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	Engineering and Design REMOVAL OF UNDERGROUND STORAGE TANKS (USTs)	
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EM 1110-1-4006
30 September 1998

ENGINEERING AND DESIGN

Removal of Underground Storage Tanks (USTs)

ENGINEER MANUAL

AVAILABILITY

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DEPARTMENT OF THE ARMY
U.S. Army Corps of Engineers
Washington, D.C. 20314-1000

EM 1110-I-4006

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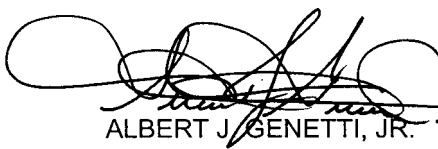
Manual
No. 1110-I-4006

30 September 1998

Engineering and Design
REMOVAL OF UNDERGROUND STORAGE TANKS (USTs)

1. **Purpose.** The primary purpose of this Engineer Manual (EM) is to provide practical guidance for removal of underground storage tanks (USTs). The manual addresses site evaluation, monitoring, testing, removal, and site restoration. A secondary purpose is to provide information relative to remediation of contaminated soil and groundwater.
2. **Applicability.** This EM applies to all USACE commands having Civil Works and/or Military Programs with hazardous, toxic, or radioactive waste (HTRW) project responsibilities.
3. **References.** References are provided in Appendix A.
4. **Distribution.** Approved for public release, distribution is unlimited.
5. **Discussion.** This manual addresses tanks subject to Resource Conservation and Recovery Act (RCRA) Subtitle I underground storage tanks requirements, and is not intended for use in the management of tanks that have stored RCRA Subtitle C hazardous wastes. Each UST project progresses through an orderly sequence of phases. These phases include initial data gathering, initial field investigations, tank removal, and site remediation. This manual is intended to guide qualified technical personnel through the activities associated with each phase and provides steps for preparing UST removal contract documents. This EM will help the designer to incorporate the proper requirements into the project documents.

FOR THE COMMANDER:



ALBERT J. GENETTI, JR.
Major General, USA
Chief of Staff

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(See Table of Contents)

This manual supersedes EM 1110-3-178, dated 31 August 1993.

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CHAPTER 1

GENERAL

1-1. Scope. The manual covers tanks subject to Resource Conservation and Recovery Act (RCRA) Subtitle I underground storage tank requirements and is not intended for use in the management of remediation projects for tanks that are believed to have been used to store RCRA Subtitle C hazardous wastes. (Note: There is a regulatory distinction between a tank used to store ignitable fuels and a tank used to store hazardous waste. Subtitle I, not Subtitle C, applies to product tanks, even though hazardous wastes may be generated from the tank upon removal from service. Therefore, generation of hazardous waste from a tank does not preclude the use of this EM.)

Each UST project progresses through an orderly sequence of phases. These phases include initial data gathering, initial field investigations, tank removal, and site remediation. This manual will describe the activities associated with each phase. It is intended to guide qualified technical personnel who prepare UST removal contract documents. It will discuss how to perform the necessary activities. Corps of Engineers Guide Specifications (CEGS) 01351 *Safety, Health, and Emergency Response (HTRW/UST)*, 01450 *Chemical Data Quality Control*, 02115 *Underground Storage Tank Removal*, 02120 *Transportation and Disposal of Hazardous Materials* are to be used with this manual. Additional references are included in Appendix A.

1-2. Quality Assurance/Quality Control. This engineering manual will help the designer to incorporate the proper requirements for a quality job into the project documents. This includes incorporating the safety and health requirements of EM 385-1-1 *Safety and Health Requirements Manual*, ER 385-1-92 *Safety and Occupational Health Document Requirements for Hazardous, Toxic and Radioactive Waste (HTRW) and Ordnance and Explosive Waste (OEW) Activities* during removal activities. The requirements of ER 1110-1-263 *Chemical Data Quality Management for Hazardous, Toxic and Radioactive Waste Remedial Activities*, EM 200-1-3 *Requirements for the Preparation of Sampling and Analysis Plans*, and EM 200-1-6 *Chemical Quality Assurance* should be followed to assure quality analytical data. It will also aid the USACE's resident engineer in assuring quality construction as required by ER 1180-1-6 *Construction Quality Management* through implementation of the USACE's Quality Assurance and Contractor's Quality Control systems as discussed in EP 415-1-260 *Resident Engineer's Management Guide* and EP 415-1-261 *Quality Assurance Representatives Guide*.

