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DOE UST INTERIM SUBSURFACE BARRIER TECHNOLOGIES WORKSHOP

TUSCON, ARIZONA
FEBRUARY 25 - 27, 1992

PREPARED BY

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1.0 INTRODUCTION

On February 25-27, 1992 Bovay Northwest, Inc. conducted a workshop in Tucson, Arizona on interim subsurface barrier technologies that could be used around underground storage tanks (UST), specifically the 241-C-106 tank at the Hanford Site in Washington State. The workshop addressed the in situ treatment of geologic media for interim confinement of wastes in underground storage tank systems. The technologies will be screened and then be tested in the field in a full scale demonstration and development project.

This report documents the information presented in the workshop, including advantages and disadvantages of all the technology and treatment options and recommendations for further engineering and development. Some of the information in this report was provided by technical experts during their review of draft versions. A list of workshop attendees can be found in Appendix A.

1.1 SCOPE AND OBJECTIVE OF THE WORKSHOP

The objective of the U.S. Department of Energy (DOE) UST workshop on "Interim Subsurface Barrier Technologies" was to identify a host of candidate technologies and to select two of those technologies for potential application to the 241-C-106 UST at the Hanford Site. Although the focus of the workshop was to discuss barrier technologies that could contain the 241-C-106 tank, clearly the technologies presented may have application to additional DOE USTs at Hanford and other DOE sites. Moreover, the technologies may also have application to commercial and industrial settings.

The scope of the workshop included all subsurface barrier technologies that could be installed around an UST or series of USTs. The scope did not include in-tank treatment.

The following general guidelines were used in the planning of this technology development workshop:

- Technologies, processes, and systems proven by application to similar situations (e.g. non-radioactive industrial) should be pursued first to save time. Therefore, analogous situations in which technologies have been applied and systems using technologies developed elsewhere should be investigated.

- As a leader in the DOE's environmental restoration program, technology demonstrations should proceed on actual waste problems as soon as feasible.

- The engineered systems and personnel available on-site and within the DOE complex should be taken advantage of to refine technologies developed by industry, national laboratories, universities, and others.

- Safety is paramount in the development and use of technologies on simulated or actual wastes.

- Priority should be considered for demonstrating those technologies with applications to private industry and/or other DOE waste applications.

1.2 PURPOSE AND SCOPE OF THE REPORT

The purpose of this report is to document information and ideas presented at the DOE Interim Subsurface Barrier Technology Workshop, including the identification of two technologies that should be investigated further for possible installation around the 241-C-106 tank.

The scope of this document includes those subsurface barriers that could be emplaced in situ near the 241-C-106 tank. It is clearly recognized, however, that the barriers discussed in this document may have application to other USTs in the DOE complex. The scope included any technologies that could be emplaced vertically, horizontally, or as a monolithic encapsulation.

The scope of this document does not include emplacement technologies (although they are briefly discussed). In addition, the scope does not include cover barriers or caps.

1.3 TECHNICAL EXPERTS

A total of 30 expert candidates were reviewed and screened down to 6. These experts were invited to attend the workshop. Selection criteria were based upon the following prioritized parameters:

- Working knowledge and experience with subsurface barrier systems
- Applicability of known barrier systems and materials to DOE USTs
- Willingness to prepare and present materials
- Availability and interest
- Rates.

A synopsis of the background of all technical experts can be found in Appendix B.

1.4 WORKSHOP PROCESS

The meeting agenda for the workshop is shown in Table 1-1. The workshop process is shown below:

- Problem identification
- Expert testimony
- Selection criteria identification
- Expert opinions
- Selection process.

The initial step in the workshop process was to introduce the problem in detail by familiarizing the participants with the scope of the problem. Presentations were made on the UST-Integrated Demonstration (ID) Program, background information on DOE USTs, and the 241-106-C UST. Background information was provided to the experts prior to attending the workshop. Each expert was asked to provide a 45-minute presentation regarding applicable barrier technologies.

Based upon expertise from DOE and contractor personnel, the third step in the process was to identify selection criteria. This step included identification and discussion of criteria that could eliminate the possible of use of some technologies for barrier application to the 241-C-106 tank.

Opportunity was then provided for the experts to once again present their opinions and ideas regarding potential solutions to the problem after consideration of mitigating concerns. This step proved to be extremely useful in the selection process that followed. Finally, informal selection was initiated to refine and screen all technologies based upon selection criteria and options presented.

The mechanics of the workshop process were geared towards an easy and free exchange of ideas. As such, the workshop attendance was kept small and all attendees were encouraged to participate via questions and comments. The facilitator purposely planned extra time for frequent interchanges. Workshop secretaries noted and recorded information presented via slides, overheads, flip-charts, and tape recorder.

Each attendee was provided with a workshop notebook. As material was presented, all attendees were provided with hard copies for placement in the book.

Table 1-1. DOE UST Interim Subsurface Barrier Technologies Workshop Agenda.

	Session I	
Registration	N.M. Motahari	Bovay Northwest
Facility Information	C.L Edison	Bovay Northwest
Welcome/Introduction	T.J. McLaughlin	Bovay Northwest
Purpose & Background	S.J. Phillips	Westinghouse Hanford
DOE/UST Integrated Demo. Program	J.K. Rouse	Bovay Northwest
DOE USTs	J.K. Rouse	Bovay Northwest
106-C SST	S.P. Airhart	Bovay Northwest
Modified Sulfur Cement	P. Colombo	Brookhaven Nat. Labs
Polymer Concretes	R. R. Davidson	Woodward-Clyde
Grouts (various)	D. W. Fowler	U. of Texas, Austin
Cryogenics	I. K. Iskandar	USCOE
Meeting Adjourned		
	Session II	
Announcements/Handouts	C.L. Edison	Bovay Northwest
Concrete Technologies	A. Naudts	ECO Geochemical
Jet Grouting	P. J. Pettit	Halliburton
Slurry Injection	S. J. Phillips	Westinghouse Hanford
In Situ Heating	J. Tixler	PNL
Horizontal Drilling	D. Russell	K&M
Screening Process	T.J. McLaughlin	Bovay Northwest/Group
Technology Selection	T.J. McLaughlin	Bovay Northwest/Group
Technology Ranking	T.J. McLaughlin	Bovay Northwest/Group
Meeting Adjourned		
	Session III	
Announcements/Handouts	C.L. Edison	Bovay Northwest
Expert Opinions	Technical Experts	
Expert Opinions (con't)	Technical Experts	
Public Participation Process	J.G. Burk, Jr.	Westinghouse Hanford
Meeting Summary	S.J. Phillips	Westinghouse Hanford/
	T.J. McLaughlin	Bovay Northwest
Meeting Questionnaire	C.L. Edison	Bovay Northwest
Workshop Adjourned		

1.5 ORGANIZATION OF THE REPORT

The remainder of the report is organized as follows. Section 2.0 briefly describes the DOE-UST Program. Section 3.0 summarizes and describes DOE USTs at Fernald, Hanford, Savannah River. Oak Ridge, and Idaho National Engineering Laboratory. Section 4.0 provides summary information on the 241-C-106 UST. Section 5.0 identifies barrier technologies discussed at the workshop. Section 6.0 identifies criteria important in the selection of barrier technologies. Section 7.0 describes technologies which were "screened" against the selection criteria. Finally, Section 8.0 provides recommendations and conclusions.

Also included in this report are several appendices. Appendix A contains a list of workshop attendees. Appendix B more fully describes the backgrounds of the workshop technical experts. Appendix C provides detailed information regarding barrier technologies.

1.5 ORGANIZATION OF THE REPORT

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2.0 DOE-UST INTEGRATED DEMONSTRATION PROGRAM

This section describes the DOE UST-ID program, its goals, beneficiaries, and a brief summary of the DOE wastes currently being stored in underground tanks.

The DOE designed the UST-ID program to demonstrate technologies for the retrieval, treatment, and closure of DOE USTs and tank waste. Preferably, these technologies should already be developed and should only need slight modifications for usage within DOE waste management systems.

There are five participating DOE sites in the UST-ID program, as coordinated by Westinghouse Hanford Company:

- Idaho National Engineering Lab (INEL), Idaho Falls, Idaho
- Fernald, Ohio
- Oak Ridge, Tennessee
- Savannah River, South Carolina
- Richland, Washington (Hanford).

There are five beneficiary categories which can receive assistance for demonstrated technologies. These are, in descending order of importance:

1. Five participating sites
2. Other DOE sites
3. Other Federal agency's sites
4. Commercial sites
5. Technology transfer to private sector

More than 250 large USTs have been built to store radioactive waste produced from over 45 years of government nuclear fuels production. This waste contains both high and low level, transuranic, and hazardous wastes and is therefore sometimes referred to as "mixed" wastes. In some cases, waste has leaked from DOE USTs and has contaminated the surrounding soil and groundwater.

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The USTs at the 5 sites have capacities ranging from 500 to 2,000,000 gallons. Construction materials include stainless steel, carbon steel, and concrete. Most of the tanks were constructed with a concrete support with either one or two carbon steel liners for waste containment. Some of the tanks are supported with carbon or stainless steel and were then placed in concrete vaults for leak containment and radiation shielding.

