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TREATABILITY STUDY WORK PLAN FOR OPERABLE UNIT 1 AUGUST 1991

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TREATABILITY STUDY WORK PLAN FOR OPERABLE UNIT 1

FERNALD SITE OFFICE
FERNALD, OHIO

REMEDIAL INVESTIGATION and FEASIBILITY STUDY

AUGUST 1991

U.S. DEPARTMENT OF ENERGY

PUBLIC ENVIRONMENTAL INFORMATION CENTER
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DRAFT

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LIST OF ACRONYMS

ARAR	applicable or relevant and appropriate requirements
ASTM	American Society for Testing and Materials
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CHP	Chemical Hygiene Plan
CIS	Characterization Investigation Study
CLP	contract laboratory program
d	day
DDT	dichlorodiphenyl trichloroethane
DOE	U.S. Department of Energy
DQO	data quality objective
EPA	U.S Environmental Protection Agency
FFCA	Federal Facilities Compliance Agreement
FMPC	Feed Materials Production Center
FS	feasibility study
HEPA	high efficiency particulate air
L	liter
µCi	microCuries
MCL	maximum contaminant level
mrem	millirem
MTCLP	modified toxicity characteristics leaching procedure
NPDES	National Pollutant Discharge Elimination System
PCBs	polychlorinated biphenyls
pCi	picoCurie
PCT	product consistency test
ppm	parts per million

LIST OF ACRONYMS
(Continued)

psi	pounds per square inch
QA	quality assurance
QAPP	Quality Assurance Project Plan
QC	quality control
QCC	Quality Control Coordinator
RAO	remedial action objective
RCRA	Resource Conservation and Recovery Act
RfD	(Toxicity based) reference dose
RI	remedial investigation
RI/FS	remedial investigation/feasibility study
TBC	to be considered
TCLP	toxicity characteristics leaching procedure
RME	reasonable maximum exposure
SAP	Sampling and Analysis Plan
UCS	unconfined compressive strength
WL	working level
WMCO	Westinghouse Materials Company of Ohio

LIST OF CHEMICAL ABBREVIATIONS

U	uranium
Th	thorium
Al	aluminum
As	arsenic
Ba	barium
Be	beryllium
B	boron
Ca	calcium
Cd	cadmium
Cr	chromium
Cs	cesium
Cu	copper
Mn	manganese
Np	neptunium
Pu	plutonium
Ra	radium
Se	selenium
Sr	strontium
Tc	technetium
Tl	thallium
V	vanadium
Zn	zinc
NaOH	sodium hydroxide

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1.0 PROJECT DESCRIPTION

The Feed Materials Production Center (FMPC) is a contractor-operated federal facility for the production of pure uranium for the U.S. Department of Energy (DOE). The FMPC is located on 1050 acres in a rural area approximately 20 miles northwest of downtown Cincinnati, Ohio. On July 18, 1986, a Federal Facilities Compliance Agreement (FFCA) was jointly signed by the U.S. Environmental Protection Agency (U.S. EPA) and DOE to ensure that human health and environmental impacts associated with past and present activities at the FMPC are thoroughly investigated so that appropriate remedial actions can be assessed and implemented. A Remedial Investigation/Feasibility Study (RI/FS) has been initiated to develop these remedial actions.

The FMPC was divided into five operable units to facilitate remediation. Operable Unit 1 consists of the Waste Pits 1 through 6, the Clearwell, and the Burn Pit. Radioactive waste, consisting of naturally occurring radionuclides left over from uranium ore processing, and various chemicals were stored in this operable unit. The waste in the pits, the Clearwell, and soil surrounding and between the pits are to be remediated. Both in situ and removal alternatives have been proposed. Removal options are expected to include some of the contaminated soils surrounding the waste. The total amount of material to be treated is approximately 1.4 million cubic yards. The scope of the treatability study discussed in this document is the laboratory screening of treatment technologies for the waste in Waste Pits 1 through 6, the Burn Pit, and the Clearwell. This Work Plan was prepared in accordance with EPA's "Guide for Conducting Treatability Studies Under CERCLA" (EPA 1988) and the Fernald RI/FS quality assurance project plan (QAPP).

1.1 PURPOSE

The initial screening of alternatives has been conducted (DOE 1991) for Operable Unit 1 with cement stabilization and vitrification being identified as two potential treatment technologies to be promoted for further consideration. However, to adequately evaluate alternatives in the detailed analysis, additional data obtained through treatability studies is needed on each of these technologies to better evaluate their performance.

The justification to conduct treatability tests on both vitrification and cement stabilization technologies is due to the lack of available data for these technologies. Literature surveys provide only a limited amount of data for these technologies or contain information, which is not specific to the waste forms common to Operable Unit 1. Treatability testing will provide data specific to the Operable Unit 1 waste, which will aid in the selection of the final waste form. Vital information such as bulking factors (percent change in waste volumes), compressive strengths, leachate characteristics, as well as permeability and durability of the final waste forms will be developed.

This treatability work plan outlines the objectives, procedures, and techniques for conducting a laboratory screening of cement stabilization and vitrification technologies for Waste Pits 1 through 6, the Burn Pit, and the Clearwell of Operable Unit 1. The data resulting from this laboratory screening will be used to support the FS by establishing or identifying the following:

- Confirmation of technology applicability to Operable Unit 1 waste
- Compliance of technology with applicable or relevant and appropriate requirements (ARARs)
- Fate and transport modeling
- Leachability data to support residual risk calculations in support of the effectiveness criteria evaluation for the detailed evaluation of alternatives
- Refinement of process requirements for cost estimation purposes
- Provide initial database for use in subsequent bench- and pilot-scale studies used in support of remedial design

1.2 BACKGROUND INFORMATION

1.2.1 Site Description

A variety of chemical and metallurgical processes were utilized at the FMPC for the manufacture of uranium products. During the manufacturing process, uranium compounds were introduced into the FMPC processes at several points. Impure starting materials were dissolved in nitric acid, and the uranium purified through solvent extraction to yield a solution of uranyl nitrate. Evaporation and heating converted the nitrate solution to uranium trioxide (UO_3) powder. This compound was reduced with hydrogen to uranium dioxide (UO_2) and then converted to uranium tetrafluoride (UF_4) by reaction with anhydrous hydrogen fluoride. Uranium metal was produced by reacting UF_4 and magnesium metal in a refractory-lined vessel. This primary uranium metal was then remelted with scrap uranium metal to yield a purified uranium ingot.

From 1953 through 1955, the FMPC refinery processed pitchblende ore from the Belgian Congo. Pitchblende ore contains all daughter products of the uranium decay chains and is particularly high in radium. No chemical separation or purification was performed on the ore before its arrival at the FMPC. Beginning in 1956, the refinery feedstock consisted of uranium concentrates (yellowcake) from Canada and the United States. Canadian concentrates were not processed after 1960. In the production of these

concentrates, most of the uranium daughters had been removed. However, radium-226 (Ra-226) and thorium-230 (Th-230) remained in the yellowcake in amounts that varied with the process.

Small amounts of thorium were produced at the FMPC on several occasions from 1954 through 1975. Thorium operations were performed in the metals fabrication plant, the recovery plant, the special projects plant, and the pilot plant. The FMPC currently serves as the thorium repository for DOE and maintains long-term storage facilities for a variety of thorium materials.

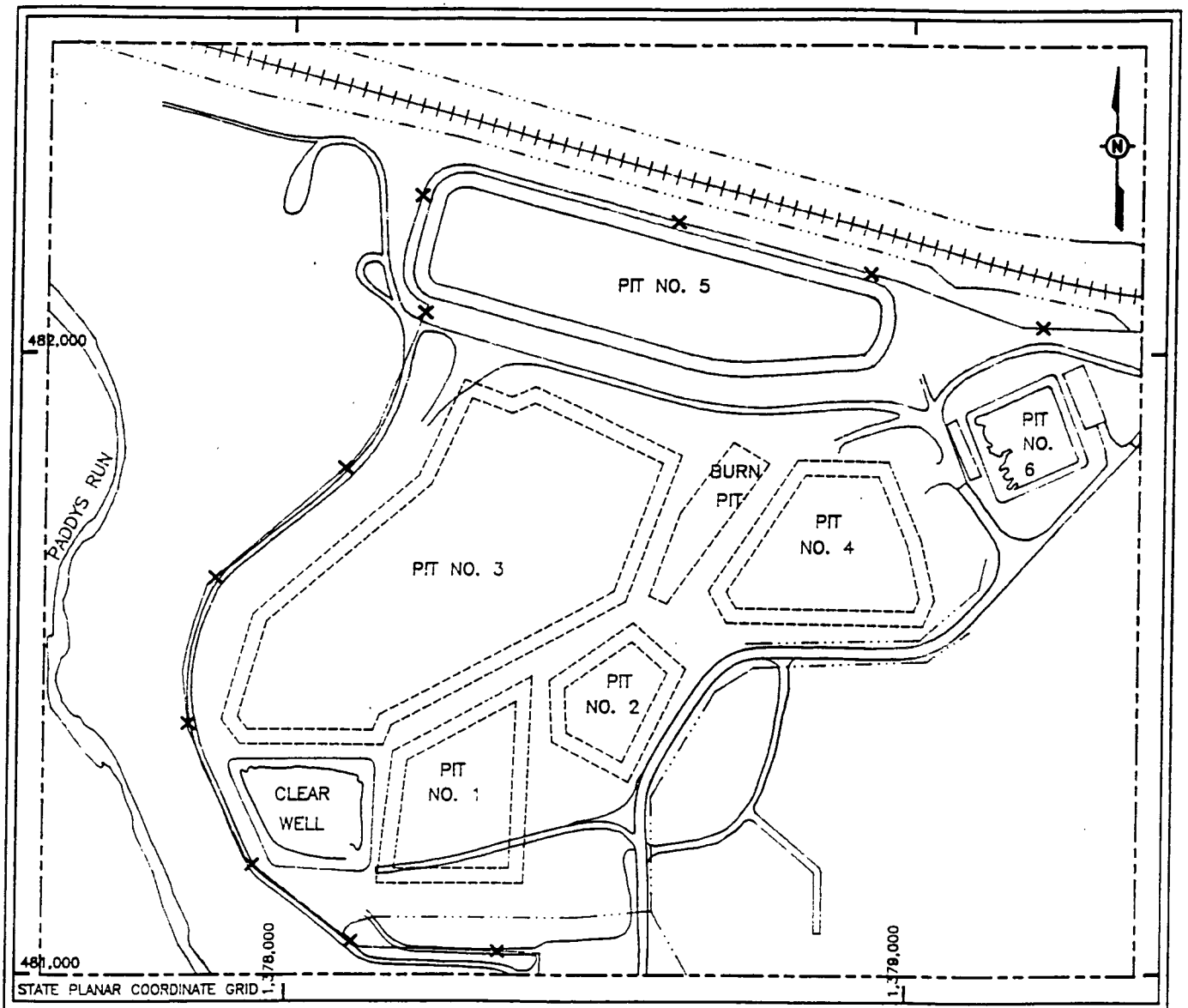
Large quantities of liquid and solid waste were generated by the various operations at the FMPC. Before 1984, disposal of solid and slurried waste from FMPC processes was in the on-property waste storage area. This area, which is located west of the production facilities, includes seven low-level radioactive waste storage pits and a clearwell; two earthen-bermed concrete silos containing K-65 waste that are high-specific activity and low-level radium-bearing residues resulting from the pitch-blende refining process; one concrete silo containing metal oxides (raffinate solids disposed of in the pits are similar to those initially dried and pneumatically transferred to that silo) and one unused concrete silo; two lime sludge ponds; and a sanitary landfill. The waste storage area is addressed under Operable Units 1, 2, and 4.

An inactive fly ash disposal area and an active fly ash pile, addressed under Operable Unit 2, are located approximately 3000 feet south-southeast of the waste storage area. One pile remains active for the disposal of fly ash from the FMPC coal-fired boiler plant. Fly ash from this area will be tested in the Operable Unit 1 treatability studies. An area between and adjacent to the fly ash areas, known as the Southfield, is believed to be the disposal site for construction debris and possibly other types of solid waste from FMPC operations. The Southfield is also being addressed as a solid waste unit under Operable Unit 2.

1.2.2 Operable Unit Description

The waste pits consist of Pits 1 through 6, the Burn Pit, and Clearwell (Figure 1-1). They are numbered chronologically in their order of construction. Pits 3 and 5 are referred to as "wet" because they received waste in mostly slurry form. Pits 1, 2, 4, and 6 are referred to as "dry" because they received mostly dry solid waste from trucks. Table 1-1 describes the characteristics of the waste pits and provides an approximate inventory of stored waste based on the limited amount of available historical information.

Waste Pit 1, constructed in 1952, was excavated into an existing clay lens and has a capacity of 33,676 cubic yards. The waste material that was placed in the waste pit consisted primarily of neutralized waste filter cakes, production plant sump cakes, depleted slag, scrap graphite, contaminated



NOTES:

OPERABLE UNIT 1 CONSISTS OF THE 6 WASTE STORAGE PITS, THE CLEAR WELL, AND THE BURN PIT.

PITS 1, 2, AND 3 ARE COVERED. PIT 4 HAS AN INTERIM CAP.

THE OUTLINES OF THE COVERED PITS ARE APPROXIMATE.

SCALE

0 275 550 FEET

LEGEND:

- OPERABLE UNIT 1 STUDY AREA
- ROADWAY
- DRAINAGEWAY
- FENCE
- RAILROAD

303317-A-C239/OU1-TS/KNOX

FIGURE 1-1. OPERABLE UNIT 1 STUDY AREA

TABLE 1-1

ESTIMATED WASTE STORAGE INVENTORY IN OPERABLE UNIT 1[a]

Waste Pit	Estimated Waste quantity (cu yd)	Depth (ft)	Contents	Estimated Radioactive Material (kg)	Construction	Operational Period	Current Status
Pit No. 1	33,676	17	Neutralized waste filter cakes, graphite, brick scrap, sump liquor and cakes, depleted slag	Uranium - 52,000	Excavated in clay lens and lined with clay	1952-59	Covered with clean fill dirt
Pit No. 2	18,478	13	Dry low-level radioactive wastes: neutralized waste filter cakes, sump liquor and cakes, brick, scrap, depleted slag	Uranium - 1,206,000 Thorium - 400	Lined with a compacted on-site native clay layer	1957-64	Covered with clean fill dirt
Pit No. 3	237,053	27	Lime neutralized raffinate concentrate, slag leach residues, filter cakes, fly ash and lime sludge	Uranium - 129,000 Thorium - 400	Excavated into clay lens and lined with clay along the pit walls	1959-77	Covered with clean fill dirt
Pit No. 4	53,706	24	Process residues, trailer cakes, slurries, raffinates, depleted graphite, asbestos, nonburnable trash, barium chloride	Uranium - 3,000,000 Thorium - 61,800	Same as Pit No. 3	1960-86	Interim RCRA cap

Waste Pit	Estimated Waste quantity (cu yd)	Depth (ft)	Contents	Estimated Radioactive Material (kg)	Construction	Operational Period	Current Status
Pit No. 5	98,841	30	Solids from neutralized raffinate, slag leach slurry, lime sludge, arsenic	Uranium - 50,309 Thorium - 17,000	Lined with 60 mil Royal-Seal EPDM elastometric membrane	1968-87	Uncovered
Pit No. 6	11,556	24	Depleted slag, sump green salt, process residue, filter cake	Uranium - 843,142	Same as Pit No. 5	1979-85	Uncovered
Burn Pit	9074	20	Reactive chemicals, pyrophoric chemicals, oils, combustible wastes, scrap iron, wood, tin cans, ashes, and gravel	Unknown	Excavated in clay Excavated clay used to line Pits 1 and 2	1957-86	Backfilled
Clear Well	5008	27	Clear process effluents and surface runoff	Unknown	Lined with clay	1959-	In use

[a]Information generated by WMCO, Weston, and Dames & Moore.

brick, and sump liquor. Although the majority of the waste was dry solids, decant pipes were constructed through the west berm. These pipes were rarely used. The quantity of uranium placed in the pit is estimated at 52,000 kilograms (kg). Waste Pit 1 was closed in 1959, backfilled, and covered with clean fill dirt. Surface water runoff is diverted to the Clearwell before being discharged to the Great Miami River.

Waste Pit 2 was constructed in 1957 and lined with a compacted on-property native clay layer. Waste Pit 2 received primarily dry, low-level radioactive waste consisting of neutralized filter cakes, sump cakes, depleted slag, contaminated brick, sump liquor, and concentrated raffinate residues. As with Pit 1, decant pipes were installed through the west berm. The pit holds approximately 18,478 cubic yards of waste that contain approximately 1,206,000 kg of uranium and approximately 400 kg of thorium. The waste pit was covered with clean uncontaminated fill and graded to direct surface drainage to the Clearwell for subsequent discharge to the Great Miami River. Waste Pit 3 was constructed in 1959 by excavating into the underlying clay lens and placing a layer of clay along the pit walls. This pit was the first "wet" pit built for the purpose of settling solids from wet waste streams. The pit received wet waste streams consisting of lime-neutralized radioactive raffinate concentrate from the recovery plant and the general sump and slag leach residue, filter cakes, fly ash, and lime sludges. The principal waste contained in Pit 3 is lime-neutralized radioactive raffinate concentrate. The pit contains an estimated 237,053 cubic yards of waste, including 129,000 kg of uranium and 400 kg of thorium. The pit was retired in 1977, and clean fill was placed over the waste. Surface water runoff from the mounded pit cover is diverted to the Clearwell before discharge to the Great Miami River.

Waste Pit 4 was constructed in 1960 and used until May 1986. This pit was constructed in a similar manner as Pit 3 with a liner consisting of two feet of compacted clay on the sides and bottom. Waste Pit 4 received process residues, filter cakes, slurries, raffinates, graphite, noncombustible trash, and asbestos. The pit contains an estimated 53,706 cubic yards of waste (23 percent of Pit 3) but has more than 3 million kg of uranium and 61,800 kg of thorium. Between May 1981 and April 1983, Pit 4 also received 10,681 kg of low-level radioactive waste containing barium chloride salt. The pit is covered with an interim Resource Conservation and Recovery Act (RCRA) cover at the present time and is no longer in service.

Waste Pit 5 was constructed in 1968 and operated from 1968 to 1983. The pit was lined with a 60-mil-thick elastomeric membrane. As with Pit 3, this waste pit received liquid waste slurries from the refinery and the recovery plant, including neutralized raffinate settled solids, slag leach slurry, sump slurries, and lime sludge. The waste volume consists of approximately 98,841 cubic yards, containing 50,309 kg of uranium and 17,000 kg of thorium. From 1983 to February 1987, when it was taken out

of service, Pit 5 received only clear decant from the general sump, filtrate from the recovery plant, or nonradioactive slurries, such as blowdown from the boiler plant and water treatment plant.

Waste Pit 6 was constructed in 1979 and operated until 1985. Pit 6 was constructed in the same manner as Waste Pit 5 and lined with a similar synthetic liner. Fine-grained solid waste, including green salt, filter cakes, and process residues containing elevated levels of uranium, have been stored in the pit. Until March 1987, rainfall that had collected in the pit was pumped to Waste Pit 5 for settling before discharge via the Clearwell. Since then, collected rainfall is pumped to the Biodenitrification Surge Lagoon. The current waste volume is approximately 11,556 cubic yards, which consists of 843,142 kg uranium. The capacity of Waste Pit 6 has not been reached; however, the pit is currently retired.

The Burn Pit was constructed in 1953 as a site to excavate clay to line Waste Pits 1 and 2. Beginning in 1957, the resulting excavation was used to dispose of laboratory chemicals and to burn combustible materials, including pyrophoric and reactive chemicals, oils, and other low-level contaminated combustible materials. The current waste volume is estimated to be 9,074 cubic yards. The actual inventory of materials or chemicals that were disposed of in the Burn Pit is unknown. The boundaries of the Burn Pit are no longer discernible from the covered Pit 4.

The Clearwell receives surface runoff from the waste pit area. The Clearwell was used until March 1987 as a final settling basin before discharge to the Great Miami River via the FMPC National Pollutant Discharge Elimination System (NPDES) discharge point. The Clearwell still receives decanted water from Pit 5. Presently the Clearwell is estimated to contain 1,546,265 gallons of water.

1.2.3 Nature and Extent of Contamination

The remedial investigation (RI) data and data from previous studies show that releases to the environment from Operable Unit 1 have occurred. The surface soils, the glacial overburden, and the groundwater beneath the waste pits are contaminated. The principal environmental concern associated with Operable Unit 1 is contaminant migration and transport in surface water and groundwater. Previous radionuclides and chemicals of concern are listed in Table 1-2. Additional compounds will be analyzed under the new sampling analysis plan (SAP). Results from the RI are briefly presented in the following paragraphs.

Waste Pit Contents

The contents of the waste pits were sampled under the Characterization Investigation Study (CIS) program conducted by Roy F. Weston in 1986 (Weston 1987). Data from the CIS sampling program indicate that the concentration of uranium-238 (U-238) was relatively high in Pits 2, 4, and 6 with

TABLE 1-2
RADIONUCLIDES AND CHEMICALS OF POTENTIAL CONCERN FOR OPERABLE UNIT 1

ENVIRONMENTAL MEDIA: WASTE PIT		
Radionuclides	Inorganics	Organics
U-234	Arsenic	Acenaphthene
U-235/236	Barium	Anthracene
U-238	Beryllium	Benzo(a)anthracene
Th-228	Cadmium	Benzo(b)fluoranthene
Th-230	Chromium	Benzo(k)fluoranthene
Th-232	Cobalt	Benzo(g,h,i)perylene
Pu-238	Copper	Benzo(a)pyrene
Pu-239/240	Lead	Chrysene
Tc-99	Magnesium	Ethyl benzene
Sr-90	Manganese	Fluoranthene
Np-237	Mercury	Fluorene
Cs-137	Nickel	Indeno(1,2,3-cd)pyrene
Ra-226	Selenium	2-methylnapthalene
	Silver	Naphthalene
	Thallium	Pentachlorophenol
	Vanadium	Phenanthrene
	Zinc	Phenol
		Pyrene
		Toluene
		Xylenes
		Acetone
		2-butanone
		PCBs (Aroclors-1242, 1248, 1254, 1260)
		DDT
		Ethyl parathion

ENVIRONMENTAL MEDIA: WASTE PIT		
Radionuclides	Inorganics	Organics
		Methyl parathion
		Bis(2-ethylhexyl)phthalate
		Di-n-butyl phthalate
		Di-n-octyl phthalate
		Chloroform
		Methylene chloride
		1,1,1-trichloroethane
		Trichloroethene

ENVIRONMENTAL MEDIA: GROUNDWATER		
Radionuclides	Inorganics	Organics
U-234	Aluminum	Butyl benzyl phthalate
U-235	Arsenic	Di-n-butyl phthalate
U-238	Barium	1,1-dichloroethane
Total uranium	Copper	1,1,1-trichloroethane
Th-228	Magnesium	Trichlorethene
Th-230	Manganese	Toluene
Th-232	Molybdenum	Acetone
Tc-99	Nickel	cis-1,2-dichloroethene
Sr-90	Vanadium	2-propanol
Ra-226	Zinc	Tetrachloroethene
		2-butanone[a]
		Chloroform[a]
		Ethyl parathion[a]
		Methyl parathion[a]
		Phenol[a]
		Methylene chloride[a]

ENVIRONMENTAL MEDIA: SURFACE WATER		
Radionuclides	Inorganics	Organics
U-234	Aluminum	Bis(2-ethylhexyl) phthalate
U-235	Beryllium	Di-n-butyl phthalate
U-238	Cobalt	
Total uranium	Manganese	
Tc-99	Vanadium	
Ra-226		
Ra-228		
ENVIRONMENTAL MEDIA: SURFACE SOIL		
Radionuclides	Inorganics	Organics
U-238	(No data available)	(No data available)
Th-232		
Ra-226		
ENVIRONMENTAL MEDIA: SUBSURFACE SOIL		
Radionuclides	Inorganics	Organics
U-234	(No data available)	2-butanone[b]
U-235		Carbon disulfide[b]
U-238		Ethyl benzene[b]
Total uranium		Acetone[b]
Th-228	(No data available)	Xylenes[b]
Th-230		
Th-232		
Tc-99		
Sr-90		
Ra-226		

ENVIRONMENTAL MEDIA: SEDIMENT		
Radionuclides	Inorganics	Organics
Total uranium	None	Acetone
		Methylene chloride
ENVIRONMENTAL MEDIA: DIRECT RADIATION		
Radionuclides	Inorganics	Organics
Penetrating radiation	Not applicable	Not applicable
ENVIRONMENTAL MEDIA: AIR		
Radionuclides	Inorganics	Organics
U-238	(No data available)	(No data available)
Th-232		
Ra-226		
Radon		

[a]Chemicals expected to reach aquifer within 500 years.
[b]Organic data for surface soil were taken from the one sample available.

concentrations ranging between 53 and 17,900 picoCuries/gram (pCi/g), 509 and 15,800 pCi/g, and 12,500 and 18,700 pCi/g, respectively. Samples from the Burn Pit contained the lowest uranium concentrations, which ranged from 22 to 454 pCi/g. Pits 3 and 5 contained higher concentrations of Th-230 than the other pits with concentrations ranging from 15 to 21,900 pCi/g and 3080 to 20,200 pCi/g, respectively. The Clearwell and Pit 5 contained higher concentrations of Ra-226 than the other pits with concentrations ranging between 22 to 458 and 235 to 999 pCi/g, respectively.