1-3. Closure Requirements. This guidance does not suggest that all of the activities must be performed. Rather the reader must decide what activities are required for each tank closure. This manual addresses the minimum tank closure requirements based on applicable federal regulations and a review of state requirements. In every case, the user of this manual must check the requirements of the local environmental Implementing Agency (IA) and plan for the specific coordination of activities specified in these IA requirements. Questions as to the applicability of federal or state UST removal requirements on active installations or Civil Works Facilities should be addressed to the installation legal office or USACE district office (Civil Works), or if no legal office exists, to the major command legal office to which the installation or Civil Works Facility is assigned. Questions as to the applicability of Federal or state UST removal requirements on former installations should be addressed to the legal office of the USACE district executing the work. A list of state UST contacts is provided in Appendix B to assist in determining these local needs. Tank closure in place must be approved by the appropriate command as detailed below prior to completion:

FUDS	-	Division Commander (DERP/FUDS Manual)
Army	-	Active Installation; MACOM
	-	Civil Works; District Commander/Operations Manager
Air Force	-	MAJCOM/Installation; AFI 32-7044
Other Customers	-	Specific Guidance should be requested.

Figures 1-1 and 1-2 identify the generic steps in the UST removal process and identify the applicable chapters in this manual for each step.

1-4. Definitions and Acronyms.

ACGIH	-	American Conference of Governmental Industrial Hygienists
ACO	-	Administrative Contracting Officer
AFI	-	Air Force Instruction
API	-	American Petroleum Institute
ASTM	-	American Standards of Testing and Materials
AWWA	-	American Water Works Association
B	-	Analyte detected in the method blank
BDL	-	Analyte not detected at the laboratory reporting limit
CFR	-	Code of Federal Regulations
CGI	-	Combustible Gas Indicator
CIH	-	Certified Industrial Hygienist
COLIWASA	-	Composite Liquid Waste Sampler
COR	-	Contracting Officer's Representative

CSP	- Certified Safety Professional
DERP	- Defense Environmental Restoration Program
DO	- Dissolved Oxygen
DOT	- Department of Transportation
EM	- Electromagnetic
EPA	- U.S. Environmental Protection Agency
FID	- Flame Ionization Detector
FSP	- Field Sampling Plan
FUDS	- Formerly Used Defense Sites
GC	- Gas Chromatography
GPR	- Ground Penetrating Radar
HTRW CX	- Hazardous, Toxic, and Radioactive Waste Center of Expertise, located in the Northwest Division, Missouri River Region, Omaha District
IA	- Implementing Agency
IDLH	- Immediately Dangerous to Life and Health
IRP	- Installation Restoration Program
IDW	- Investigation-Derived Waste
J	- Analyte detected below the laboratory reporting limit, concentration is estimated
LEL	- Lower Explosive Limit - the lowest concentration of gas or vapor in air by volume that can be ignited and cause an explosion or flame propagation
MSDS	- Material Safety Data Sheet
NA	- Not Analyzed
NFPA	- National Fire Protection Association
NIOSH	- National Institute for Occupational Safety & Health
NIST	- National Institute of Standards Technology
NR	- Not Reported
ORP	- Oxidation-Reduction Potential
OSHA	- Occupational Safety & Health Administration
PEL	- Permissible Exposure Limit
PID	- Photoionization Detector
POLs	- Petroleum, Oils, and Lubricants
POTW	- Publicly Owned Treatment Works
QA	- Quality Assurance
QAPP	- Quality Assurance Project Plan
QC	- Quality Control
RCRA	- Resource Conservation and Recovery Act
SAP	- Sampling and Analysis Plan
SOP	- Standard Operating Procedure