The waste stored in the USTs has five general forms:

- Salt cake
- Sludge
- Slurry
- Calcine
- Liquids (supernatant).

Salt cake is formed from the evaporation of the liquid portion of the waste for waste volume reduction: the chemical constituents are very similar to the liquid waste, containing mainly nitrate and nitrite salts. Sludge contains mainly insoluble precipitated metal oxides and hydroxides from the neutralization of the process waste. Slurry waste is a mixture of sludge and liquid waste that has a composition near the solubility limit of the chemical components. Calcine consists of liquid waste that has been solidified for long-term storage (this waste type is unique to the Idaho Falls site and in very small quantities). Liquid, or as it is commonly called "supernatant", waste is the product of the neutralized process waste. Idaho Falls liquid waste is not neutralized and stays acidic for storage.

The major contaminates at the five participating sites include a large quantity of nitrate and nitrite salts and smaller quantities of other sodium salts. The wastes also contains several metal oxides and hydroxides, especially iron and aluminum hydroxide. There are also quantities of mercury, lead, nickel, and some organic compounds mixed within the various waste forms. The major radionuclides include the fission products cesium-137 and strontium-90 and their decay products, such as technetium and iodine. The waste also contains small quantities of transuranics, mainly uranium and plutonium isotopes.

3.0 DOE-UST DESCRIPTION SUMMARY

This section briefly describes the USTs at the five DOE sites participating in the DOE UST program.

3.1 IDAHO FALLS USTs

The majority of USTs at the INEL (or Idaho Falls) are managed by the chemical processing contractor, Westinghouse Idaho Nuclear Company for the Department of Energy. It runs the Idaho Chemical Processing Plant (ICPP) and the INEL. The major mission of ICPP is the reprocessing of spent nuclear fuels for reuse. The liquid high level waste produced by this process is temporarily stored in large USTs and is eventually solidified by calcining the waste for permanent storage.

The ICPP liquid waste is temporarily stored in 11 stainless steel tanks. The tanks each have 300,000 gal operating capacities and are located within concrete vaults for leak containment and radiation shielding. They were placed into service between 1953 and 1966. There are three different tank and vault designs:

Tank Designs	Vault Designs
Cast-in-place	Individual octagonal
Precast concrete components	Pillar and panel
Cast-in-place concrete walls and precast T-beam roof	Partitioned square

Eight of the 11 tanks have cooling coils on the inner walls and floor. None of the tanks meet current underground tank regulations.

The ICPP process waste is not neutralized, and as such remains in a purely liquid form. The waste is highly acidic; hence the need for the stainless steel tanks. The waste is allowed to buildup in the tanks until they are full. When time allows, the waste is then pumped from the tanks to be solidified in a calcination process for permanent storage. After pumping is complete, a 10 to 12 in. heel remains in the tanks that can not be removed. There is a possibly of a small sludge layer in the bottom of the tanks from repeated filling and emptying.

3.2 FERNALD USTs

The USTs at the DOE Fernald site are primarily managed by the Westinghouse Environmental Management Company for the DOE. Fernald's original mission was the refinement of uranium ore from various locations around the world, mainly from the Belgian Congo, South Africa, and

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Australia. Part of the waste generated in this process was sent to three of four storage silo's for long-term storage. The fourth silo was a spare and was never used. These silos have capacities of approximately 2 MG and are arranged in two groups of two silos each. They are bermed with earth to reduce the radon flux to the surface. The silos were constructed with reinforced concrete. and have a 80 ft diameter and 26 ft outer wall height. The dome is 10 ft higher then the side walls at the center of the tank.

Silos 1 and 2 contain a raffinate sludge from the processing of "K-65" Belgian Congo pitchblende uranium ores. These silos are equipped with drain slots on the interior walls to drain away the interstitial liquid to a sump tank for volume minimization. A 2- to 3-ft bentonite layer has been added on top of the sludge to retard the radon gas emissions from the waste.

Silo 3 contains cold metal oxides in the form of a dry powder. This is from dried raffinate wastes from ore concentrates. Silo 4 was built identical to Silo 3 but has never been used.

The major chemical contaminates in the silo waste are arsenic. barium. chromium. lead. and selenium. The major radionuclide constituents are thorium. radium. and uranium.

3.3 OAK RIDGE USTs

The Oak Ridge site has had two primary missions since its conception during World War II. The first was pioneering the field of uranium enrichment on a large scale. The second was research and development in related nuclear fields through the Oak Ridge National Laboratory. Over the years large quantities of extremely complex mixed wastes were generated and stored in several USTs. Thirty-three of these low level liquid waste (LLLW) tanks are still considered active. There are also 51 inactive LLLW tanks that need to be remediated and closed.

The 33 active LLLW tanks are between 20 and 30 years of age. There are various tank designs. mainly using a stainless steel tank housed within underground concrete vaults. Twenty-five of the tanks have capacities ranging from 500 to 15.000 gal. The remaining 8 tanks have 50.000 gal capacities and are located in the Melton Valley area. There are approximately 360.000 gal of liquid and 115.000 gal of sludge waste stored in the tanks. It is estimated that they contain 30.000 Ci of radioactive waste.

The 51 inactive LLLW tanks are all greater then 30 years of age. As with the active tanks. there are various tank designs using stainless steel. carbon steel. and gunite construction. The tank capacities range from 1.000 to 170.000 gal. There are approximately 290.000 gal of liquid and 39.000 gal of sludge stored in these tanks. although 99% of the waste is in 13 tanks. Approximately 56.000 Ci of radioactive waste is in the tanks.

3.4 SAVANNAH RIVER USTs

The USTs at the Savannah River site are primarily managed by the Westinghouse Savannah River Company for the DOE. The primary missions have been plutonium, tritium, and enriched uranium production. More modern missions include nuclear naval fuels production and plutonium-238 production for deep space power generation. Waste generated at the plutonium recovery areas (F and H areas) were placed in USTs for storage until permanent disposal methods are implemented. The process waste was neutralized and sent to USTs to allow the insoluble components to settle into a sludge layer in the tank. The liquid layer on top of the sludge was kept constant by pumping excess liquid out of the tank to evaporators. The pumped liquid was reduced to a salt cake concentrate which was returned to salt cake holding USTs for storage.

There are a total of 51 high level waste storage tanks in the F and H areas. Of these, 43 have a double shell (DST) construction and 8 single shell (SST). There are four different tank designs:

Number	Type	Construction	Capacity (gal)
12	1	DST	750,000
4	2	DST	1,030,000
27	3	DST	1,300,000
8	4	SST	1,300,000

The Type 3 tanks are the most modern, and are to be increasingly used as the other tanks are phased out. The tanks are constructed with a concrete structure with carbon steel liners. The DSTs have multiple coiling coils suspended from the tank ceilings. Savannah River has also emptied and cleaned one of their Type 2 tanks and is currently deciding how to decommission the tank for closure.

Savannah River has approximately 32.4 MG of waste. Of this, there are 14 MG of liquid, 14.7 MG of salt cake, and 3.7 MG of sludge. The principal radionuclides consist of strontium-90, cesium-137, and plutonium-239. The chemical composition of the sludge is mainly iron, manganese, aluminum, and mercury oxides. Liquid and salt cake wastes contain sodium and potassium salts of nitrate, nitride, carbonate, sulfate, aluminate, and hydroxide.

3.5 HANFORD USTs

The majority of USTs on Hanford Site are managed by Westinghouse Hanford Company. Other prime contractors at Hanford with USTs include Battelle Pacific Northwest Laboratories and Kaiser Engineers Hanford. The primary mission of this site was the production and purification of weapons grade plutonium. This was done by irradiating uranium in nine production reactors along the Columbia River. The irradiated fuel was then sent to the 200 Areas where the chemical recovery processes are located. Waste generated at these process plants was neutralized and then sent to USTs for storage. Hanford has 177 of these large USTs. Of these. 149 of the tanks are SSTs and 28 are the more modern DSTs.

3.5.1 Process History

There have been six different chemical process in the 200 Areas that have contributed to the UST tank wastes. The first was the bismuth phosphate process ($BiPO_4$) used from 1944 to 1956. It was used to recover plutonium only, using a carrier-precipitation process. This process was used in the T and B plants in the 200 West and East Areas respectfully. At the start of operations for this process. over 17,000 gal of waste was generated for every ton of uranium processed. This was reduced over the years to over 5,000 gal by various waste minimization techniques.

The reduction and oxidation process (REDOX) was the second generation plutonium recovery process. It also recovered and separated uranium so it could be reprocessed for further plutonium production. This process was in operation from 1951 to 1967 in the S plant in the 200 West Area. This process used a solvent extraction technique using hexone as the solvent. At first this process generated over 4,400 gal of waste per ton of uranium processed. This was reduced over time to approximately 600 gal/ton uranium.

The tributyl phosphate process (TBP) was used to recover the waste uranium generated in the $BiPO_4$ process in both T and B plant. The U plant in the 200 West Area was used for this process. The U plant was originally built as a $BiPO_4$ plant but was never used as such. This process was used from 1952 to 1958. It used a solvent extraction process with tributyl phosphate. which was used later in the plutonium uranium extraction (PUREX) process.