Results from the CIS for the inorganic chemical analysis show that all pit residues had elevated concentrations of aluminum, calcium, iron, and magnesium. Pits 3 and 5 had elevated concentrations of arsenic with a maximum concentration of 3049 parts per million (ppm) in Pit 3. Vanadium was present in all pits with concentrations ranging up to 9696 ppm in Pit 3. Pits 2, 3, 6, and the Burn Pit had elevated lead concentrations. These ranged from detection limits to 613 ppm that was found in Pit 3. Pits 3 and 5 and the Clearwell had elevated mercury concentrations. These ranged from detection limits to 4.0 ppm, which was found in Pit 3 and the Clearwell. Pits 4, 6, and the Burn Pit had the higher silver concentrations that measured 444, 158, and 506 ppm, respectively. Pit 4 had fluoride and barium with concentrations ranging from 47,812 ppm to 124,576 ppm and from 444 to 6669 ppm, respectively.

Results from the organic chemical analysis identified the presence of polychlorinated biphenyls (PCBs) in Pits 1 through 6 and the Burn Pit. The PCBs most frequently detected were Aroclor-1254, Aroclor-1248, and Aroclor-1260. The concentrations of PCBs in the waste storage area ranged from detection limits to 10.0 ppm with Pit 1 containing the highest concentrations. Various organic chemicals found in other storage areas outside Operable Unit 1 were also detected in individual pits. In Pit 1, chrysene and phenanthrene were detected and ranged in concentration up to 0.51 and 2.3 ppm, respectively. In Pits 1 and 2, 4,4'-DDT was detected in concentrations ranging up to 1.6 and 1.4 ppm, respectively. In Pit 4, tetrachloroethene was detected at 30.0 ppm. In Pit 6, a concentration of 29.0 ppm 1,1,2,2-tetrachloroethane was detected.

Surface Soils

A review of the surface soil data obtained during the CIS program shows that uranium and thorium are the predominant and most widespread radionuclides in the waste pit area. Surface U-238 concentrations are elevated around the perimeter of Pit 6 and east of Pits 1 and 2. Several locations within the waste pit area had concentrations greater than 35 pCi/g and at some locations as high as 10,900 pCi/g. The majority of sampling locations show Th-232 concentrations to range between 1 and 5 pCi/g.

Several locations that are associated with elevated U-238 activity show Th-232 concentrations ranging from 5 to 15 pCi/g. The areal extent of Ra-226 concentrations greater than background levels of 1.5 pCi/g is quite low. The Th-232 levels range between 1 to 5 pCi/g in the majority of the waste storage area surface samples.

Subsurface Soils

A total of 26 subsurface soil samples were collected from various depths from the wells installed within the Operable Unit 1 study area during the RI/FS. These samples were analyzed for a full range of radionuclides. Radium-226, Ra-228, Th-228, Th-230, Th-232, U-234, and U-238 were consistently detected in these samples. The concentration range for these radionuclides in pCi/g are: 0.4 to 1210 for Ra-226; <0.5 to 160 for Ra-228; <0.6 to 22.9 for Th-228; <0.6 to 710 for Th-230; <0.6 to 33.1 for Th-232; <0.6 to 112 for U-234; and <0.6 to 320 for U-238.

Surface Water

Surface water samples were collected at 12 locations along drainageways within Operable Unit 1. Data from this RI sampling program, as well as data from previous studies, indicate the presence of radionuclides in the storm water runoff from the waste pits. Most of the radionuclides are present at background concentrations. Total uranium concentrations range from 54 to 9318 micrograms/liter (μg/L). Concentrations of U-234 and U-238 in two samples exceed the DOE-Derived Concentrations Guide (DCG) limit of 500 and 600 pCi/L, respectively. These samples contained 597 and 653 pCi/L of U-234 and 2840 and 2506 pCi/L of U-238. Radium and thorium concentrations in all the samples were well within the DOE guidelines. Radium and thorium were not detected in any surface water samples with the exception of a single sample, which had a radium level of 6.1 pCi/L. Thorium was not detected in any samples.

Sediments

No sediment samples were collected within Operable Unit 1 during the RI. However, several drainage ditches within Operable Unit 1 were sampled during the CIS program. Review of the CIS data indicates widespread uranium contamination in most of the drainage ditches. A sample from a drainage ditch that flows parallel and adjacent to the south berm of Pit 5 contained U-238 activity concentrations ranging from 46 to 728 pCi/g. The radium and thorium concentrations were low in all the drainageway samples, with the concentrations ranging from nondetectable to slightly greater than detection limits (approximately 1 pCi/g). A shallow drainage ditch flowing north and south over the Burn Pit area contained U-238 activity concentrations ranging from 170 to 408 pCi/g. A minor drainage ditch flowing east of Pit 4 contained U-238 activity concentrations ranging from 96 to 746 pCi/g.

Groundwater

The perched groundwater in the glacial till overburden is contaminated with uranium as a result of leaking waste pits. A sample from a well in this region contained 15,330 µg/L of total uranium. Many other wells contained high concentrations of uranium greater than 1000 µg/L. All the wells that contain high concentrations of uranium are located in the east central part of the waste storage pits. Leakage from the waste pits is suspected of being the source of contamination in the eastern groundwater plume. Contaminants from the heavily contaminated overburden have infiltrated into the Great Miami Aquifer from the perched groundwater zones as evidenced by uranium levels of up to 218 µg/L found in deeper wells.

Biological Resources

The investigation of biological resources conducted during the RI determined that there is uptake of radionuclides by both plants and animals within the FMPC. Total uranium concentrations in samples of vegetation collected within the Operable Unit 1 study area ranged from 1.8 to 31.3 pCi/g. Results from background uranium concentrations obtained from macro-invertebrate (taken from the vicinity of Paddys Run, north of the FMPC) have been reported as nondetectable. This site is upstream of the FMPC. At another site just above the confluence of Paddys Run and the Great Miami River, uranium concentrations in a bluegill sample ranged from below detection limits of 1.8 to 3.7 pCi/g.

1.2.4 Remedial Action Objectives

Remedial action objectives (RAOs) are medium-specific cleanup goals for protecting human health and the environment. They address the contaminants of concern as well as exposure routes and receptors identified in the baseline risk assessment. The primary purposes of RAOs are to ensure site-wide compliance with:

- Chemical-specific ARARs and to be considered (TBC) guidelines
- U.S. EPA guidance for risk to public health from hazardous chemicals
- Regulatory standards for control of radiation and radioactivity in the environment

The remediation objectives for Operable Unit 1 must cover all constituents (radiological and chemical) that contribute to a reasonable maximum exposure (RME) scenario. Alternatives for remediation must meet airborne RAOs at a point immediately adjacent to the waste pits or at a location determined by an RME scenario to be of greatest risk to human and environmental receptors, as well as drinking water RAOs in the aquifer that might be encountered directly below Operable Unit 1.

RAOs were developed based on chemical-specific and radionuclide-specific ARARs. The media for which RAOs were developed included: air, soils, sediments and surface water, groundwater, and pit waste. RAOs are presented in Figure 1-2.

MEDIA		REMEDIAL ACTION OBJECTIVES
1. PIT WASTES	1-1	For Human Health: Prevent inhalation of/ingestion of/direct contact with pit wastes which would result in doses of non-carcinogens greater than the RfDs or in doses of carcinogens posing cancer risk levels greater than 1.0E-04 to 1.0E-06.
	1-2	Prevent migration of contaminants which would result in groundwater concentrations greater than the MCLs or that would result in doses of carcinogens posing cancer risk levels greater than 1.0E-04 to 1.0E-06 or in doses of non-carcinogens greater than the RfDs.
	1-3	Prevent current and future direct radiation doses from exceeding 100 mrem/yr.
	1-4	For Environmental Protection: Prevent migration of contaminants that would result in surface water levels greater than ambient water quality criteria.
	1-5	Prevent current and future direct radiation doses from causing detectable chronic effects.
2. AIR	2-1	For Human Health: Prevent inhalation of contaminants which would result in doses greater than the RfD or doses which pose cancer risk levels greater than 1.0E-04 to 1.0E-06.
	2-2	Prevent inhalation of airborne radiation from exceeding a 10 mrem dose, and radon flux from exceeding 20pCi/square meter/second.
	2-3	For Environmental Protection: Prevent current and future radiation emissions from causing detectable chronic effects.

FIGURE 1-2. REMEDIAL ACTION OBJECTIVES

FL/FMPC-0115-3/2-1a

MEDIA		REMEDIAL ACTION OBJECTIVES
3. SOILS	3-1	For Human Health: Prevent inhalation of/ingestion of/direct contact with soils surrounding the waste pits which would result in doses of non-carcinogens greater than the RfDs or doses of carcinogens posing cancer risk levels greater than 1.0E-04 to 1.0E-06.
	3-2	Prevent migration of contaminants which would result in groundwater concentrations greater than the MCLs or that would result in doses of carcinogens posing cancer risk levels greater than 1.0E-04 to 1.0E-06 or doses of non-carcinogens greater than the RfDs.
	3-3	Prevent contact with radium and thorium above 5 pCi/g in the first 15 cm of soil, and 15 pCi/g at lower depths. Prevent contact with other nuclides at concentrations resulting in doses greater than 100 mrem/yr.
	3-4	For Environmental Protection: Prevent migration of contaminants that would result in surface water contamination levels greater than ambient water quality criteria.
4. SEDIMENTS	4-1	For Human Health: Prevent ingestion of/direct contact with sediment contaminants which would result in doses of non-carcinogens greater than the RfDs or doses of carcinogens posing cancer risk levels greater than 1.0E-04 to 1.0E-06.
	4-2	For Environmental Protection: Prevent releases of contaminants from sediments that would result in surface water contamination levels greater than ambient water quality criteria.

FIGURE 1-2.
(CONTINUED)

MEDIA		REMEDIAL ACTION OBJECTIVES
5. SURFACE WATER	5-1	For Human Health: Prevent ingestion of water having contaminants greater than the MCLs or which would result in doses of non-carcinogens greater than the RfDs or doses of carcinogens posing cancer risk levels greater than 1.0E-04 to 1.0E-06.
	5-2	For Environmental Protection: Restore surface water to below ambient water quality criteria.
6. GROUNDWATER	6-1	For Human Health: Prevent ingestion of water having contaminant levels greater than the MCLs or TBCs, or which would result in doses of non-carcinogens greater than the RfDs or doses of carcinogens posing cancer risk levels greater than 1.0E-04 to 1.0E-06.
	6-2	For Environmental Protection: Restore groundwater aquifer to contaminant concentrations below the MCLs.

FIGURE 1-2.
(CONTINUED)

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1.2.5 EPA Guidance

The U.S. EPA's "Guide for Conducting Treatability Studies Under CERCLA" outlined a three-tiered approach to conducting treatability studies for a Superfund site. The original interpretation of the approach can be seen in Figure 1-3. The remedy evaluation phase of the RI/FS, in accordance with proposed revised EPA guidance, may require a maximum of three tiers of treatability testing:

- Remedy screening
- Remedy selection
- Remedy design

The terminology of this approach has been revised to reflect Figure 1-4. This illustrates these three levels of treatability testing and how this treatability plan compares with these requirements.

The three levels of treatability testing are divided into pre-ROD and post-ROD studies. The remedy screening and remedy selection testing are pre-ROD studies, and the remedy design studies are post-ROD.

Pre-ROD treatability studies provide the critical performance and cost data needed to (1) evaluate all potentially applicable treatment alternatives and (2) select an alternative for remedial action based on the nine RI/FS evaluation criteria. The detailed analysis of alternatives phase of the RI/FS follows the development and screening of alternatives and precedes the actual selection of a remedy in the ROD. During the detailed analysis, all remedial alternatives are evaluated based on nine RI/FS evaluation criteria. These criteria are as follows:

- Overall protection of human health and the environment
- Compliance with ARARs
- Long-term effectiveness and permanence
- Reduction of toxicity, mobility, or volume through treatment
- Short-term effectiveness
- Implementability
- Cost
- State acceptance
- Community acceptance

These criteria are described in detail in "Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA."

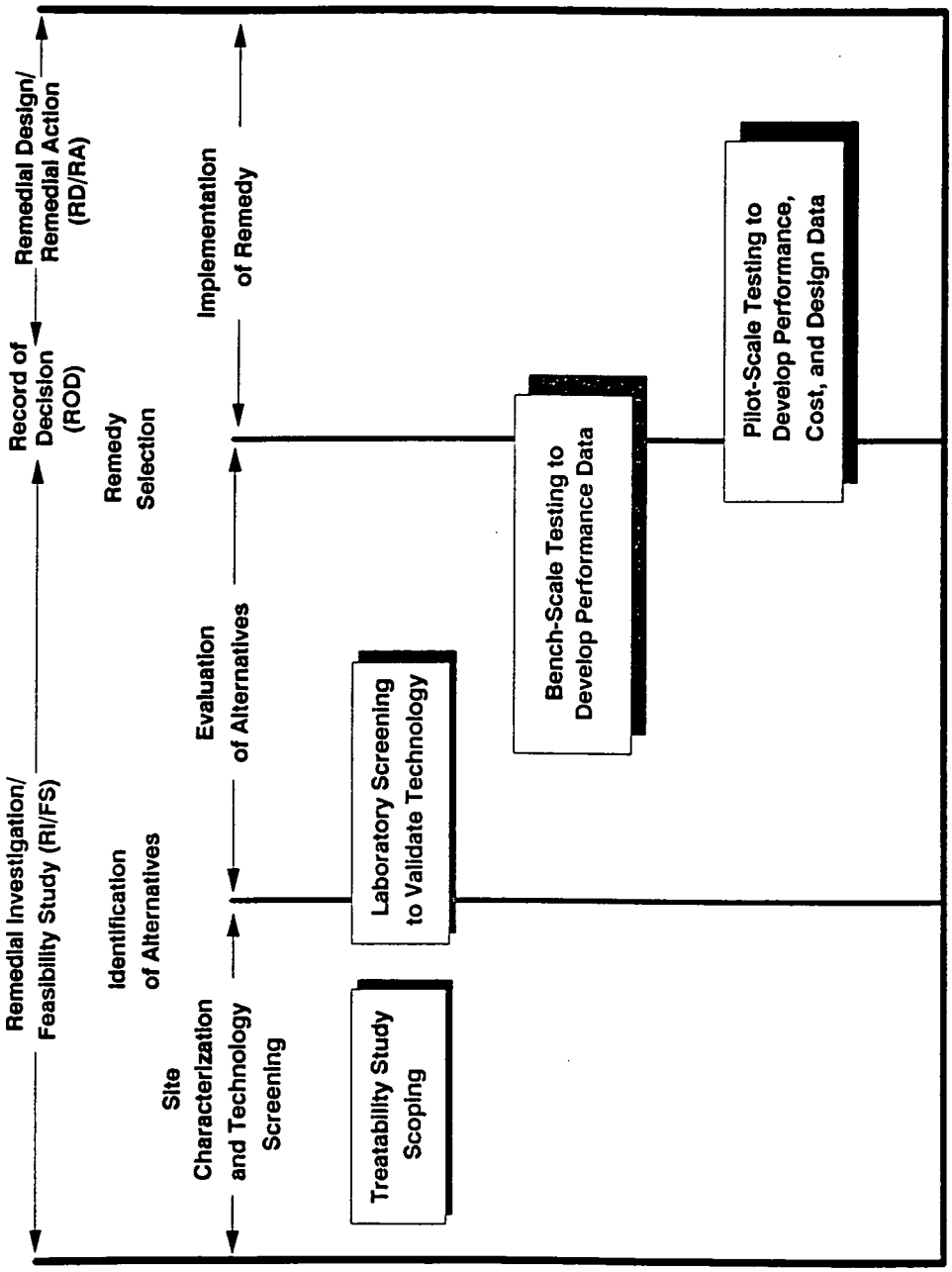

FIGURE 1-3. THE ROLE OF TREATABILITY STUDIES IN THE RI/FS AND RD/RA PROCESS.

Source: Guide for Conducting Treatability Studies Under CERCLA. Interim Final 12/89.

Remedy screening is the first step in the tiered approach. Its purpose is to determine the feasibility of a treatment alternative for the contaminants/matrix of interest (Figure 1-4). These tests are typically conducted under conditions that are favorable to the technology. These small-scale studies are designed to provide a qualitative evaluation of the technology and are conducted with minimal levels of QA/QC. Tests conducted under this tier are generic in nature (not vendor specific). If the feasibility of the treatment cannot be demonstrated, the alternative should generally be screened out at this time.

The remedy selection tier of the treatability study program is designed to determine whether a treatment alternative can meet the operable unit's cleanup criteria and at what cost (Figure 1-4). The purpose of this tier is to generate the performance and cost data necessary for remedy evaluation in the detailed analysis of alternatives phases of the FS. The cost data developed in this tier should support costs estimates of +50 percent/-30 percent accuracy. The performance data will be used to determine if this technology will meet ARARs or cleanup goals. Remedy selection studies are typically small-scale, incorporating generic tests using bench- or pilot-scale equipment in either the laboratory or field. The study costs are higher than those encountered in the remedy screening tier and require longer durations to complete. The levels of QA/QC are moderate to high because the data from these studies will be used to support the ROD.

In the post-ROD remedy design tier treatability study, detailed scale-up, design, performance, and cost data are generated to implement and optimize the selected remedy (Figure 1-4). Remedy design studies are performed after the ROD, usually as part of the remedy implementation. These studies are performed on full-scale or near full-scale equipment with the purpose of generating detailed, scale-up design and cost data. The study should focus on optimizing process parameters, which are not a part of this treatability study. These studies require moderate to high QA/QC and are typically vendor specific.

This work plan covers the remedy screening and remedy selection tiers of the treatability studies as described in the EPA guidance. The remediation screening is performed in the preliminary phase study, and the remediation selection is performed in the advanced treatability study. The remedy selection phase involves an optional treatability study task. This optional treatability task will be used if necessary to develop additional data for incorporation in the Final Review of the FS. This testing will be done as a task that is not on the critical path, and the data will be provided as an addendum to the FS and not as part of the treatability study report.

The estimated number of experiments by phase and stage are in Table 1-3 for cement stabilization and Table 1-4 for vitrification.

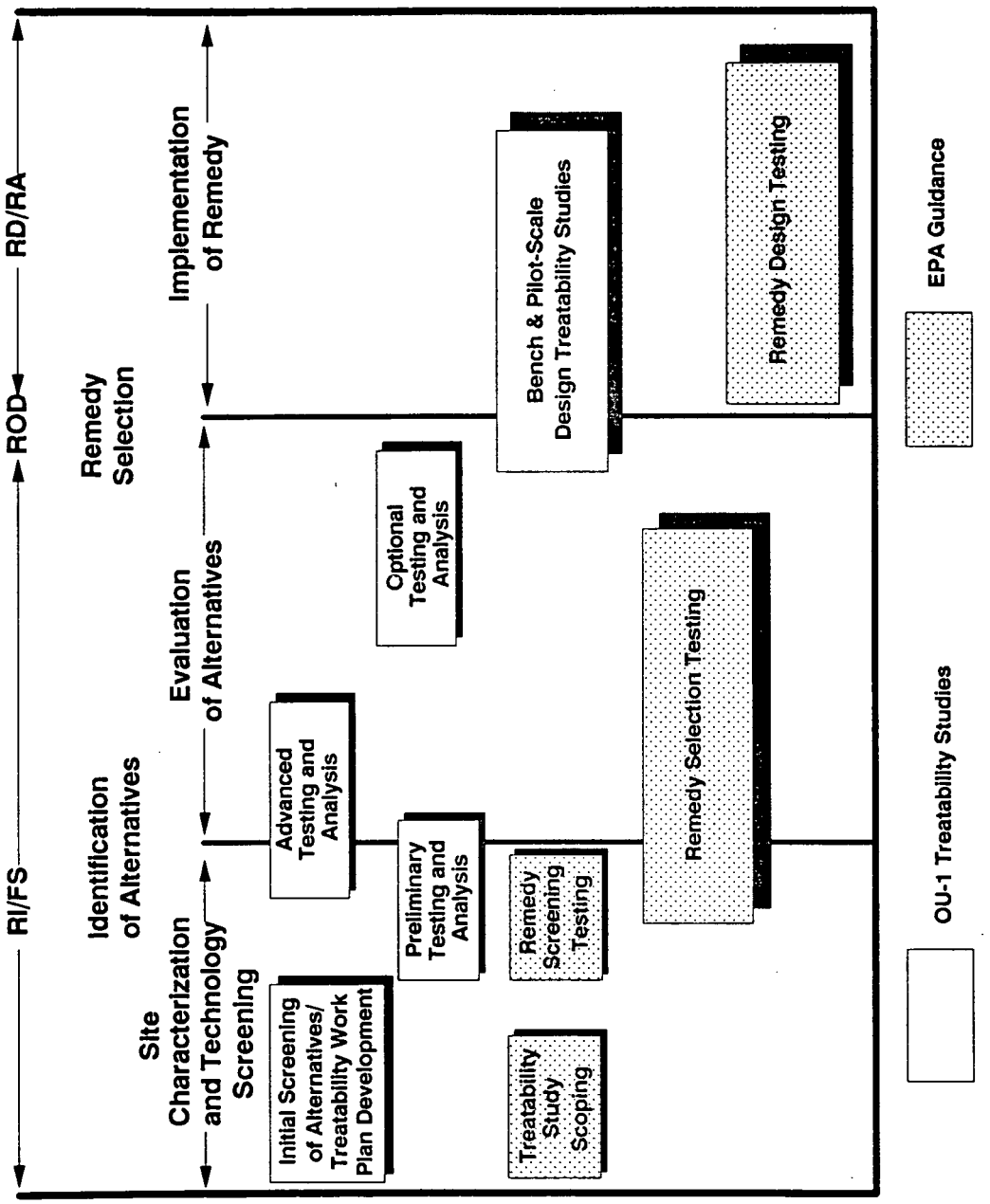

FIGURE 1-4. RELATIONSHIP OF THE OPERABLE UNIT 1 TREATABILITY STUDIES TO THE RI/FS PROCESS.

TABLE 1-3. ESTIMATED NUMBER OF EXPERIMENTS BY PHASE
CEMENT STABILIZATION

	PHASE				
	Remedy Screening (Preliminary)		Remedy Selection (Advanced)		
Waste Pit Number	Stage I	Stage II[a]	Stage I	Stage II[a]	Optional[b]
1	20	0 to 5	6	6 to 8	
2	20	0 to 5	6	6 to 8	
3	20	0 to 5	6	6 to 8	
4	20	0 to 5	6	6 to 8	
5	20	0 to 5	2	2 to 3	
6	20	0 to 5	2	2 to 3	
Burn Pit	20	0 to 5	6	6 to 8	
Clearwell	20	0 to 5	2	2 to 3	
Subtotal	160	0 to 40	36	36 to 49	
Duplicate	0	0	7	0 to 10	
Total	160	0 to 40	43	36 to 59	

[a]The total number of experiments in Stage II will depend on the results from the previous stage.
[b]The scope of the optional stage will be based on the results from the remedy selection Stages I and II.

TABLE 1-4. ESTIMATED NUMBER OF EXPERIMENTS BY PHASE VITRIFICATION

	PHASE			
	Remedy Screening (Preliminary)	Remedy Selection (Advanced)		
Waste Pit Number	Stage I	Stage I	Stage II[a]	Optional[b]
1	6	6	6 to 8	
2	6	6	6 to 8	
3	6	6	6 to 8	
4	6	6	6 to 8	
5	6	2	2 to 3	
6	6	2	2 to 3	
Burn Pit	6	6	6 to 8	
Clearwell	6	2	2 to 3	
Subtotal	48	36	36 to 49	
Duplicate	0	7	0 to 10	
Total	48	43	36 to 59	

[a]The total number of experiments in Stage II will depend on the results from the previous stage.
[b]The scope of the optional stage will be based on the results from the remedy selection Stages I and II.

