches wide or greater. Equally significant to the design of the Waste Retrieval System, however, is the precise location of dome penetrations, both radially from the tank center as well as orientation with respect to the rows and columns of tanks. The 12 tank farms with large single-shell tanks shown in Figure 3 represent seven distinct arrangements of large penetrations. All manholes appear to be capped and/or plugged at the dome; some risers stop a short distance above the domes while others end at the bottom of concrete sluice pits.

An additional factor bearing on the Waste Retrieval System configuration is the arrangement of tank farms in rectangular patterns of rows and columns. The 533,000-gallon tanks (B, BX, C, T, and U) are emplaced at intervals of 100-feet; while the 758,000 and 1,000,000-gallon (single-shell) tanks are at 102-feet spacing (A, AX, BY, SX, TX, and TY). The newer 1,000,000-gallon double-shell units are on a center-to-center spacing of 107-feet. The 55,000-gallon tanks are emplaced at 50-foot intervals in a row 100-feet from the adjacent row of larger tanks.

SINGLE SHELL TANKS - 75 FEET DIAMETER

FIGURE 1

TANK INTERIOR GEOMETRY
LARGE SINGLE-SHELL

DOUBLE SHELL TANKS - 75 FEET DIAMETER

SINGLE SHELL TANKS -
20 FEET DIAMETER

FIGURE 2

TANK INTERIOR GEOMETRY
DOUBLE-SHELL AND SMALL (55,000 gal.)

SINGLE SHELL TANKS

* TY TANKS CAN BE GROUPED WITH (B, BX, C, T, U) WITH THE ADDITION OF CENTRAL 42" RISERS TO THE LATTER.

FIGURE 3

ARRANGEMENT OF (LARGE) DOME PENETRATIONS - SINGLE-SHELL, LARGE AND SMALL TANKS

DOUBLE SHELL TANKS

FIGURE 4

ARRANGEMENT OF (LARGE) DOME
PENETRATIONS - DOUBLE-SHELL TANKS

4.2 TANK WASTE CONTENTS

Because different nuclear fuel processing schemes were used over the years, as well as a variety of blending, evaporation and admixture schemes, the waste is extremely varied from tank to tank in chemical and radionuclide content and/or physical characteristics.

To proceed as quickly and as efficiently as possible with the design of a complete Waste Retrieval System, substantial knowledge of the quantity and quality of each waste type (especially physical characteristics) would be required. Both of these features, however, are a function of time due to ongoing use of vacuum-evaporator crystallizers, salt-well pumps, the encapsulation process, addition of desiccants, etc. Additional information as to the physical, chemical, and radionuclide characteristics of the waste material will be forthcoming from the Waste Characterization Program and will be incorporated into the present effort as it becomes available. As one might expect, insufficient knowledge of the specific physical character of the solid waste material will cause large uncertainties in the design of the working tools. These tools, to be mounted on the end of the articulated arm, will be developed throughout the program as information and working experience is obtained.

Table II illustrates the bulk volume of solidified waste which is projected to be contained in the seventeen tank farms at the end of calendar year 1980. A detailed listing of tank waste contents is provided in Appendix B wherein each tank is tabulated with the present liquid and solid content as well as the bulk volume of solid waste projected for the end of calendar year 1980. Significant items to note are: from the total of 168 tanks (133 large single-shell tanks) - 68 are on inactive status; of the large single-shell tanks, only 19 are scheduled to receive

TABLE II

**SUMMARY OF WASTE TANK SOLIDS CONTENT ^a
PROJECTED TO END OF CY 1980**

**BULK VOLUME OF SOLIDS ^b
(MILLIONS OF GALLONS)**

TANK CAPACITY GALLONS	200 WEST AREA	200 EAST AREA	TOTAL
1,000,000	4.8	2.4	7.2
758,000	13.3	4.6	17.9
533,000	5.1	5.1	10.2
55,000	0.2	0.2	0.4
TOTAL	23.4	12.3	35.7

a FOR DETAILS, SEE APPENDIX B.

b SOLIDS ARE COMPOSED OF SLUDGE AND SALT CAKE

additional solid waste (salt cake); and, a large proportion of the tanks will contain a volume of solids amounting to only a fraction of tank capacity. While there is no absolute assurance that this material distribution will exist, it will serve as a guide for design considerations as well as future operations.

With reference to the tank profiles shown in Figures 1 and 2, it will be noted that the apparent headspace (dome ceiling to maximum liquid level) on the 1,000,000, 758,000 and 533,000 gallon tanks is 13'-7", 13'-4", and 12'-6", respectively. Considering the solid levels indicated by the projected solid volumes listed in Appendix B, however, the headspace for the 1,000,000 gallon tanks becomes 19'-7" (assuming maximum salt cake fill to 80 percent capacity). Waste tanks scheduled for additional salt cake will be filled to approximately 80 percent of capacity unless a lower limit is necessary because of hydrostatic head or temperature limitations. In the case of the two smaller size tanks, although some have already been filled beyond 80 percent, the majority contain a solids volume of only a fraction of tank capacity.

The purpose of the above discussion is to outline a realistic design criterion to allow the most reasonable configuration of the mining arm. For example, taking the absolute minimum headspace for insertion as a design condition would result in an articulated arm of four main segments. It may be possible to achieve a more simple, rugged and reliable (cost-effective) design by considering the lesser filled majority of the tanks and handling the few which have been filled beyond 80 percent as special cases. Further study will determine if this approach will result in an overall more efficient operation and be less costly in terms of equipment as well as retrieval operations.

A survey of the projected tank solid contents revealed the fact that if the allowable headspace criterion were increased to 16.5 feet only 11 tanks would be filled over this level in amounts ranging from a few inches to, at most, 3 feet. Additional in-tank conditions which must be established in order to achieve the "best" design (affecting hydraulic fluid, seals, hoses, bearings, etc.) are the temperature and radiation environments. In the case of radiation, the concentration of specific radionuclides ("typical levels" and "extreme values") will be significant and will affect choices of material as well as shielding and waste transport container size.