Sodium ferrocyanide was added to several of the $BiPO_4$ waste tanks to precipitate the soluble cesium-137 so the liquid portion of the waste could be disposed in ground cribs. Ferrocyanide was added to waste tanks themselves and as part of the TBP process at the U plant.

The PUREX is the third generation in plutonium recovery process and was used from 1955 to 1989 in the A processing plant in the 200 East Area. It used a solvent extraction process with tributyl phosphate to recover plutonium and uranium. Both were later separated for individual purification. Waste volumes for PUREX were approximately 400 gal/ton of uranium processed.

The final process was a modification to the old $BiPO_4$ process building (B Plant) to separate strontium-90 and cesium-137 from UST waste to reduce the heat generation and radioactive content. This process was used from 1965 to 1976.

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3.5.2 Tank Descriptions

There are 18 tank farms at Hanford containing 2 to 18 USTs each. Twelve of the tank farms contain SSTs and six contain DSTs. These tanks were constructed using concrete as the base support with one or two carbon steel liners for leak prevention.

The original four SST farms were built from 1943 to 1944 (B, C, T, and U). Each contain twelve 530,000-gal tanks and four 55,000-gal tanks. The BX Tank farm was built from 1946 to 1947 and contained twelve 530,000-gal SSTs but no 55,000-gal SSTs. Between 1947 and 1951 four more SST farms were built (BY, TY, TX, and S). These each had 758,000 gal capacities. From 1953 and 1964, three 1,000,000 gal SST farms were built. These were the last SSTs built and no waste has been added to the SSTs since 1980.

The 28 DSTs were built between 1968 and 1986 in 6 tank farms. They mark a major design change from the SSTs with the addition of a second, heat-stressed, carbon steel liner for additional leak prevention capabilities. All of the DSTs have approximately 1,000,000 gal operating capacities.

Table 3-1 show a summary of all the USTs at Hanford. Figure 3-1 shows the dimensions and different construction designs for the five Hanford tank types.

Table 3-1. HANFORD USTS.

Number	Capacity (gal)	Construction
16	55.000	SST
60	533.000	SST
48	758.000	SST
25	1.000.000	SST
28	1.000.000	DST

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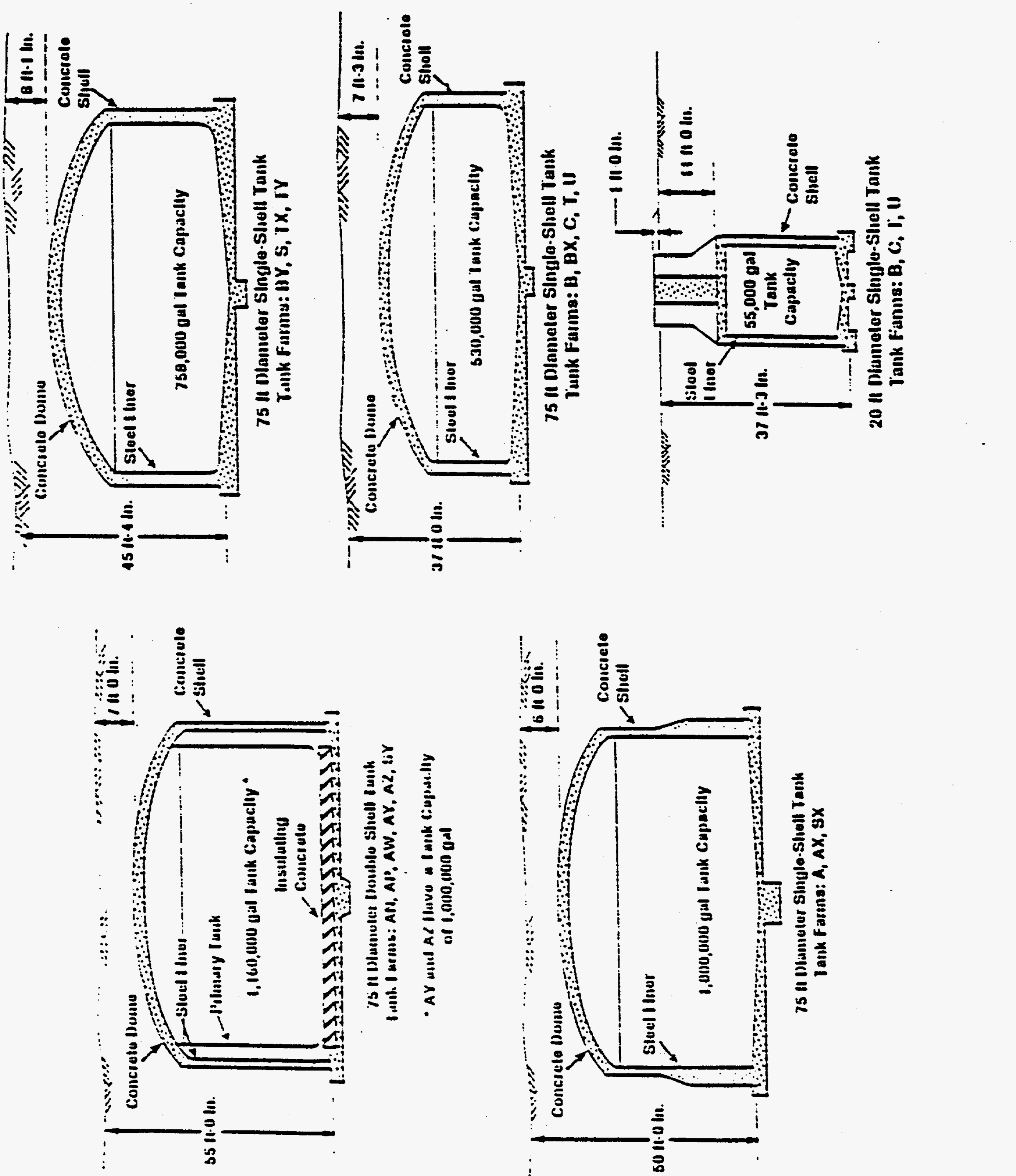

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Figure 3-1. CONFIGURATION OF HANFORD HIGH LEVEL WASTE TANKS.

3.5.3 Hanford Tank Priorities

There are four high priority tank categories that pose the greatest danger to people and the environment:

- Tanks containing potentially explosive ferrocyanide (> 1,000 gmoles)
- Tanks that produce potentially flammable mixtures of gases, especially hydrogen gas
- Tanks containing large amounts of organic salts that may be either highly reactive and/or flammable (> 10% TOC)
- Tanks that contain waste that generate extreme amounts of heat from nuclear decay (>40,000 Btu/hr).

The ferrocyanide was added to the tank waste to precipitate cesium-137 from the liquid waste. Ferrocyanide is potentially explosive at temperatures above 300°F. There are 24 SSTs that are estimated to contain greater then 1,000 gmoles of ferrocyanide.

Five of the DSTs and 18 of the SSTs contain waste that produces mixtures of flammable gases, especially hydrogen and nitric oxides. Tank 101-SY is the worst of these tanks, producing periodic "burps" or gas releases that sometimes exceed the lower flammability level of hydrogen gas. It is theorized that the hydrogen is produced by the polymerization of organic compounds in the waste by the high radiation fields within the tank.

Seven SSTs contain greater then 10% organic compounds within the waste. There is concern that the waste crust could ignite and burn.

Eleven SSTs contain waste that generates greater then 40,000 Btu/hr from the nuclear decay of the fission products. Tank 241-C-106 is the worst, generating over 150,000 Btu/hr or 100 Btu/hr/ton of waste. The other 10 tanks generate heat between 40 and 60,000 Btu/hr. Because of this heat, water has to be added to two tanks (241-C-106 and 241-C-105) to prevent overheating. If overheating occurred, the tank steel liner could fail releasing waste to the surrounding soil.

3.5.4 Waste Descriptions

Hanford USTs contain approximately 60 MG of high level mixed waste. The following is a break down of the different types.

- 19,060,000 gal of supernatant (liquid)
- 14,380,000 gal of sludge
- 23,910,000 gal of salt cake
- 2,070,000 gal of double-shell slurry.

The liquid and salt cake portion of the waste contains primarily nitrate and nitrite salts, mainly sodium. The sludge and double-shell slurry contains mainly hydrated metal oxides and phosphate precipitates. The waste also contains a number of radionuclides, especially strontium-90, technetium-99, iodine-129, cesium-137, and transuranics.

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4.0 241-C-106 TANK DESCRIPTION SUMMARY

This section summarizes the attributes and environment of the 241-C-106 tank.

4.1 241-C-106 TANK

Located in the 241-C tank farm in the 200 East Area of the Hanford Site, 241-C-106 tank (C-106) is a 533,000 gal capacity single-shell, high-level waste storage tank. Constructed from 1941 to 1943, the tank consists of a 1/4-in. to 5/16-in. (top and bottom thicknesses, respectively) carbon steel liner, enclosed in a 13-in. thick concrete shell (Figure 4-1). In 1971, C-106 was placed on a "high heat watch list" when measurements inside the tank were recorded in excess of 210°F. At that time, C-106 and an adjoining tank (241-C-105) were designated inactive and were placed on an active exhauster to facilitate heat removal. In addition, approximately 6,000 gals of raw water are added to the tank each month to remove heat from the tank through evaporative cooling (Barnes, et al. 1991). The heat generation in the tank is due to the decay of strontium in the waste sludge (158,000 Btu/hr estimated heat output). Without additions of water, it is suspected that the heat generation would adversely effect the integrity of the tank. Currently, the tank is considered sound (e.g., not leaking) (Barnes, et al. 1991). In September, 1991, the waste volumes inside the tank were estimated at 229,000 gals (197,000 gals sludge and 32,000 gals liquid).