1.3 TREATABILITY STUDY DESCRIPTION

1.3.1 Approach

Treatability studies on the pit materials will be performed to aid in the selection of a remedial action alternative that is feasible, implementable, and cost effective. A preliminary laboratory screening of various cement stabilization and vitrification technologies is proposed for application to the Operable Unit 1 waste. Reagent formulations for cement stabilization and vitrification of the waste material will be determined. For cement stabilization, binding agents being considered are portland cement, fly ash, and sodium silicate. Various ratios of waste to binder will be tested to minimize the amounts of binder required to produce an acceptable stabilized waste form. Clay (attapulgite and clinoptilolite) will be added to reduce the leachability of metals in the waste. Glass-forming agents, for vitrification, being considered are fly ash, soil, and sodium hydroxide.

Composite and strata samples from the 1991 sampling effort will be subjected to this screening process. The objectives of the laboratory screening are to determine:

- Reagents required so that the waste passes Toxicity Characteristics Leaching Procedure (TCLP) criteria
- Reagents required to achieve a compressive strength of the waste of approixmately 500 pounds per square inch (psi) for the cement stabilization process
- Increases in treated waste volumes
- Provide preliminary cost, risk assessment, ARARs, and design data for the RI/FS and the subsequent bench- and pilot-scale treatability studies

The cement stabilization of the treatability study consists of the following:

- Preliminary Phase - Stage I on composite samples
- Preliminary Phase - Stage II on composite samples
- Advanced Phase - Stage I
- Advanced Phase - Stage II
- Advanced Phase - Optional

This approach is consistent with that currently recommended by DePercin et al. (1991). Figure 1-4 shows the outline between the treatability study testing program and the EPA guidance. The preliminary phase corresponds to remedy screening. The strata sample experiments, or

advanced phase, which correspond to the remedy selection testing, are expected to provide sufficient data to perform detailed analysis of alternatives so that remedy selection can be made. This treatability study will not provide enough data for remedy design. Further testing will be conducted as part of the post-ROD. To implement and optimize the selective remedy, remedy design will develop data for :

- Detailed scale-up
- Design
- Performance
- Cost data

The objectives of the treatability study are to identify formulations that will have pocket penetrometer values of approximately 500 psi or greater, metal concentrations in the modified TCLP (MTCLP) near to the TCLP limits, or a relatively low bulking factor.

The preliminary phase experiments will apply a wide range of stabilization reagents to the pit waste samples to identify these reagent mixtures that achieve some degree of success in stabilization. Composite samples will be used in the remedy screening phase to minimize the total number of experiments, and therefore, costs and generation of laboratory waste. The most promising formulations from this stage will have metal concentrations in the MTCLP near to the TCLP limits, a relatively low bulking factor, and pocket penetrometer values of approximately 500 psi or greater. The 500 psi value is a recommended value for low-level waste set forth by NRC in Technical Position on Waste Form (Revision 1), prepared by Low-Level Waste Management Branch Division of Low-Level Waste Management and Decommissioning, January 1991. An excerpt of the document that describes the reasoning is in Appendix A. Where possible, these experiments will be based on a statistically designed matrix to maximize the information gained in the fewest experiments.

The Stage II screening will test additional reagent mixtures in the event that the preliminary phase was unsuccessful, or refine the formulation of those successful mixtures. This stage is designed to achieve a greater level of confidence in the data. The most promising formulations, from this stage, will have pocket penetrometer values greater than 500 psi, metal concentrations in the MTCLP at or below the TCLP limits, and relatively low bulking factor.

The remedy selection phase of the laboratory screening, the strata sample experiments, will apply the best formulations discovered in the previous stages to strata samples. It is important to test the individual layers of the waste pits because much of the material was added in batch to the pits (i.e., truck loads) over an extended period of time, so it is highly likely that the waste pits are heterogeneous. The effect of waste material variability will be tested in this stage.

The vitrification laboratory screening will have only two phases:

- Preliminary phase for remedy screening
- Advanced phase - Stages I, II, and Optional for detailed analysis of alternatives and remedy selection

The design, reasoning, and intent of the vitrification laboratory screening is similar to the cement stabilization laboratory screening.

1.3.2 Cement Stabilization

The composite and strata samples will be treated with varying combinations of cement, sodium silicate, clay, zeolite, and fly ash from the active fly ash pile to determine the viability of the cement stabilization option. Portland Type I and II cements, PQ Corporation Type N sodium silicates, and Type F and site fly ash, attapulgite, clinoptilolite, and water will be used in various combinations to determine the optimum overall mix. Site fly ash from the active fly ash pile in Operable Unit 2 will be used as an additional pozzolanic agent in the screening in an effort to determine its effectiveness in achieving an adequate stabilized waste form. This will allow for the stabilization of contaminated material from two operable units in the same treatment system. Section 4.0 contains more details on the experimental design.

1.3.3 Vitrification

The first step of the vitrification screening will be to determine the glassforming characteristics of the waste without the addition of vitrifying reagents. This step will be performed in a simple laboratory furnace. Following this test, glassforming agents such as fly ash from the site (Operable Unit 2), contaminated soil/sand from the site, and modifiers such as sodium hydroxide will be added separately to the waste and the mix vitrified to determine the best combination of waste and glassforming/modifying agents. Section 4.0 contains more details on the experimental design.

1.3.4 General Selection Criteria

For cement stabilization, the most promising formulations will have unconfined compressive strength of at least 500 psi, pass all of the TCLP leaching requirements, and have minimal volume increase after treatment. For vitrification, the formulations should pass all of the TCLP leaching requirements, form a durable glass and have minimal volume increase.

The best technology will be determined by comparison of multiple criteria during the detailed analysis. The detailed analysis of alternatives phase of the RI/FS follows the development and screening of alternatives and precedes the actual selection of a remedy in the ROD. During the detailed analysis,

all remedial alternatives are evaluated based on nine RI/FS evaluation criteria. These criteria are as follows:

- Overall protection of human health and the environment
- Compliance with ARARs
- Long-term effectiveness and permanence
- Reduction of toxicity, mobility, or volume through treatment
- Short-term effectiveness
- Implementability
- Cost
- State acceptance
- Community acceptance

The relationship between the evaluation criteria and the data that will be generated during treatability studies is shown in Table 1-5. For example the ability of a particular waste formulation or technology (cement stabilization versus vitrification) to provide protection of human health and the environment would be determined by evaluating factors such as; concentration of contaminants in the leachate, the durability of the waste form, its compressive strength as it relates to disposal and handling, permeability, and intrinsic properties of the waste form (glass versus cement).

Compliance with ARARs would be determined by whether the treated material meets compressive strength requirements for disposal, whether these leachate exceeds established discharge standards and on factors relating to waste form. A full evaluation of the technology for compliance with ARARs will be performed in the feasibility study.

Treatability testing that relates to a technology's long-term effectiveness and permanence includes its shear strength and durability for handling and disposal purposes, its solubility as measured by leachability, and the extent to which it transmits water based on permeability. The waste form itself (glass or cement) also influences long-term stability. A glass, for instance, would tend to be a more stable waste form provided it is of good quality.

The ability of a technology or formulation to reduce the toxicity, mobility, or volume will be measured by indicators such as; bulking factor for volume reduction, leachate analysis for toxicity and mobility, and permeability, and waste form for mobility reduction.

Short-term effectiveness is impacted primarily by bulking factor, which is an indicator of the volume of treated waste that must be handled and disposed of and by the specific technology chosen. The short-term impacts associated with implementing cement stabilization would be different from

TABLE 1-5. RELATIONSHIP OF TREATABILITY DATA TO FS EVALUATION CRITERIA

FS Evaluation Criteria	Treatability Data					
	Compressive Strength - UCS - Penetrometer	Leachate Analysis - TCLP - Static Leach	Bulking Factor (% volume change)	Permeability	Durability - PCT - Shear Strength - Waste Form	Treatment Method - Cement Stabilization - Vitrification
• Overall protection of human health and the environment	X	X		X	X	X
• Compliance with ARARs	X	X				X
• Long-term effectiveness and permanence	X	X		X	X	X
• Reduction of toxicity, mobility, or volume through treatment		X	X	X		X
• Short-term effectiveness			X			X
• Implementability			X		X	X
• Cost			X			X
• State acceptance	X	X	X	X	X	X
• Community acceptance	X	X	X	X	X	X

vitrification because they have significantly different requirements to construct, operate, and maintain during remediation.

The implementability of a particular technology is influenced by the volume of waste to be handled as measured by bulking factor and by the waste form itself (glass versus cement). As with implementability, cost is impacted by the technology selected and the volume of waste to be generated. Because cement stabilization and vitrification are radically different processes, each will require different equipment and facilities.

The final two evaluation criteria, state and community acceptance are influenced by the results of all the data and by the other seven criteria.

Additional information on use of the evaluation criteria and treatability data in the feasibility study process can be found in "Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA" (EPA 1988).

2.0 REMEDIAL TECHNOLOGY DESCRIPTION

Several remediation technologies are being considered for the Operable Unit 1 RI/FS. These alternatives have been described in detail in the Department of Energy report "Initial Screening of Alternatives for Operable Unit 1, Task 12 Report, January 1991."

Summary of Alternatives

In addition to the no-action alternative, seven distinct remedial action alternatives were developed for Operable Unit 1. These alternatives are briefly described in the following sections.

Alternative 0 - No Action

The no-action alternative provides no remediation of any sort and simply leaves the waste pits in their present condition.

Alternative 1 - Nonremoval, Slurry Wall, and Cap

The first nonremoval alternative for Operable Unit 1 is intended to isolate the waste from the environment and to minimize the generation and release of contaminated leachate to the underlying Great Miami Aquifer. This alternative includes removing and treating any standing water, installing subsurface flow control measures, building a closure cap, and providing storm water runoff and run-on control measures. The subsurface flow control measures combine a slurry wall, subsurface drains, and a temporary groundwater extraction system.

Alternative 2 - Nonremoval, Physical Stabilization, Slurry Wall, and Cap

The second nonremoval alternative for Operable Unit 1 is identical to Alternative 1 with the addition of a waste stabilization step. The purpose of this additional process is to promote the compaction (densification) of the waste to minimize both the potential for long-term settlement and the release of contaminated waste pit water into the underlying till. The need for continuing maintenance of the cap due to settling will be correspondingly reduced.

Alternative 3 - Nonremoval, In Situ Vitrification, and Cap

Because a waste immobilization step has been incorporated into the nonremoval scenario, this alternative is similar to Alternative 2. However, this solidification/stabilization step specifies that a vitrification technology be used rather than physical stabilization technologies. A second important difference: the subsurface control measures are not included in this alternative. It is reasoned that the resultant vitrified mass precludes the future release of contaminated water from the waste.

Alternative 4 - Removal, Waste Treatment, and On-Property Disposal

The alternatives for Operable Unit 1, which include removing the waste material, are intended to completely eliminate the waste source from its current location above the Great Miami Aquifer and to obviate future problems through the treatment and disposal of the wastes. This alternative utilizes technologies that include removing and treating the standing water, removing the waste, waste segregation and treatment, and on-property disposal. The waste treatment portion of this alternative retains two distinct process options: cement stabilization and continuous vitrification. Treatment of residual water will be handled by the existing FMPC wastewater treatment facility and the FMPC advanced wastewater treatment facility. If any pretreatment is necessary, it will consist of waste segregation/separation.

Alternative 5 - Removal, Waste Treatment, and Off-Site Disposal

This alternative is identical to Alternative 4 except that the treated and packaged waste is to be transported to and disposed of at an approved off-site location.

Alternative 6 - Waste Removal, Treatment, On-Property Disposal, and Cap

This alternative, like Alternative 4, addresses the removal and treatment of the waste pit caps (or standing surface water on those pits without caps) and pit wastes from each of the waste pits including the Burn Pit and the Clearwell. However, in this alternative, the contaminated soils that make up and surround the pits will be left in place and fitted with a closure cap. The treated and packaged waste is to be housed on site in an engineered waste management facility.

Alternative 7 - Waste Removal, Treatment, On-Property Disposal, Soil Treatment, and Cap

This alternative is identical to Alternative 6, except that the soil in the pits will be treated by in situ technologies following the excavation of the waste materials.

The following alternatives were removed from further consideration during initial screening of alternatives because of concerns about technology implementability and reliability:

- Alternative 1 Nonremoval - Slurry Wall and Cap
- Alternative 3 Nonremoval - In Situ Vitrification and Cap

No treatability testing is planned for Alternatives 1, 2, or 3.

3.0 TEST AND DATA QUALITY OBJECTIVES

The purpose for this laboratory screening is to assess the performance of various stabilization technologies on the Operable Unit 1 waste in support of the RI/FS. To select a preferred alternative for the Operable Unit 1 RI/FS, a waste treatment technology must be screened to support evaluations of the alternative during the detailed analysis of alternatives. In addition, the level of quality assurance applied during experimentation and analysis must be established.

This section will establish the performance objectives for the treatment technologies, the additional data desired for use in subsequent stages of the RI/FS, and the data quality objectives (DQOs).

3.1 PERFORMANCE OBJECTIVES AND DESIRED DATA

Specific test objectives have been established so that the performance of the various stabilization mixtures can be evaluated in the areas of leachability, unconfined compressive strength (UCS), and final waste form volume. These performance objectives will be used to determine if a particular reagent mixture produces an acceptable waste form. The specific objectives of the treatability study are as follows:

- To determine the cement stabilization and vitrification reagents and relative quantities required so that the final waste form meets TCLP criteria
- To determine the cement stabilization reagents and relative quantities required so that the final waste form achieves a compressive strength of approximately 500 psi
- To estimate the volumes of treated waste that will be generated by each process
- To provide preliminary cost and design data for the RI/FS
- To provide leaching characteristics for use in fate and transport modeling
- To develop preliminary reagent mixtures
- To develop preliminary process parameter data for use in the bench- and pilot-scale studies as follows:
  - For cement: shear strength, waste form temperature rise with reagent addition, general description of waste before and after reagent addition, permeability of the stabilized waste, and percent moisture in the raw waste
  - For vitrification: percent moisture in the raw waste
- The chemical and radiological data as shown in Table 3-1

TABLE 3-1. CHEMICAL AND RADIOLOGICAL INFORMATION TO BE ACQUIRED

PRELIMINARY PHASE

Modified TCLP List (MTCLP) for Vitrification		PCT List for Vitrification		Modified TCLP List for Cement Stabilization	
Metals	Radionuclides	Metals	Radionuclides	Metals	Radionuclides
Arsenic (As) Barium (Ba) Cadmium (Cd) Chromium (Cr) Lead (Pb) Selenium (Se) Silver (Ag)	Uranium by IC Gross alpha Gross beta	Aluminum (Al) Boron (B) Iron (Fe) Potassium (K) Sodium (Na)	Uranium by IC Gross alpha Gross beta	Arsenic (As) Barium (Ba) Cadmium (Cd) Chromium (Cr) Lead (Pb) Selenium (Se) Silver (Ag)	Uranium by IC Gross alpha Gross beta
		General chemistry Chloride Nitrate Sulfate			
Physical parameters Bulking factor Temperature of oven Time of sample heating				Physical parameters Bulking factor Temperature rise Pocket penetrometer resistance Shear strength	

TABLE 3-1 (continued)

ADVANCED PHASE

TCLP Organic List[a]	Five-Day Static Leach Test, PCT, and TCLP Inorganic List			
	Metals		Radionuclides	General Chemistry
TCL[b] Volatiles TCL Semivolatiles TCL Pesticides/PCBs	Aluminum (Al) Antimony (Sb) Arsenic (As) Barium (Ba) Beryllium (Be) Boron (B) Calcium (Ca) Cadmium (Cd) Chromium (Cr) Cobalt (Co) Copper (Cu) Cyanide (CN) Lead (Pb)	Magnesium (Mg) Manganese (Mn) Mercury (Hg) Molybdenum (Mo) Potassium (K) Nickel (Ni) Selenium (Se) Silicon (Si) Silver (Ag) Sodium (Na) Thallium (Tl) Vanadium (V) Zinc (Zn)	Cs-137 Np-237 Pu-total Ra-total Ru-106 Sr-90 Tc-99 Th-total U-total Radon	alkalinity chloride reactivity fluoride ammonia nitrate pH phosphorus sulfate
Physical Parameters : Bulking factor Temperature rise (cement only) Shear Strength (cement only) UCS (ASTM D2166) (cement only) Permeability (cement only) Temperature of oven (vitrification only) Time of sample heating (vitrification only)				

[a]TCLP organics will not be analyzed if the compounds are not found in the Characterization Study.
[b]Target Compound List (TCL).

FER/WP350.3A/JE.OU1/07-22-91

3.2 DATA QUALITY OBJECTIVES

DQO analytical levels are defined in EPA's "Guide for Conducting Treatability Studies Under CERCLA." This guide states that the requisite analytical levels are dictated by the types and magnitudes of decisions to be made based on the data and the objective of the screening. A description of the analytical levels is presented in Table 3-2, an excerpt from EPA's guide. A discussion of the DQOs for each stage of the treatability study for cement stabilization and vitrification follows.

The establishment of DQOs is the part of the process that defines the data quality needs of the project. The implementation of an appropriate quality assurance/quality control (QA/QC) program is required to ensure that data of known and documented quality are generated. The DQOs will define the level of QA/QC for the treatability testing and analysis. The DQOs for this treatability study are quantitative in nature because the stabilized waste must meet specific performance criteria, namely UCS greater than 500 psi and TCLP and 5-day static leachability criteria. A list of tests and associated DQOs for cement stabilization and vitrification are in Tables 3-3 and 3-4, respectively.

Composite samples will be used in the initial stage(s) to minimize the total number of experiments, cost, and waste generation. These experiments will aid in the resolution of general ranges of reagent formulations needed to stabilize and vitrify the waste and to elucidate on potential problems with different stabilization schemes. Pocket penetrometer compressive strength, bulking factor, and MTCLP screening data will be acquired in the initial stage(s) to minimize costs and waste generation. Also, the MTCLP provides results in a much quicker time frame than TCLP. Experiments with strata samples will be conducted to determine the effects of waste material variability on the stabilization and vitrification processes.

3.2.1 Preliminary Remedy Screening - Stage I (Composite Samples)

The preliminary phase will be an initial run of experiments on eight composite samples and will not require a high statistical confidence level. The tests performed on the stabilized waste samples will be a compressive strength test with a pocket penetrometer (Soiltest CT-421), a bulking factor test, and a MTCLP. Data from the CT-421 will be DQO Level I. The tests performed on the vitrified waste samples are bulking factor and MTCLP. The MTCLP differs from the standard TCLP as follows: the MTCLP uses only 2.5 grams of material rather than 100 grams; the MTCLP generates only 50 milliliters of leachate rather than 2 liters; and the leachate from the MTCLP is analyzed for metals only rather than metals and organics. The data from the MTCLP will be DQO analytical Level V because the method is nonstandard.

TABLE 3-2. SUMMARY OF ANALYTICAL LEVELS

Level I	
Type of analysis	Field screening or analysis with portable instruments.
Limitations	Usually not compound-specific, but results are available in real time. Not quantifiable.
Data quality	Can provide an indication of contamination presence. Few QA/QC requirements.
Level II	
Type of analysis	Field analysis with more sophisticated portable instruments or mobile laboratory. Organics by GC; inorganics by AA, ICP, or XRF.
Limitations	Detection limits vary from low parts per million to low parts per billion. Tentative identification of compounds. Techniques/instruments limited mostly to volatile organics and metals.
Data quality	Depends on QA/QC steps employed. Data typically reported in concentration ranges.
Level III	
Type of analysis	Organics/inorganics performed in an off-site analytical laboratory. May or may not use CLP procedures. Laboratory may or may not be a CLP laboratory.
Limitations	Tentative compound identification in some cases.
Data quality	Detection limits similar to CLP. Rigorous QA/QC.
Level IV	
Type of analysis	HSL organics/inorganics by GC/MS, AA, ICP. Low parts-per-billion detection limits.
Limitations	Tentative identification of non-HSL parameters. Validation of laboratory results may take several weeks.
Data quality	Goal is data of known quality. Rigorous QA/QC.
Level V	
Type of analysis	Analysis by nonstandard methods.
Limitations	May require method development or modification. Method-specific detection limits. Will probably require special lead time.
Data quality	Method-specific

Source: EPA, "Guide for Conducting Treatability Studies under CERCLA, "December 1989.

TABLE 3-3. CEMENT STABILIZATION TEST DQOS

PRELIMINARY (REMEDY SCREENING)		
TEST	**DQO/COMMENT**	**DQO Level**
Bulking Factor by Solvent Displacement	Minimize waste volume increase. To estimate the volume of waste that will be generated.	V
Pocket Penetrometer	During screening phases, to determine stabilization reagent formulation so that the final waste form achieves a unconfined compressible strength of at least 500 psi.	I
Modified Toxicity Characteristic Leaching Procedure (MTCLP)	During the screening phases, to determine stabilization reagent formulations so that the final waste form meets the TCLP metal leaching criteria. In addition, the test data will indicate the relative leachability of uranium with the various reagent formulations.	V
Waste Form Temperature	Preliminary Process Parameters	I
Shear Strength	Preliminary Process Parameters	I
ADVANCED (REMEDY SELECTION)		
Bulking Factor by Bulk Density Calculation	Minimize waste volume increase. To estimate the volume of waste waste that will be generated.	I

TABLE 3-3. (CONTINUED)

TEST	DQO/COMMENT	DQO Level
Unconfined Compressive Strength (ASTM D2166)	To determine the stabilization reagent formulation so that the final waste form achieves an unconfined compressive strength of at least 500 psi. In addition to provide preliminary cost and design data for the RI/FS.	III
Full TCLP	To determine stabilization reagent formulations so that the final waste form meets the TCLP metal leaching criteria. To provide data for the FS risk assessment calculations.	III
5-day static leach test	To provide data for the FS risk assessment calculations.	V
Permeability	To provide data for the FS risk assessment calculations.	III
Waste Form Temperature Rise	To provide preliminary process parameters	I
Shear Strength	To provide preliminary process parameters	I

TABLE 3-4 VITRIFICATION TEST DQOS

TEST	DQO/COMMENT	DQO LEVEL
PRELIMINARY (REMEDY SCREENING)		
Bulking Factor by Solvent Displacement	Minimize waste volume increase. To estimate the volume of water.	V
MTCLP	During the screening phases, to determine stabilization reagent formulations so that the final waste form meets the TCLP metal leaching criteria. In addition, the test data will indicate the relative leachability of uranium with the various reagent formulations.	V
PCT	To provide data for the FS risk assessment calculations. To provide data on the relative leachability or uranium and glass components with the various reagent formulations.	V
ADVANCED (REMEDY SELECTION)		
Bulking Factor by Solvent Displacement	Minimize waste volume increase. To estimate the volume of waste that will be generated.	V
Full TCLP	To determine stabilization reagent formulations so that the final waste form meets the TCLP metal leaching criteria. To provide data for the FS risk assessment calculations.	III
PCT	To provide data for the FS risk assessment calculations. To provide data on the relative leachability of uranium and glass components with the various reagent formulations.	V

The bulking factor is the measured percent volume increase/decrease of the treated waste, relative to the original waste volume. The bulking factor measurement will follow the Standard Operating Procedure (SOP) in Appendix B for the Preliminary Phase.

3.2.2 Preliminary Phase - Stage II (Composite Samples)

Stage II screening will consist of an additional zero to five experimentation runs to refine the mixes that showed promise in the Stage I screening. The pocket penetrometer test, the bulking factor test, and the MTCLP procedure will be run on the stabilized samples also; therefore, the data will have the same DQO level as in Stage I. This low level of QA is also due to the fact that this Stage II will be followed by advanced experiments. There is no Stage II screening for the vitrification preliminary phase.