1-4

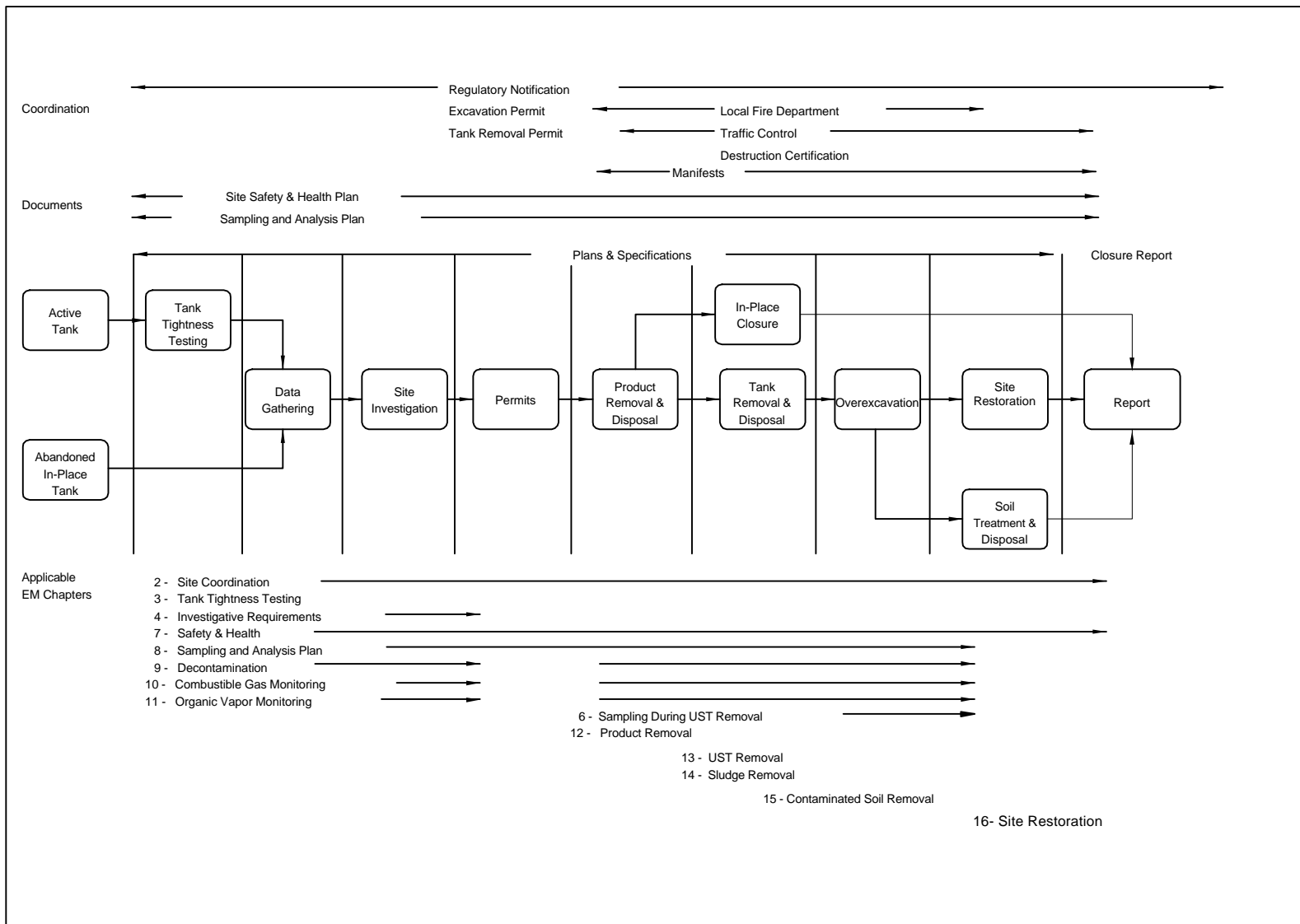


FIGURE 1-1. FLOWCHART FOR CLEAN TANK CLOSURE

1-5

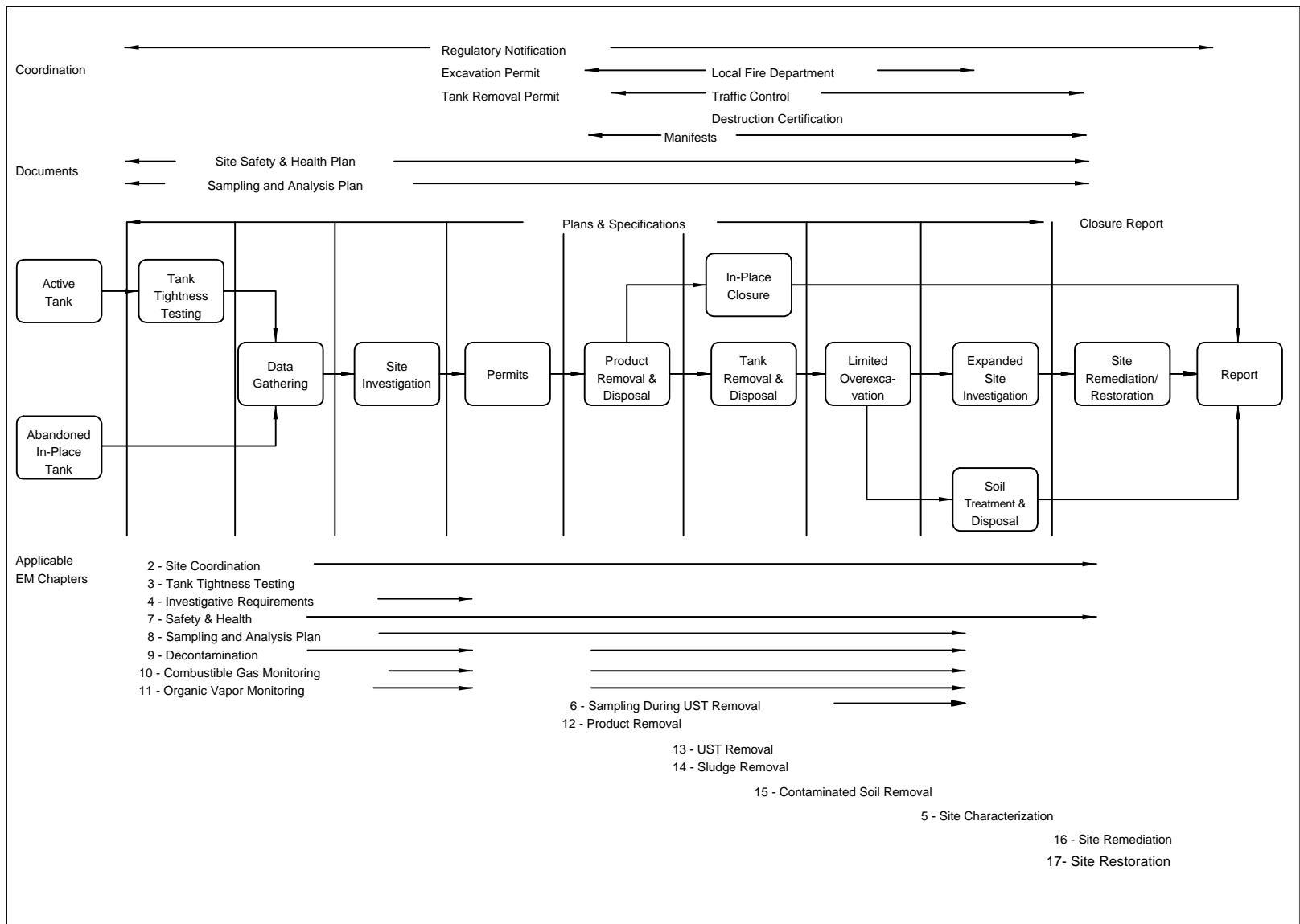


FIGURE 1-2. FLOWCHART FOR TANK CLOSURE REQUIRING REMEDIATION/RESTORATION

SOW	- Scope of Work
SSHO	- Site Safety and Health Officer
SSHP	- Site Safety and Health Plan
TCLP	- Toxicity Characteristic Leaching Procedure
TLV	- Threshold Limit Value
TRPH	- Total Recoverable Petroleum Hydrocarbons
TWA	- Time Weighted Average
U	- Analyte not detected at the laboratory reporting limit
UEL	- Upper Explosive Limit - the concentration of gas in air above which there is insufficient oxygen available to support combustion and explosion is unlikely
USACE	- United States Army Corps of Engineers
UST	- Underground Storage Tank. This term describes any tank, including underground piping that has at least 10 percent of its volume below grade as defined by 40 CFR Part 280
VOA	- Volatile Organic Analysis
VOCs	- Volatile Organic Compounds

1-5. Regulations.

- a. RCRA Subtitle I. The Hazardous and Solid Waste Amendments of 1984 extended and strengthened the provisions of the Solid Waste Disposal Act as amended by the RCRA of 1976. Subtitle I provides for the development and implementation of a comprehensive regulatory program for USTs containing regulated substances and releases of these substances to the environment.
- (1) Subtitle I defines *underground storage tank* as a tank system, including its piping, that has at least 10 percent of its volume underground. This term does not include any:
- (a) Farm or residential tank of 1,100 gallons or less used for storing motor fuel for noncommercial purposes.
 - (b) Tank used for storing heating oil for consumptive use on the premises where stored; however, it is Army policy per AR 200-1, Chapter 4, to manage heating oil tanks 250 gallons (946 liters) or larger similarly to Subtitle I underground storage tanks.
 - (c) Septic tank.

- (d) Pipeline facility regulated under The Natural Gas Pipeline Safety Act of 1968 or The Hazardous Liquid Pipeline Safety Act of 1979 or an intrastate pipeline facility regulated under state laws comparable to these acts.