4.2 NEAR-FIELD ENVIRONMENT CHARACTERISTICS

Sediment stratigraphy is well defined in the vicinity of 241-C Tank Farm based on sediment samples collected during the drilling and installation of unsaturated zone monitoring and groundwater monitoring wells (Price and Fecht, 1976; Pearson, 1990). Unsaturated zone monitoring wells (six around C-106) were emplaced for leak detection monitoring of the individual tanks. The unsaturated zone wells are 6-in. diameter, carbon steel cased wells with open bottoms, with an average depth of 75 ft below land surface. Locations of these wells are shown in Figure 4-2. Figure 4-3 shows the locations of five groundwater monitoring wells around 241-C Tank Farm. Well 299-E27-7 was drilled in 1982, and wells 299-E27-12, -13, -14, -15 were drilled in 1989 as part of the SST RCRA Groundwater monitoring program (Jensen, et al. 1989; Pearson, 1990). Unfortunately, sediment geotechnical data (e.g., density, compaction, cementation) which may be integral to the placement of subsurface barriers, was not collected during the drilling of these wells.

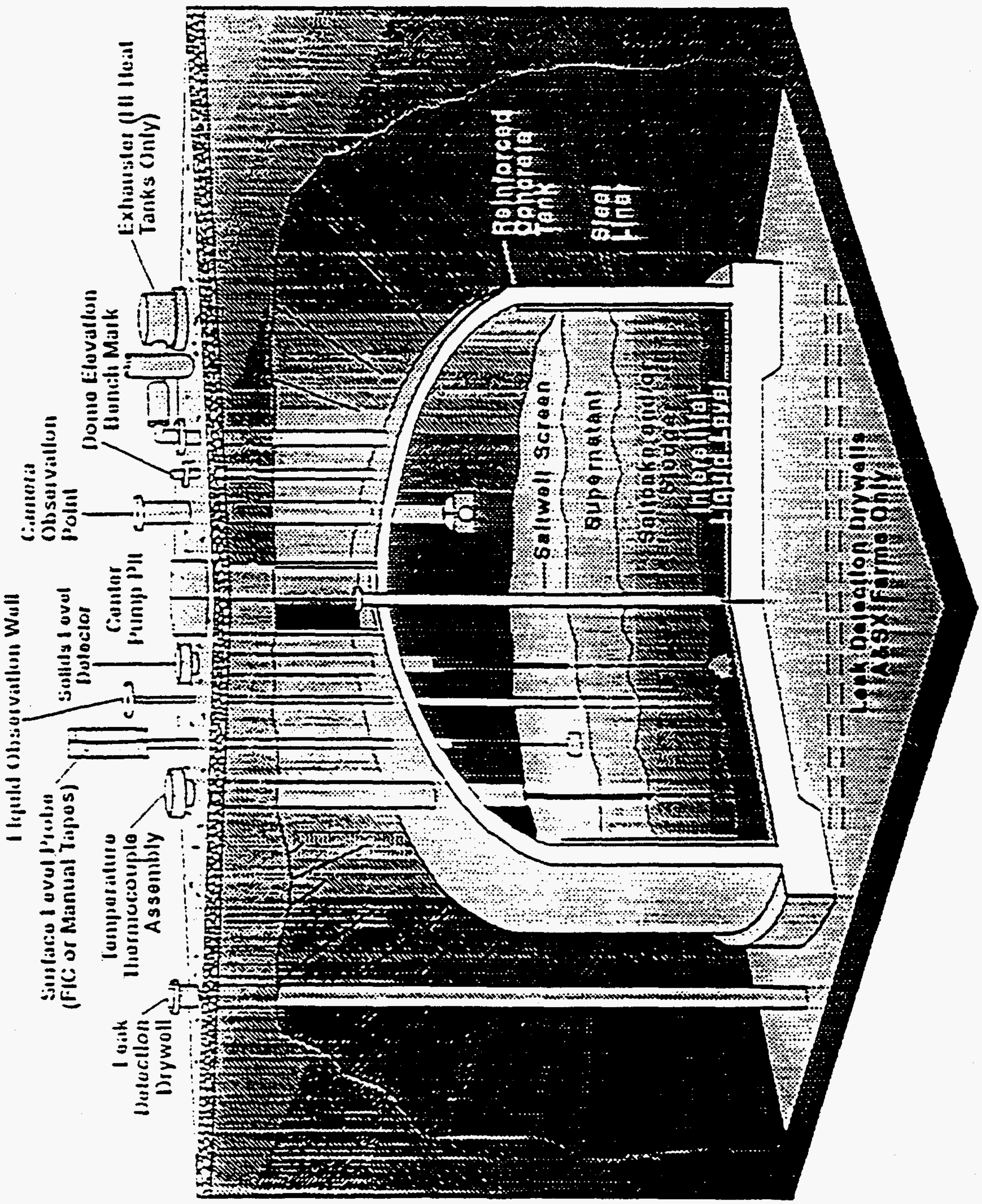

Figure 4-1. DESIGN FEATURES OF A TYPICAL HANFORD SINGLE SHELL TANK.

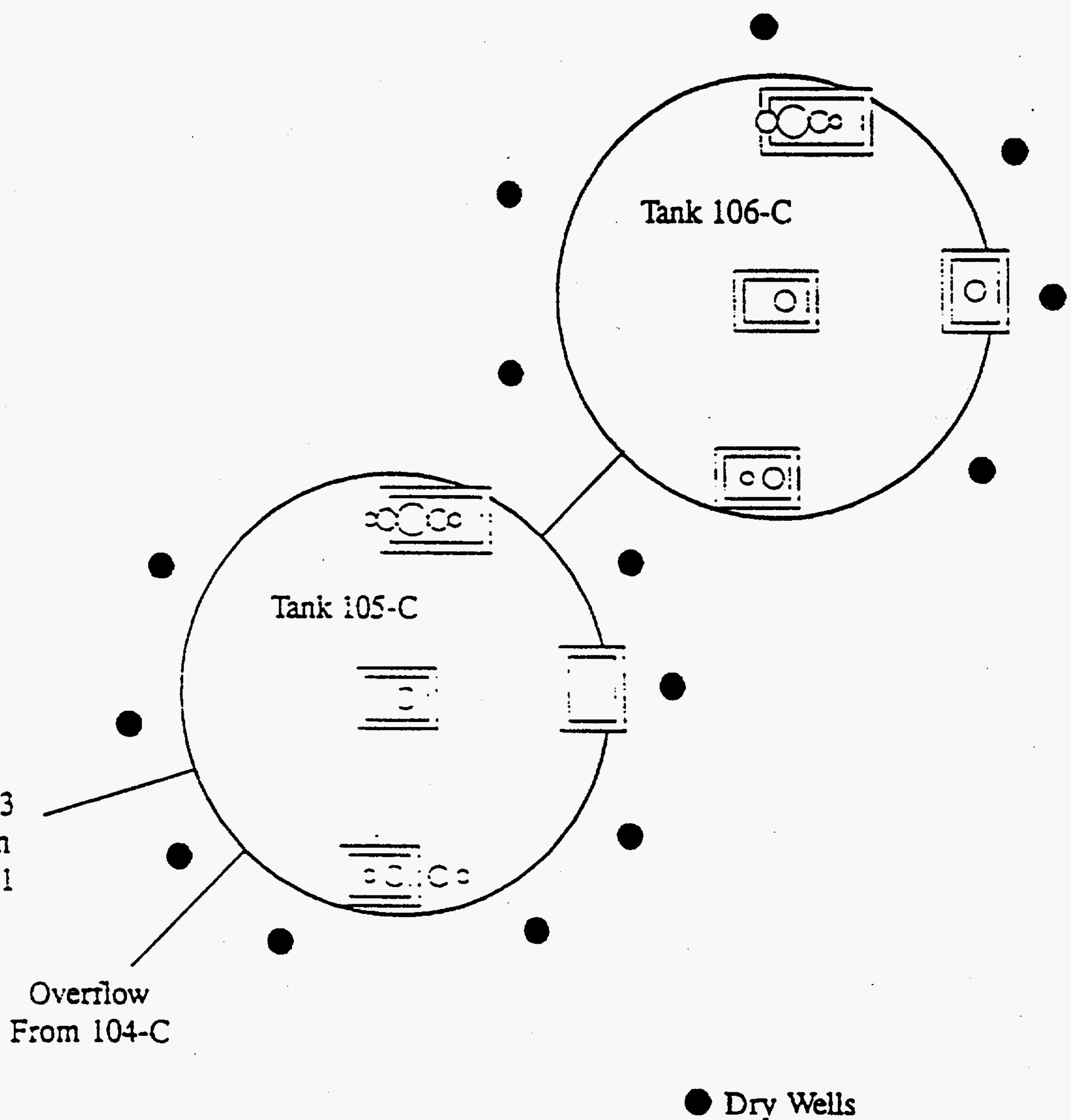

Figure 4-2. LOCATION OF UNSATURATED ZONE MONITORING WELLS NEAR 241-C-106.