3.2.3 Advanced Phase Experiments

All previous stages of this treatability study have tested composite samples. This stage will take the one or two of the most promising reagent mixes, as determined in the previous stages, and apply them to the 18 samples. The 18 samples consist of 15 strata samples (will composite horizontal locations, top, middle, and bottom, from each boring for Pits 1 through 4 and the Burn Pit) and 3 composite samples from Pits 5 and 6 and the Clearwell. This will allow for the determination of the effect of the mixes on the individual strata. Samples for Pits 5 and 6 and the Clearwell are being taken as composite rather than as strata samples. This stage of the screening will also repeat the best sample mixes (those with the lowest reagent loading and the lowest bulking factor) to confirm their performance. For those samples that do not produce an adequate waste form, additional reagent formulations will be attempted. The resultant cement stabilized waste forms will be subjected to a UCS (ASTM D2166, SOP in Appendix B), TCLP, bulking factor, permeability, and a five-day static leaching test. Vitrified waste forms will be subjected to bulking factors, TCLP, and PCT. DQO levels for the various tests are given in Table 3-3 and 3-4. The bulking factor will be determined for cement stabilization using the following equation:

$$BF = 100 * \frac{(100 + A)/P_t - 100/P_r}{100/P_r}$$

where

BF = percent bulking factor
A = percent additives added
P_t = density of treated waste

P_r = density of raw waste

The density of the raw waste will be measured as in the preliminary phase. The bulk density of the treated waste will be calculated by dividing the weight of the UCS solid cylinder (2 by 4 inches) by its volume. (See EPA document EPA/625/6-89/022, Section 4.2.4 for a description of bulk density measurement of stabilized waste.)

Bulk density values used in the treatability study will be averaged values from several locations in each pit. These average values will be used in the bulking factor calculation during the advanced phase.

5-Day Static Leach Test

The 5-day static leach test is a modification of the American National Standard Measurement of the Leachability of Solidified Low-Level Radioactive Waste by a Short-Term Procedure, American National Standards Institute, 1986 (ANSI/ANS-16.1-1986) leaching procedure. The 5-day static leach test differs from the ANSI/ANS-16.1-1986 as follows: the treated sample is leached for a continuous period of 5 days instead of 12 wash-leach periods over 90 days, the sample is supported in the leaching solution by a permeable polymeric material instead of a Teflon® cage, and the concentration of the metals in the treated sample will not be analyzed.

PCT

The PCT leaching procedure was developed to test the durability of vitrified high level radioactive waste produced in the Defense Waste Processing Facility at the Savannah River Site.

The introduction section of the PCT procedure, which summarizes the test, is in Appendix C.

Permeability

The permeability of the treated samples will be determined by using procedures in EPA SW-846 and EM-1110-2-1906 as guidelines. There are several methods to choose from, depending on the sample matrix, sample constraints (e.g., radioactivity and hazardous contaminants, sample condition on receipt, and clients' end use.

4.0 EXPERIMENTAL DESIGN AND PROCEDURES

4.1 CEMENT STABILIZATION EXPERIMENT DESIGN

There are many unknown variables regarding the behavior and activity of the waste and the performance of the stabilizing reagents with the waste. Therefore, this treatability study will consist of three distinct stages. The first or preliminary phase will be divided into two sets of experiments: the first will involve a statistically designed mixture experiment (Group I experiments in Table 4-1); the second will involve five single variable experiments (Group II through V experiments in Table 4-1). The statistically-designed matrix was developed through a statistical analysis of the variable parameters and the practical ranges of these parameters. The stabilization matrix is based on the extreme vertices design for mixtures that have constraints on the values of each factor (McLean and Anderson 1966; Diamond 1981). Because this is a screening study, and to decrease the number of experiments, only the matrix vertices and center point of the complete matrix values will be used. The single variable matrices, Group II, III, IV, and V experiments, are similar in structure to the Group I experiment but differ in that a single variable is changed for each experiment group. All of these experiments will be conducted on the composite samples. The preliminary studies on the composite samples will entail up to 160 experiments (8 composite samples x 20 experiments/sample). Preliminary characterization of the samples is discussed in Section 6.0.

Mathematical models relating UCS and bulking factors will be generated from the data gathered during the Group I experiments of the preliminary phase. These models will aid in the interpretation of data and in the formulation of reagent combinations for the additional testing phase of the screening. The second stage of the preliminary phase will consist of 0 to 5 experiments depending on the success of the preliminary phase. This stage will use new combinations of reagents if the preliminary phase is unsuccessful in producing adequate waste forms or it will refine the mixtures of those successful experiments run in the preliminary phase. The preliminary phase experiments will be run on composite samples.

The advanced phase will apply the 2 most promising mixtures discovered in the preliminary Stages I and II to each of the 15 strata composite samples from Pits 1 through 4 and the Burn Pit, and 3 composite samples from Pits 5 and 6 and the Clearwell. This will prove that the successful mixtures will work on the strata samples. These two formulations will result in approximately 43 samples. See Figure 4-1 for the logic of the cement stabilization laboratory screening and Table 1-3 for estimated number of experiments per phase and stage. Experimental conditions of the optional stage of the advanced phase will be determined based on results from the preceding stages.

TABLE 4-1. CEMENT STABILIZATION EXPERIMENT MATRICES (STAGE I)

GROUP I EXPERIMENTS-STATISTICALLY-BASED MATRIX						
Run Number	Waste (g)	Portland Cement Type II (g)	Fly Ash Type F (g)	Sodium Silicate Type N (g)	Attapulgite and Clinoptilolite Each (g)	Potential Range of Water Needed (g)
1	100	64	64	0.00	6	9 - 65
2	100	68	68	0.07	6	11 - 71
3	100	51	31	0.00	6	0 - 35
4	100	54	33	0.07	6	0 - 38
5	100	31	51	0.00	6	0 - 35
6	100	33	54	0.07	6	0 - 38
7	100	26	26	0.00	6	0 - 15
8	100	27	20	0.07	6	0 - 16
9	100	43	43	0.04	6	0 - 37
GROUP II EXPERIMENTS-SINGLE VARIABLE MATRIX, EFFECT OF SITE FLY ASH						
Run Number	Waste (g)	Portland Cement Type II (g)	Site Fly Ash (active) (g)	Sodium Silicate Type N (g)	Attapulgite and Clinoptilolite Each (g)	Potential Range of Water Needed
10	100	43	43	0.00	6	0 - 37
11	100	43	43	0.04	6	0 - 37
GROUP III EXPERIMENTS-SINGLE VARIABLE MATRIX, EFFECT OF ADSORBENT						
Run Number	Waste (g)	Portland Cement Type II (g)	Fly Ash Type F (g)	Sodium Silicate Type N (g)	Attapulgite or * Clinoptilolite (g)	Potential Range of Water Needed (g)
12	100	43	43	0.04	12A	0 - 37
13	100	43	43	0.04	12C	0 - 37
14	100	26	26	0	0	11 - 71
15	100	64	64	0	0	11 - 71

TABLE 4-1. (CONTINUED)

GROUP IV EXPERIMENTS-SINGLE VARIABLE MATRIX, EFFECT OF CEMENT TYPE						
Run Number	Waste (g)	Portland Cement Type I (g)	Fly Ash Type F (g)	Sodium Silicate Type N (g)	Attapulgite and Clinoptilolite Each (g)	Potential Range of Water needed (g)
16	100	43	43	0.04	6	0 - 37
17	100	43	43	0.00	6	0 - 37
18	100	43	43	0.00	0	0 - 37
GROUP V EXPERIMENTS-CEMENT ONLY						
Run Number	Waste (g)	Portland Cement Type II (g)	Fly Ash Type F (g)	Sodium Silicate Type N (g)	Attapulgite and Clinoptilolite Each (g)	Potential Range of Water needed (g)
19	100	60	0	0	0	11 - 71
20	100	80	0	0	0	11 - 71

*12A and 12C: Add 12 grams of attapulgite and clinoptilolite, respectively.
Total number of experiments is 160. (160 experiments = 8 composite samples x 20 runs/sample.)

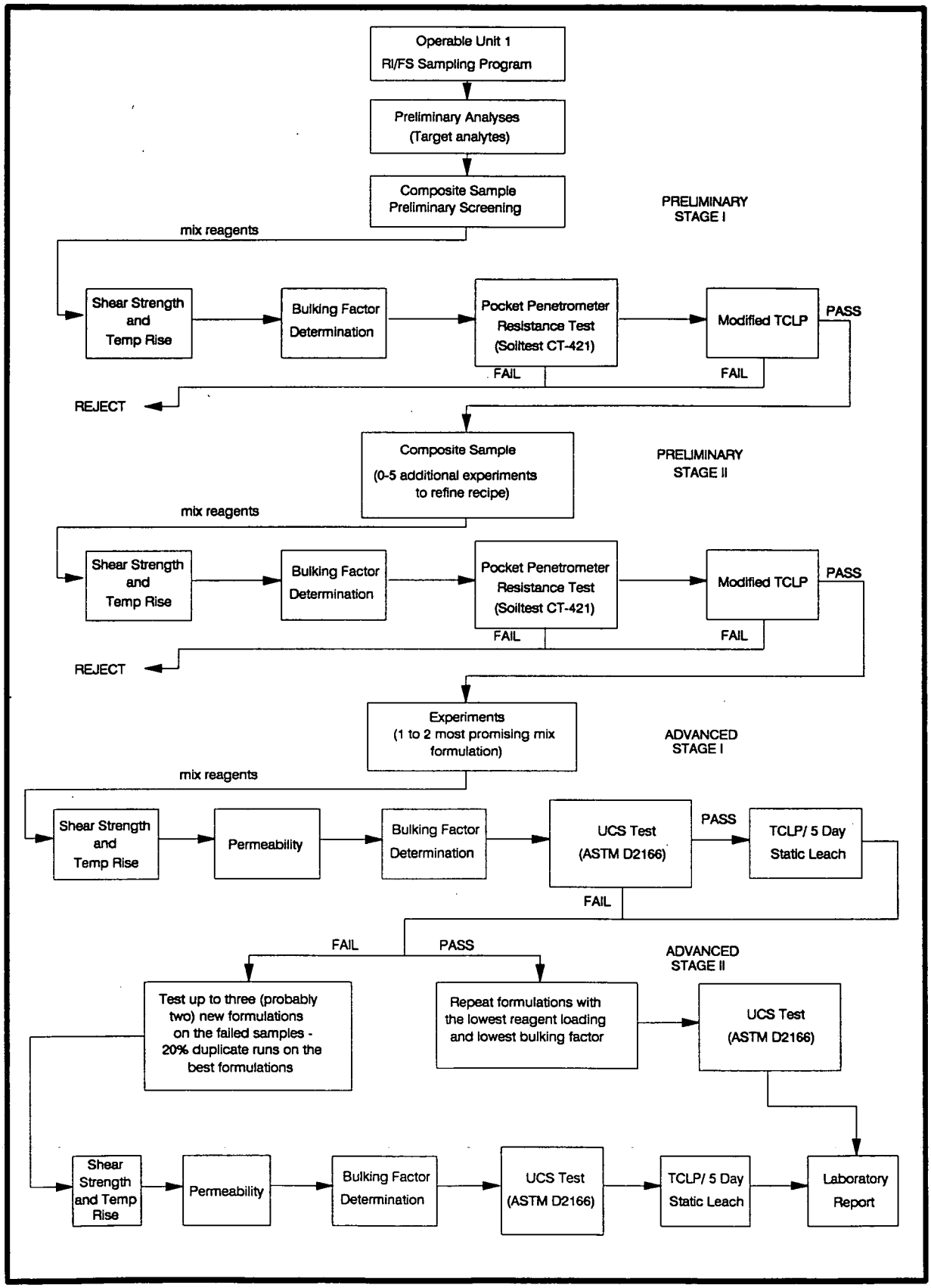

FIGURE 4-1. CEMENT STABILIZATION LABORATORY SCREENING FLOWCHART

4.1.1 Preliminary Phase (Stage I)

The Group I experiments will treat each composite sample with a combination of portland Type-II cement, PQ Corporation Type N sodium silicate, Type F fly ash, clay (attapulgite and/or clinoptilolite), and water according to the matrix shown in Table 4-1.

The Group II, III, IV, and V experiments will change a single variable in the reagent mixture. The Group II experiment will substitute site fly ash from the active fly ash pile (Operable Unit 2) for the Type F fly ash. This will allow for the stabilization of contaminated material from two operable units in the same treatment system. The Group III experiment will modify the type and level of adsorbents that may affect the leachability of the heavy metals and radionuclides in the treated waste. In the Group IV experiments, portland Type I cement will be substituted for Type II cement. This is being done due to the cost difference between the two types of cement. In Group V experiments, portland Type II cement with water will be the only additive.

For each of the test runs, the waste form temperature rise, bulking factor, shear strength, and general appearance will be recorded. The waste form temperature rise and shear strength will be measured within 10 minutes after reagents and waste are mixed. These temperature measurements are relative values only because they are performed in an open, plastic container. The shear strength will be measured with a Soiltest Torvane. The compressible strength (Soiltest concrete penetrometer CT-421) of the stabilized mixture will be recorded on days 0, 7, 14, and 28 of the experiment. A modified TCLP (as described in Section 3.2.1) leaching test will be performed on those mixtures with a 28-day penetrometer resistance of approximately 500 psi. It is expected that 20 to 30 percent of the samples will meet this requirement.

4.1.2 Preliminary Phase - Stage II (Composite Samples)

The preliminary phase may not yield a successful mixture or it may indicate a promising reagent combination that requires more data for adequate evaluation. Additionally, analysis of the preliminary phase data may indicate that lesser quantities of reagents will yield adequate results. If any of these are the case, an additional experimental matrix will be designed to gather this data. The mathematical models developed from the Group I experiment data will be used to aid in the development of this additional experiment matrix. It is expected that this additional testing could consist of 0 to 5 experiments.

The same data will be required for these experiments as was required for the preliminary phase.

4.1.3 Advanced Experiments - Stage I

The two most promising stabilization formulations encountered during the composite sample preliminary phase will then be applied to the top, middle, and bottom strata of strata composites from the borings to determine the effect of varying waste composition. The two most formulations will also be applied to Pits

5, 6, and the Clearwell. The most promising formulations are those that meet the compressive strength and leachability criteria and that minimize the volume increase of the resultant waste and the cost of reagents. It is expected that two formulations per strata per pit and per composite sample from Pits 5, 6, and the Clearwell, will be tested with 20 percent of testing in duplicate resulting in approximately 43 experiments performed. The mathematical models developed from the Group I experiment data will also be used to aid in the development of these experiments.

For this phase, a full TCLP, a bulking factor, permeability test, shear strength, temperature rise, and a five-day static leachability test will be run in addition to a UCS (ASTM D2166) test.

4.1.4 Advanced Experiments - Stage II

The successful formulations from Stage I of advanced experiments with the lowest reagent loading and lowest bulking factor will be repeated in Stage II. If any formulations fail in Stage I of the advanced experiments, two or three new formulations will be tested on each of the failed samples (Stage II). Twenty percent duplicate runs will be made.

The tests to be run are shear strength, temperature rise, permeability, bulking factor, UCS (ASTM D2166), full TCLP, and 5-day static leach.

4.1.5 Advanced Experiments - Optional

It is possible that some waste forms that appear to be promising will fail TCLP, or exhibit other traits casting doubt on the formulations. If this occurs, optional experiments might be designed. Waste forms from optional tests would, as a minimum, be subjected to the same tests used in Stages I and II of the advanced experiments.

4.1.6 Procedure

The waste will be sieved through a 3/8-inch mesh screen before testing. Obvious debris will be removed. The percent weight and visual observation of debris will be noted. In the preliminary phase, 100 grams of waste and correct amounts of reagents will be mixed in a plastic container, slightly compacted by tapping with a bolt, and the container sealed with a lid. The amount of water added will be determined empirically. Enough water will be added to make the mixture into a paste. The treated samples will be cured at room temperature in sealed containers. In the preliminary phase the lid will be removed briefly from the container to measure the penetration resistance on days 0, 7, 14, and 28. The lid will be replaced after the measurements. Mixing will be done by hand with a spatula until the mixture has an even consistency without any lumps.

In the advanced phase, approximately 300 grams of waste per mold will be mixed with the correct amount of reagents, in an American Society for Testing and Materials (ASTM) grade Hobart Planetary mixer. The mixture will be placed into a two- by four-inch Jatco plastic cylinder in three to six aliquots. The mixture will be compacted using a vibratory table. After the molds are loaded, they will be capped and sealed with tape until the sample is tested on Day 28.

4.1.7 Data Required

The following data will be recorded during cement stabilization screening:

- Compressive strength measured by a Soiltest concrete penetrometer CT-421 (for preliminary and additional screening) or UCS (ASTM D2166) with a U-610 instrument (for strata sample experiments)
- Permeability (for advanced, strata sample experiments)
- MTCLP (for preliminary phase and advanced phase) or TCLP and five-day static leachate test (for strata sample experiments) leaching procedures results on those mixtures with a compressive strength of approximately 500 psi
- Bulking factor
- Waste form temperature rise after waste and reagents are mixed
- General descriptions of the waste before and after reagent addition
- Approximate shear strength measured within 10 minutes after waste and reagents are mixed
- Physical characteristics: percent moisture, bulk density
- The amount of water added to each waste form

4.2 VITRIFICATION EXPERIMENT DESIGN

This laboratory screening will consist of two phases: preliminary phase and advanced phase. There will be approximately 48 experiments (8 composites samples x 6 experiments/sample) in the preliminary screening. There will be several range finding experiments where various amounts of NaOH are added to the mixture of waste, fly ash, and soil to determine the NaOH concentration needed to lower the melting point temperature to about 1250°C. The effects of the addition of sodium hydroxide, site fly ash, and site soil will be demonstrated. The advanced phase will apply the most promising mixtures discovered in the preliminary phase to each of the samples. This will prove that the successful mixtures will work on the samples. These formulations will be applied to each of the 18 samples (1 strata composite each from Pits 1 through 4 and the Burn Pit x 3 strata per pit plus composite samples from Pits 5 and 6 and the Clearwell) resulting in approximately 36 experiments with 20 percent duplication giving 43 experiments

possible for Stage I. See Figure 4-2 for the logic of the vitrification laboratory screening and Table 1-4 for estimated number of experiments per phase and stage.

4.2.1 Preliminary Phase - Stage I (Composite Samples)

Table 4-2 is an example test matrix for the preliminary phase. Except for the raw waste tests, no experiment will be conducted until the chemical characterization of the waste, soils, and fly ash are completed. As a target, the reagent waste mixture will have between 40 to 60 percent SiO_2 + Al_2O_3 combined content and 10 to 20 percent sodium oxide (Na_2O) content when dried. Enough NaOH will be added to cause the mixture to melt at 1250°C in a muffle furnace.

According to Table 4-2, sodium hydroxide will be added at three levels: 0 percent, 10 percent, and 20 percent as the dry weight of the waste. The site fly ash and site soil will be added at 50 percent of the dry weight of the waste.

For each of the test runs, the vitrified mixture bulking factor will be recorded. An MTCLP (as described in Section 3.2.1) and Product Consistency Test (PCT) leaching tests will be performed.

4.2.2 Advanced Phase - Stage I

The one to two most promising vitrification formulations encountered during the composite sample preliminary phase will be applied to the top, middle, and bottom strata of each boring from Pits 1 through 4 and the Burn Pit, to determine the effect of varying waste composition. In addition, the one or two most promising formulation will also be applied to composite samples from Pit 5 and 6 and the Clearwell. The most promising formulations are those that meet the leachability criteria and that minimize the volume increase of the resultant waste and the cost of reagents.

For this stage, full TCLP, bulking factor, and PCT tests will be run.

4.2.3 Advanced Phase - Stage II

Successful formulations from advanced Stage I with the lowest reagent loading and lowest bulking factor will be repeated. Vitrified samples will be subjected to PCT, and bulking factor will be determined. If any formulations from advanced Stage I fail, two or three new formulations will be tested on each failed sample. Vitrified samples with the new formulations will be tested for TCLP, PCT, and bulking factor.

4.2.4 Advanced Phase - Optional

Experimental conditions of the optional stage will be determined based on the results of the first two stages.

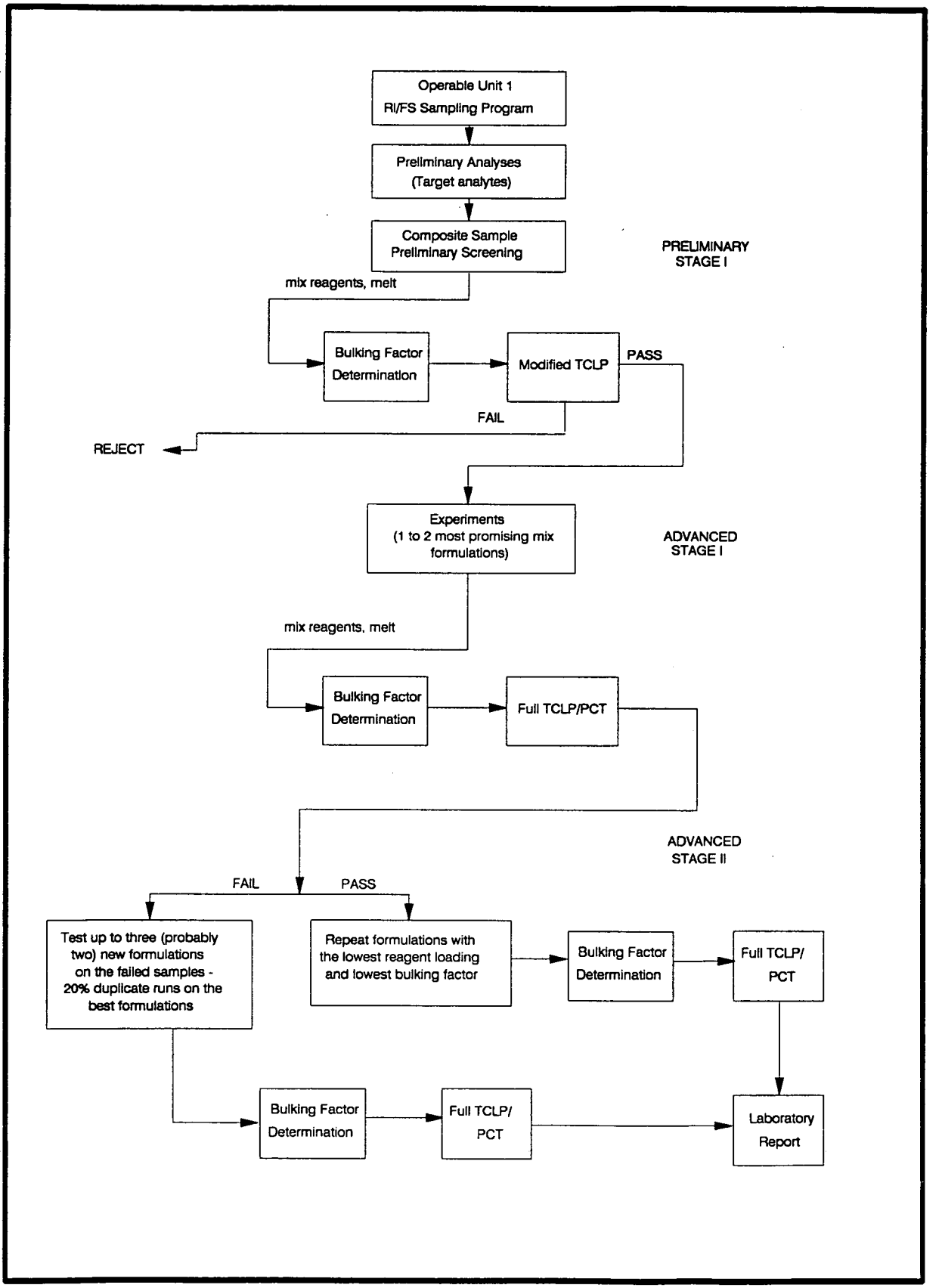

FIGURE 4-2. VITRIFICATION LABORATORY SCREENING FLOWCHART

TABLE 4-2. VITRIFICATION EXPERIMENT MATRIX PRELIMINARY SCREENING (STAGE I)

Run Number	NaOH[a] (w/w)	Active Site Fly Ash[a] (w/w)	Site Soil[a] (w/w)
1	0	0	0
2	0	50	0
3	0	0	50
4	10	50	0
5	10	0	50
6	20	50	0

[a]Weight of reagent to dry weight of waste.

4.2.5 Procedure

The waste will be sieved through a 3/8-inch mesh before use. Obvious pieces of debris will also be removed. According to the prescribed experiment matrix, vitrification reagents will be blended with 100 to 300 grams of pit waste in a crucible. Mixing will be done by hand with a spatula until the mixture is homogeneous (>2 minutes). The mixture will then be melted in a 1250°C muffle furnace.

4.2.6 Data Required

The following data will be recorded during the vitrification laboratory screening:

- MTCLP (for preliminary phase), and PCT (for strata sample experiments) leach procedure
- Weights of reagents and waste in final waste form
- Temperature of oven
- Time heating sample
- Bulking factor
- General description of the waste before and after melting
- Physical characteristic: percent moisture, bulk density
- Metal characterization (SiO_2, Al_2O_3, Na_2O) of the site soil, site fly ash, and successfully vitrified samples.