 - (e) Surface impoundment, pit, pond, or lagoon.
 - (f) Storm water or wastewater collection system.
 - (g) Flow-through process tank.
 - (h) Liquid trap or associated gathering lines directly related to oil or gas production and gathering operations.
 - (i) Storage tank situated in an underground area (such as basement, cellar, mineworking, drift, shaft, or tunnel) if the storage tank is situated upon or above the surface of the floor.
- (2) *Regulated substances* include but are not limited to petroleum and petroleum-based substances comprised of a complex blend of hydrocarbons derived from crude oil through processes of separation, conversion, upgrading, and finishing such as motor fuels, distillate fuel oils, residual fuel oils, lubricants, petroleum solvents, and used oils.
- (3) The following UST systems are excluded from the requirements of this part:
- (a) Any UST system holding hazardous wastes listed or identified under Subtitle C of the Solid Waste Disposal Act, or a mixture of such hazardous waste and other regulated substances.
 - (b) Any wastewater treatment tank system that is part of a wastewater treatment facility regulated under Section 402 or 307(b) of the Clean Water Act.
 - (c) Equipment or machinery that contains regulated substances for operational purposes, e.g., hydraulic lift tanks and electrical equipment tanks.

- (d) Any UST system whose capacity is 110 gallons or less.
 - (e) Any UST system that contains a *de minimis* concentration of regulated substances.
 - (f) Any emergency spill or overflow containment UST system that is expeditiously emptied after use.
- b. RCRA Subtitle C. Subtitle C provides for the handling of hazardous wastes as defined by RCRA. Specifically, a hazardous waste is a waste that meets the following criteria:
- (1) It exhibits any of the characteristics of hazardous waste identified in 40 CFR Part 261 Subpart C. These characteristics include:
 - (a) Ignitability.
 - (b) Corrosivity.
 - (c) Reactivity.
 - (d) Toxicity.
 - (2) It is listed in Subpart D of 40 CFR Part 261. 40 CFR Part 261 also details exclusions to these criteria and should be consulted for exact definitions.