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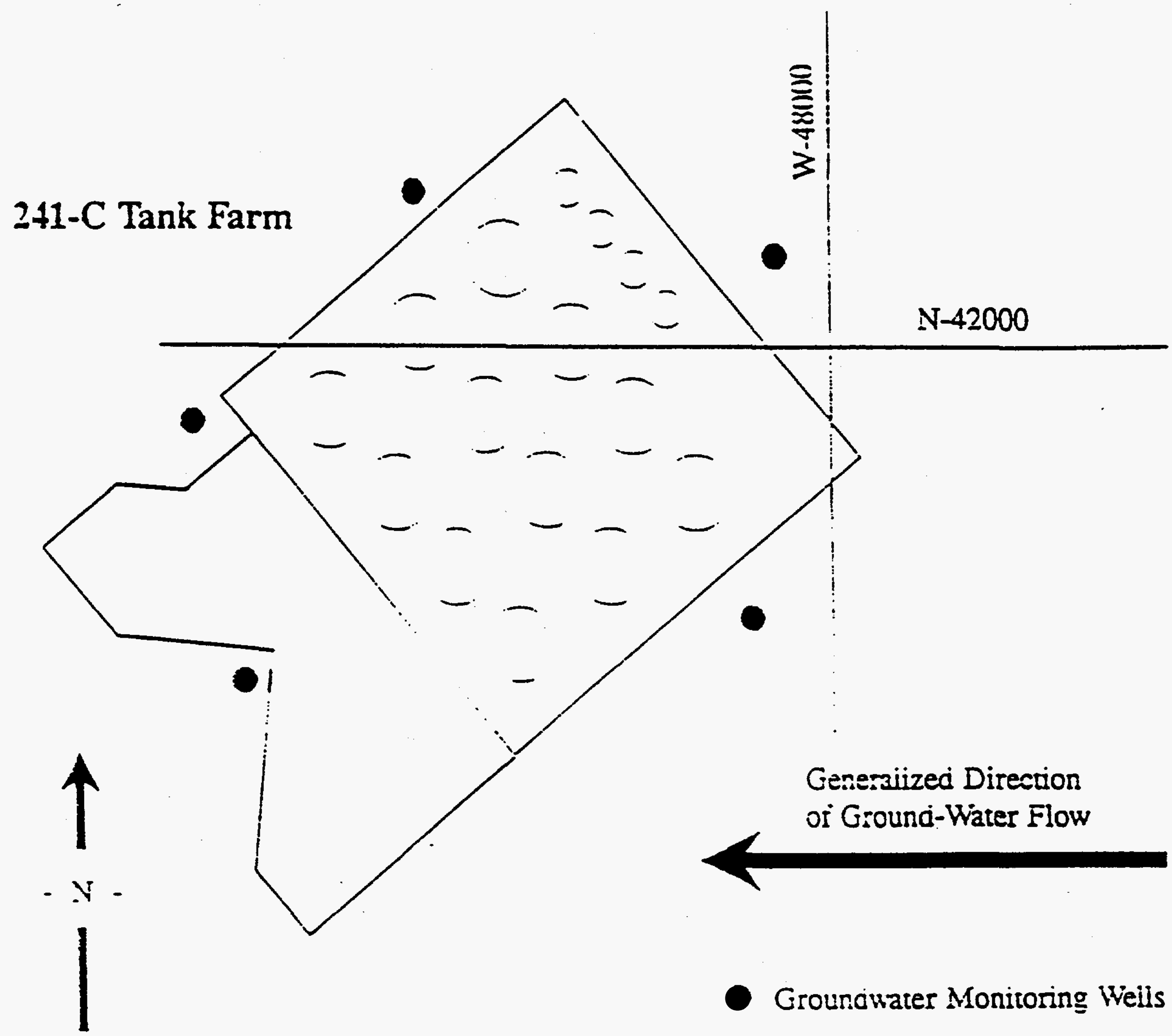

Figure 4-3. LOCATION OF GROUNDWATER MONITORING WELLS AROUND 241-C TANK FARM.

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The sediment immediately surrounding the tanks (to approximately 40 ft below land surface) is backfill material which was described by Price and Fecht, 1976 as "gravelly very coarse to medium sand to slightly silty gravelly very coarse to medium sand" (based on the Folk soil classification scheme). The sediments underlying the tank farm are predominantly gravelly sand (<30% gravel) to sand with minor layers of sandy silt to sandy gravel. Detailed granulometric data from sediments collected during the drilling and installation of the 241-C Tank Farm unsaturated zone monitoring wells can be found in Fecht and Price, 1977. At a depth of approximately 240 ft below land surface the sediments coarsen predominately to a sandy gravel. Based on driller's logs from well 299-E27-7, depth to basalt beneath 241-C Tank Farm is approximately 300 ft below land surface.

The water table (uppermost unconfined aquifer) beneath the C-tank farm is 245 ft to 260 ft below land surface, depending upon the elevation of the measuring point. Hydraulic information of the unsaturated sediments underlying the C-Tank is very poor. Soil moisture in the upper 100 ft beneath C-Tank Farm (based on samples collected during the installation of the 1989 groundwater monitoring wells) ranges from 1.5% to 23.6% water (on a weight to weight basis). Most measured moisture contents are within a range of 2% to 4%, however. Hydraulic conductivity values of sediments in the upper 100 ft below the tank farm have not been measured: however, the values are estimated at 10^{-2} to 10 cm/sec. Porosity of the sediments is estimated at 10% to 30% (Graham et al. 1981).

5.0 IDENTIFIED BARRIER TECHNOLOGIES

This section describes the subsurface barrier technologies discussed at the workshop. Additional detail regarding the advantages, disadvantages, and technology description can be found in Appendix C.

5.1 VERTICAL BARRIERS

A total of nine technologies were identified with potential application to 241-C-106 and are shown below.

Vertical Barrier Technologies

- Cement Slurry Wall (Figure 5-1)
- Deep Soil Mixing
- In Situ Vitrification
- Jet Grout Curtain (Figure 5-2)
- Ground Freeze Barriers (Figure 5-3)
- Modified Sulfur Cement
- Permeation Grouting (Figure 5-4)
- Polymer Impregnated Concrete
- Sheet Metal Piling (Figure 5-5).

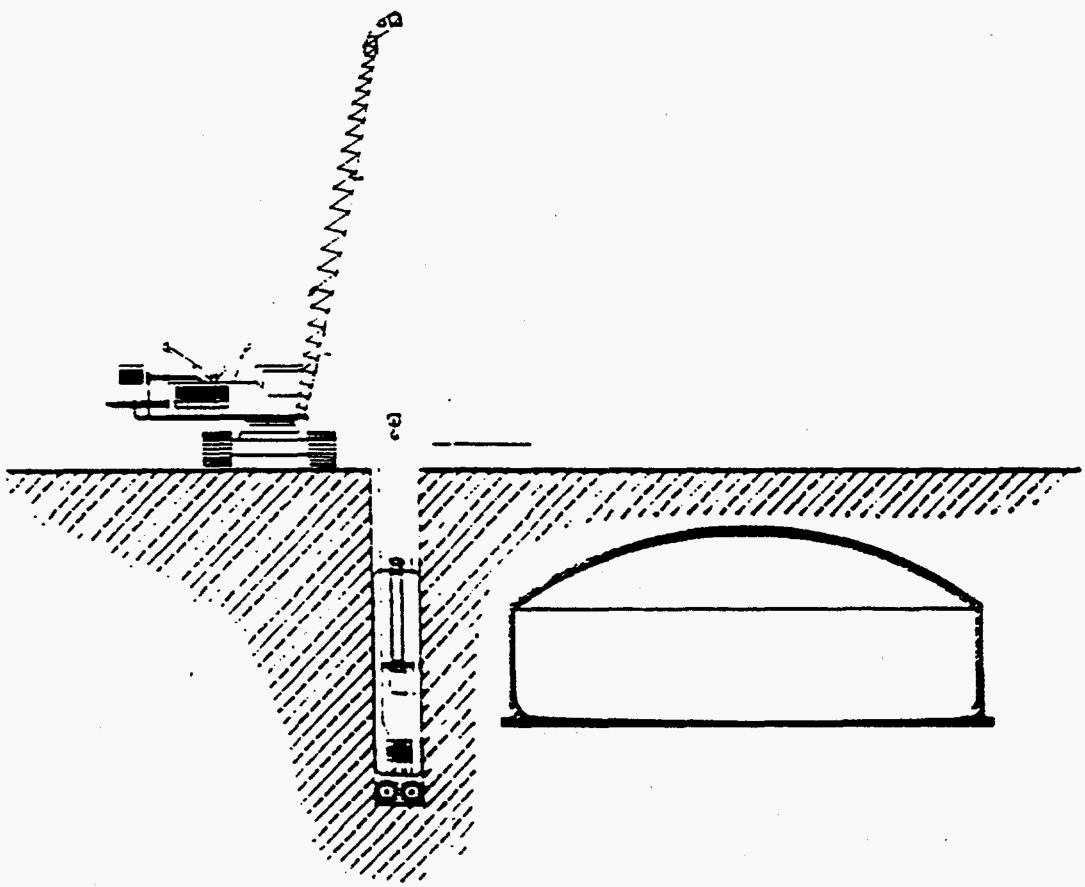

Figure 5-1. CEMENT SLURRY WALL.