5.0 EQUIPMENT AND MATERIALS

See Table 5-1 for a listing of the major equipment to be used during the laboratory screening.

TABLE 5-1. EQUIPMENT AND MATERIALS[a]

No. of Items	Item Description
Multiple	Plastic containers, 8 oz. and 5 oz.
Multiple	Spatulas
Multiple	Crucibles
1	HACH digital pH meter
3	Glass melter furnace
1	Soiltest Laboratory vibrating shaker
1	Thermometer, calibrated and traceable
1	Scale, calibrated
1	Soiltest Torvane
Multiple	2 X 4 Jatco Co. plastic molds for UCS
1	Hobart ASTM Grade Planetary Mixer
1	Soiltest U-610 instrument
1	Soiltest concrete penetrometer CT-421
1	Drying oven
Multiple	High temperature gloves
Multiple	Crucible tongs

[a]This equipment list does not include analytical instrumentation for leachate analyses; equipment for TCLP, PCT, or 5-Day Station leach test; or general laboratory equipment.

6.0 SAMPLING AND ANALYSIS

The data from the CIS sampling program were used to estimate the amount of waste in the pits. The results obtained were significantly different from the waste inventory records. This discrepancy may have resulted from the inability to sample the full waste column in the pits. A review of the CIS data revealed additional data requirements. These data are needed for the final design of the remedial actions and also for the evaluation of the risks associated with remediation. Consequently, a Sampling and Analysis Plan (SAP) for the waste pits has been prepared and approved. Actual field sampling began in June 1991. The samples taken in this sampling program will be used for this laboratory screening.

A total of 13 borings will be taken from the waste Pits 1 through 4 and the Burn Pit under the sampling program. The borings will be sectioned into top, middle, and bottom zones from which 39 strata samples will be taken. If a greater number of strata are observed, more samples will then be taken from the boring. A total of five composite samples will be prepared, one each from Pits 1 through 4 and the Burn Pit. The composites will be collected based on details as described in the SAP. These samples will consist of waste material from each identified stratum in the boring such that a representative sample is prepared. In a separate program, composite samples will be collected from Pits 5 and 6 and the Clearwell for support of the treatability study.

According to the SAP, a full range of radionuclide, organic, and inorganic analyses will be conducted on the retrieved samples. For the material to be treated, this laboratory screening requires that the presence and concentrations of a number of analytes be known as well as a number of physical parameters. After collection, the composite and strata samples will potentially be analyzed for the parameters as listed in Table 6-1 in addition to the parameters specified in the SAP. These targeted analytes, listed in Table 6-1, are of interest because their presence and or high concentrations may have adverse effects on the proposed cement stabilization and vitrification testing. These parameters will be analyzed for on all of the composite and strata samples.

TABLE 6-1. CHEMICAL CHARACTERIZATION OF PIT WASTE

Inorganic, Nonmetallics

Alumina
Barium
Boron
Calcium
Carbonate
Chloride
Cyanides
Fluoride
Iron
Lead
Magnesium
Nitrogen and ammonia
Nitrate
Nitrite
Potassium
Total phosphorous
Alkyl phosphorous and alkyl phosphorous oxide compounds
Silica
Sodium
Sulfate
Sulfide
Sulfite
Zinc

Organics

Total organic carbon
Oil and grease
Alcohol
Carboxylic acids

Physical Properties

pH
Acidity

7.0 DATA MANAGEMENT

Two types of laboratory notebooks will be used for this project. All laboratory notebooks are uniquely numbered and have sequentially numbered pages (Appendix B).

Project-specific notebooks will be signed out by the facility quality control coordinator (QCC) to the individuals working on the project. All daily laboratory activities associated with the project will be recorded in the project-specific notebooks.

Separate nonproject-specific logbooks will be used to record the injection or introduction of samples into analytical instrumentation. These logbooks are also used to record maintenance or problems with the instrument (Appendix B).

At the completion of the project, the project-specific laboratory notebooks and logbooks will be returned to the facility QCC for retention. Instrument logbooks are returned to the facility QCC when the books are filled.

All data will be written into standard laboratory notebooks or on to standard formatted data entry sheets. All records management and reporting will follow standard QA/QC protocol. Standard QA/QC protocol, as it applies to testing within the laboratory, will adhere to the following guidelines:

- 100 percent verification on all numerical results - All raw data entries, transcriptions, and calculations are checked.
- Data validation through test reasonableness - Summaries of all test results for individual reports are reviewed to determine the overall reasonableness of data and to determine the presence of any data that may be considered outliers.
- Routine instrument calibration - Will be performed per the Quality Assurance Project Plan (QAPP).
- Use of trained personnel conducting tests - All technicians are trained in the application of standard laboratory procedures for analyses as well as the QA measures implemented for internal QC checks.

8.0 DATA ANALYSIS AND INTERPRETATION

8.1 EFFECTIVENESS OF WASTE FORMS

The results of the leaching tests will be used to evaluate the long-term effectiveness of each waste form. The concentrations of radioactive and hazardous constituents in the leachate will be used as input into the geochemical models described in the RI/FS Work Plan Draft Addendum on risk assessment methodology. These models will be used in conjunction with groundwater fate and transport models to generate data which will then be used to calculate concentrations of contaminants in the aquifer at the location of the reasonable maximum exposure. These concentrations will in turn be used to calculate the magnitude of that exposure, and the resulting risks to human health and the environment.

8.2 CEMENT STABILIZATION

For the preliminary phase, Stages I and II, advanced phase testing, the reagent formulation, unconfined compressive strength (where appropriate), reaction temperature, permeability (when appropriate) shear strength, physical characteristics, and the bulking factor increase will be presented in a tabular format for each test run. The results of the MTCLP, TCLP, and 5-day static leaching procedures will also be listed for those mixtures achieving a compressive strength of approximately 500 psi.

8.3 VITRIFICATION

For the preliminary phase and advanced phase testing, the reagent formulation and the bulking factor decrease will be presented in a tabular format for each test run. The results of the MTCLP, TCLP, and PCT leaching procedures will also be listed.

8.4 DATA PRECISION, ACCURACY, AND COMPLETENESS

The following procedures are used to assess data precision, accuracy, and completeness. Calculations of precision, accuracy, and completeness will be used to assess data quality.

Example calculations of precision:

$$RPD = \frac{(C_1 - C_2) \times 100\%}{(C_1 + C_2)/2}$$

where

RPD = relative percent difference
C_1 = larger of the two observed values
C_2 = smaller of the two observed values.

Example of calculation of completeness:

$$\%R = \frac{100\% \times (S-U)}{C_{sa}}$$

where

%R = percent recovery
S = measured concentration in spiked aliquot
U = measured concentration in unspiked aliquot
C_{sa} = actual concentration of spike added.

Example of calculation of completeness:

$$\%C = 100\% \times \frac{V}{n}$$

where

%C = percent completeness
V = number of measurements judged valid
n = total number of measurements necessary to achieve a specified statistical level of confidence in decision making.

An example of the TDL form used for reporting precision of duplicates and accuracy of spikes is given in Figure 8-1.

Figure 8-1
General QA/QC Report

Analyte:
Matrix:
Sample Number:

		Concentration. ( )
Precision of Duplicates Spike Value (b)= Spike Dup. Value (a)=		
Precision (RPD[a])	$\frac{\lvert a-b \rvert}{(a+b)/2} \times 100\% =$	
Accuracy of Spike Original Value (a)= Observed Spike Value (b)= Spike Level (c)=		
Accuracy=	$\frac{b-a}{c} \times 100\% =$	
Accuracy of Spike Dup. Original Value (a)= Observed Spike Dup. Value (b)= Spike Level (c) =		
Accuracy =	$\frac{b-a}{c} \times 100\% =$	

9.0 HEALTH AND SAFETY

See Appendix D for the Health and Safety Plan.

10.0 RESIDUALS MANAGEMENT

10.1 STABILIZED WASTE

This project will generate approximately 220 kg of cement stabilized waste and approximately 150 kg of vitrified waste. There may also be waste samples that have not undergone treatment that must also be handled as residual waste. These residuals will be shipped to the Fernald site for disposal. All waste and residual shipments must comply with the provisions of the Federal Treatability Study Sample Exemption Rule (see Section 3.9 of Guidance for Conducting Treatability Studies Under CERCLA). All disposal of materials conducted by WMCO will be in accordance with requirements of CERCLA, RCRA, and the waste management requirements of the FMPC.

All treatability studies will be conducted in accordance with Tennessee's Hazardous Waste Management Regulations for treatability study samples (Tennessee Rule Chapter 1200-1-11-.02-16) and samples undergoing treatability studies at laboratories and testing facilities (Tennessee Rule Chapter 1200-1-11-.02-19).

10.2 LEACHATE

As a result of the MTCLP, TCLP, and 5-day static leaching procedures, approximately 1100 liters of stabilized waste leachate, a RCRA waste, will be generated. This leachate will be sent to the IT Oak Ridge Laboratory in Oak Ridge, Tennessee for analysis and then will be shipped to FMPC for disposal. All waste and residual shipments must comply with the provisions of the Federal Treatability Study Sample Exemption Rule (see Section 3.9 of Guidance for Conducting Treatability Studies Under CERCLA).

All treatability studies will be conducted in accordance with Tennessee's Hazardous Waste Management Regulations for treatability study samples (Tennessee Rule Chapter 1200-1-11-.02-16) and samples undergoing treatability studies at laboratories and testing facilities (Tennessee Rule Chapter 1200-1-11-.02-19).

11.0 COMMUNITY RELATIONS

Treatability studies and community information and involvement activities are required in the CERCLA process. Community relations activities shall be conducted: 1) to support treatability studies in Operable Unit 1 to explain the role of treatability studies in the RI/FS and 2) to raise the public's confidence in cleanup alternatives and technologies identified in the alternatives screening/analysis process and in the preferred alternative for this operable unit. The Treatability Study Community Relations activities for Operable Unit 1 will comply with the Community Relations Plan (CRP) -- RI/FS and Removal Actions at the DOE FMPC, Fernald, Ohio, August 1990. At a minimum, the following Community Relations activities will be conducted to explain treatability studies for Operable Unit 1.

- Community Meetings - Held a minimum of three time/year to provide status on cleanup issues, and to ensure that interested area residents have a routine public forum for receiving new information, expressing their views, and getting answers to their questions. The meetings shall focus on operable unit updates, removal actions, major RI/FS documents, and other appropriate topics. During the July 1991 community meeting, an initial discussion of treatability was held to make the community aware of treatability studies underway.

- Publications - RI/FS materials such as progress reports, fact sheets and a community newsletter, *Fernald Site Cleanup Report*, provide updates of CERCLA-related activities at the FMPC and will include information on treatability study activities for this operable unit.

- Presentations to Community Groups - Information about treatability studies for this operable unit shall be included in briefings to community groups in Ross, Crosby, and Morgan townships, and to Fernald Residents for Environment Safety and Health, as appropriate. Also, this information shall be included in presentations to other organizations, as requested.

Key Milestones in treatability studies will be identified and progress reported to the community in these presentations and publications. These milestones include:

- Submittal of work plans to DOE and EPA
- EPA approval of work plan
- Treatability testing
- Treatability testing report submittal.

Other activities identified in Section 4 of the CRP may be utilized as appropriate to effectively communicate treatability information to the community. Such activities may include workshops and community roundtables.

12.0 REPORTS

An interim draft report will be issued following the completion of the preliminary phase that will document the results of the stabilization and extraction procedures. This report will identify those reagent combinations that yielded the best results and will recommend further testing for the treatability work plan. In addition, all raw data will be presented in a tabular format.

The advanced phase will be issued after reviews by concerned organizations have been made. The following outline can be used as a guide when preparing the reports.

SUGGESTED ORGANIZATION OF TREATABILITY STUDY REPORT

1.0 Introduction
- 1.1 Site description
  - 1.1.1 Site name and location
  - 1.1.2 History of operations
  - 1.1.3 Prior removal and remediation activities
- 1.2 Waste stream description
  - 1.2.1 Waste matrices
  - 1.2.2 Pollutants/chemicals
- 1.3 Remedial technology description
  - 1.3.1 Treatment process and scale
  - 1.3.2 Operating features
- 1.4 Previous treatability studies at the site

2.0 Conclusions and recommendations
- 2.1 Conclusions
- 2.2 Recommendations

3.0 Treatability Study Approach
- 3.1 Test objectives and rationale
- 3.2 Experimental design and procedures
- 3.3 Equipment and materials
- 3.4 Sampling and analysis
  - 3.4.1 Waste stream
  - 3.4.2 Treatment process

3.5 Data management
3.6 Deviations
4.0 Results and discussion
4.1 Data analysis and interpretation
4.1.1 Analysis of waste stream characteristics
4.1.2 Analysis of treatability study data
4.1.3 Comparison to test objectives
4.2 Quality assurance/quality control
4.3 Costs/schedule for performing the treatability study
4.4 Key contacts
References
Appendices
A. Data summaries
B. Standard operating procedures

13.0 MANAGEMENT AND STAFFING

The project organization for this laboratory screening is shown in Figure 13-1.

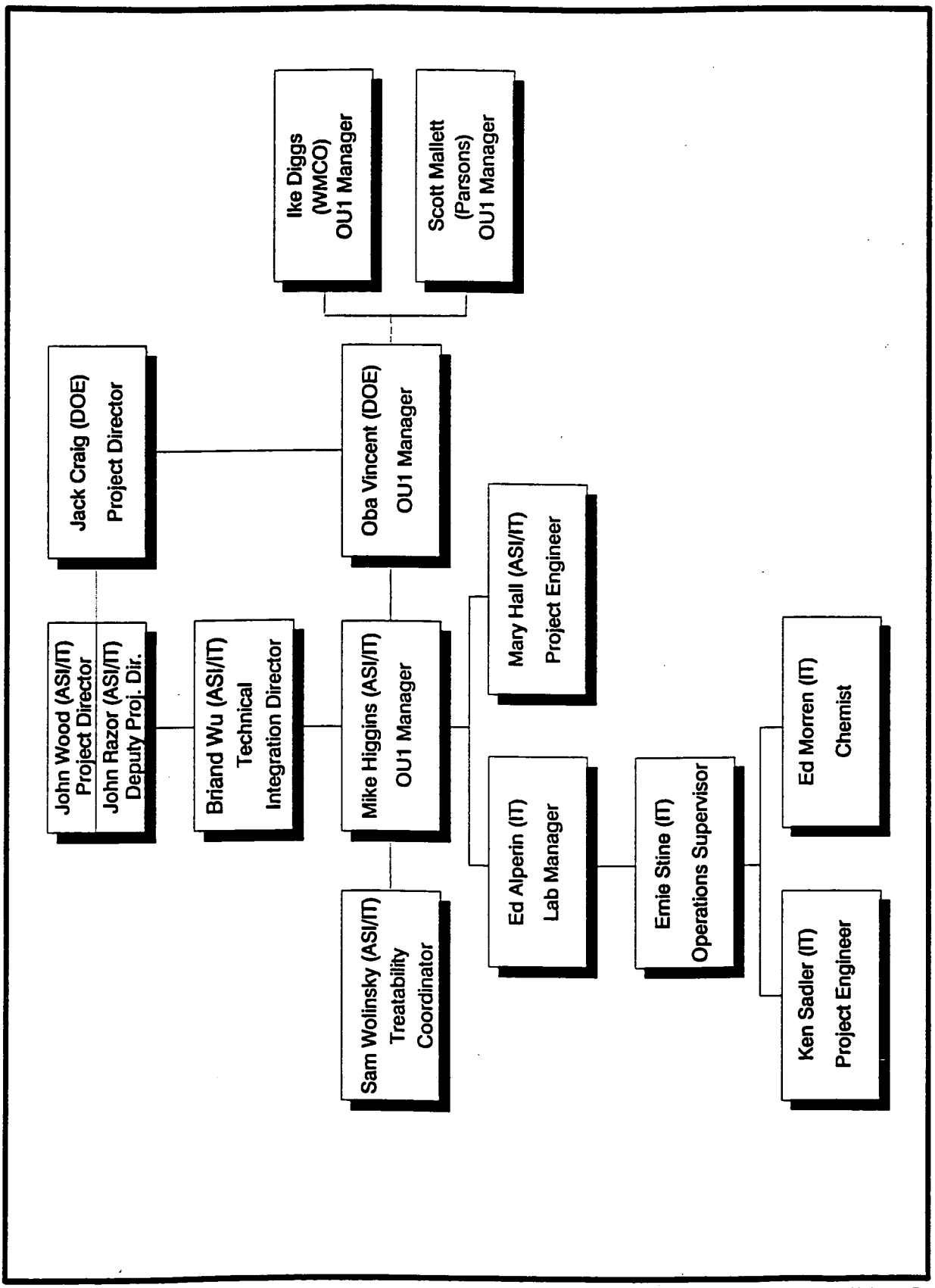

FIGURE 13.1 TREATABILITY STUDY MANAGEMENT AND STAFFING

FL/RI/PC-0405-2/13-1

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APPENDIX A

JUSTIFICATION FOR USING A MINIMUM UCS VALUE OF 500 psi

APPENDIX A

JUSTIFICATION FOR USING A MINIMUM UCS VALUE OF 500 psi

Portland cement mortars, which are comprised of mixtures of cement, lime, silica, sand, and water, are readily capable of achieving compressive strengths of 5000 to 6000 psi; that is approximately two orders of magnitude greater than the minimum compressive strength required to resist deformation under load in current low-level waste burial trenches. Therefore, to provide greater assurance that there will be sufficient cementitious material present in the waste form to not only withstand the burial loads, but also to maintain general "dimensions and form" (i.e., to not disintegrate) over time, it is recommended that cement-stabilized waste forms possess compressive strengths that are representative of the values that are reasonably achievable with current cement solidification processes. Taking into consideration the fact that low-level radioactive waste material constituents are not in most cases capable of providing the physical and chemical functions of silica sand in a cement mortar, a mean compressive strength equal to or greater than 500 psi is recommended for waste form specimens cured for a minimum of 28 days. This value of compressive strength is recommended as a practical strength value that is representative of the quality of cementitious material that should be used in the waste form to provide assurance that it will maintain integrity and thus possess the long-term structural capability required by Part 61.

Source: U.S. Nuclear Regulatory Commission Office of Nuclear Material Safety and Safeguards, prepared by Low-Level Waste Management Branch Division of Low-Level Waste Management and Decommissioning.

APPENDIX B

TECHNOLOGY DEVELOPMENT LABORATORY

STANDARD OPERATING PROCEDURES

International Technology Corporation

IT Analytical Services

Technology Development Laboratory Standard Operating Procedure

Title: Bulking Factor Measurement

Prepared by: Charley Morgan **Date:** 2/7/91

Reviewed by: Ed Olpek **Date:** 2/8/91
Technical Specialist

Patti B. Carswell **Date:** 2/8/91
Quality Control Coordinator

James M. Jones **Date:** 3-26-91
Director, Quality and Compliance, ITAS

Approved by: R L Miller **Date:** 3/27/91
Laboratory Director

Controlled Copy No: Uncontrolled Copy

Key Words:

Revision #	0					
Date	9/16/90					

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IT Corporation is a wholly owned Subsidiary of International Technology Corporation.

1.0 Purpose and Application

1.1 The purpose of this SOP is to determine the volume increase when additives are mixed with homogenized sludge. This procedure proves to be the best test instead of trying to read the volume increase directly from a plastic or glass container because the sludge tends to stick to the sides, therefore giving an erroneous result.

2.0 References

2.1 ITAS-TDL Chemical Hygiene Plan.

3.0 Associated SOPs and Applicable Methods

3.1 None

4.0 Definitions

4.1 Container Volume (A)

The volume of deionized water that the container will hold.

4.2 Volume of Water Plus Sludge (B)

The amount of deionized water it takes to fill container with a known weight of sludge

4.3 Initial Volume (I)

Initial volume of sludge in cm^3.

4.4 Volume of Water with Treated Sludge (C)

Amount of deionized water needed to fill container that contains treated sludge.

4.5 Treated Sludge

Raw sludge that has been mixed with additives.

4.6 Treated Volume (D)

Treated volume amount of sludge.

4.7 Change in Volume (BF)

Difference of initial volume (I) of sludge and treated volume (D) of sludge.

5.0 Procedure

5.1 Summary

5.1.1 A known volume of deionized water is added to a known weight of a sludge sample. A percent volume change is then calculated.

5.2 Interferences

5.2.1 No known interferences.

5.3 Sample Handling, Preservation, and Holding Time

5.3.1 Application of these procedures on hazardous waste samples must consider the known or suspected hazardous compounds present. Project-specific selection of work area, safe working practices, and personal protective equipment shall be made based upon exposure potential to the hazardous components.

5.3.2 All applicable safety and compliance guidelines set forth by IT Corporation and by federal, state, and local regulations must be followed during performance of this procedure. All work must be stopped in the event of a known or potential compromise to the health or safety of any ITAS Associate, and must be reported immediately to a laboratory supervisor.

5.3.3 There are no holding times applicable to this procedure.

5.3.4 There are no preservation requirements applicable to this procedure.

5.4 Required Equipment

5.4.1 Two 5-oz. S/P Dispo® polypropylene container or equivalent.

5.4.2 Graduated cylinder.

5.5 Reagents/Standards

5.5.1 Deionized water.

5.5.2 Additives.

5.0 Procedure (continued)

5.6 Calibration

5.6.1 Determine the container volume (A). For example, a 5-oz. S/P Dispo® polypropylene container which is graduated from 10 to 140 ml is used. Calibrate the 5-oz container by filling the container with deionized water using a graduate cylinder.

5.7 Analysis/Operation

5.7.1 Add a known weight in grams of raw sludge to a 5-oz container. Tap container with raw sludge to release air bubbles. Add deionized water by a graduate into container until full. Designate the volume of deionized water added as the volume of water plus sludge (B).

5.7.2 In another 5-oz container, add same weight as above of raw sludge plus the percent additives and mix well. Tap container to release air pockets. Fill rest of container using a graduate with deionized water. Designate the volume of deionized water added as volume of water with treated sludge (C).

5.8 Calculations

5.8.1 Initial volume (I) of sludge is equal to (A-B) and units are in cm^3.

$$A - B = I$$

where: A = container volume and
B = volume of water plus sludge.

5.8.2 (A-C) equals treated volume (D).

$$A - C = D$$

where: A = container volume,
C = volume of water with treated sludge, and
D = treated volume.

5.8.3 Calculate the difference of initial volume (I) and treated volume (D). Designate this amount as change in Volume (BF).

$$D - I = BF$$

where: I = initial volume,
D =treated volume, and
BF = change in volume.

5.0 Procedure (continued)

5.8.4 To get percent change in volume, take (BF) divided by initial volume (I) and multiply by 100.

$$\% \text{ Change in Volume} = BF/I \times 100$$

where: BF = change in volume and
I = initial volume.

5.9 Quality Control

5.9.1 None

6.0 Nonconformance and Corrective Action

6.1 Any failure to follow this procedure will be noted on a nonconformance memo. The corrective action will be verified by the Quality Control Coordinator and approved by the appropriate Operations Manager.

7.0 Records Management

7.1 All data will be recorded in standard laboratory notebooks.

International Technology Corporation

IT Analytical Services

Technology Development Laboratory Standard Operating Procedure

Title: Laboratory Notebook Recording Procedures

Prepared by: Patti B. Carswell Date: 2/7/91

Reviewed by: Bruce F. Wagner Date: 2/7/91
Technical Specialist

Patti B. Carswell Date: 2/7/91
Quality Control Coordinator

Janet M. Jones Date: 3-26-91
Director, Quality and Compliance, ITAS

Approved by: R. Miller Date: 3/27/91
Laboratory Director

Controlled Copy No: Uncontrolled Copy

Key Words: NOTEBOOK

Revision #	0					
Date	1-21-91					

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IT Corporation is a wholly owned Subsidiary of International Technology Corporation.

1.0 Purpose and Application

1.1 The purpose of this method is to describe the required methods of data entry in Technology Development Laboratory notebooks.

1.2 This procedure applies to laboratory notebooks used for project-specific and non-project-specific documentation.

1.3 The purpose of each entry in your notebook is to provide a complete record of your work, one that would enable a co-worker to repeat, if necessary, exactly what you did and produce the same results, without having to ask any questions.