1-6. Job Qualifications and Training.

- a. Training. By the time onsite activities are initiated, all personnel entering into the exclusion area and contamination/reduction zone (including the contractor) must complete the appropriate safety and health training as required by 29 CFR 1926.65(e) and as outlined in Chapter 7 of this manual. The contractor must provide, and have available to the onsite project manager at all times, copies of all certifications described above. This includes documentation of having participated in the most recent refresher course, if required. The contractor must also have available documentation of certification in the UST testing method to be used and in UST removal (if required by the state).

- b. Work History. The contractor must provide, and have available to the onsite project manager at all times, work history of all personnel employed by the contractor for the specific purpose of fulfilling the tasks dictated by the subcontract and site-specific plans and instructions. This should be construed to mean any personnel used for purposes of administration or logistical support within the confines of the exclusion/contamination reduction zone as determined by the project manager.
- c. UST Removal Experience. In addition, the tank removal contractor must have a minimum of 2 years of tank removal experience and, if applicable, must be trained and certified by the state in which the removal is occurring.
- d. Unqualified Personnel. Any personnel deemed unqualified by the onsite project manager should be removed from the site.

1-7. Corrective Action Planning. The guidance in this manual is based on the requirements of federal regulations, AR 200-1 for FUDS and Installation Restoration Program (IRP) sites, and a review of state regulations. The IA may either be the U.S. Environmental Protection Agency (EPA) in states which have not adopted their own UST regulations, or a state agency where regulations have been adopted, or a local agency. The reader is responsible for determining the governing agency for each tank removal. Appendix B lists the state UST agencies.

- a. Release Response. A *release* is defined as any spilling, leaking, emitting, discharging, escaping, leaching, or disposing from an UST into groundwater, surface water, or subsurface soils. If there has been a release of petroleum hydrocarbons into the environment, the initial response requirements of 40 CFR 280.61 or the local IA requirements must be followed. The IA must be notified within 24 hours of discovery or within another reasonable time period determined by the IA. Simultaneously, Army Regulation 200-1 also requires the reporting of spills through command channels to the major Army command. After this, the requirements for initial abatement and site check (40 CFR 280.62) must be met including a report within 20 days of discovery or as required by the local IA.

Abatement activities include:

- (1) Removal of regulated substances from the UST system to prevent further release.
- (2) Visual inspection to prevent further migration to surrounding soils and ground water.
- (3) Mitigation of fire and safety hazards posed by vapors or free product
- (4) Remedy of hazards posed by excavated or contaminated soils exposed as a result of release confirmation.
- (5) Measure for the presence of a release where most likely to be present.
- (6) Investigation for free product.
- (7) Initiation of free product removal as soon as practicable.

If a release is confirmed, an Initial Site characterization report consistent with 40 CFR 280.63 may be required. Check with the local IA on the need for such a report and the deadline for submittal. You may be required to submit the report within 45 days of release confirmation or another reasonable time period as determined by the IA. The IA will then make a determination of whether a Corrective Action Plan with subsequent Remedial Action is required. This manual does not address spill responses. Information regarding spill response for Army installations is included in AR 200-1. Civil Works guidance on spill response for Civil Works activities is included in ER 200-2-3 and EP 200-2-3. Information concerning spill response notification for Air Force facilities is included in Air Force Instruction (AFI) 32-4002, Hazardous Material Emergency Planning and Response Compliance, and AFI 32-7002, Environmental Information Management System.

- b. Tank Closure. Figure 1-1 details the steps that are typically required for a clean tank closure, and Figure 1-2 details the procedures for a closure that requires site remediation. Both figures depict how these steps relate to coordination activities, project documents, and the chapters contained in this manual. Figure 1-3 provides a checklist for tank closure.

UST CLOSURE CHECKLIST	
<u>Date Completed/ & Initials</u> _____	1. Have the major decision-makers been identified? <input type="checkbox"/> Environmental Coordinator <input type="checkbox"/> USACE District Office Contracting Representative <input type="checkbox"/> Implementing Agency Contact
_____	2. Has the tank been identified and located?
_____	3. Is the tank history complete? <input type="checkbox"/> As-built Drawings <input type="checkbox"/> Utility Surveys
_____	4. Have the contents been identified?
_____	5. Has a visual site inspection been performed to identify potential construction difficulties and/or signs of leakage?
_____	6. Have the planning documents been prepared and approved? <input type="checkbox"/> Site Safety & Health Plan <input type="checkbox"/> Sampling and Analysis Plan <input type="checkbox"/> Project Work Plan
_____	7. Has an acceptable laboratory been identified and approved?
_____	8. Has a preliminary site investigation been conducted to determine whether site remediation is required?
_____	9. Have all permits been obtained? <input type="checkbox"/> Excavation <input type="checkbox"/> Tank Removal (regulatory agency permit)
_____	10. Have provisions been made for product and sludge removal? <input type="checkbox"/> Recycle of POLs <input type="checkbox"/> Manifest for Waste Disposal
_____	11. Have provisions been made for disposal of contaminated water? <input type="checkbox"/> POTW Acceptance of Waters <input type="checkbox"/> Recycle/Separation/Treatment <input type="checkbox"/> Manifest Waste Disposal
_____	12. Have the appropriate agencies been notified of exact date of tank removal? <input type="checkbox"/> Fire Department <input type="checkbox"/> Implementing Agency <input type="checkbox"/> Environmental Coordinator
_____	13. Have action levels and screening methods been determined for excavation of soils?
_____	14. Have the methods for soil treatment and/or disposal been identified?
_____	15. Have provisions been made for the tank ? <input type="checkbox"/> Destruction certification <input type="checkbox"/> Recycling
_____	16. Have provisions been made for site restoration?