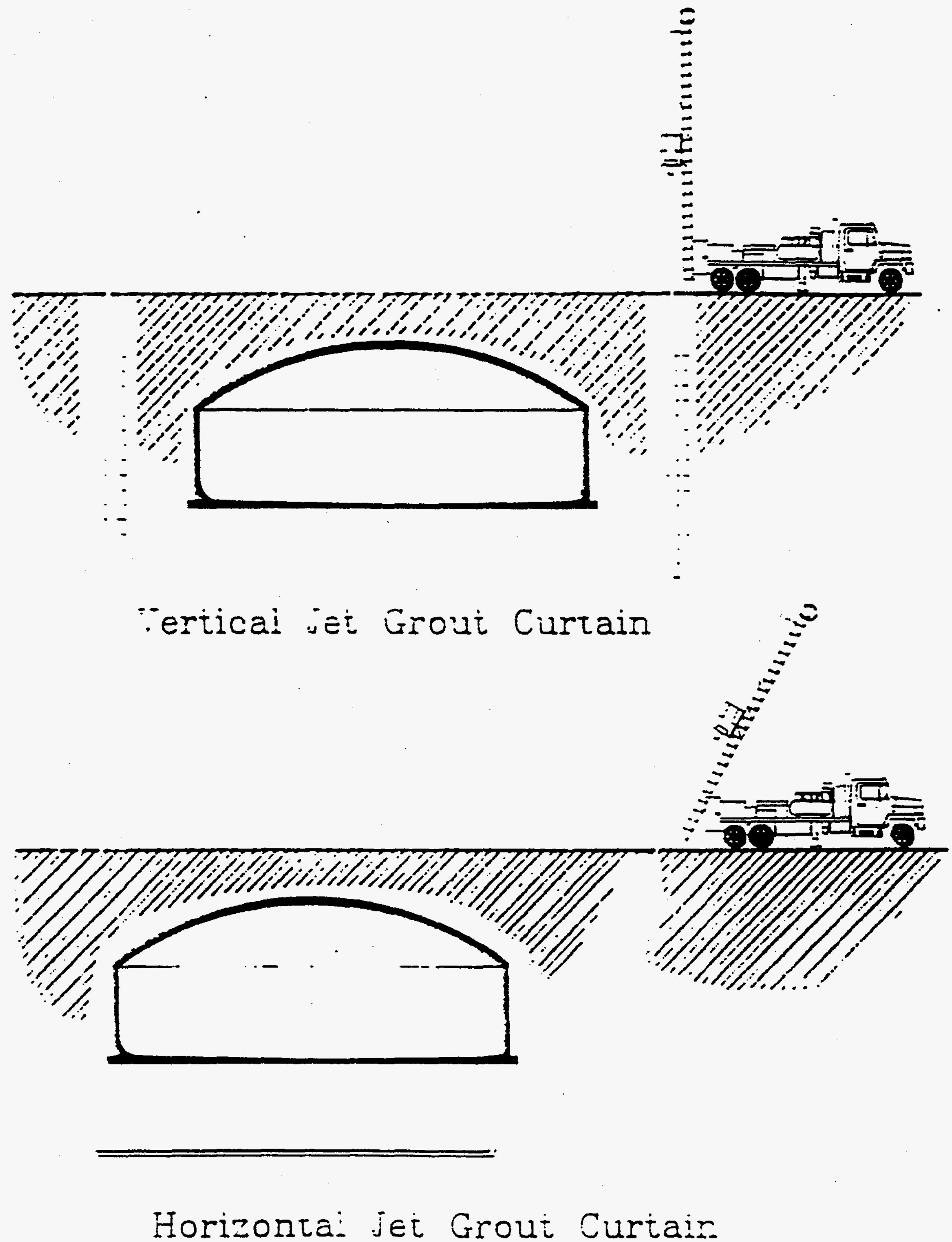

Figure 5-2. JET GROUT CURTAIN.

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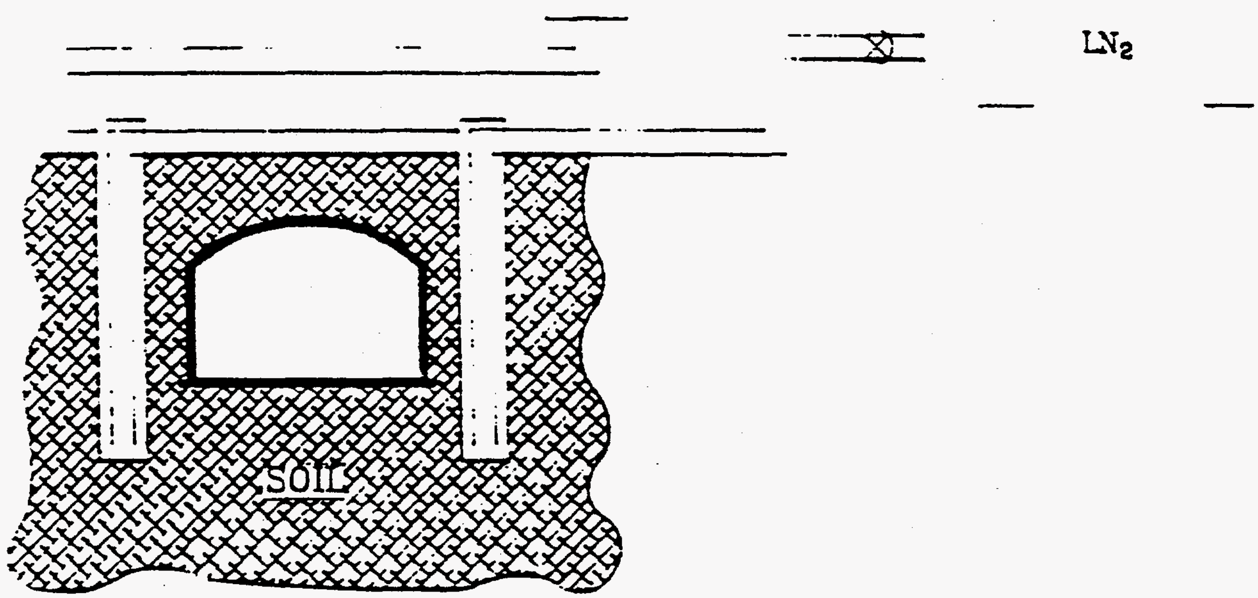

Figure 5-3. GROUND FREEZE BARRIERS.

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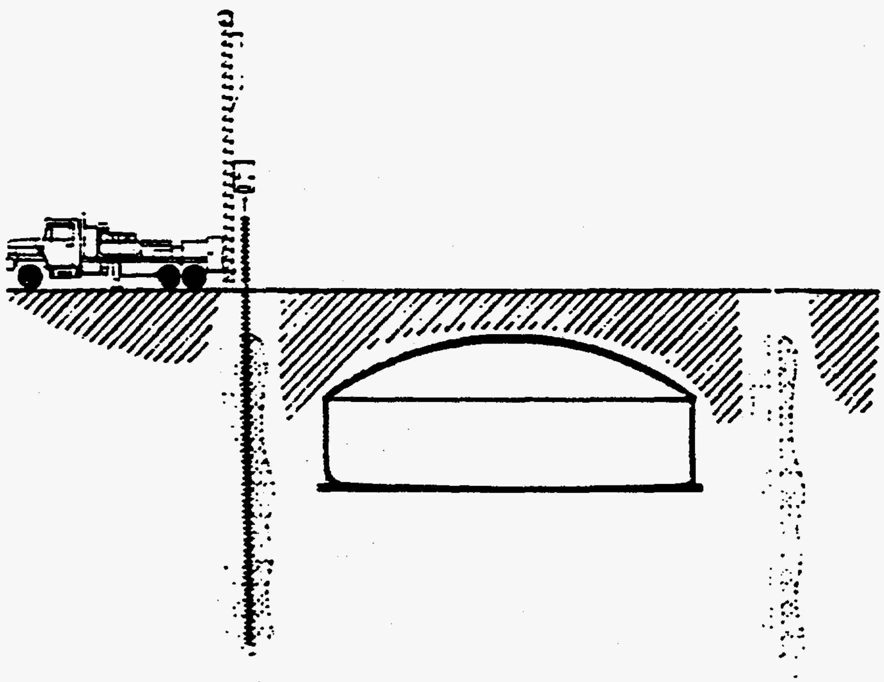
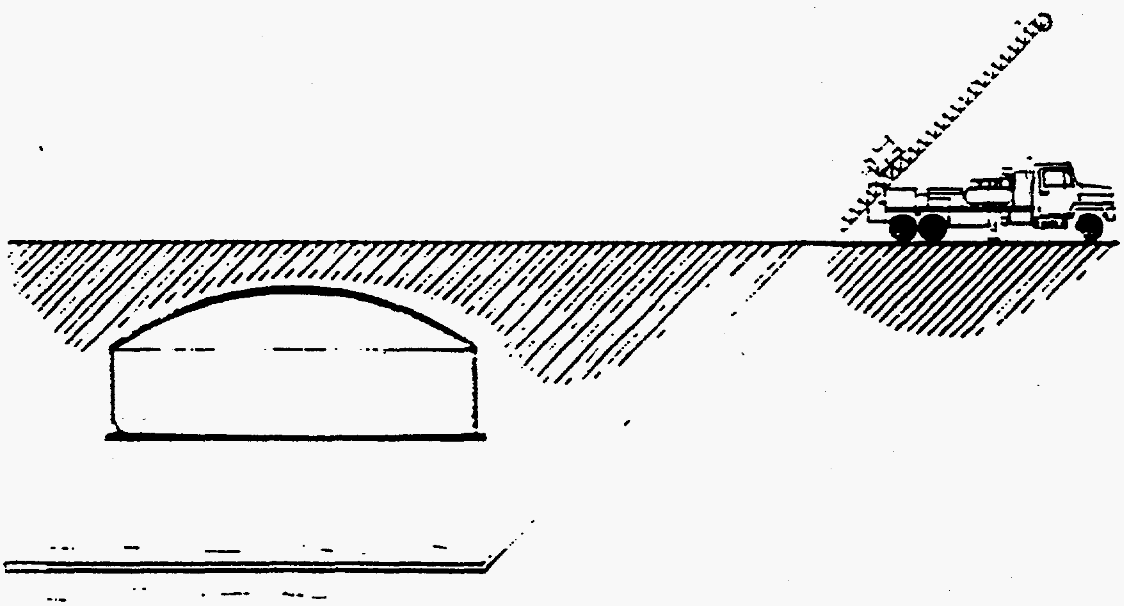