5.0 PROTOTYPE RETRIEVAL SYSTEM DESCRIPTION

The objective in this section will be to describe the Prototype Retrieval System in a broad, functional sense. Recall that the uppermost consideration in the system design is that the prototype equipment shall be functionally complete and truly representative of a system capable of being used in a future, full-scale retrieval operation. That is, all aspects of retrieval operations are to be considered in the scope of the prototype design--not only minimum tank site preparation and riser additions as mentioned earlier, but additionally, due regard will be given to the control and viewing systems, tool change capability, subsystem maintenance, repair and decontamination, waste and debris packaging and transportation, system movement from tank to tank, etc. Further, since the scope of the Waste Retrieval Task includes the development of a fully capable Prototype Retrieval System which may be replicated for full-scale retrieval operations including delivery of wastes to a waste processing facility, items which must necessarily be included from the beginning are all facets of

a hazard review, safety analysis (including radiation shielding), environmental assessment (including ventilation with effluent monitoring), retrieved waste quantity and quality measurements, and equipment quality assurance and operating procedures.

5.1 IN-TANK EQUIPMENT

The in-tank subsystems are fundamental to the Waste Retrieval System and of these the foremost is the mechanical (articulated) arm and the associated tools. The following paragraphs include descriptions of these subsystems based on existing conceptual designs or reflecting current thinking on functional requirements.

5.1.1 Articulated Arm

The basic design problem in the retrieval of solid waste from underground tanks is that of devising the means to insert retrieval tools into the tanks through 42-inch circular risers and maneuver these material recovery devices to all points in space within the tank. In addition, this mechanism shall have the capability to maneuver by remote control around obstacles (principally air-lift circulators) and at some stage dismantle and remove them. Prior conceptual design work in this area resulted in an articulated arm composed of four segments, each approximately 9-feet long, with individual hydraulic actuators (Figure 5). A tower with telescoping tube mechanism would be used for entry and exit of the arm as well as for positioning the arm at various working levels within the tanks. This four-segment arm resulted from the criteria that the minimum headspace was 12'-7 inch and that a single (central) location was preferable to the option of moving the arm from one off-center riser to another in order to reach all parts of the tank.

WASTE RETRIEVAL PROGRAM IN-TANK EQUIPMENT CONCEPT

Remotely controlled Articulated Arm with 0 to 37.5 feet
Reach Capability for positioning waste recovery and
removal tools.

21

ARH-LD-144

FIGURE 5

ARTICULATED ARM CONCEPT

While this latter argument is still valid, the survey of tank waste contents suggests that a significantly larger headspace will exist for most tanks. An illustration of a Waste Retrieval System concept using a retractable articulated arm capable of reaching all points within each size tank is shown in Figure 6.

Larger actual headspace may make it possible to design a suitable three-segment arm. In any event, the arm must have the capability of reaching all points within a tank including reaching to the center (i.e., under the point of entry). There may be significant advantages for the case of a three- versus a four-segment arm in improved rigidity, stability and control as well as fewer components for maintenance, repair and decontamination. In either case, a critical design area will be the end of the arm for the attachment of a number of waste-working tools which will be necessary but, as yet, are not well defined.

5.1.2 Retrieval Tools

Basically, the articulated arm serves as a mechanism to position and/or maneuver the waste retrieval (recovery) tools throughout the volume of the tank occupied by solid waste. As mentioned earlier, the solid waste — salt cake and sludge — will have a wide range of physical properties and radioactive content. Photographic evidence and a small number of samples and probings suggest that considerable differences in consistency (hardness) exist not only within a tank (i.e., layers) but also from tank to tank. Variations in the latter case stem from, in some cases,

COMPOSITE SECTION WASTE RETRIEVAL SYSTEM CONCEPT

V7606-2.2

FIGURE 6

WASTE RETRIEVAL SYSTEM CONCEPT

different process chemistry and in others from forced drying, addition of desiccants (one tank had 63 tons of cement added to the salt cake - large amounts of diatomite have been added to 6 tanks) and, perhaps more importantly, varying degrees (time) of salt well pumping of interstitial liquid.

The above implies, of course, that several waste recovery tools will be required to effectively and efficiently handle the solid waste. Considering the general nature of the waste, the tools appear to fall into two broad categories - first, the strictly mechanical type (clamshells, scoop shovel, backhoe, etc.) for picking up the waste "as is" and moving it in small batches to an elevator type of device for transport out of the tank to the surface for packaging - and second, making a slurry by appropriate addition of water to controlled quantities of waste within the tank, (slurry pools in the sludge or salt cake or in a small mixing vessel) and transport to the shipping containers via pumping. The relative use of these two types of recovery tools depends primarily on at least two outside factors. These are, (1) the addition of water to the tanks may not be desirable and/or (2) water addition is not consistent with the immobilization scheme as for example, the process of making glass. The first factor may be overcome by mixing the water and tank solids in a secondary, small vessel suspended within the tank and pumping the resulting slurry directly to the surface. The second factor will not exist if the first step in the immobilization scheme is radionuclide removal (i.e., requiring dissolved salt cake for feed).

It is in the light of these uncertainties that development of waste removal tools will proceed. The end of the articulated arm will be designed to be compatible with all of the potential tool types. Consideration will include tool orientation (with respect to last arm segment) for insertion through a 42-inch riser, adjustable orientation for proper tool use, suitability for decontamination and ease of remote tool change. Sturdy and reliable power connections to the tools will be required since most, if not all, of these will be powered - probably by hydraulic, possibly by electrical or pneumatic means. There will be continuous effort devoted to the development of waste recovery tools throughout the course of designing and building the Prototype Retrieval System - using past and future bench-scale test results and becoming more definitive as experience and knowledge is gained. Inasmuch as simplicity generally connotes ruggedness and reliability, some compromise may be appropriate, that is, one or more less efficient or otherwise less desirable tool may be chosen in order to keep the overall mechanism less complicated to assure fewer maintenance and repair problems.

Additional tools will be necessary for the task of cutting up and removing in-tank obstacles and debris. Equipment will be devised to cut into pieces of manageable size the air-lift circulators which occur in numbers from three to twenty-two in a number of tanks. Removal of these and other metallic objects may best be done using a mechanical grabber on the articulated arm with transfer to an elevator (bucket) for transport to the surface. Should the slurry form of waste removal become the premier method, then metallic object removal might best be accomplished using an electro-

magnet and cable winch system. Early conceptual design and systems studies will continue with these alternatives until it becomes clear which combination will result in a desirable, efficient and cost effective arrangement.

5.1.3 Lights and Television Cameras

Although the need for adequate lighting and viewing in remote operations such as this is obvious, no unusual problems are anticipated since suitable equipment is readily available. Because of the large work space, and, in some cases, accurate tool control, careful attention will be given to the use of a stereoscopic viewing system to provide the operator with the necessary depth perception. It may be necessary to mount a camera on the final segment of the arm near the work point to allow accurate alignment of cut-off tools and suitable viewing of other operations.