FIGURE 1-3

1-8. Plan of Work. The tank removal contractor shall develop, implement, maintain, and supervise a comprehensive plan for tank removal and related operations. The work plan should be based on project specification requirements, work experience, the guidance provided in this manual, and the latest versions of the following guidance references: API Recommended Practice 1604, API Publication 2015, API Recommended Practice 2003, API Publication 2217, and API Publication 2219. This work plan will provide the USACE with the contractor's approach to performing the work. No work at the site is permitted to commence until the work plan is approved. At a minimum, the work plan should include:

- a. Scheduling and operational sequencing.
- b. Discussion of the approach for tank removal, tank cleaning, and tank destruction procedures.
- c. A Sampling and Analysis Plan (SAP) that describes sampling procedures and lists analysis parameters, methods, and laboratory or laboratories (as detailed in Chapter 8 of this manual). The SAP should include data quality objectives.
- d. Soil sampling locations and rationale for locations.
- e. Explanation of how the analytical results will be used.
- f. Identification of applicable regulatory requirements and permits including methods to be used to control volatile organic compound (VOC) emissions from decontamination fluids constituting RCRA regulated hazardous waste.
- g. Methods to be employed for residue, vapor, liquid, and contaminated water removal; purging; and storage and methods proposed for control of surface water.
- h. Identification of waste, tank, and contaminated-soil transporters and means of transportation.
- i. Disposal facilities, alternate disposal facilities, and means of disposal or remediation.
- j. Borrow source.

- k. Spill prevention plan.
- l. Spill contingency plan.
- m. Decontamination procedures.
- n. A statement that the contractor meets the qualification requirements.

1-9. Report Requirements. Typically a report is required by the IA for documentation of tank removal. For each UST site, a Tank Closure Report (Report) must be prepared and submitted. The Report must be prepared by the tank removal contractor and should be submitted within 14 days of site work completion to the COR with copies to the Installation Environmental Coordinator or Civil Works Environmental Compliance Coordinator. Number of copies required (for regulatory agency submittal) must be coordinated with the Environmental Coordinator or Civil Works Environmental Compliance Coordinator and included in the project specifications. The Report must be reviewed by the designers with incorporation of comments by the contractor before the Report is approved as final by the COR. Tank Closure Reports must include the following information as a minimum:

- a. A cover letter signed by a Certified Tank Remover certifying that all services involved have been performed in accordance with the requirements outlined in the specifications. The report shall contain the name, address, and phone number of the primary contractor and all subcontractors.
- b. A narrative report describing what was encountered at each site, including:
 - (1) Condition of the UST.
 - (2) Any visible evidence of leaks or stained soils.
 - (3) Results of vapor monitoring readings.
 - (4) Actions taken including quantities of materials treated or removed.
 - (5) Reasons for selecting sample locations.
 - (6) Sample locations.

- (7) Collection data such as time of collection and method of preservation.
 - (8) Procedures for backfilling site.
 - (9) Whether or not groundwater was encountered.
 - (10) Date of removal or closure.
 - (11) Capacity and construction of tanks.
- c. Notarized statement from the tank cleaning service, certifying the tank is clean.
 - d. Copies of tank destruction certification, verifying that the tank has been rendered useless.
 - e. Copies of all analyses performed for disposal.
 - f. Copies of all waste analyses or waste profile sheets.
 - g. Copies of all certifications of final waste disposal signed by the responsible disposal facility official. The original of all manifests must be returned to the generator.
 - h. Information on who sampled, analyzed, transported, and accepted all wastes encountered and copies of manifests.
 - i. Copies of all analyses performed for verification that underlying soil is not contaminated, with copies of the custody form for each sample. All analyses must give the identification number of the sample used. Sample identification numbers must correspond to those provided on the one-line drawings.
 - j. Conversation records/correspondence between contractors, subcontractors, and facility personnel or regulators.
 - k. Scaled one-line drawings referenced to a bench mark or other permanent point showing tank locations, limits of excavation, limits of contamination, underground utilities within 50 feet, sample

locations, sample identification numbers, locations of stockpiled soils, and sample locations with depths.