2.0 References

2.1 Writing the Laboratory Notebook, Howard M. Kanare, 1985.

3.0 Associated SOPs and Applicable Methods

3.1 ITAS SOP No. TDL1503, "Analytical Logbook Recording Procedures."

4.0 Definitions

4.1 None

5.0 Procedure

5.1 Safety

5.1.1 All applicable safety and compliance guidelines set forth by IT Corporation and by federal, state, and local regulations must be followed during performance of this procedure. All work must be stopped in the event of a known or potential compromise to the health or safety of any ITAS Associate, and must be reported immediately to a laboratory supervisor.

5.1.2 All laboratory notebooks must be kept free of chemical contamination while being used on benchtops, in field settings, etc.

5.2 Summary

5.2.1 All laboratory notebooks are the property of the International Technology Corporation (IT) Technology Development Laboratory (TDL). It is assigned to you so that you may keep a complete, careful, chronological record of your work. The work which you do and the data which you enter in the notebook are confidential; they must not be disclosed to unauthorized persons. The notebook's security and maintenance are your responsibility. In case of damage, loss, or disappearance, report the

5.0 Procedure (continued)

facts to your supervisor at once. When the notebook is filled or upon termination of your employment, it must be returned to the laboratory quality/operation files.

5.3 Procedure

5.3.1 All data is to be recorded directly into the notebook. Recording of original data on loose pieces of paper for later transcription into the logbook is to be avoided. Should loose paper be necessary for proper conduct of an experiment:

5.3.1.1 Write on the logbook page itself identification of what is affixed to that page.

5.3.1.2 Firmly affix the loose paper with clear tape

5.3.1.3 Initial and date over the edge of the tape.

5.3.2 All entries must be made in black ink. Red ink is reserved for Quality Control (QC) checking purposes only. Erasures, blacking out, or use of correction fluid is not permitted. If a mistake is made, draw a single line through the erroneous material and make a corrected entry, initial, and date the correction.

5.3.3 It is necessary to fill each page and keep the sequence of entries in chronological order. Several pages may be reserved for a particular experiment. However, if the continuity of pages for a particular experiment is broken for lack of reserved space, notations will be made on both sides of the break. The unused balance of a page will be cancelled by a diagonal line. Spaces intentionally left blank in tables or logs will contain horizontal lines.

5.3.4 Stock or standard solutions must reference:

5.3.4.1 Source
5.3.4.2 Lot number
5.3.4.3 Date received
5.3.4.4 Notebook and page numbers whenever available.

5.3.5 When reference is made to samples, the TDL sample number must be used. Additional sample identification may be offered, but not to the exclusion of the TDL sample number.

5.3.6 A co-worker performs a QC check on your calculations by recalculating 20 percent and verifying the formula used. Have him make a check in red ink beside each answer which was recalculated and sign and date

5.0 Procedure (continued)

calculations that lead to the generation of a result which is reported to the client either verbally or in writing. Any values which have not had a 20 percent QC check (one of every five calculations has been checked) are considered "preliminary" and will be marked as such on any material leaving the TDL lab. If an error is found during the 20 percent check, then a 100 percent QC check will be performed.

5.3.7 If one of your co-workers has witnessed an experiment you have conducted, to an extent that enables him to state of his own knowledge what you did and what results you secured, have him sign and date the notebook page(s) as "Witnessed and understood by." If the experiment seems to you to be of sufficient importance (i.e., is potentially patentable), arrange to have it witnessed for content and date of entry.

5.4 Project Documentation Requirements

5.4.1 Every page of the notebook will contain project name, project number, date, and initials of persons entering data. Each project will then be described by the following entries:

5.4.1.1 Objective - briefly describe the planned experiment and the expected or desired result.

5.4.1.2 Plan - give an overview of what you intend to do.

5.4.1.3 Calibrations and Standards - list frequency of calibration, acceptance limits, and concentrations.

5.4.1.4 Analytical Methods - state SOP, standard reference or give a brief description.

5.4.1.5 Experimental Set-ups - sketch and describe the set-up.

5.4.1.6 Data and Observations - provide tables including units and space for observations within or below.

5.4.1.7 Results - include formula and calculations which are necessary to produce results from raw data.

5.4.1.8 Conclusion - how objective was met and any interpretation of results.

6.0 Nonconformance and Corrective Action

6.1 A nonconformance is a deficiency in procedure sufficient to render the quality of an item unacceptable or indeterminate or any event which is beyond the limits documented and established for laboratory operation. A nonconformance may include data recording errors, transcription errors, and failure to document. A nonconformance memo associated with this procedure will be filed with the QC Coordinator.

7.0 Records Management

7.1 TDL Notebooks are the property of IT Corporation.

7.2 Document control of TDL Notebooks is handled by the QC Coordinator (QCC). The QCC will issue all notebooks. All completed notebooks will be returned to the QCC.

7.3 All returned Laboratory Notebooks are filed in TDL Central Files.

International Technology Corporation

No: TDL1503
Page: 1 of 4

IT Analytical Services

Technology Development Laboratory Standard Operating Procedure

Title: Analytical Logbook Recording Procedures

Prepared by: Patti B. Carswell Date: 2/7/91

Reviewed by: Bruce F. Wagner Date: 2/7/91
Technical Specialist

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Approved by: R S Miller Date: 6/7/91
Laboratory Director

Controlled Copy No: Uncontrolled Copy

Key Words: Logbook, Notebook

Revision #	0					
Date	[illegible]					

Technology Development Laboratory
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IT Corporation is a wholly owned Subsidiary of International Technology Corporation

1.0 Purpose and Application

1.1 The purpose of this method is to describe the required methods of data entry in Technology Development Analytical Logbooks.

1.2 This procedure applies to analytical logbooks such as instrument injection logbooks, maintenance logbooks, and balance logs.

2.0 References

2.1 Writing the Laboratory Notebook, Howard M. Kanare, 1985.

3.0 Associated SOPs and Applicable Methods

3.1 ITAS SOP No. TDL1504, "Laboratory Notebook Recording Procedures."

4.0 Definitions

4.1 None

5.0 Procedure

5.1 Safety

5.1.1 All applicable safety and compliance guidelines set forth by IT Corporation and by federal, state, and local regulations must be followed during performance of this procedure. All work must be stopped in the event of a known or potential compromise to the health or safety of any ITAS Associate, and must be reported immediately to a laboratory supervisor.

5.1.2 All analytical logbooks must be kept free of chemical contamination while being used on benchtops, in field settings, etc.

5.2 Summary

5.2.1 All logbooks are the property of the International Technology Corporation (IT) Technology Development Laboratory (TDL). It is assigned to you so that you may keep a complete, careful, chronological record of your work. The work which you do and the data which you enter in this book are confidential; they must not be disclosed to unauthorized persons. The logbook's security and maintenance are your responsibility. In case of damage, loss, or

5.0 Procedure (continued)

disappearance, report the facts to your supervisor at once. When the logbook is filled, or upon termination of your employment, it must be returned to the laboratory quality/operation files.

5.3 Procedure

5.3.1 Briefly define in the front pages of the book what type of log is contained within. Definitions of column headings, references, and acceptance limits will be addressed on the first pages as well.

5.3.2 All entries are to be recorded directly into the logbook. Recording of original data on loose pieces of paper for later transcription into the logbook is to be avoided. Should loose paper be necessary for proper conduct of an experiment:

5.3.2.1 Write on the logbook page itself identification of what is affixed to that page

5.3.2.2 Firmly affix the loose paper with clear tape

5.3.2.3 Initial and date over the edge of the tape.

5.3.3 All entries must be made in black ink. Red ink is reserved for Quality Control (QC) checking purposes only. Erasures, blacking out, or use of correction fluid is not permitted. If a mistake is made, draw a single line through the erroneous material and make a corrected entry, initial, and date the correction.

5.3.4 It is necessary to fill each page and keep the sequence of entries in chronological order. Any unused section of a page will be cancelled with a diagonal line. Spaces intentionally left blank in tables or logs will contain horizontal lines.

5.3.5 When reference is made to samples, the TDL sample number will be used. Additional sample identification may be offered, but not to the exclusion of the TDL sample number.

5.3.6 Use a ruler to draw lines defining columns. Label columns including units when appropriate. Injection logs, balance logs, and other similar logs will include columns for the operators' initials and date.

5.3.7 Each entry in an analytical logbook is to be initialed and dated. The "Completed by" is signed by the last person to make entry on a given page and indicates that the page has been checked for completeness of entries.

6.0 Nonconformance and Corrective Action

6.1 A nonconformance is a deficiency in procedure sufficient to render the quality of an item unacceptable or indeterminate or any event which is beyond the limits documented and established for laboratory operation. A nonconformance may include data recording errors, transcription errors, and failure to document. A nonconformance memo associated with this procedure will be filed with the QC Coordinator.

7.0 Records Management

7.1 TDL Analytical Logbooks are the property of IT Corporation.

7.2 Document control of TDL Logbooks is handled by the QC Coordinator (QCC). The QCC will issue all notebooks. All completed logbooks will be returned to the QCC.

7.3 All returned Laboratory Logbooks are filed in TDL Central Files.

INTERNATIONAL TECHNOLOGY CORPORATION

IT Analytical Services

Technology Development Laboratory Standard Operating Procedure

Title: STANDARD LABORATORY SIEVES : SPECIFICATION, CALIBRATION, AND MAINTENANCE

Prepared by: Coy A. Lauer Date: March 5, 1991

Reviewed by: Tom Leist Date: 3/6/91
Technical Specialist

Patti B. Carswell Date: 3/13/91
Quality Control Coordinator

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Approved by: John M. Hall Date: 7/5/91
Laboratory Director

Controlled Copy No: Uncontrolled Copy

Key Words: Sieve, ASTM E 11-87, Geotechnical

Revision #	0					
Date	03/05/91					98

LABORATORY SIEVES
SPECIFICATION, CALIBRATION, AND MAINTENANCE

1.0 Purpose and Application

1.1 This SOP defines the standards for standard laboratory sieves used in the Geotechnical Analysis Laboratory. It also describes calibration requirements and maintenance of the sieves.

2.0 References

2.1 ASTM E 11-87, Standard Specification For Wire Cloth Sieves For Testing Purposes.

3.0 Associated SOPs

3.1 None.

4.0 Definitions

4.1 None.

5.0 Procedure

5.1 All standard sieves will meet the specifications in ASTM E 11-87, Standard Specifications for Wire Cloth Sieves For Testing Purposes. Upon receipt, each sieve will be checked for a label which has the ASTM specification, sieve size, and a identification number or serial number. If the ASTM specification is not on the sieve, that sieve will be returned to the vendor and not used. If the sieve size or a serial number is not on the label, prepare a permanent label with the appropriate information and affix it to the side of the sieve. Due to the corrosive nature of some samples, brass sieves with stainless steel mesh are preferred.

5.2 Sieves put into use prior to this SOP do not require a serial number.

5.3 Calibration certificates should be provided by the manufacturer. If a calibration certificate did not come with the sieve, either return it, or get a certificate from the vendor. Calibration certificates will be kept in the Quality/Operations files maintained

by the lab QC Coordinator.

5.4 If a sieve calibration is suspect, it shall be either checked or replaced. Due to the amount of time involved in checking sieve calibration, replacement is usually the preferred alternative. AASHTO proficiency samples may also be used as an indication of sieve calibration. If the results from a proficiency sample are too far out of line (as determined by the lab supervisor), the suspect sieve shall be pulled for calibration or replacement.

5.5 Sieves with a mesh size of #200 or smaller will be replaced one year after initially being placed into service. Each sieve will be labeled with the replacement date at the time it is placed into service.

5.6 Prior to use, each sieve will be visually inspected for holes, broken mesh, or any other condition which may make the sieve unsuitable for use. Sieves which are clogged will be cleaned with a suitable brush. Caution shall be used when cleaning fine sieves with a wire bristle brush as this may damage the sieve. Any sieve deemed unsuitable for use will be immediately discarded.

5.7 Sieves used in washing samples or sieves used with corrosive samples will be cleaned with water and a brush after use. It may be useful to place the sieve in a drying oven (<120 °C) to dry. This will help to keep corrosion to a minimum.

5.8 Sieves will be stored in a clean, dry environment.

6.0 <u>Nonconformance and Corrective Action</u>

6.1 Sieves which do not meet the required specifications, are damaged, or otherwise unsuitable for use will be discarded or returned to the vendor if newly purchased. If a sieve is discovered nonuseable during use, the sample(s) will be retested and a nonconformance memo generated to describe the problem with the sieve and the fact that the sample(s) are being retested.

7.0 Records Management/Documentation

7.1 Sieve calibration records will be kept in the Quality/Operations files by the QA coordinator.

IT Analytical Services

Technology Development Laboratory Standard Operating Procedure

Title: CALIBRATION OF THERMOMETERS

Prepared by: David McNeil **Date:** 5/17/91

Reviewed by: Walter W. [illegible]
Technical Specialist **Date:** 5/29/91

Patti B. Carswell
Quality Control Coordinator **Date:** 5/29/91

Janet M. Jones
Director, Quality and Compliance, ITAS **Date:** 6-24-91

Approved by: James H. Cell
Laboratory Director **Date:** 6-22-91

Controlled Copy No: Uncontrolled Copy

Key Words: CALIBRATION, THERMOMETER, NBS

Revision #	1					
Date	02/27/91					102

1.0 Purpose and Application

1.1 The purpose of this SOP is to detail proper procedures for the calibration of all laboratory thermometers, such that temperature measurements are accurate and traceable.

1.2 This procedure applies to any thermometer used in the laboratory directly or indirectly in the preparation, storage or analysis of samples.

1.3 Working thermometers in the laboratory shall be calibrated annually against reference thermometers that have initial NBS traceability and that are recertified every three years with equipment directly traceable to the NBS.

2.0 References

2.1 ITAS-SW SOP No. MW104R0, "Calibration of Thermometers."

3.0 Associated SOPs and Applicable Methods

3.1 ITAS System Procedure No. 9014-HSC-01, "General Health and Safety Practices for Tasks Performed in the Laboratory."

4.0 Definitions

4.1 None.

5.0 Procedure

5.1 Copies of the NBS traceable certification of reference thermometers will be kept in the Quality/Operations files.

5.2 Every three years reference thermometers will be recertified with equipment directly traceable to the NBS. A record of the date of this certification will be kept in the Equipment Maintenance and Calibration files by the QCC.

5.3 Each working thermometer in use in the laboratory will be assigned a unique number and will be calibrated annually against a reference thermometer using the calibration methods listed below as appropriate for the specific use of the thermometer:

5.0 Procedure (continued)

5.3.1 Calibration Method 1:

5.3.1.1 Working thermometer and reference thermometers are allowed to remain together in the same room for at least 24 hours. The bulbs are then put together on desk top for at least 30 minutes and read.

5.3.2 Calibration Method 2:

5.3.2.1 A one-liter beaker is filled with regular refrigerator ice cubes prepared with deionized water. The remainder of space in beaker is filled with deionized water. The working thermometer and reference thermometer are immersed with bottom of bulbs at same level. Wait at least 30 minutes and read.

5.3.3 Calibration Method 3:

5.3.3.1 Fill a one liter glass beaker with deionized water and bring to a boil on a hot plate. The working and reference thermometer are immersed with bottom of bulbs at same level. At least the whole bulb on each thermometer must be completely immersed. Wait 5 minutes and read.

5.3.4 Calibration Method 4:

5.3.4.1 Working thermometers and a reference thermometer are allowed to remain together in a freezer for at least one hour. After one hour, read the thermometers.

5.4 A Thermometer Calibration form (Figure TDL102-1) shall be completed for each working thermometer calibrated and placed in the Quality/Operation files.

5.5 Any thermometer that does not meet the acceptance criteria (± 1°C) shall be tagged to prevent inadvertent use. New thermometers that do not meet the acceptance criteria will be sent back to the vendor. Old thermometers that do not meet the acceptance criteria will be removed from the lab.

5.6 All applicable safety and compliance guidelines set forth by IT Corporation and by federal, state, and local regulations must be followed during performance of this procedure. All work must be stopped in the event of a known or potential compromise to the health or safety of any ITAS Associate, and must be reported immediately to a laboratory supervisor.

6.0 Nonconformance and Corrective Action

6.1 Any thermometer that does not meet the acceptance criteria (± 1°C) shall be tagged to prevent inadvertent use. New thermometers that do not meet the acceptance criteria will be sent back to the vendor. Old thermometers that do not meet the acceptance criteria will be removed from the lab.

7.0 Records Management

7.1 A Thermometer Calibration form (Figure TDL102-1) shall be completed for each working thermometer calibrated and placed in the Quality/Operation files.

FIGURE TDL102-1

ITAS TECHNOLOGY DEVELOPMENT LABORATORY

THERMOMETER CALIBRATION

Date: _____

Number of thermometer being calibrated: _____

Description of thermometer being calibrated: _____

_____

Date last calibrated: _____

Time since last calibration _____

Description of reference thermometer: _____

_____

_____

Calibration Method Number	Temperature Reading	
	Reference Thermometer	Thermometer Being Calibrated

Working range: _____

Acceptance criteria: _____ ± _____ °C

Signed: _____

STANDARD OPERATING PROCEDURE

ITAS-TECHNOLOGY DEVELOPMENT LABORATORY

TITLE:	SOP NO: TDL1109
UNCONFINED COMPRESSIVE STRENGTH	DATE INITIATED: 7/31/89 REVISION NO: 1 DATE REVISED: 3/28/90 PAGE 1 OF 18

PREPARED BY	APPROVED BY	DATE	QA CONCURRENCE	DATE
[illegible]	[illegible]	3/28/90	[illegible]	9-4-90

1.0 Purpose and Application

1.1 This test method covers the determination of the unconfined compressive strength of cohesive soil in the undisturbed, remolded, or compacted condition using strain-controlled application of the axial load.

1.2 This test method provides an approximate value of the strength of cohesive soils in terms of total stresses.

1.3 This test method is applicable only to cohesive materials which will not expel bleed water during the loading portion of the test and which will retain intrinsic strength after removal of confining pressures, such as clays or cemented soils.

2.0 References

2.1 Annual Book of ASTM Standards. 1988. "Soil and Rock; Building Stones; Geotextiles. Vol. 4.08.

3.0 Associated SOPs and Applicable Methods

3.1 ASTM D-422.

3.2 ASTM D-854.

3.3 ASTM D-2216.

3.4 ASTM D-2850.

3.0 Associated SOPs and Applicable Methods (continued)

3.5 ASTM D-4220.

3.6 ASTM D-4318.

4.0 Definitions

4.1 Unconfined compressive strength - the compressive stress at which an unconfined cylindrical specimen of soil will fail in a simple compression test.

4.2 Shear strength - for unconfined compressive strength test specimens, the shear strength is calculated to be one-half of the compressive stress at failure.

4.3 Bleed water - water expelled from the soil due to deformation or compaction.

5.0 Procedure

5.1 ASTM Standard Method D-2166.

6.0 Nonconformance and Corrective Action

6.1 If this procedure cannot be followed for any reason, a nonconformance memo will be filed with the Quality Control Coordinator. Corrective action will be approved by the Operations or Project Manager.

7.0 Records Management

7.1 Data is to be recorded in a standard laboratory notebook with the project it pertains to clearly labeled on the notebook page.

Designation: D 2166 – 85

Standard Test Method for Unconfined Compressive Strength of Cohesive Soil[1]

This standard is issued under the fixed designation D 2166; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This test method covers the determination of the unconfined compressive strength of cohesive soil in the undisturbed, remolded, or compacted condition, using strain-controlled application of the axial load.

1.2 This test method provides an approximate value of the strength of cohesive soils in terms of total stresses.

1.3 This test method is applicable only to cohesive materials which will not expel bleed water (water expelled from the soil due to deformation or compaction) during the loading portion of the test and which will retain intrinsic strength after removal of confining pressures, such as clays or cemented soils. Dry and crumbly soils, fissured or varved materials, silts, peats, and sands cannot be tested with this method to obtain valid unconfined compression strength values.

NOTE 1—The determination of the unconsolidated, undrained strength of cohesive soils with lateral confinement is covered by Test Method D 2850.

1.4 This test method is not a substitute for Test Method D 2850.

1.5 The values stated in SI units are to be regarded as the standard. The values stated in inch-pound units are approximate.

1.6 *This standard may involve hazardous materials, operations, and equipment. This standard does not purport to address all of the safety problems associated with its use. It is the responsibility of whoever uses this standard to consult and establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*

D 422 Method for Particle-Size Analysis of Soils[2]
D 653 Terminology Relating to Soil, Rock, and Contained Fluids[2]
D 854 Test Method for Specific Gravity of Soils[2]
D 1587 Practice for Thin-Walled Tube Sampling of Soils[2]
D 2216 Method for Laboratory Determination of Water (Moisture) Content of Soil, Rock, and Soil-Aggregate Mixtures[2]
D 2487 Test Method for Classification of Soils for Engineering Purposes[2]
D 2488 Practice for Description and Identification of Soils (Visual-Manual Procedure)[2]
D 2850 Test Method for Unconsolidated, Undrained Compressive Strength of Cohesive Soils in Triaxial Compression[2]
D 4220 Practices for Preserving and Transporting Soil Samples[2]
D 4318 Test Method for Liquid Limit, Plastic Limit, and Plasticity Index of Soils[2]

3. Terminology

3.1 Refer to Terminology D 653 for standard definitions of terms.

3.2 *Descriptions of Terms Specific to this Standard:*

3.2.1 *unconfined compressive strength (q_u)*—the compressive stress at which an unconfined cylindrical specimen of soil will fail in a simple compression test. In this test method, unconfined compressive strength is taken as the maximum load attained per unit area or the load per unit area at 15 % axial strain, whichever is secured first during the performance of a test.

3.2.2 *shear strength (s_u)*—for unconfined compressive strength test specimens, the shear strength is calculated to be ½ of the compressive stress at failure, as defined in 3.2.1.

4. Significance and Use

4.1 The primary purpose of the unconfined compression test is to quickly obtain the approximate compressive strength of soils that possess sufficient cohesion to permit testing in the unconfined state.

4.2 Samples of soils having slickensided or fissured structure, samples of some types of loess, very soft clays, dry and crumbly soils and varved materials, or samples containing significant portions of silt or sand, or both (all of which usually exhibit cohesive properties), frequently display higher shear strengths when tested in accordance with Test Method D 2850. Also, unsaturated soils will usually exhibit different shear strengths when tested in accordance with Test Method D 2850.

4.3 If both an undisturbed and a remolded test are performed on the same sample, the sensitivity of the material can be determined. This method of determining sensitivity is suitable only for soils that can retain a stable specimen shape in the remolded state.

NOTE 2—For soils that will not retain a stable shape, a vane shear test or Test Method D 2850 can be used to determine sensitivity.

5. Apparatus

5.1 *Compression Device*—The compression device may be a platform weighing scale equipped with a screw-jack-activated load yoke, a hydraulic loading device, or any other

[1] This test method is under the jurisdiction of ASTM Committee D-18 on Soil and Rock and is the direct responsibility of Subcommittee D18.05 on Structural Properties of Soils.

Current edition approved July 26, 1985. Published September 1985. Originally published as D 2166 – 63T. Last previous edition D 2166 – 66 (1979)[ε1].

[2] *Annual Book of ASTM Standards*, Vol 04.08.

compression device with sufficient capacity and control to provide the rate of loading prescribed in 7.1. For soil with an unconfined compressive strength of less than 100 kPa (1.0 ton/ft^2) the compression device shall be capable of measuring the compressive stress to within 1 kPa (0.01 ton/ft^2). For soil with an unconfined compressive strength of 100 kPa (1.0 ton/ft^2) or greater, the compression device shall be capable of measuring the compressive stress to the nearest 5 kPa (0.05 ton/ft^2).

5.2 *Sample Extruder*, capable of extruding the soil core from the sampling tube in the same direction of travel in which the sample entered the tube, at a uniform rate, and with negligible disturbance of the sample. Conditions at the time of sample removal may dictate the direction of removal, but the principal concern is to keep the degree of disturbance negligible.

5.3 *Deformation Indicator*—The deformation indicator shall be a dial indicator graduated to 0.03 mm (0.001 in.) or better and having a travel range of at least 20 % of the length of the test specimen, or some other measuring device, such as an electronic deformation measuring device, meeting these requirements.

5.4 *Dial Comparator*, or other suitable device, for measuring the physical dimensions of the specimen to within 0.1 % of the measured dimension.

NOTE 3—Vernier calipers are not recommended for soft specimens, which will deform as the calipers are set on the specimen.

5.5 *Timer*—A timing device indicating the elapsed testing time to the nearest second shall be used for establishing the rate of strain application prescribed in 7.1.

5.6 *Balance*—The balance used to weigh specimens shall determine the mass of the specimen to within 0.1 % of its total mass.