The most outstanding concerns at present for the lighting and viewing subsystem are those of location on the various tanks, that is, making full use of existing risers (i.e. intermediate size — 8 to 24-inch), coordination with the main structural platform, and integration with the control station. Because of the extraordinary variations in dome penetrations, it appears that the in-tank lighting and viewing subsystem should be mechanically independent of the main structure and thus be installed in a tank prior to arrival of the retrieval system.

5.1.4 Material Removal

Early thoughts in the definition of a Waste Retrieval System were to have a waste material removal device consisting of a bucket mounted in a manner such that it could be moved from the in-tank working level to the waste transport

container level using a mechanically guided elevator system. The reason for this approach was that the bulk of the waste material (principally salt cake) would be acquired via mechanical mining techniques (e.g., clam-shell or back-hoe buckets mounted on the articulated arm). Inclusion of hydraulic waste recovery and removal techniques may significantly alter the original elevator concept. An important alternate use of the removal device, however, is the transport to the surface of all in-tank objects such as cut up air circulators and piping as well as all forms of debris. The latter includes items such as lengths of railroad rail, 55 gallon drums containing "other" waste, abandoned equipment and components, etc.

It would appear that the "best" approach to the waste removal problem for the Prototype Retrieval System would be to have the initial hardware sufficiently flexible and adaptable to accommodate each potential operational requirement. The danger of this approach, however, is that an undesirable degree of complexity may occur making problems of decontamination, maintenance and repair unduly difficult. To avoid this, the final version of the Prototype Retrieval System's removal apparatus will be modified to reflect the latest in operational plans, or if necessary, redesigned to a configuration which is operationally acceptable (i.e. prior to radioactive demonstration). In any event, the waste removal machinery design must be coordinated with the design of recovery devices as well as waste transport methods and equipment.

5.2 SUPPORT STRUCTURE

When one considers the operational phase (retrieval of all Hanford high-level solidified waste) and the fact that the Prototype Retrieval System must be representative of the

equipment necessary to perform that task, certain features affecting design appear which might not otherwise be considered. Among these are spacing of the tanks in orderly (but different) rows and columns and variations in large dome penetrations (indeed, some tanks have no readily available large openings). One additional, especially significant factor has been assumed. Since it may be many years before the actual retrieval operations will be accomplished, it has been assumed that tank age and deleterious effects of the contents (temperature and caustic) on tank integrity may require that the Waste Retrieval System not impose significant additional loads on the tank structure. A further concern is for the minimization of site preparation requirements. One example of an undesirable trade-off would be to compensate for the Waste Retrieval System weight by the costly process of removal of some of the soil overburden.

These considerations, plus the fact that safety and environmental requirements will necessitate a system which is self contained, carefully sealed, and coupled to the tank with a controlled ventilation system, suggest a close coupled and well integrated arrangement of the retrieval machinery. An appropriate configuration would appear to be a platform, suspended over the tank, housing all of the recovery and removal machinery as well as the control station, tool change facilities, maintenance and repair equipment, waste packaging and handling area, and radiation alarms and monitoring equipment. This platform could be supported by three or four peripheral jacks and sized so as to minimize the cost and complexity of site preparation. An early consideration in the forthcoming engineering studies will be the conceptual design of the retrieval machinery on such a platform and the most appropriate means of moving the system from tank to tank as well as from farm to farm.

Since there will be as many as 168 work locations, and considering that the 200 West area tank farms extend over approximately 1-1/2 miles, the method chosen for retrieval system transport is significant. These studies will include operational considerations and site preparation requirements to obtain an efficient and cost-effective solution. Illustrations of two potential approaches to a mobile retrieval system are shown in Figure 7. For any approach it will be necessary to clear the tank farm areas of all obstructions extending beyond 12-inches above grade and construct concrete pads to support the retrieval system securely during operations. Most risers and pump pits terminate at or below this level and much of the tank operations associated equipment will be removed or deactivated during the storage tank isolation procedure (i.e., complete removal from additional waste storage service).

The most demanding aspect of the Waste Retrieval System platform design will be the accommodation and coordination of the principal and auxiliary subsystems in both the structural and functional sense. Of particular importance at this time, for the Prototype Retrieval System particularly, will be the design of major components to enable testing of a variety of recovery and removal techniques without undue compromises on system performance or maintainability.

Schematically illustrated in Figure 8 is an arrangement of the platform concept which is mobile, built on the 100 foot tank spacing module, and could contain all operating and service functions.

5.3 CONTROL AND AUXILIARY SYSTEMS

To operate and maintain a smooth running and efficient remote waste retrieval operation considerable attention must be paid to the functions of control, lighting and visual access, material handling, tool change, maintenance and repair, etc. The following paragraphs describe the

FIGURE 7

MOBILE PLATFORM CONCEPTS

FIGURE 8

WASTE RETRIEVAL SYSTEM
PLATFORM ARRANGEMENT

highlights of these important functions.

5.3.1 Control Station

The routine operation of the Waste Retrieval System will be controlled and monitored from a single location by a minimum of two specially trained operations personnel. Of the two possibilities for the location of this control station, on board the platform or removed to a separate, portable building, the on-board choice appears preferable. Reasons for this lie mainly in the fact that all connections from control point to function (as well as instrumentation to read out or alarm) can be hard wired in place and protected. Though the separate control building (or van) approach would not require as much personnel shielding, it would require movable and exposed wiring for all control and monitoring functions.

The principal concern in the design of the control station, of course, is to provide the means for adequate control of the recovery/removal equipment to ensure continuous and efficient progress. Although the operator must be able to position the tools accurately and smoothly, many routine motions can be handled automatically. An example of this, for the mechanical retrieval option, is that the movement of the mechanical arm from the tool working position to the elevator and the motions of dumping and returning to the work position will be controlled by a micro-computer system. Further, the automatic feature will be included in the elevator system such that a full elevator bucket will be raised to the unloading elevation, emptied into the transport container and lowered to its previous elevation in the tank. Each of these functions will be capable of manual control at the discretion of the operator. Additional remote control capability will be provided for the packaging and shipping area of the Retrieval System.

For the case where the waste material is to be sent to immobilization in a "dry" form (as recovered, rather than as a slurry) the transport container will be sealed and, for example, put into a shipping cask and transferred to a truck for transport.