1. Progress Photographs. The contractor should provide color photographs of four or more different views of the site showing such things as the location of each tank, entrance/exit road, and any other notable site conditions before work begins. After work has been started at the site, the contractor should photographically record activities at each work location daily. Photographs should be 3 by 5 inches and may include:

- (1) Soil removal, handling, and sampling.
- (2) Unanticipated events such as discovery of additional contaminated areas.
- (3) Soil stockpile area.
- (4) Tank.
- (5) Site- or task-specific employee respiratory and personal protection.
- (6) Fill placement and grading.

- m. Post-construction Color Photographs. After completion of work at each site, the contractor should photograph a minimum of four different views of the site. Color prints should illustrate the condition and location of work and the state of progress. The photographs should be mounted and enclosed back-to-back in a double-face plastic sleeve punched to fit a standard three-ring binder. Each color print should have a corresponding information box, 1-1/2 by 3-1/2 inches. The box should be typewritten and arranged as follows:

Project No.	Contract No.
Location	
Contractor/Photographer	
Photograph No.	Date/Time:
Description	
Direction of View	

CHAPTER 2

SITE COORDINATION

2-1. General. The purpose of this chapter is to outline the site coordination that must be performed prior to tank removal. The list should be modified to satisfy the needs of each site.

2-2. Environmental Coordinator. The environmental coordinator, or on Civil Works facilities the facility manager, must be identified for each site where a UST is to be removed. The coordinator will be the interface between the regulatory agencies and the site. All impending work must be approved by the environmental coordinator.

2-3. Site Representative. The site representative must be contacted to determine if as-built drawings are available for the tanks, utilities, and facilities in the immediate area of the UST. Other aspects of the UST history should be investigated with the site representative, or on Civil Works facilities the facility manager.

2-4. Utilities. Prior to excavation, all necessary excavation permits must be completed. The utilities that must be located include but are not limited to water, gas, electricity, communications, sewer, and fuel lines. Excavation must not proceed until all utilities have been notified.

2-5. Transportation Routes and Traffic. Site representatives must be contacted to determine approved transportation routes for contaminated soil, excavated tanks, and backfill. If possible, the route should be one that is not subject to heavy traffic. Traffic control requirements (pedestrian and vehicular) around the excavation site and the transportation route must be established prior to excavation.

2-6. Fire Department Notification. The local fire department must be given sufficient notice to allow them to be present during tank excavation. The local fire chief must be contacted to determine whether any local ordinances apply during excavation.

2-7. Regulatory Agency. The governing regulatory authority requires notification upon discovery of a leak and prior to UST removal. The notification and permitting requirements must be completed for every tank removal. Appendix B lists state offices to expedite this process.

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2-8. Excavations. Each site should be evaluated to determine the appropriateness of leaving the excavation site open pending analytical results. The environmental coordinator or facility manager should indicate which sites may be left open. Barricades, safety fencing, or other precautions are required adjacent to the excavation in accordance with EM 385-1-1.

2-9. Cultural Resources. The facility coordinator responsible for oversight of archeological or cultural resources should be contacted prior to excavation to insure that the potential UST site is not located in a sensitive area. In the event that human remains or other cultural artifacts are accidentally discovered, discontinue excavation activities and contact the facility coordinator for cultural resources to initiate proper artifact removal.

CHAPTER 3

TANK TIGHTNESS TESTING PROCEDURES

3-1. General. The purpose of underground storage tank (UST) integrity tightness or tank tightness testing procedures is to determine the physical integrity of UST. The EPA, under 40 CFR 280 Subpart D, has established release detection requirements for all USTs. Tank tightness testing is used to indicate whether an UST meets the applicable release standards. Tank tightness testing should only be performed on tanks that are to be abandoned in place or tanks that are to remain active. You should choose a tank tightness test carefully to ensure that the test does not promote additional contamination of the surrounding environment. Both volumetric and nonvolumetric methods of tank tightness testing are described in this chapter. Some of these methods may be used for pipe integrity testing; however, pipe integrity testing is not the focus of this chapter.

3-2. Methods. Tank tightness testing can be performed in a variety of ways. A tank tightness test is a precision test that can be volumetric or nonvolumetric. A volumetric test measures volume changes quantitatively, while a nonvolumetric test measures changes qualitatively. Some methods require filling tanks to capacity, known as overfilling, where the fluid level reaches the fill tube. In these tests, the integrity of the entire tank and associated piping can be assessed. Other methods employ partially filled tanks, where only the integrity of the filled portion of the tank can be assessed. Tests can also be divided between constant-level and variable-level tests. In constant-level tests, product is added or removed to maintain a constant fluid level. Both overfilled and partially filled tanks can be used in constant-level tests. Variable-level tests allow the fluid level to fluctuate and are typically conducted on overfilled tanks. Tables 3-1 and 3-2 contain a summary of the various methods.

- a. Volumetric. Most tank tightness test methods account for volume changes as a function of product-level changes. A constant-level volumetric test directly measures the volume added or subtracted from a tank in order to maintain a constant level. A variable-level test measures changes in the level of the product and converts these level changes to volume changes using a height-to-volume conversion factor.