5.7 *Equipment*, as specified in Method D 2216.

5.8 *Miscellaneous Apparatus*, including specimen trimming and carving tools, remolding apparatus, water content cans, and data sheets, as required.

6. Preparation of Test Specimens

6.1 *Specimen Size*—Specimens shall have a minimum diameter of 30 mm (1.3 in.) and the largest particle contained within the test specimen shall be smaller than one tenth of the specimen diameter. For specimens having a diameter of 72 mm (2.8 in.) or larger, the largest particle size shall be smaller than one sixth of the specimen diameter. If, after completion of a test on an undisturbed specimen, it is found, based on visual observation, that larger particles than permitted are present, indicate this information in the remarks section of the report of test data (Note 4). The height-to-diameter ratio shall be between 2 and 2.5. Determine the average height and diameter of the test specimen using the apparatus specified in 5.4. Take a minimum of three height measurements (120° apart), and at least three diameter measurements at the quarter points of the height.

NOTE 4—If large soil particles are found in the sample after testing, a particle-size analysis performed in accordance with Method D 422 may be performed to confirm the visual observation and the results provided with the test report.

6.2 *Undisturbed Specimens*—Prepare undisturbed specimens from large undisturbed samples or from samples secured in accordance with Practice D 1587 and preserved and transported in accordance with the practices for Group C samples in Practices D 4220. Tube specimens may be tested without trimming except for the squaring of ends, if conditions of the sample justify this procedure. Handle specimens carefully to prevent disturbance, changes in cross section, or loss of water content. If compression or any type of noticeable disturbance would be caused by the extrusion device, split the sample tube lengthwise or cut it off in small sections to facilitate removal of the specimen without disturbance. Prepare carved specimens without disturbance, and whenever possible, in a humidity-controlled room. Make every effort to prevent any change in water content of the soil. Specimens shall be of uniform circular cross section with ends perpendicular to the longitudinal axis of the specimen. When carving or trimming, remove any small pebbles or shells encountered. Carefully fill voids on the surface of the specimen with remolded soil obtained from the trimmings. When pebbles or crumbling result in excessive irregularity at the ends, cap the specimen with a minimum thickness of plaster of paris, hydrostone, or similar material. When sample condition permits, a vertical lathe that will accommodate the total sample may be used as an aid in carving the specimen to the required diameter. Where prevention of the development of appreciable capillary forces is deemed important, seal the specimen with a rubber membrane, thin plastic coatings, or with a coating of grease or sprayed plastic immediately after preparation and during the entire testing cycle. Determine the mass and dimensions of the test specimen. If the specimen is to be capped, its mass and dimensions should be determined before capping. If the entire test specimen is not to be used for determination of water content, secure a representative sample of cuttings for this purpose, placing them immediately in a covered container. The water content determination shall be performed in accordance with Method D 2216.

6.3 *Remolded Specimens*—Specimens may be prepared either from a failed undisturbed specimen or from a disturbed sample, providing it is representative of the failed undisturbed specimen. In the case of failed undisturbed specimens, wrap the material in a thin rubber membrane and work the material thoroughly with the fingers to assure complete remolding. Avoid entrapping air in the specimen. Exercise care to obtain a uniform density, to remold to the same void ratio as the undisturbed specimen, and to preserve the natural water content of the soil. Form the disturbed material into a mold of circular cross section having dimensions meeting the requirements of 6.1. After removal from the mold, determine the mass and dimensions of the test specimens.

6.4 *Compacted Specimens*—Specimens shall be prepared to the predetermined water content and density prescribed by the individual assigning the test (Note 5). After a specimen is formed, trim the ends perpendicular to the longitudinal axis, remove from the mold, and determine the mass and dimensions of the test specimen.

NOTE 5—Experience indicates that it is difficult to compact, handle, and obtain valid results with specimens that have a degree of saturation that is greater than 90 %.

7. Procedure

7.1 Place the specimen in the loading device so that it is centered on the bottom platen. Adjust the loading device carefully so that the upper platen just makes contact with the specimen. Zero the deformation indicator. Apply the load so as to produce an axial strain at a rate of ½ to 2 %/min. Record load, deformation, and time values at sufficient intervals to define the shape of the stress-strain curve (usually 10 to 15 points are sufficient). The rate of strain should be chosen so that the time to failure does not exceed about 15 min (Note 6). Continue loading until the load values decrease with increasing strain, or until 15 % strain is reached. The rate of strain used for testing sealed specimens may be decreased if deemed desirable for better test results. Indicate the rate of strain in the report of the test data, as required in 9.1.7. Determine the water content of the test specimen using the entire specimen, unless representative cuttings are obtained for this purpose, as in the case of undisturbed specimens. Indicate on the test report whether the water content sample was obtained before or after the shear test, as required in 9.1.2.

NOTE 6—Softer materials that will exhibit larger deformation at failure should be tested at a higher rate of strain. Conversely, stiff or brittle materials that will exhibit small deformations at failure should be tested at a lower rate of strain.

7.2 Make a sketch, or take a photo, of the test specimen at failure showing the slope angle of the failure surface if the angle is measurable.

7.3 A copy of a sample data sheet is included in Appendix X1. Any data sheet can be used, provided the form contains all the required data.

8. Calculations

8.1 Calculate the axial strain, ϵ_1, to the nearest 0.1 %, for a given applied load, as follows:

$$\epsilon_1 = \Delta L / L_0$$

where:

ΔL = length change of specimen as read from deformation indicator, mm (in.), and

L_0 = initial length of test specimen, mm (in.).

8.2 Calculate the average cross-sectional area, A, for a given applied load, as follows:

$$A = A_0/(1 - \epsilon_1)$$

where:

A_0 = initial average cross-sectional area of the specimen, mm² (in.²), and

ϵ_1 = axial strain for the given load, %.

8.3 Calculate the compressive stress, σ_c, to three significant figures, or nearest 1 kPa (0.01 ton/ft²), for a given applied load, as follows:

$$\sigma_c = (P/A)$$

where:

P = given applied load, kPa (ton/ft²),

A = corresponding average cross-sectional area mm² (in.²).

8.4 *Graph*—If desired, a graph showing the relationship between compressive stress (ordinate) and axial strain (abscissa) may be plotted. Select the maximum value of compressive stress, or the compressive stress at 15 % axial strain, whichever is secured first, and report as the unconfined compressive strength, q_u. Whenever it is considered necessary for proper interpretation, include the graph of the stress-strain data as part of the data reported.

8.5 If the unconfined compressive strength is determined, the sensitivity, S_T, is calculated as follows:

$$S_T = \frac{q_u \text{ (undisturbed specimen)}}{q_u \text{ (remolded specimen)}}$$

9. Report

9.1 The report should include the following:

9.1.1 Identification and visual description of the specimen, including soil classification, symbol, and whether the specimen is undisturbed, remolded, compacted, etc. Also include specimen identifying information, such as project, location, boring number, sample number, depth, etc. Visual descriptions shall be made in accordance with Practice D 2488,

9.1.2 Initial dry density and water content (specify if the water content specimen was obtained before or after shear, and whether from cuttings or the entire specimen),

9.1.3 Degree of saturation (Note 7), if computed,

NOTE 7—The specific gravity determined in accordance with Test Method D 854 is required for calculation of the degree of saturation.

9.1.4 Unconfined compressive strength and shear strength,

9.1.5 Average height and diameter of specimen,

9.1.6 Height-to-diameter ratio,

9.1.7 Average rate of strain to failure, %,

9.1.8 Strain at failure, %,

9.1.9 Liquid and plastic limits, if determined, in accordance with Test Method D 4318,

9.1.10 Failure sketch or photo,

9.1.11 Stress-strain graph, if prepared,

9.1.12 Sensitivity, if determined,

9.1.13 Particle size analysis, if determined, in accordance with Method D 422, and

9.1.14 *Remarks*—Note any unusual conditions or other data that would be considered necessary to properly interpret the results obtained, for example, slickensides, stratification, shells, pebbles, roots, or brittleness, the type of failure (that is, bulge, diagonal shear, etc.).

10. Precision and Bias

10.1 No method presently exists to evaluate the precision of a group of unconfined compression tests on undisturbed specimens due to specimen variability. Undisturbed soil specimens from apparently homogeneous soil deposits at the same location often exhibit significantly different strength and stress-strain properties.

10.2 A suitable test material and method of specimen preparation have not been developed for the determination of laboratory variances due to the difficulty in producing identical cohesive soil specimens. No estimates of precision for this test method are available.

APPENDIX

(Nonmandatory Information)

X1. Example Data Sheet

UNCONFINED COMPRESSION TEST—UI

Name _____ Date _____ Job No. _____

Location _____

Boring No. _____ Sample No. _____ Depth/Elev. _____

Description of Sample _____

Proving Ring No. _____ Apparatus No. _____

Water Content Determination

Tare No. _____

Wt. Specimen Wet + Tare

Wt. Specimen Dry + Tare

Wt. Water _____

Wt. Tare _____

Wt. Specimen Wet _____

Wt. Specimen Dry _____

Water Content in % Dry Wt.

at 105°C _____ %

Wet Density _____

Dry Density _____

Unconfined Compressive Strength

Initial Diameter D_o _____

Initial Area A_o _____

Initial Height L_o _____

Initial Volume V_o _____

Specific Gravity _____

$$\text{Stress} = \frac{\text{Load}}{\text{Corr. Area}}$$

Test Data

Unit Strain $\frac{\Delta L}{L_o}$

$\frac{L}{D}$ = _____

$$\text{Corr. Area} = \frac{A_o}{1 - \text{Unit Strain}}$$

Elapsed Time-min	Load Dial	Axial Load	Strain Dial	Total Strain	Unit Strain	Corrected Area	Stress	

Type of Sample _____

Attach a photo or sketch of the specimen after failure to this form

Strain Rate _____ %/Min

Remarks _____

The American Society for Testing and Materials takes no position respecting the validity of any patent rights asserted in connection with any item mentioned in this standard. Users of this standard are expressly advised that determination of the validity of any such patent rights, and the risk of infringement of such rights, are entirely their own responsibility.

This standard is subject to revision at any time by the responsible technical committee and must be reviewed every five years and if not revised, either reapproved or withdrawn. Your comments are invited either for revision of this standard or for additional standards and should be addressed to ASTM Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee, which you may attend. If you feel that your comments have not received a fair hearing you should make your views known to the ASTM Committee on Standards, 1916 Race St., Philadelphia, PA 19103.

APPENDIX XI:

UNCONFINED COMPRESSION TEST

1. INTRODUCTION. The unconfined compression test is used to measure the unconfined compressive strength of a cohesive soil. The unconfined compression test is applicable only to coherent materials such as saturated clays or cemented soils that retain intrinsic strength after removal of confining pressure; it is not a substitute for the Q test. Dry or crumbly soils, fissured or varved materials, silts, and sands cannot be tested meaningfully in unconfined compression. In this test, a laterally unsupported cylindrical specimen is subjected to a gradually increased axial compression load until failure occurs. The unconfined compression test is a form of triaxial test in which the major principal stress is equal to the applied axial stress, and the intermediate and minor principal stresses are equal to zero. The unconfined compressive strength, q_u, is defined as the maximum unit axial compressive stress at failure or at 15 percent strain, whichever occurs first. The undrained shear strength, s_u, is assumed to be equal to one-half the unconfined compressive strength. The axial load may be applied to the specimen either by the controlled strain procedure, in which the stress is applied to produce a predetermined rate of strain, or by the controlled stress procedure, in which the stress is applied in predetermined increments of load.

2. APPARATUS. The apparatus consists of the following:

a. Equipment for Preparing Specimen. A trimming frame as described in paragraph 3e of Appendix X, TRIAXIAL COMPRESSION TESTS, or a trimming cylinder with beveled cutting edges may be used for trimming specimens. The equipment should include wire saws and knives of various sizes and types for use with the trimming frame. A motorized soil lathe may be used advantageously under certain circumstances. A miter box or cradle is required to trim the specimen to a fixed length and to ensure that the ends of the specimen are parallel with each other and perpendicular to the vertical axis of the specimen.

b. Loading Device. A number of commercially available controlled-strain or controlled-stress types of loading devices are suitable for applying the axial loads in the unconfined compression test. In

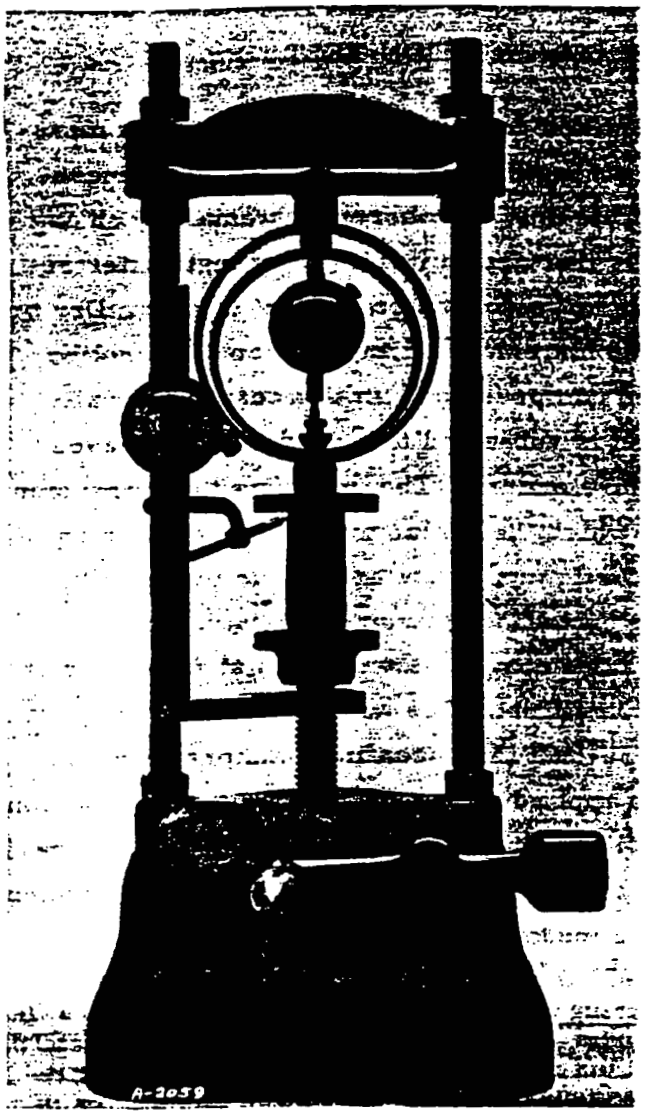


Figure 1. Typical unconfined compression test apparatus

general, controlled-strain type loading devices are preferable, and the procedures described herein are based on the use of this type of equipment. If available, an automatic stress-strain recorder may be used to measure and record applied axial loads and displacements. A typical loading device is shown in Figure 1. Any equipment used should be calibrated so that the loads actually applied to the soil specimen can be determined. The required sensitivity of stress-measuring equipment for both controlled-stress and controlled-strain testing will vary with the strength characteristics of the soil. For relatively weak soils (compressive strengths less than 1.0 ton per sq ft), the unit load should be measurable to within 0.01 ton per sq ft. For soils with compressive strengths of 1.0 ton per sq ft or greater, the loads should be measurable to the nearest 0.05 ton per sq ft.

c. Measuring equipment, such as dial indicators and calipers, suitable for measuring the dimensions and axial deformation of a specimen

to the nearest 0.001 in.

d. Timing device, either a watch or clock with second hand.

e. Balances, sensitive to 0.1 g.

f. Other. Apparatus necessary to determine water content and specific gravity (see Appendixes I, WATER CONTENT - GENERAL, and IV, SPECIFIC GRAVITY).

3. PREPARATION OF SPECIMENS. a. Specimen Size. Unconfined compression specimens shall have a minimum diameter of 1.0 in. (preferably 1.4 in.), and the largest particle in any test specimen will be no greater than one-sixth the specimen diameter. The height-to-diameter ratio shall be not less than 2.1. Commonly used diameters of unconfined compression specimens are 1.4 and 2.8 in. Specimens of 1.4-in. diameter are generally used for testing cohesive soils which contain a negligible amount of gravel.

b. Undisturbed Specimens. Generally, undisturbed specimens are prepared from undisturbed tube or chunk samples of a larger size than the test specimen. Core or thin-wall tube samples of relatively small diameter may be tested without further trimming except for squaring the ends, if the condition of the soil requires this procedure. Specimens must be handled carefully to prevent remolding, changes in cross section, or loss of moisture. To minimize disturbance caused by skin friction between samples and metal sampling tubes, the tubes should be cut into short lengths before ejecting the samples. Sample ejection should be accomplished with a smooth continuous, and fairly rapid motion in the same direction that the sample entered the tube. All specimens shall be prepared in a humid room to prevent evaporation of moisture. The specimen shall be prepared as follows:

(1) From the undisturbed sample cut a section somewhat larger in length and diameter than the desired specimen size.

It is generally desirable to prepare duplicate specimens for unconfined compression testing, and selection of material for testing should be made with this in mind.

(2) Carefully trim the specimen to the required diameter using a trimming frame and various trimming tools (see Fig. 7, Appendix X, TRIAXIAL COMPRESSION TESTS). Remove any small shells or pebbles encountered during the trimming operations. Carefully fill voids on the surface of the specimen with remolded soil obtained from the trimmings. Cut the specimen to the required length, using a miter box (see Fig. 8, Appendix X, TRIAXIAL COMPRESSION TESTS). Where the presence of pebbles or crumbling results in excessive irregularity at the ends, cap the specimens with a minimum thickness of plaster of Paris, hydrostone, or other support material. Care must be taken to insure that the ends of the specimen are parallel with each other and perpendicular to the vertical axis of the specimen.

(3) From the soil trimmings obtain 200 g of material for specific gravity and water content determinations (see Appendixes I, WATER CONTENT - GENERAL, and IV, SPECIFIC GRAVITY).

(4) Weigh the specimen to an accuracy of ±0.01 g for 1.4-in.-diameter specimens and ±0.1 g for 2.8-in.-diameter specimens. If specimens are to be capped, they should be weighed before capping.

(5) Measure the height of the specimen with calipers or a scale and the diameter with calipers or circumference measuring devices. If the specimen is cut to a fixed length in a miter box, the length of the miter box can be taken as the height of specimen for routine tests, and additional height measurements are not usually necessary. It is always advisable to measure the diameter of the specimen after trimming, even though specimens are cut to a nominal diameter in a trimming frame. Make all measurements to the nearest ±0.01 in. Determine the average initial diameter, D_o, of the specimen using the diameters measured at the top, D_t, center, D_c, and bottom, D_b, of the specimen, as follows:

$$D_o = \frac{D_t + 2D_c + D_b}{4}$$

(6) If the specimen is not tested immediately after preparation, precautions must be taken to prevent drying and consequent development of capillary stresses. When drying before or during the test is anticipated, the specimen may be covered with a thin coating of grease such as petrolatum. This coating cannot be used if the specimen is to be used in a subsequent remolded test.

c. Remolded Specimens. Remolded specimens usually are prepared in conjunction with tests made on undisturbed specimens after the latter has been tested to failure. The remolded specimens are tested to determine the effects of remolding on the shear strength of the soil. The remolded specimen should have the same water content as the undisturbed specimen in order to permit a comparison of the results of the tests on the two specimens. The remolded specimen shall be prepared as follows:

(1) Place the failed undisturbed specimen in a rubber membrane and knead it thoroughly with the fingers to assure complete remolding of the specimen. Take reasonable care to avoid entrapping air in the specimen and to obtain a uniform density.

(2) Remove the soil from the membrane and compact it in a cylindrical mold with inside dimensions identical with those of the undisturbed specimen. The compaction effort is not critical since the water contents of soils subjected to remolded tests are always considerably wetter than optimum. Care must be taken, however, to insure uniform density throughout the specimen. A thin coat of petrolatum on the inside of the molding cylinder will assist in the removal of the specimen after compaction.

(3) Carefully remove the specimen from the mold, preferably by means of a close fitting piston, and plane off the top of the specimen. The specimen is then ready for testing.

(4) Follow the steps outlined in paragraphs 3b(4) and 3b(5).

4. PROCEDURE. The procedure shall consist of the following steps:

a. Record all identifying information for the sample such as project, boring number, visual classification, and other pertinent data on the data sheet (see Plate XI-1 which is a suggested form). The data sheet is also used for recording test observations described below.

b. Place the specimen in the loading device so that it is centered on the bottom platen; then adjust the loading device carefully so that the loading ram or upper platen barely is in contact with the specimen. If a proving ring is used for determining the axial load, contact of the platen and specimen is indicated by a slight deflection of the proving ring dial. Attach a dial indicator, sensitive to 0.001 in., to the loading ram to measure vertical deformation of the specimen. Record the initial reading of the dial indicator on the data sheet (Plate XI-1). Test the specimen at an axial strain rate of about 1 percent per minute. For very stiff or brittle materials which exhibit small deformations at failure, it may be desirable to test the specimen at a slower rate of strain. Observe and record the resulting load corresponding to increments of 0.3 percent strain for the first 3 percent of strain and in increments of 1 or 2 percent of strain thereafter. Stop the test when the axial load remains constant or when 20 percent axial strain has been produced.

c. Record the duration of the test, in minutes, to peak strength (time to failure), type of failure (shear or bulge), and a sketch of specimen after failure on the data sheet (Plate XI-2).

d. After the test, place the entire specimen or a representative portion thereof in a container of known weight and determine the water content of the specimen in accordance with Appendix I, WATER CONTENT - GENERAL.

5. COMPUTATIONS. The computations consist of the following steps:

a. From the observed data, compute and record on the data sheet (Plate XI-1) the water content, volume of solids, void ratio, degree of

saturation, and dry density, using the formulas presented in Appendix II, UNIT WEIGHTS, VOID RATIO, POROSITY, AND DEGREE OF SATURATION.

b. Compute and record on the data sheet the axial strain, the corrected area, and the compressive stress, at each increment of strain by using the following formulas:

$$\text{Axial strain, } \varepsilon = \frac{\Delta H}{H_o}$$

$$\text{Corrected area of specimen, } A_{corr}\text{, sq cm} = \frac{A_o}{1 - \varepsilon}$$

$$\text{Compressive stress, tons per sq ft} = \frac{P}{A_{corr}} \times 0.465$$

where

ΔH = change in height of specimen during test, cm

H_o = initial height of specimen, cm

A_o = initial area of specimen, sq cm

P = applied axial load, lb

6. PRESENTATION OF RESULTS. The results of the unconfined compression test shall be recorded on the report form shown as Plate XI-2. Pertinent information regarding the condition of the specimen, method of preparing the specimen, or any unusual features of each specimen (such as slickensides, stratification, shells, pebbles, roots, or brittleness) should be shown under "Remarks." The applied compressive stress shall be plotted versus the axial strain in Plate XI-2. The unconfined compressive strength, q_u, of the specimen shall be taken as the maximum or peak compressive stress. For tests continued to 20 percent strain without reduction of axial load occurring, the unconfined compressive strength as a rule shall be taken as the compressive stress at 15 percent strain.

Where the unconfined compressive strength of a specimen is also obtained after remolding, the sensitivity ratio, S_t, shall also be calculated and reported. The sensitivity ratio is defined as follows:

$$S_t = \frac{q_u \text{ (undisturbed)}}{q_u \text{ (remolded)}}$$

7. POSSIBLE ERRORS. Following are possible errors that would cause inaccurate determinations of unconfined compressive strength:

a. Test not appropriate to type of soil.

b. Specimen disturbed while trimming.

c. Loss of initial water content. A small change in water content can cause a larger change in the strength of a clay, so it is essential that every care be taken to protect the specimen against evaporation while trimming and measuring, during the test, and when remolding a specimen to determine the sensitivity.

d. Rate of strain or rate of loading too fast.

8. USE OF OTHER TYPES OF EQUIPMENT FOR UNDRAINED SHEAR STRENGTH DETERMINATIONS. Various other types of laboratory equipment, such as cone penetrometers and vane shear apparatus, may be used advantageously in the laboratory as a supplement to the basic unconfined compression test equipment for determining the undrained shear strength of cohesive soils. The use of these testing devices generally results in savings in cost and time. However, the devices should be used with caution until sufficient data and procedural details are established to assure their successful application. Use of such testing apparatus, as a rule,

should be preceded by careful correlations with the results of tests with the basic unconfined compression test equipment on the same type of soil, and correlations developed for a given type of soil should not be used indiscriminately for all soils.