A key feature of the control subsystem will be the ability of the operator to monitor the recovery and removal operations both visually and audibly. Sight and sound contact with the working tool will aid immeasurably for both the early stages where tool performance may be optimized through configuration modifications, and in the later stages of field use, where maintenance of efficient operations will be the watchword. A single stereoscopic television system mounted on the mechanical arm may be of relatively greater value than the few general view cameras placed in available 12-inch (or larger) risers. The latter cameras and lights would be inserted through small risers, mounted on a telescoping tube for elevation change, and have a tilt and pan capability operated from the central control console adjacent to the monitors.

Additional features included in the control room will be items related to ventilation system performance, viewing and control of waste packaging and handling operations, tool change operations, and all appropriate indicators, alarms and interlocks.

5.3.2 Auxiliary Systems

Some of the necessary, but secondary, subsystems have been mentioned previously mainly as items of support function to the retrieval operations. The following paragraphs briefly describe these subsystems from a functional point of view; however, it should be noted that substantial effort will be required to structurally integrate these into a smooth working set for efficient, remote operation.

5.3.2.1 Tool Change

There is no doubt that several tool types will be needed to retrieve solid waste - not only because waste types are different from tank to tank but also since the physical character of the material can be different in strata of a given tank. Furthermore, recovery operations may be suspended in order to cut up and set aside or remove obstacles and debris, and surely the primary mechanical tools will leave a residue requiring a "finer" touch for more complete waste removal.

A viable concept for the tool change procedure would be to have the several tool types mounted on a carriage which could be moved to the base of the tower with the mechanical arm in the straight, vertical position (i.e., withdrawn from the tank into the tower). A manipulator at the platform level, then, would be used for tool attachment to the boom and for connecting pipes, hoses, etc. An air lock would be incorporated for moving tools into and out of this cell (after decontamination).

5.3.2.2 Maintenance and Repair

By using the mechanical arm hoist on the tower, all parts of the arm can be made accessible at the platform level and, therefore, the manipulator used for tool change can also be used to perform light maintenance. Items such as lubrication and tightening or replacing hydraulic lines can be performed with this pair of master slave manipulators.

Heavier maintenance, repairs and any necessary modifications will be performed in a shielded and sealed horizontal cell adjacent to the tower. This cell will be equipped with suitable remotely controlled jacks and hoists to permit substantial work on the mechanical arm. This work, possibly

the changing of large hydraulic cylinders, for example, will be accomplished with an electro-mechanical manipulator and viewed through shielded glass windows.

5.3.2.3 Equipment Decontamination

Thorough decontamination of the mechanical arm, and especially the recovery and removal tools, does not appear to be an easy task if indeed at all possible. The basic structure of the articulated arm is relatively simple. However, in consideration of hydraulic cylinders and supply hoses for each arm segment, power cables or hoses to the tools, arm position encoders and signal cables, etc., the space and effort required for routine thorough decontamination will be prohibitive. Contact maintenance, therefore, will not be possible. Wash down, then, will be in the form of steam and/or hot water spray rings at floor level in the tower base to clean off the mechanical arm and tools as they are withdrawn from the tank. The modest quantities of water involved (a few tens of gallons, infrequently) will be drained directly into the tank through the 42-inch insertion riser. In like manner, if a wash down capability is necessary at the transport container loading position, the small quantities of water will be drained directly back into the tank.

To facilitate the light and heavy maintenance and tool change operations, manipulator-positioned wash down nozzles may be appropriate (experience with the Prototype Retrieval System in the Prototype Test Facility will help determine this). Furthermore, a sealed floor and hose down capability would appear appropriate for the maintenance and repair cell to prevent accumulation of radioactive materials to an unreasonable level.

5.3.2.4 Waste Packaging and Transportation

This aspect of the waste retrieval operations will be more clearly defined over the next few years as the plans evolve for the techniques to be used in the Waste Processing Task, as determined by factors such as the preferred product form for terminal (or long-term) storage. For the interim, the Prototype Retrieval System will be designed with a considerable degree of flexibility to accommodate a variety of waste retrieval and removal techniques. This, in turn, implies substantial differences in the equipment for waste handling and packaging on board the platform as well as in waste transport and lag storage before processing. The disadvantage in this multipurpose approach, of course, is that individual item performance (hence, efficiency) may be compromised.

Before engineering studies and comprehensive designs can be completed, two questions must be addressed. These are, first, the quality of the waste in each tank (waste characterization program) and, second, the desirable product form for input to the immobilization scheme. Perhaps the most significant item relevant to the first question is the planned, extensive salt well pumping program of the Waste Tank Management Plan. According to this plan, all but a few of the single-shell tanks will be isolated and stabilized (salt well pumped) by the end of calendar year 1980. In any event, by the time retrieval operations are underway, all single-shell tanks will have been pumped to remove all drainable interstitial liquid. The consequence of long-term salt well pumping is shown in the photographs of Figures 9 and 10 for salt cake and sludge, respectively. If the material shown in Figure 9 is typical of well-drained salt cake and water addition is not allowed or not desired, then mechanical mining techniques may be the

FIGURE 9

EXTENSIVE SALT-WELL PUMPING
TANK 105-B, ITS SALTS

FIGURE 10

SLUDGE - AIR COOLED
TANK 114-SX

only recourse with the waste material placed in sealed bulk transport containers. This approach may be quite appropriate for an immobilization scheme going directly to a glass product (requiring comparatively dry solids and a modest lag storage capability depending on the number of retrieval systems in operation).

On the other hand, if limited water additions are permitted and the first step in the waste processing scheme is radionuclide removal (i.e., first process step being the dissolving of the salt cake and washing sludge), then quite different removal, packaging, and transport methods will be used. For example, recovery and removal could be accomplished by forming a slurry pool within the tank and pumping the slurry to a holding tank for further dilution (e.g., dissolution in one double-shell tank in each area), with transport to the processing facility (radionuclide removal) via existing or new underground transfer lines. While this approach affords much simplification of the recovery, removal, and transportation problems (transport containers are eliminated), considerable equipment and procedural development will be required and is applicable to salt cake only.

There is little doubt that, in most cases for salt cake and in some for sludge, mechanical devices mounted on the articulated arm will be necessary to "grind" the solid waste to a chunk size appropriate to feed the type of slurring pump currently under development. In this concept, the slurring pump, with controlled recirculation mode, could be mounted in a small tank on the material elevator mechanism and the articulated arm used to bring solid waste material to this position in the tank.