Vertical Permeation Grouting



Horizontal Permeation Grouting

Figure 5-4. PERMEATION GROUTING.

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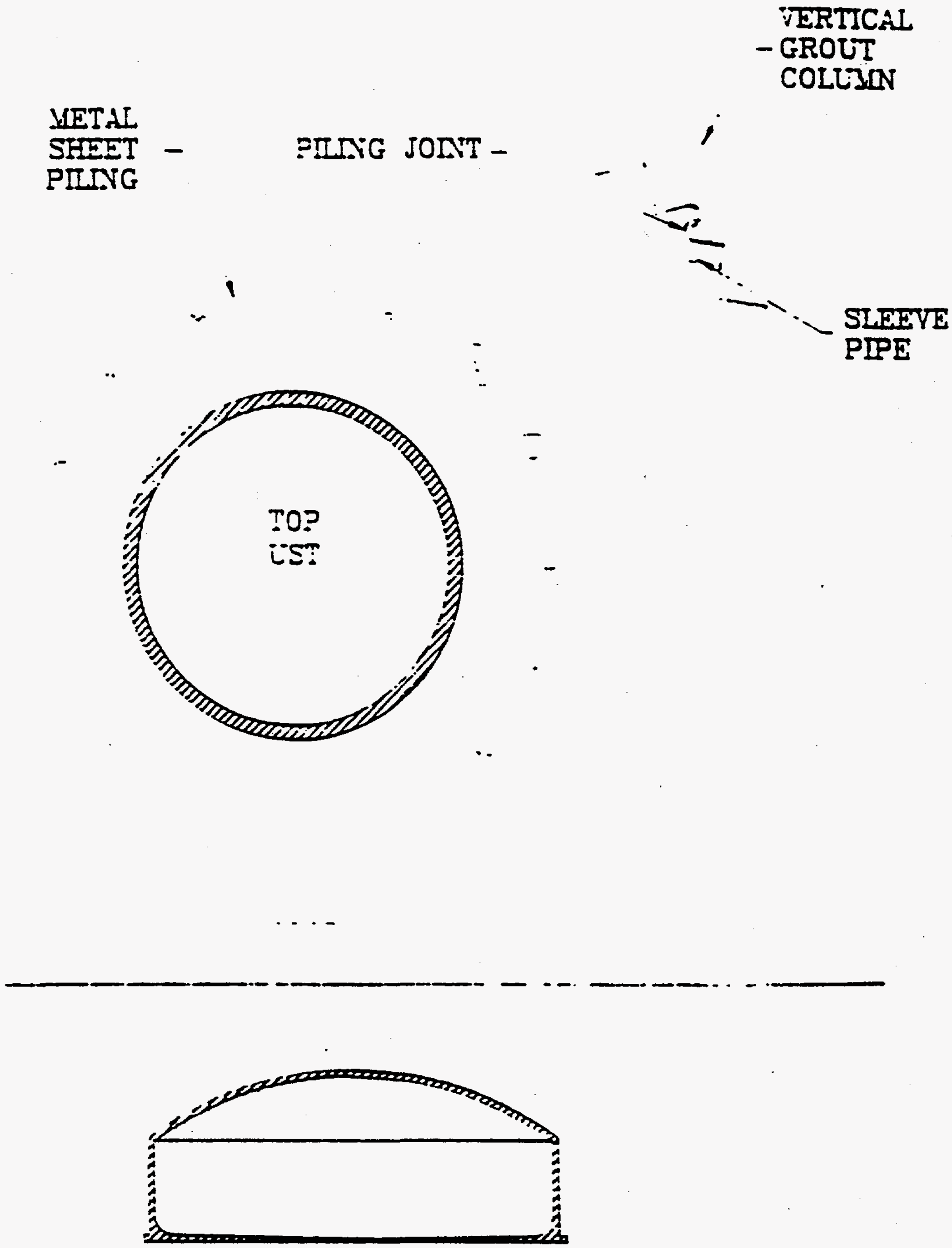

Figure 5-5. SHEET METAL PILING.

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5.2 HORIZONTAL BARRIERS

A total of five horizontal barriers with potential application to C-106 were identified during the workshop process and are shown below:

Horizontal Barrier Technologies Identified

- In Situ Vitrification
- Ground Freeze Barriers (Figure 5-3)
- Jet Grout Curtain (Figure 5-2)
- Modified Sulfur Cement
- Permeation Grouting (Figure 5-4).

5.3 OTHER BARRIER TECHNOLOGIES

Three barrier technologies that did not fit alone as a vertical or horizontal barrier were identified for potential application to C-106. These encapsulation barrier technologies are listed below:

Encapsulation Technologies Identified

- Induced Liquefaction
- Grout Encapsulation (Figure 5-6)
- Macro Cryogenics.

Four other miscellaneous technologies were also identified and are shown below:

Miscellaneous Technologies Identified

- Fracturing
- Long Wall Mining
- Sequestering Agents
- Wicks.

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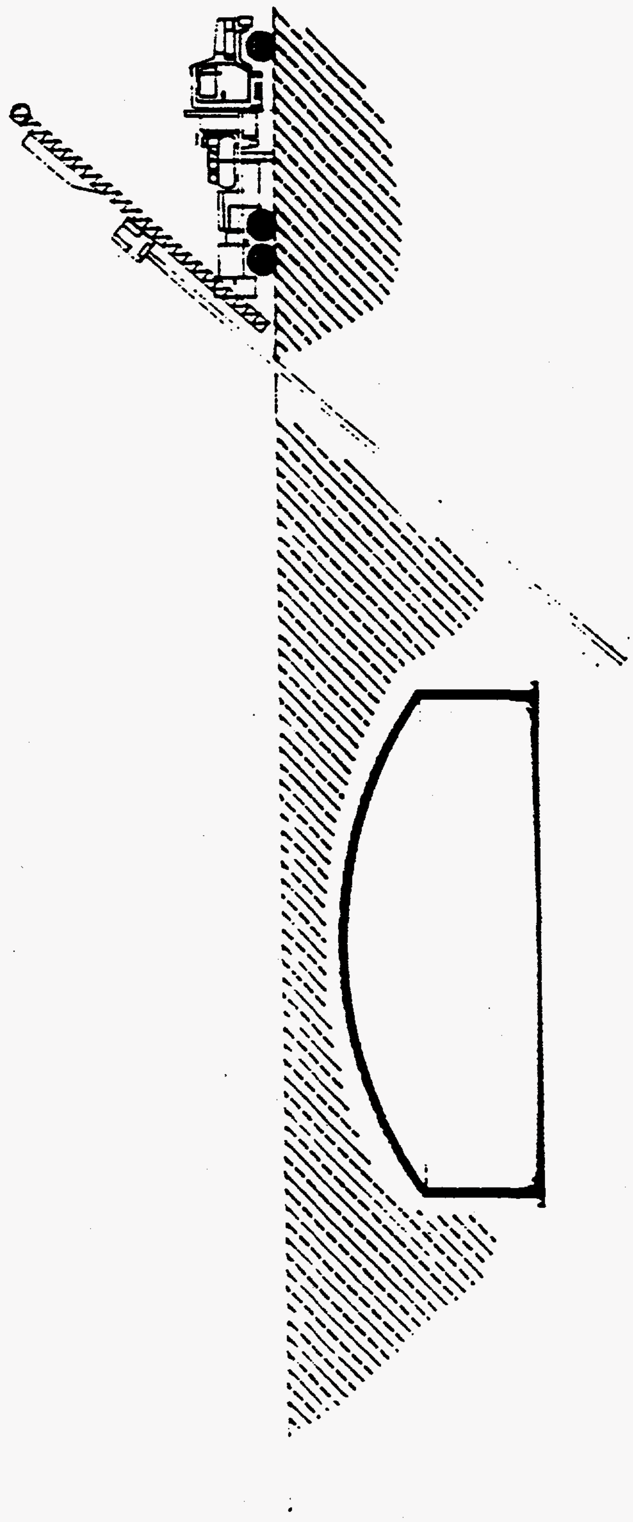

Figure 5-6. GROUT ENCAPSULATION.