UNCONFINED COMPRESSION TEST

Date _____

Project _____

Boring No. _____ Sample No. _____

Specimen No.		Classification					
Tare No.			Height	H_o	in.	H_o	cm
Weight, g: Tare plus wet specimen			Average diameter	D_o	in.	D_o	cm
Tare plus dry specimen			Initial area	A_o	sq in.	A_o	sq cm
Water	W_w		Volume in cc = A_oH_o			V_o	
Tare			Volume of solids in cc = $W_s \div G_s$			V_s	
Wet specimen	W		Void ratio = $(V_o - V_s) \div V_s$			e_o	
Dry specimen	W_s		Saturation in % = $G_s w_o \div e_o$			S_o	%
Water content	w_o	%	Dry dens., lb/cu ft = $62.4\ (W_s \div V_o)$			γ_d	
Specific gravity of solids	G_s		Note: If only a portion of the specimen is used for the water content determination, $W_s = W \div \left(1 + \frac{w_o}{100}\right)$				

Elapsed Time min	Dial Reading 10^{-} in.	Cumulative Change, ΔH 10^{-} in.	Proving Ring Dial Reading 10^{-} in.	Axial Load, P lb	Axial Strain $\epsilon = \Delta H/H_o$	$1 - \epsilon$	$A_{corr} = A_o/(1-\epsilon)$ sq cm	Compr Stress tons/sq ft $0.465(P/A_{corr})$

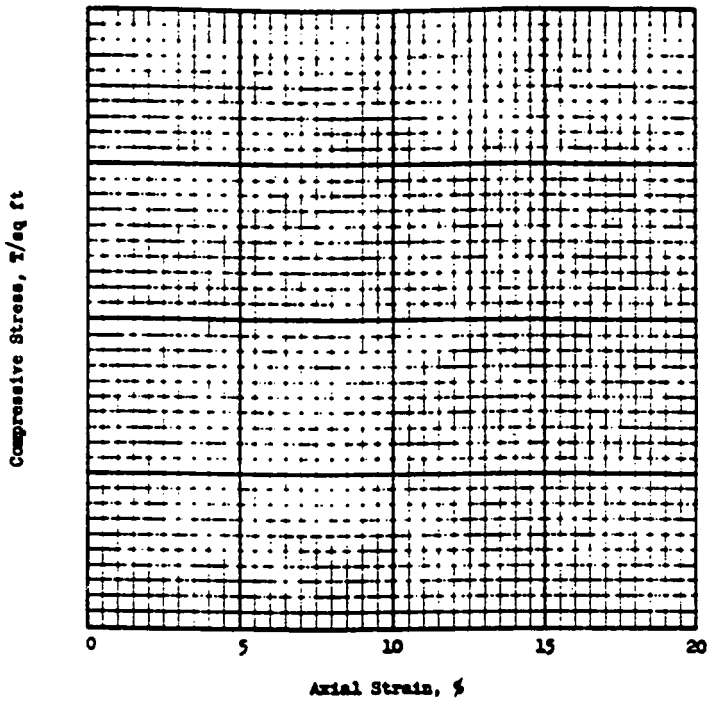
Remarks _____

_____ Type Failure _____

Technician _____ Computed by _____ Checked by _____

PLATE XI-1 ENG FORM 1 JUN 68 3857

Failure Sketches



☐ Controlled stress

☐ Controlled strain

Test No.						
Type of specimen						
Initial	Water content	w_o	%	%	%	%
	Void ratio	e_o				
	Saturation	S_o	%	%	%	%
	Dry density, lb/cu ft	γ_d				
Time to failure, min		t_f				
Unconfined compressive strength, T/sq ft		q_u				
Undrained shear strength, T/sq ft		s_u				
Sensitivity ratio		S_t				
Initial specimen diameter, in.		D_o				
Initial specimen height, in.		H_o				

Classification			
LL	PL	PI	G_s

Remarks	Project
	Area
	Boring No. / Sample No.
	Depth El / Date
	UNCONFINED COMPRESSION TEST REPORT

ENG FORM 1 JUN 68 2659

PLATE XI-2

APPENDIX C

NUCLEAR WASTE GLASS PRODUCT CONSISTENCY TEST (PCT) - VERSION 3.0 (U)

NUCLEAR WASTE GLASS PRODUCT CONSISTENCY TEST (PCT) - VERSION 3.0 (U)

A durability test, designated for Product Consistency Test (PCT), has been developed for glasses produced in the Defense Waste Processing Facility (DWPF).[1] The test is designed to meet the requirements of the Waste Acceptance Preliminary Specifications (WAPS) 1.3 and 1.4.[2] Specification 1.3 requires the DWPF to demonstrate control of the radionuclide release properties of the final waste form. Changes in phase composition due to devitrification do not greatly alter the rate of release of material from the glass[3] of the type which will be produced in DWPF. However, the WAPS Specification 1.4 requires that the release properties of devitrified glass be similar to those determined in Specification 1.3. The DWPF is responsible for relating the results of the PCT to a repository site-specific release test, or alternatively, for performing the repository site-specific release tests.

The PCT has been developed, in part, to satisfy the WAPS requirements by providing a test which is (1) sensitive to glass composition and homogeneity, and (2) has the potential to be related to repository site-specific release tests. The test was designed to provide confirmation of the consistency of DWPF glass while considering the following:

- Sensitivity of the test to glass composition and homogeneity
- Time necessary to demonstrate product quality
- Ease of sample preparation for radioactive glass
- Ease of test procedure for remote operation
- Precision of the test results
- Acceptance of waste form developers and repository projects

During PCT development, sample size was limited to 100-200 mesh (149-74 m) crushed glass because leaching of finer mesh sizes can cause overestimation of saturation concentrations, e.g. if finer powders are used, mass balance calculations need to be used to determine the maximum saturation concentration expected from a given particle size.[4] Fine particles also contribute larger errors to the estimation of the sample surface area than coarser sized samples. Moreover, use of a coarser mesh crushed glass simplifies sample preparation for radioactive service.

One test temperature, 90°C, was chosen for the PCT. This temperature is representative of the anticipated temperature in a repository because of the heat of decay of the radionuclides in DWPF waste glass. A single leachant, ASTM Type I water, was specified so that the test would be dominated by elemental species leached from the glass.

The v_{soln}/m_{solid} ratio for the PCT was chosen as 10 mL/g and test durations of 1, 3, 7, 14, and 28 days were evaluated. Seven days was chosen as the minimum test duration which optimized test precision but did not sacrifice discrimination.[1]

Leachate filtration to <0.45μm was determined to improve the precision of the PCT. Filtering is advantageous because if removes colloidal species which would otherwise dissolve during the leachate acidification step and erroneously be measured as soluble elemental species. Filtering the leachate also removes the potential for fine glass particulates becoming entrained in the leachate acidification.[5] Such a dissolved particulate of glass would give an erroneously high soluble leachate concentration or contribute excessive radioactivity to the leachate.

PCT sample preparation specifies that the sieved glass should be washed in ASTM Type I water and absolute ethyl alcohol to remove electrostatically adhering fine particles. Comparisons of B.E.T. specific surface area measurements of alcohol washed and unwashed crushed basalt demonstrated that there was less than a 5% difference in the total surface area.[5] Other studies[6-9] have demonstrated that the <1μm fine particles only affect the initial non-linear kinetics of dissolution, e.g. the first 24 hour period. Thereafter, the fines are consumed with no further effect on the bulk dissolution. However, the amount of fines adhering to a glass sample is an uncontrollable quantity and, hence, sample washing was included in the PCT. Later experimental studies verified that sample washing improved the precision and the accuracy of the PCT.

An SRL internal round robin[1] and a seven laboratory external round robin were completed[10] in order to determine the precision and accuracy of the PCT. Confirmatory testing on radioactive samples was also performed.[11] These studies indicated that the PCT was very reproducible, yielded reliable results rapidly, and could be easily performed in shielded cell facilities with radioactive samples.

This draft was submitted to ASTM subcommittee C26.13 on Repository Waste Package Materials Testing in January 1990.

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APPENDIX D

HEALTH AND SAFETY PLAN
FOR THE
FEED MATERIALS PRODUCTION CENTER
WASTE PITS 1,2,3,4,5,6, the CLEARWELL, AND
THE BURN PIT TREATABILITY STUDY
REMEDIAL SCREENING, REMEDY SELECTION PHASES

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D.1.0 INTRODUCTION

This Health and Safety Plan (HSP) in conjunction with the laboratory Chemical Hygiene Plan (CHP) establishes the work practices necessary to help ensure protection of IT Corporation (IT) personnel during the Operable Unit 1 (OU1) laboratory screening to be performed at IT's Environmental Technology Development Center (ETDC) Laboratory in Oak Ridge, Tennessee.

The objective of this plan is to provide a mechanism for the establishment of safe and healthy working conditions at the laboratory. The safety procedures have been established following an analysis of potential hazards at the laboratory, and procedures have been developed to minimize the potential of accident or injury.

All laboratory operations will be performed in accordance with applicable state, local and IT Corporate regulations and procedures and OSHA requirements.

D.1.1 SCOPE OF WORK

This laboratory screening will involve mixing OU1 waste pit samples with various reagents to conduct cement stabilization and vitrification testing. These stabilized wastes will then be tested for compressive strength using a pocket penetrometer (Soiltest CT-421) and the unconfined compressive strength (UCS) method (ASTM D2166) using a Soiltest U-610. Following compressive strength testing, the wasteforms will be tested for leaching characteristics using a modified Toxicity Characteristics Leaching Procedure (TCLP) test, a full TCLP test, and on five-day static leach test, "Measurement of the Leachability of Solidified low-level Radioactive Wastes by a Short-Term Test Procedure". This testing will be performed at IT's ETDC Laboratory. The samples for this treatability study will be drawn under the OU1 Sampling and Analysis Plan (SAP). Detailed information on the laboratory screening is contained in the OU1 Laboratory Screening Treatability Plan (May 1991).

D.1.1.1 Preliminary Characterization

The samples drawn under the OU1 SAP will be composited at the Feed Materials Production Center in Ross, Ohio. These activities will be governed by the Health and Safety Plan for the SAP.

D.1.1.2 Cement Stabilization

The cement stabilization laboratory screening will consist of mixing cement stabilization reagents (Portland cement, fly ash, sodium silicate, attapulgite, clinoptiloite, water) in varying quantities with waste pit material. These stabilization reagents will be mixed with 100 grams of composited pit waste in a graduated plastic cup. Mixing will be performed by hand with a spatula until the mixture is homogeneous (approximately 2 minutes). After a prescribed setting period the stabilized wastes will be tested for compressive strength and leachability characteristics.

D.1.1.3 Vitrification

The vitrification laboratory screening will consist of first attempting to vitrify the waste pit material in a laboratory furnace without the benefit of vitrifying agents. Waste pit material will then be mixed with vitrifying agents (sodium hydroxide, site/commercial fly ash, site soil in varying quantities in a manner identical to that described in the previous section and vitrified. After a prescribed cooling period the stabilized wastes will be tested for leachability characteristics.

D.2.0 RESPONSIBILITIES

The following is a listing of those personnel responsible for various activities in the Health and Safety program and their responsibilities:

- ETDC Health & Safety (H&S) Officer (Keith Hood) - responsible for the technical development and coordination of the Health and Safety Plan (HSP). Inquiries regarding the HSP, IT Corporate H&S Procedures, and other technical or regulatory items shall be addressed to the Health and Safety Officer.

- Laboratory Project Supervisor (Ernie Stine) - responsible for implementation of the HSP. This shall include communication of requirements to all personnel and interaction with client representatives and regulatory agencies. Additional communication may include consultation with the H&S Manager regarding the execution of the project and the HSP.

- Laboratory personnel - responsible for understanding and complying with all site H&S requirements. Each team member shall be provided training on the requirements of this HSP prior to the beginning of the project.

- Emergency Coordinators (Tom Geisler, Rick Greene) - shall be responsible for and have the full authority to commit any personnel or equipment necessary for response and recovery operations during spills, disasters, or other emergencies.

D.3.0 SITE HISTORY

A variety of chemical and metallurgical processes were utilized at the Feed Materials Production Center (FMPC) for the manufacture of uranium products. During the manufacturing process, high quality uranium compounds are introduced into the FMPC processes at several points. Impure starting materials are dissolved in nitric acid, and the uranium is purified through solvent extraction to yield a solution of uranyl nitrate. Evaporation and heating convert the nitrate solution to uranium trioxide (UO_3) powder. This compound is reduced with hydrogen to uranium dioxide (UO_2) and then converted to uranium tetrafluoride (UF_4) by reaction with anhydrous hydrogen fluoride. Uranium metal is produced by reacting UF_4 and magnesium metal in a refractory-lined vessel. This primary uranium metal is then remelted with scrap uranium metal to yield a purified uranium ingot.

The waste pits to be studied consist of Pits 1 through 4 and the Burn Pit. They are numbered chronologically in their order of construction. Pits 3, 5, and 6 and the Clearwell are referred to as "wet" because it received mostly waste in slurry form. Pits 1, 2 and 4 and the Burn Pit are referred to as "dry" because they received mostly dry solid waste from trucks. These low-level radioactive waste storage pits received varying quantities of neutralized waste filter cakes, graphite, brick scrap, sump liquor and cakes, depleted slag, process residues, slurries and raffinates. The volumes of waste in the pits range from a low of 11,556 cubic yards (cy) in Pit 6 to a high of 237,053 cy in Pit 3.

D.4.0 TASK SPECIFIC HAZARD ASSESSMENT

The following hazard assessment is based on historical information and defined task activities. The laboratory personnel routinely reassess the hazards before starting work to ensure that conditions have not changed. All newly identified hazards will be addressed with the Health and Safety Officer to determine the degree of hazard and if any changes to the HSP are needed.

D.4.1 PHYSICAL HAZARDS

- Radiological Hazards
- U-238 and daughters
- U-235 and daughters

Contaminant	Derived Air Concentration	Action Limit .25DAC
Thorium-230	3E-12 uCi/mL	7.5E-13 uCi/mL
Uranium-238	2E-11 uCi/mL	5E-12 uCi/mL
Uranium-235 (trace levels of actinium series)	2E-11 uCi/mL	5E-12 uCi/mL
Uranium-234	2E-11 uCi/mL	5E-12 uCi/mL

D.4.2 CHEMICAL HAZARDS

The following chemicals will be present, either in the samples, or in the reagents, and pose potential hazards. Other materials, such as fly ash, lime, and cement/sodium silicate will be present but pose no significant hazard due to their relatively low toxicity and small quantities.

Chemical	PEL	
	TWA	STEL
Reagents		
Acetic Acid	10 ppm	None
1,1,1-Trichloroethane	350 ppm	450 ppm
Sodium hydroxide	None	2 mg/m^3 (C)
Uranium	0.05 mg/m^3*	
	0.02 mg/m^3**	0.6 mg/m^3**

PEL - Permissible exposure limit, or maximum airborne exposure allowed by OSHA.

Types of PELs include TWAs, STELs, and ceilings.
TWA - Time weighted exposure limit, or average exposure allowed over an 8-hour shift.
STEL - Short term exposure limit, or maximum average exposure during a 15-minute period
C - Ceiling, or maximum exposure allowed, even instantaneously.
* - Soluble compounds
** - Insoluble compounds

D.4.3 POTENTIAL ROUTES OF EXPOSURE AND HAZARD ASSESSMENT

The identified site contaminants are solids in nature and the majority of the reagents to be used are liquids. The potential routes of entry into the body are inhalation, absorption and ingestion, in their order of importance. Radioisotopes in the sample pose an external and internal exposure hazard. The internal hazard is largely eliminated by the procedures to be utilized. The external hazard will be controlled through air monitoring. Direct skin contact with the corrosives may result in destruction of skin tissue and absorption of other contaminants if in solution.

In order to minimize the potential exposure hazards, nearly all of the operations to be carried out during this project will be performed inside a laboratory exhaust hood, which is located inside an environmental containment cubicle. These operations include sample preparation, pouring reagents, and packaging for disposal. The only operations planned to be performed outside the hood are transport of the waste pit samples to and from the hood and transport of reagents to the hood. All

container opening will be done only inside the hood. Reagents have been prepared and packaged off-site to further minimize on-site handling.

The use of the hood greatly minimizes any potential for exposure to the hazards associated with the pit samples or the reagents. To minimize the potential for radiation exposure, air monitoring will be conducted to quantify the exposure and assure that the procedures in use are appropriate.

D.5.0 MONITORING

D.5.1 GOALS

Air monitoring will be performed to ensure that contaminant concentrations in the breathing zone do not exceed the concentrations specified by established exposure levels.

Exposures to chemicals should be kept as low as possible because there are insufficient data to predict the combined effects of most chemical mixtures.

D.5.2 EXTERNAL RADIATION HAZARD MONITORING

A health physics technician will monitor all locations before start of work and will frequently monitor exposures in all areas that exceed the one millirem (mrem)/hour action limit. Measures such as increasing shielding, increasing distance, or reducing exposure time will be taken to minimize exposures. Radiation monitoring instruments include:

- Ludlum Model 177, or equivalent, with a G-M pancake probe
- Ludlum Model 3, or equivalent, with a ZnS alpha scintillation probe
- Eberline Model Alpha-5A alpha air monitor.

D.5.3 ACTION LIMITS

The following table provides types, scheduling, and actions for monitoring.

Instrument/chem.	Need	Interval	Limit	Action
Alpha probe	Y	Pre-job and inter-mittent	20 cpm[a]	HP Review
Beta/gamma probe	Y	Pre-job and inter-mittent	500 cpm[a]	HP Review
External radiation	Y	Pre-job	>1 mrem/hour	HP Review
Continuous air monitor (CAM)	Y	Continuous	>0.075 or >7.5 working level	APR Withdraw
Thermolumi-nescent dosimetry (TLD) badge	Y	Continuous	N/A, no real time results	
TLD ring	Y	Continuous	N/A, no real time results	

[a]Above background

D.6.0 PERSONAL PROTECTIVE EQUIPMENT AND EXPOSURE REDUCTION

D.6.1 PERSONAL PROTECTIVE EQUIPMENT

D.6.1.1 Respiratory Protection

The need for respiratory protection will be evaluated prior to the commencement of activities by a professional industrial hygienist and health physicist.

D.6.1.2 Eye Protection

A face shield with goggles is required when performing the tests due to the potential for splash when using concentrated acids and bases.

D.6.1.3 Protective Clothing

A rubber apron and long sleeves are required when performing tests due to the potential for splash when using concentrated acids and bases. Additionally, chemical-resistant gloves will be worn when performing tests.

D.6.2 EXPOSURE REDUCTION

D.6.2.1 Engineering Controls

The operations will be performed under a laboratory exhaust hood in an environmental containment cubicle which is under negative ventilation. This cubicle is located in the environmental containment cubicle room which is also under negative ventilation. A slant manometer or magnehelic gage will be utilized to measure and indicate the pressure differential created by the air flow.

The laboratory exhaust hoods are in the work area and will be kept free of materials placed where they will block the vents, reducing air flow.

D.6.2.2 Administrative Controls

Control Access to Work Area

Access to contamination work areas will be regulated and limited to authorized personnel. Warning signs will be affixed in readily visible locations in or near the work area as required by applicable regulations. The work area shall be divided into the following three zones:

- Exclusion zone - This zone will include the highest potential concentrations of contamination. This zone has the highest potential for skin contamination and inhalation exposures. The exclusion zone will be the environmental containment cubicle.

- Contamination reduction zone - This zone includes all areas immediately adjacent to the exclusion zone. Personnel contamination monitoring will take place in this zone.

- Support zone - This area covers all areas outside of the contamination reduction zone. Exposure to harmful chemicals or radioactive materials in this zone is highly unlikely.

D.6.2.3 Safe Work Practices

All personnel will follow the safe work practices outlined in the chemical hygiene plan for the ETDC.

D.6.2.4 Equipment Inspection

All equipment used in the testing will be inspected prior to use. Defective equipment will reported to the Project Manager and repaired prior to use.

D.7.0 LABORATORY ACCESS AND ENTRY PROCEDURES

Access to the environmental containment cubicles during treatability studies will be limited to personnel who have completed required training and have had required medical exams.

D.7.1 BIOASSAY SAMPLING

A baseline 24-hour urine sample will be taken before starting treatability activities and a post-work 24-hour urine sample will be submitted upon completion of activities.

Additional urine samples will be required if air samples indicate an acute exposure of 40 DAC-hours (2 percent of the annual limit of intake [ALI]). This correlates to a gross alpha activity for the most conservative nuclide, Th-230, of 1E-10 µCi/mL averaged over a one-hour exposure. No respirator protection factors are built into these action levels.

D.7.2 MEDICAL MONITORING

In accordance with 20 CFR 1910.120 OSHA requirements, all personnel involved in the treatability study are required to participate in a medical monitoring program which includes:

- A baseline medical examination
- Annual medical examination
- Medical examinations that may be required after potential exposures

D.7.3 TRAINING REQUIREMENTS

All personnel at the ETDC involved in the treatability study have the following training:

- IT Chemical Hygiene Plan
- ETDC Emergency Contingency Plan

- General Employee Training - Rad Worker Training
- Hazard Communication Training

D.7.4 CONTAMINATION ZONES

The Exclusion Zone is the zone of high potential hazard due to physical, chemical, or radiological dangers. Access to the Exclusion Zone is restricted to employees who are required to enter to perform their job functions. The area inside the environmental containment cubicles is considered to be the Exclusion Zone.

D.7.5 LABORATORY ENTRY PROCEDURES

The following activities shall be conducted prior to and during the work day, as appropriate:

- Perform respirator check out and fit test prior to use.
- Locate the nearest eyewash/shower and fire extinguisher prior to initiating activities.
- Verify all instruments are calibrated.
- Visually scan the laboratory for signs of contamination.

Note: The Health and Safety Manager and any member of the team have the authority to stop work when imminent or serious safety hazards or conditions exist. Restart of work will be allowed only after the hazard or condition has been abated or reduced to an acceptable level.

D.8.0 LABORATORY EXITING PROCEDURE

D.8.1 CONTAMINATION DETECTION

All personnel are required to follow decontamination procedures themselves and then confirm the effectiveness of the decontamination. The effectiveness will be determined by frisking with a hand held radiation monitor.

The monitor must be held within 1/2 inch of the surface and moved at a rate of approximately one inch per second for effective radiation monitoring. If frisking count exceeds DETECTABLE, additional decontamination is required. This decontamination will be conducted by gently scrubbing with soap and water.

In the event that contamination can not be removed to below the action levels (100 cpm beta/gamma or detectable alpha radiation above background), notify the Health and Safety Manager.

D.8.2 DECONTAMINATION

Decontamination reduces contaminant concentrations to acceptable levels, but does not generally remove it totally. Try to avoid contamination where possible by making minimum contact with the contaminant.

Personnel: Dry removal of disposable protective equipment; wash hands, face and any other exposed skin. Detergent and tepid water should be used to gently scrub skin surfaces which have contacted potentially contaminated wastes.

Equipment: Any exposed areas of the equipment surface will be wiped with a damp paper towel/cloth to remove contamination. Wiping and cloth dampened with detergent solution may be necessary to remove greasy materials.

The effectiveness of decontamination must be confirmed by frisking.

D.9.0 EXPOSURE SYMPTOMS

Acute exposure to solvents and corrosives may produce dizziness and/or irritation. Exposure to low levels of radioactivity do not produce acute exposure symptoms. The exposures may cause delayed effects such as cancer. Since biological effects from radiation exposures are cumulative, exposures are to be kept As Low As Reasonably Achievable (ALARA).

No treatment is anticipated for the predicted contaminants and concentrations. Any emergencies arising during the performance of work will covered by IT's Emergency Contingency Plan (ECP) prepared for the ETDC.

D.10.0 OPERATIONALLY DERIVED WASTES

Operationally derived wastes are wastes generated in the performance of various activities. These wastes include, but are not limited to:

- Disposable PPE such as Tyvek coveralls, gloves, booties.
- Disposable decontamination supplies.

Protective clothing will be placed in plastic bags, placed in a B-25 box or metal drum for disposal as compactible, potentially contaminated waste by Westinghouse Materials Company of Ohio (WMCO).

Operationally derived wastes are the property of the client and are to be shipped back to WMCO unless otherwise specified in the written contract.

The client will be responsible for proper transport, shipment or disposal unless otherwise specified in the written contract.

D.11.0 CONTINGENCY PLANS

Contingency plans for injuries, spills, releases, fires, and explosions are given in the Emergency Contingency Plan (ECP) for the ETDC. The ECP identifies ETDC emergency coordinators. Agencies that may be requested to provide assistance in an emergency are also listed along with phone numbers. Copies of the ECP will be available on site to all personnel.

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