For this recovery/removal technique, water and/or heat would be added in modest quantities (water to ~30 volume percent and temperatures to ~140° F) and the material pumped via flexible hoses direct to a tanker truck. This truck-mounted, shielded tank would be used to deliver waste to lag storage tanks at the waste processing facility. The size of these temporary storage tanks would depend on, for example, the size of the production plant and would require only small recirculation pumps to keep the contents in a suspended slurry state.

5.3.2.5 In-Tank Obstructions and Debris

The foremost problem in the area of in-tank obstructions is the large number of airlift circulators installed in many of the Hanford waste tanks. Within the single-shell tanks (A, AX, SX, BY, and TX farms) there are approximately 220 air circulators of two basic types - floor-mounted (24-inches diameter with 10- or 19-foot height - See Figure 11) and riser-suspended (30-inches diameter with 17- or 22-foot height or 10-inches diameter with 3-foot height suspended 13-feet above the tank floor - see Figures 12 and 13 for the two styles). Air-lift circulators exist in quantities of 2, 3, 4, or 22 per tank.

Four of the double-shell tanks (AY and AZ) each contain 22 suspended-type circulators. However, since these tanks are scheduled to contain only small amounts of sludge and because of their double-shell design, they may be sluiced and, therefore, may not be a problem for these retrieval operations.

Additional obstructions will be encountered in many tanks, except for the 533,000-gallon tanks which appear to be comparatively free of internal "plumbing". In-tank

FIGURE 11

FLOOR MOUNTED AIR-LIFT CIRCULATOR
TANK 101-A

FIGURE 12

RISER SUSPENDED AIR-LIFT
CIRCULATORS - TANK 101-AX

FIGURE 13

RISER SUSPENDED AIR-LIFT
CIRCULATORS - TANK 105-TX

items which will be encountered include liquid-level and/or thermocouple pipes, slurry distributors, a variety of liquid pumps, steam coils, air-lift circulator supply pipes, crust breakers, (prototype) bottoms cooler, a few as yet unidentified objects, as well as a quantity of discarded objects. This last category includes, at least, a few known cases of discarded, damaged equipment and, for one tank, a variety of solid waste items - experimental fuel elements, ceramic balls, cobalt slugs, etc.

The contents of some tanks may present unusual difficulties, not only for debris disposal, but for the basic problem of waste recovery as well. For example, the liquid of many tanks has been agitated through the use of air-lift circulators to prevent self-heating from forming large bubbles within the settled sludge layer (i.e., bumping). Apparently, in many cases this action (and conduction to the walls) has provided enough cooling to cause the solids to coat the cooled surfaces. The result, shown in Figure 14, is a large "lollypop" clinging to an air circulator, as well as a substantial ledge of material extending out from the tank wall. The disturbing feature of the presence of this apparently hard material is the fact that a later photograph shows only a "smooth sea" of damp salt cake (Figure 15), with no evidence of this underlying strata. For many tanks, later photographs may be deceiving and earlier pictures of the contents were not obtained.

5.3.2.6 Ventilation

Environmental considerations dictate that the retrieval operations be conducted such that there will be no significant release of radioactive material to the surroundings. Since some of the waste may be handled dry, or may become a dry residue on above-ground equipment, a positive,

FIGURE 14

TANK 112-TX SHOWING SALT ENCRUSTATION
(LOLLYPOP ON AN AIR-LIFT CIRCULATOR)

FIGURE 15

TANK 112-TX WITH SALT CAKE
COVERING ENCRUSTATION

controlled ventilation system is necessary. This system will be designed to control radioactive particulate emissions to the environment as low as practicable but in no case exceeding the limits established by ERDA Manual Chapter 0524.

Control of airborne radioactive material will be provided by roughing and final (HEPA) filters and air monitoring equipment included with a portable exhaust unit located adjacent to the retrieval system platform. Apparatus for remotely changing and bagging contaminated filters will be considered, as well as alarms and instrumentation to monitor the levels of radioactivity.

Routine operation of the Waste Retrieval System(s) will use conventional sources of electricity and water available in the tank farm areas. In the event of a main electrical power failure, however, a standby diesel powered generator will be located nearby and used to maintain the air ventilation system in operation.

5.4 PERSONNEL SAFETY AND SHIELDING

The most important design features of the Waste Retrieval System are those involving the safety of the personnel required to operate and maintain the equipment. The radioactive waste material will be recovered and moved from the tank to the platform in sizeable quantities. The size of the individual waste transport containers will be determined by type and activity level of the waste being recovered so as to minimize (and make uniform) the shielding requirements and maximize the amount of material carried per trip to the waste processing facility. As an illustration, consider the following situations:

- From the 242-S Vacuum Evaporator-Crystallizer samples taken to date, the extremes of ^{137}Cs activity are 0.015 Ci/liter (Tank 105-S) to 0.34 Ci/liter (Tank 106-S) (a factor of more than 20).
- Redox sludge samples vary from a high of 5.7 Ci/liter ($^{89} + ^{90}\text{Sr}$) and 0.5 Ci/liter (^{137}Cs) to a low of 10^{-4} Ci/liter ($^{89} + ^{90}\text{Sr}$) and 10^{-2} Ci/liter (^{137}Cs).
- The majority of tanks containing Purex sludge are scheduled for sluicing operations; however, measurements from Tank 104-A (25,000 gallons sludge) indicate activity levels of 44 Ci/liter ($^{89} + ^{90}\text{Sr}$) and 1.2 Ci/liter (^{137}Cs). Relatively small amounts of residual sludge in the sluiced tanks may have activity levels two times ($^{89} + ^{90}\text{Sr}$) or five times (^{137}Cs) these levels.
- Consideration of the decay schemes of ^{90}Sr and ^{137}Cs shows that, in nearly all cases, the bulk of the exposure rate will be due to the ^{137}Cs content - ^{137}Cs decay includes a 0.662 MeV photon, while the average Bremsstrahlung from the 2.27 MeV beta particle involved in ^{90}Sr is less than 10 KeV.

The consequences of the above factors suggest that containerization and transport of "as recovered" waste (dry) may best and most efficiently be accomplished by sets of containers of different sizes. This procedure would provide a definite advantage in uniformity of shielding requirements for personnel protection, as well as allow

larger units for transport of lower activity waste. Personnel shielding requirements will be quite different, however, if the hydraulic material handling option is chosen. Transfer of salt cake slurry to a holding tank and additions of very large amounts of water (i.e., dissolution) may allow bulk transport via existing or new underground pipelines to the waste processing facility (radionuclide removal option).