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5.4 PREVIOUSLY DISCUSSED TECHNOLOGIES WITH DIFFERENT APPLICATIONS

During the brainstorming portion of the workshop, several previously addressed barrier technologies were discussed but with different applications. These applications are discussed below.

Several in situ barrier technologies could be used in or near the tank. Vacuum grouting, for example, could be used to apply a layer of grout on the outside of the C-106 tank. This would require a vacuum be applied to the tank wall coupled with the injection of grouts adjacent to the tank wall. This technology was quickly discounted due to the possibility of breaching the tank and preferential pathways that might be taken in the event of a leak.

Polymer Impregnated Concrete (PIC) penetration between the steel liner and the reinforced concrete was also discussed. This barrier technology method was discounted due to the difficulty in accessing the annulus, the small annulus space, and the need to penetrate the tank dome in many places.

Coring the reinforced concrete followed by injection of concretes, grouts, or cryogenic material was also discussed. These barrier options were discounted due to the need to bore into the tank walls from the top which could result in the possible loss of containment.

Deliberately providing a "window" in the subsurface barrier followed by collection and treatment of leached wastes was discussed but not pursued since it would require active and continuous controls and environmental monitoring.

The installation of cooling/freeze coils adjacent to C-106 was also discussed, primarily as a secondary containment barrier. Use of freeze coils adjacent to the tank was dropped due to the need for excavation around the tank walls which could result in radiation occupational exposures. The use of cryogenic materials in conjunction with another barrier seems to be the best option since another barrier could keep water in the soil to accomplish freezing.

Hydraulic fracturing and injecting in a manner similar to the method used by the petrochemical industry to enhance oil and gas production was also discussed. However, this method was discounted since little control is possible.

Long wall mining, similar to the technology used to mine coal seams, was also discussed. This technology may not be desirable for application to C-106 since it would require multiple shafts, expose personnel to radioactive materials for long periods of time, and create subsidence.

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7.0 SCREENED AND COUPLED TECHNOLOGIES

Based upon the screening and selection criteria discussed in Section 6.0, vertical, horizontal, and other barrier technologies were rated as to potential applicability as a barrier around C-106. Table 7-1 identifies the ratings for all screened vertical barrier technologies.

Table 7-1. RATING OF VERTICAL BARRIER TECHNOLOGIES FOR POTENTIAL APPLICATION TO 241-C-106.

Vertical Barrier Technology	Rating
Cement Slurry Wall	High
Deep Soil Mixing	Medium
In Situ Vitrification	Low
Jet Grouted Curtain	High
Ground Freeze Barriers	Medium
Modified Sulfur Cement	Medium
Permeation Grouting	High
Polymer Impregnated Concrete	Low
Sheet Metal Piling	High

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Table 7-2 presents the ratings of all screened horizontal barrier technologies with potential application to the C-106 tank.

Table 7-2. RATING OF HORIZONTAL BARRIER TECHNOLOGIES FOR POTENTIAL APPLICATION TO 241-C-106.

Horizontal Barrier Technology	Rating
In Situ Vitrification	Low
Ground Freeze Barriers	Medium
Jet Grouted Curtain	High
Modified Sulfur Cement	Medium
Permeation Grouting	High

Table 7-3 rates those technologies that did not fit as stand-alone vertical or horizontal barriers.

Table 7-3. RATING OF OTHER BARRIER TECHNOLOGIES FOR POTENTIAL APPLICATION TO 241-C-106.

Encapsulation	Rating
Fracturing	Low
Induced Liquefaction	Medium
Grout Encapsulation	Medium
Long Wall Mining	Low
Macro Cryogenics	Low
Sequestering Agents	Low
Wicks	Low

Through this analysis, it is possible to couple those "high" rated vertical and horizontal technologies for potential application for installation around the C-106 tank. Four vertical and two horizontal barriers fall into this category as shown by for a total of eight pairings Table 7-4. Two barrier technologies (jet curtain grouting and in situ polymer permeation grout) have potential application both horizontally and vertically.

Table 7-4. COUPLED TECHNOLOGIES WITH HIGH RATINGS FOR POTENTIAL APPLICATION TO 241-C-106.

Vertical		Horizontal
Permeation Grouting	coupled with	Jet Grout Curtain
Permeation Grouting	coupled with	Permeation Grouting
Cement Slurry Wall	coupled with	Jet Grout Curtain
Cement Slurry Wall	coupled with	Permeation Grouting
Sheet Metal Piling	coupled with	Jet Grout Curtain
Sheet Metal Piling	coupled with	Permeation Grouting
Jet Grout Curtain	coupled with	Jet Grout Curtain
Jet Grout Curtain	coupled with	Permeation Grouting

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8.0 CONCLUSIONS AND RECOMMENDATIONS

This section discusses the conclusions and recommendations reached by the workshop.

8.1 WORKSHOP OBJECTIVES

The DOE UST-ID Subsurface Barriers Workshop objectives were met in that confinement technologies were identified, screened for application to the C-106 tank, and two selected for further study. In addition to these meeting objectives, the workshop accomplished the following:

- Presented a proven set of technologies.
- Presented technologies that will have application to other DOE USTs.
- Gained knowledge through background information on the USTs at INEL, Hanford, Fernald, Oak Ridge, and Savannah River.
- Provided summary information about the in-tank and near-field environment associated with the C-106 tank.

8.2 DATA NEEDS

Prior to the final selection of a subsurface barrier technology for application near the C-106 UST, basic data should be obtained regarding the following:

- Expected temperatures in the barrier emplacement zone (currently estimated as 150°F or lower)
- Definitive soils information (new boreholes may be in order)
- More definitive information regarding buried obstacles (perhaps surface geophysical surveys)
- Contamination levels in soil.

8.3 CONCLUSIONS

The following conclusions are presented as an integral portion of the DOE UST-ID Subsurface Barriers workshop:

- Cryogenic systems may not be suitable as a primary or single barrier system for C-106 for two reasons: 1) soil must be saturated prior to freezing; this may not be possible in Hanford's unsaturated soils unless a system is devised to hold the water in place prior to freezing and 2) should a leak occur from the tank, the salt content of the leachate could lower the freezing point of the cryogenic systems. To prove or disprove these potential problems, a field demonstration is appropriate.

- Although few of the cement-based technologies have been applied for radioactive environments, they have been applied thousands of times throughout the world and, with minor adaptations, will have application to C-106 and other DOE tanks.

- Of the more than two dozen technologies discussed at the DOE Interim Subsurface Barrier Technologies Workshop, the following coupled technologies should be explored further:

Vertical		Horizontal
Permeation Grouting	coupled with	Jet Grout Curtain
Permeation Grouting	coupled with	Permeation Grouting
Cement Slurry Wall	coupled with	Jet Grout Curtain
Cement Slurry Wall	coupled with	Permeation Grouting
Sheet Metal Piling	coupled with	Jet Grout Curtain
Sheet Metal Piling	coupled with	Permeation Grouting
Jet Grout Curtain	coupled with	Jet Grout Curtain
Jet Grout Curtain	coupled with	Permeation Grouting

- A continuous barrier may not be absolutely necessary in a scenario where the barrier window is known and liquids that move through that window can be monitored, collected, and treated if necessary. A policy decision should be made in this regard.

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8.4 RECOMMENDATIONS

Recommendations presented at the workshop include the following:

- A subsurface barrier system should be installed in situ around the 241-C-106 UST as close as possible to the tank without unnecessarily stressing the tank itself. This will minimize the quantity of soil that will be contaminated should the tank leak. As a result, the research and development program should focus on near-tank barrier technologies.

- Most horizontal and some vertical barrier technologies will require the installation of piping for injection, permeation, and/or distribution of barrier materials. Vertical systems should have overlapping "cylinders" of material; horizontal systems should have pipe systems that preferably have 2 to 5 ft spacings.

- Barrier systems (in particular horizontal) being applied to critical radioactive environments should be duplicated, e.g. a grout barrier backed up by a cryogenics system to provide redundant containment.

- Barrier systems should include mechanisms to inject barrier material in multiple phases. Such systems will prevent windows from forming if barrier materials slump during the curing process.

- One technology, grout encapsulation, may be viable but is firmly dependent on emplacement technologies. Once directional drilling technologies are in place and can be used in tank farm configurations (i.e. tight spaces), this technology should be demonstrated on a large scale.

- Based upon a preliminary screening, the following two coupled technologies warrant further large scale demonstration by Westinghouse Hanford Company for potential application to the C-106 tank: vertical metal sheet piling coupled with either a horizontal jet grout curtain or in situ permeation grout; and a vertical and horizontal grout curtain installed via either grout or in situ permeation.

9.0 REFERENCES

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