The magnitude of the actinide content of the waste is indicated in Table III. While the quantities are formidable, these materials are dispersed in nearly 36,000,000 gallons of salt cake and sludge. The highest measured concentration of ^{239}Pu to date has been 0.2 gram/liter (Redox sludge, tank 115-SX) which, from the criticality viewpoint, is well below the infinite sea concentration of 7.2 grams/liter (H/Pu ratio ~ 3680). The importance of controlled ventilation and general system cleanliness is emphasized by the fact that the maximum plutonium body burden by ingestion is 0.6×10^{-6} grams. Radiation monitors will assure that radionuclide concentrations are less than the limits prescribed by ERDA Manual Chapter 0524 for controlled areas.

The design of the Waste Retrieval System shall consider all aspects of potentially hazardous materials, equipment, and controls. Radiation level monitors and audio/visual alarms will be incorporated in accordance with operational needs. Because of the fact that the Waste Retrieval System is a large, isolated metal structure with a substantial electrical power supply, extraordinary measures will be included for electrical safety. All equipment will be designed for fail-safe operation in the event of a power failure.

The motive power for most of the in-tank equipment will be hydraulic - e.g., articulated arm, mechanical tools, slurring pumps, etc. Personnel protection from hot, high-

TABLE III

**TANK FARM ACTINIDE CONTENTS,
ESTIMATED, KILOGRAMS**

TANK FARM	U TOTAL	^{235}U	^{233}U	$^{239+240}\text{Pu}$	^{232}Th	^{237}Np
A	55,000	360	1	99	390	0.4
AX	8,000	60	3	18	1,100	2.2
B	47,000	310	-	20	-	-
BX	67,000	440	-	11	-	-
BY	154,000	1,010	-	25	-	-
C	178,000	1,190	38	69	13,000	5.1
S	40,000	270	-	27	-	-
SX	48,000	320	-	45	-	-
T	52,000	340	-	32	-	-
TX	127,000	840	-	10	-	-
TY	32,000	210	-	7	-	-
U	90,000	590	-	3	-	-
TOTAL	900,000	5,900	42	370	14,500	8

pressure hydraulic fluid will be included; however, key factors in choosing the working fluid will be radiation resistance and fire resistance. The possibility of an on-board or in-tank fire must be reduced to an absolute minimum. This will be accomplished by using a fire-resistant fluid with additional considerations of compatibility of the fluid with radiation resistant seal and hose materials, and for its lubricity, viscosity, etc. These latter items are especially important because of the requirements for long operational life and the minimization of repair and replacement problems.

5.5 QUALITY ASSURANCE

The Waste Retrieval System may be characterized in the following manner. First and foremost in order of importance is the capability to handle the Hanford high-level waste in a safe manner — for both personnel safety and prevention of dispersal of radioactive material to the environment. Secondly, the waste retrieval operation must be conducted such that the material is made available for subsequent processing (immobilization) in as efficient and cost-effective a manner as possible. A third characterization is related to the previous one and the fact that a very large quantity of material must be dealt with over a number of years and supplied to a processing facility at a relatively constant rate. This item relates to the need for a system capable of reliable operation with low maintenance requirements. These objectives will be met with the aid of a conscientious effort to establish engineering design criteria and adherence to strict quality control. It appears reasonable to include the objectives and requirements of the Quality Assurance Program (QAP) at the Title II design stage for major components and subsystems of the Prototype Retrieval System. Indeed, it would be a distinct advantage if the prototype

system, or major components thereof, could simply be replicated to provide as many retrieval systems as will be needed for full-scale retrieval operations (Phase II, Reference 2).

The intent of the QAP is well understood; however, it must be recognized that the Waste Retrieval Task is a developmental effort charged with the task of devising and demonstrating the machinery (system) necessary for the safe removal of wastes from the underground storage tanks. Upon completion of contractor-performed engineering studies and conceptual designs and prior to Title I design, the retrieval system will be examined for appropriate assignment of the Quality Assurance Levels I, II, III or none. The "none" category will include a variety of experimental (not prototype) waste recovery/removal tools and equipment as required through the development/cold test operations phase. All tool and equipment designs resulting from the developmental/cold testing cycle will be assigned appropriate QA levels prior to detailed design/fabrication for the radioactive demonstration operations.

6.0 SYSTEM ANALYSES

From the functional or operational point of view, the Waste Retrieval System is a large, complex arrangement of interrelated subsystems. The overall system performance and safety are directly related to the suitability and performance/controllability of each of these functional components. As stated earlier, personnel safety and environmental concerns are of the utmost importance and will be addressed in separate documents at appropriate times relative to each of the two system demonstration portions of the program.

6.1 SAFETY ANALYSIS

A comprehensive safety analysis will be undertaken at a suitable time during Title II - detail design. Any recommendations from this study can, therefore, be applied to the prototype retrieval system, either during the fabrication for cold test operations or in the preparations for the radioactive demonstration phase, as required. Any system or component modifications dictated by "cold" operating experience with the system in the prototype test facility (see Section 8.1) will be re-examined in a supplemental safety report prior to any radioactive demonstration.

Before this formal safety analysis, however, all safety-related problems will be addressed in the conceptual design/engineering studies sequence. Engineering studies and subsequent detail design efforts will include consideration of wind loading (winds to 100 mph) and earthquake forces [safe shutdown for seismic loads to 0.25 g horizontal and $(2/3) \times 0.25g$ vertical]. As mentioned in Section 5.4, fire prevention is an item of paramount importance, and the hydraulic system(s) design will proceed accordingly. Other features affecting safe system operation will be studied early in the conceptual design phase as, for example, subsystem failure modes and associated repair/replacement procedures. Further, procedures will be established (equipment provided) for assured safe auxiliary operations. Examples of these are: for waste transport, a driver-controlled interlock (enablement device) to allow opening of the exterior door of the loading platform airlock; and for the maintenance-repair-tool change hot cell, an interlock which could, for example, enable the hot cell manipulators while disabling the articulated arm when it is in position in the cell (e.g., duplicate lock switches with single key).

6.2 ENVIRONMENTAL ASSESSMENT

As stated previously, one or more environmental statements will be prepared and evaluated during the course of technology developments and alternative assessments necessary for the selection of methods and machinery for long-term waste management. A generic environmental impact statement is planned for the overall Hanford Long-Term High-Level Waste Management Program (reference 2). Further, it is anticipated that an assessment (project specific) of environmental impact will be prepared prior to the retrieval of wastes by the Prototype Retrieval System in the radioactive demonstration.

7.0 PROTOTYPE RETRIEVAL SYSTEM - TEST AND EVALUATION

Considerable testing of individual components, as well as complete subsystems of the Waste Retrieval System, will be necessary. Further, testing of combinations of subsystems will be required to gain assurance that the total system will perform the retrieval task in a safe and efficient manner. Recall that the objective of the present Waste Retrieval Task is to develop and demonstrate a functionally complete waste retrieval system which, in the most desirable situation, can be replicated should retrieval of all Hanford high-level solidified wastes be found necessary. In any event, this developmental effort will serve as the foundation for the design and operation of the system(s) required for an operational retrieval program.

7.1 PROTOTYPE TEST FACILITY

The character of the solid waste and the constraints imposed by the underground storage tank configurations make it mandatory that the Waste Retrieval System be tested and demonstrated at full-scale and over all conceivable ranges of operation. Accomplishment of this phase of the system development will occur at a facility constructed specifically for that purpose. Present plans call for a mock waste tank approximating the size, shape, and location relative to ground level of the largest existing tanks (see Figure 16). This underground structure will, therefore, describe an envelope of space within which the waste recovery/ removal machinery must operate. To further simulate the constraints of access holes (risers, manholes) and the requirement of no allowed additional dome loading, the relatively light tank cover will contain the variety of access hole locations, and concrete support pads for the retrieval system will assure that no loads are applied to the dome or risers.

The current plan is for the Prototype Test Facility to be a part of the Long-Term Waste Management Equipment Test Facility. A contingency plan is being considered in the event that this equipment test facility will not be available at the necessary time in the Waste Retrieval Task schedule. This alternate plan of constructing the mock waste tank and cover separately would allow the Waste Retrieval Task to proceed independently of the equipment test facility availability or schedule. The necessary event sequence for the Prototype Test Facility is shown in the Timetable of Appendix A.

FIGURE 16
PROTOTYPE TEST FACILITY
(MOCK WASTE TANK)

7.2 SYSTEM PERFORMANCE TESTS

To achieve the goal of a safe, workable, efficient retrieval system, a large number of tests and demonstrations will be undertaken involving components, subsystems, sets of subsystems, and finally the whole system. These will follow the general order of:

1. Does this item perform as intended (designed)?
2. Does this item accomplish the objective?
3. Is the operation safe, effective, and does it appear reliable (low maintenance requirements)?
4. Does this subsystem work in harmony with adjoining subsystems?
5. Does the collection of subsystems (total system) accomplish the basic task?
6. Are the control and monitoring functions sufficient for routine retrieval operations?

Probably the most critical items for equipment development lie in the area of waste recovery/removal tools. Some equipment evaluation tests have been conducted using synthetic salt cake and, applying this experience, conceptual designs of composite tools (mechanical-slurrying) are currently in progress. It does appear, however, that the development of the waste handling tools will be a continuous process, with the devices being modified as experience and knowledge is gained throughout the program. For example, the appropriate degree of tank "clean-up" has not been established and will depend in large measure on the activity of the waste and final

disposition of the tank structure and contaminated soil. The nature of this problem is illustrated in Figure 17 which shows the condition of the steel liner and some of the waste residue for one of the oldest tanks.

Beyond the equipment/subsystem development phase, the Prototype Test Facility will be used for two very significant purposes. First is to establish operational procedures and train operators and maintenance/repair personnel. The second, by operating the prototype retrieval system under simulated operational conditions, is to certify that the system is operationally capable and suitable for the radioactive demonstration phase.

7.3 RADIOACTIVE DEMONSTRATION

The basic purpose of this stage in the development of the retrieval machinery is to show clearly that the means exist for the recovery of Hanford high-level waste and that this job could be done in a safe and environmentally acceptable manner. At this stage, the complete Prototype Retrieval System will have been thoroughly tested, operational procedures established, and operators trained. This step, then, will be a "proof-test" of the methods and machinery chosen for the Hanford High-Level Waste Retrieval Task. This demonstration, as mentioned earlier, may operate in conjunction with the Waste Processing Task if it becomes necessary to demonstrate processes or immobilization techniques on a significant scale. The selection of a tank or tanks for this retrieval demonstration phase will be deferred until decisions are made regarding processing and immobilization schemes and size of the demonstration facility.

As examples of extremes in input material requirements, consider these two schemes: radionuclide removal (first step in the immobilization process) or feed directly to a glass melter. If radionuclide removal is included prior

FIGURE 17

STEEL LINER AND WASTE
RESIDUE - TANK 101-U

to immobilization of the wastes, then because dissolution of the salt cake is the first step, water addition to the delivered material is not a problem. Sufficient water may be added in the retrieval operations to make the salt cake/sludge a pumpable slurry, and tank truck transport and small tank lag storage are viable options. If, on the other hand, the waste will be used directly as feed to a glass making facility, then a low water content is necessary. It may be appropriate in this case to deliver the material as dry as possible (as retrieved). Otherwise a substantial evaporation capability would be necessary. For this case, truck transport of waste in sealed containers would be used, with these same containers used for temporary (lag) storage at the waste processing facility.

There are indications, from in-tank photographs and a few core samples, that the physical consistency of the solid material within a single tank is extremely varied. It is not likely that the waste characterization effort will be able to document all desired information as to the quantity and quality of the solid wastes to be encountered. Therefore, it may be necessary that tool development (more likely modification) be continued, even through the radioactive demonstration phase.

8.0 OPERATIONAL RETRIEVAL SYSTEM(S) AND OPERATIONS PLANNING

Although a future waste management decision may require the retrieval of all Hanford high-level waste in tanks, this effort is beyond the scope of the present program. The current objective remains, nevertheless, to establish and demonstrate retrieval technology so as to confidently evaluate alternatives. The present program can be considered complete when it is possible to specify the design,

construction, and operation of as many retrieval systems as would be required for the retrieval of Hanford high-level waste from underground storage tanks. In many respects, for full-scale operations, it would be desirable to simply replicate the final version of the Prototype Retrieval System. However, considering the fact that this prototype system will come into existence and undergo development before a final commitment is made on the immobilization scheme (process and/or scale), it may be more cost-effective to proceed with a modified design. This modified design would have the basic structure and features of the prototype system, but differ perhaps in certain auxiliary systems and tooling, depending on the final determination of feed character and rate to the waste processing facility.

Final contributions of this program will include a document containing studies and recommendations on tank farm site preparations which would be required to implement a full-scale waste retrieval operation. Additionally, if considered appropriate at the time, a manual of operational procedures for the Waste Retrieval System will be prepared.

REFERENCES

1. ERDA-1538 (unclassified), December 1975, "Final Environmental Statement - Waste Management Operations, Hanford Reservation, Richland, Washington."
2. ARH-LD-142 (unclassified), June 1976, Compiled by D. D. Wodrich, "Hanford Long-Term High-Level Waste Management Program Plan - Phase I: Technology Development."
3. News Release RLO-76-8 (unclassified), February 19, 1976, "ERDA Administrator Announces Expanded Program in Management of ERDA, Commercial Nuclear Wastes," Richland Operations Office, U. S. Energy Research and Development Administration, Richland, Washington.

APPENDIX A
WASTE RETRIEVAL TASK
Timetable and Funding Estimates

*UNCERTAIN TERM OF CAMPAIGN

↑
10-1-76

REDUCED SCALE EFFORT

FULL SCALE EFFORT

APPENDIX B

WASTE STORAGE TANK CONTENTS^a

Current Status as of August 1, 1976
and projection for end of calendar year 1980

1,000,000 Gallon Tanks (Single Shell)

A-Farm Tank	Current		Projected End CY'80	SX-Farm Tank	Current		Projected End CY'80
	Liquid	Solid	Solid		Liquid	Solid	Solid
101	19	3	241 ^c	101	465	466	466
102	3	3	3	102	467	475	659 ^c
103	55	17	800 ^c	103	709	249	580 ^c
104L ^b	0	25	25	104	121	563	563
105L	17	33	33	105	256	491	803 ^c
106	776	91	2	106	943	26	792 ^c
AX-Farm				107L	0	109	109
101	0	3	315 ^c	108L	0	87	87
102	663	17	800 ^c	109L	MH	257	257
103	0	69	2	110N	MH	32	32
104	259	47	2	111L	0	125	125
				112L	0	106	106
				113L	0	6	6
				114N	0	200	200
				115L	0	6	6

1,000,000 Gallon Tanks (Double Shell)

AY-Farm				AW-Farm			
101	916	52	52	101	-	-	0
102	209	0	50	102	-	-	0
AZ-Farm				103	-	-	0
101	0	0	20	104	-	-	0
102	103	0	0	105	-	-	0
SY-Farm				106	-	-	0
101	-	-	10	AN-Farm			
102	-	-	0	101	-	-	0
103	-	-	10	102	-	-	0
				103	-	-	0
				104	-	-	0
				105	-	-	15
				106	-	-	17

APPENDIX B (Continued)

758,000 Gallon Tanks

BY-Farm Tank	Current		Projected End CY'80 Solid	TX-Farm Tank	Liquid	Solid	Projected End CY'80 Solid
	Liquid	Solid					
101	330	398	398	101	96	73	73
102	426	200	200	102	525	194	194
103L	MH	461	461	103	727	3	3
104	250	469	469	104	707	18	118 ^e
105N	MH	626	626	105	209	502	502
106	330	351	351	106	275	257	257
107N	MH	367	367	107	690	24	60 ^e
108L	MH	359	359	108	314	81	81
109	160	425	425	109	564	123	262 ^e
110	382	296	296	110	300	420	420
111	371	299	299	111	325	389	399
112N	MH	310	310	112N	MH	664	664
				113N	MH	681	681
				114N	MH	678	678
				115	50	640	640
				116N	MH	631	631
				117N	0	626	626
				118	267	260	260
S-Farm				TY-Farm			
101	382	332	332	101N	0	169	169
102	402	200	285 ^e	102	283	29	29
103	300	37	37	103L	MH	219	219
104N	MH	299	299	104N	MH	29	29
105N	MH	541	541	105L	0	285	285
106	22	673	673	106L	0	18	18
107	360	343	343				
108	22	706	706				
109	74	653	653				
110N	MH	689	689				
111N	MH	750	750				
112N	MH	706	706				

APPENDIX B (Continued)

533,000 Gallon Tanks

B-Farm Tank	Current Liquid	Current Solid	Projected End CY'80 Solid	C-Farm Tank	Current Liquid	Current Solid	Projected End CY'80 Solid
101N	MH	103	103	101N	MH	73	73
102	17	35	35	102N	MH	431	431
103	63	68	68	103	217	73	73
104N	MH	395	395	104	270	235	235
105N	0	293	293	105	83	139	139
106	17	125	125	106	402	106	106
107N	MH	194	194	107N	MH	191	191
108	44	112	112	108N	MH	65	65
109	143	117	117	109N	MH	62	62
110N	MH	282	282	110N	MH	211	211
111N	MH	246	246	111N	MH	62	62
112	294	35	35	112N	MH	109	109

BX-Farm

101N	MH	46	46
102L	0	40	40
103	105	54	54
104	187	65	65
105	454	54	54
106	297	26	26
107	96	376	376
108L	0	15	15
109N	MH	208	208
110	250	249	249
111	294	216	216
112	25	178	178

T-Farm

101N	297	37	37
102N	MH	62	62
103N	MH	35	35
104N	MH	483	483
105N	MH	114	114
106L	MH	26	26
107N	MH	131	131
108N	MH	35	35
109N	MH	147	147
110N	MH	466	466
111N	MH	488	488
112	69	32	32

U-Farm

101L	19	40	40
102	404	43	413 ^c
103	245	32	413 ^c
104L	0	125	125
105	481	32	413 ^c
106	382	26	413 ^c
107	352	15	15
108	311	200	413 ^c
109	253	255	413 ^c
110L	MH	161	161
111	473	26	265 ^c
112N	MH	37	37

APPENDIX B (Continued)

55,000 Gallon Tanks							
B-Farm Tank	Current Liquid	Current Solid	Projected End CY'80 Solid	C-Farm Tank	Current Liquid	Current Solid	Projected End CY'80 Solid
201N	MH	29	29	201	4	0	0
202	25	27	27	202	2	0	0
203	6	44	44	203	5	3	3
204	3	46	46	204	44	0	0
T-Farm				U-Farm			
201N	MH	31	31	201	45	4	4
202N	MH	25	25	202	47	4	4
203N	MH	35	35	203	43	4	4
204N	MH	44	44	204	50	1	1

^aQuantities in 10³ gallons (MH = minimum heel)

^bL - Leaker, N - Inactive

^cAdditional solid is salt cake only - current solids include sludge and salt cake.

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