**TABLE 3-1
VOLUMETRIC LEAK TESTING METHODS**

Method	Principle	Claimed Accuracy, gal/h	Total Downtime for Testing	Requires Empty or Full Tank for Test
Ainlay Tank Integrity Testing	Pressure measurement by a coil-type manometer to determine product-level change in a propane bubbling system.	0.02	10-12 h (filled a night before 1.5-h testing)	Full
ARCO HTC Underground Tank Detector	Level change measurement by float and light-sensing system.	0.05	4-6 h	No
Certi-Tec Testing	Monitoring of pressure changes resulting from product-level changes.	0.05	4-6 h	Full
"Ethyl" Tank Sentry	Level change magnification by a J tube manometer.	Sensitive to 0.02-in level change	Typically 10 h	No
EZY-CHEK Leak Detector	Pressure measurement to determine product-level change in an air bubbling system.	Less than 0.01	4-6 h (2 h waiting after fillup, 1-h test)	Full
Fluid-static (standpipe) Testing	Pressurizing of system by a standpipe; keeping the level constant by product addition or removal; measuring rate of volume change.	Gross	Several days	Full
Heath Petro Tite Tank and Line Testing (Kent-Moore)	Pressurizing of system by a standpipe; keeping the level constant by product addition or removal; measuring rate of volume change; product circulation by pump.	Less than 0.05	6-8 h	Full
Helium Differential Pressure Testing	Leak detection by differential pressure change in an empty tank; leak rate estimation by Bernoulli's equation.	Less than 0.05	Minimum 48 h	Empty
Mooney Tank Test Detector	Measuring level change with a dip stick.	0.02	14-16 h ¹ (12 to 14 h waiting after fillup)	Full
PACE Tank Tester	Magnification of pressure change in a sealed tank by using a tube (based on manometer principle).	Less than 0.05	14 h	Full
PALD-2 Leak Detector	Pressurizing system with nitrogen at three different pressures; level measurement by an electrooptical device; estimate of leak rate based on the size of leak and pressure difference across the leak.	Less than 0.05	14 h (preferably 1 day before, 1-h fill testing, includes sealing time)	Full
Pneumatic Testing	Pressurizing system with air or other gas; leak rate measurement by change in pressure.	Gross	Several hours	No
Tank Auditor	Principle of buoyancy.	0.00001 in the fill pipe; 0.03 at the center of a 10.5-ft-diameter tank	1.5-3 h	Typically full
Two-tube Laser Interferometer System	Measuring level change by laser beam and its reflection.	Less than 0.05	4-5 h ²	No (at existing level)

1 Including the time for tank end stabilization when testing with standpipe.

2 Including 1 to 2 h for reference tube temperature equilibrium.

Source: USEPA 1986. *Underground Storage Tank Leak Detection Methods: A State of the Art Review*. EPA/600/2-86/001.

TABLE 3-2 NONVOLUMETRIC LEAK TESTING METHODS				
Method	Principle	Claimed Accuracy, gal/h	Total Downtime for Testing	Requires Empty or Full Tank for Test
Acoustical Monitoring System (AMS)	Sound detection of vibration and elastic waves generated by a leak in a nitrogen-pressurized system; triangulation techniques to detect leak location.	Does not provide leak rate; detects leaks as low as 0.01 gal/h.	1-2 h	No
Leybold-Heraeus Helium Detector, Ultratest M2	Rapid diffusivity of helium; mixing of a tracer gas with products at the bottom of the tank; helium detected by a sniffer mass spectrometer.	Does not provide leak rate; helium could leak through 0.005-in leak size.	None	No
Smith & Denison Helium Test	Rapid diffusivity of helium; differential pressure measurement; helium detection outside a tank.	Provides the maximum possible leak detection based on the size of the leak (does not provide leak rates); helium could leak through 0.05-in leak size.	Few-24 h (excludes sealing time)	Empty
TRC Rapid Leak Detector for Underground Tanks and Pipes	Rapid diffusion of tracer gas; mixing of a tracer gas with product; tracer gas detected by a sniffer mass spectrometer with a vacuum pump.	Does not provide leak rate; tracer gas could leak through 0.005-in leak size.	None	No
Ultrasonic Leak Detector (Ultrasound)	Vacuuming the system (5 lb/in ²); scanning entire tank wall by ultrasound device; noting the sound of the leak by headphones and registering it on a meter.	Does not provide leak rate; a leak as small as 0.001 gal/h of air could be detected; a leak through 0.005-in could be detected.	Few hours (includes tank preparation and 20-min test)	Empty
VacuTect (Tanknology)	Applying vacuum at higher than product static head; detecting bubbling noise by hydrophone; estimating approximate leak rate by experience.	Provides approximate leak rate.	1 h	No
Varian Leak Detector (SPY2000 or 938-41)	Similar to Smith & Denison.	Similar to Smith & Denison.	Few-24 h (excludes sealing time)	Empty

Source: EPA/600/2-86/001, "Underground Storage Tank Leak Detection Methods: A State of the Art Review."

b. Nonvolumetric.

- (1) Nonvolumetric tests can be divided into vacuum tests, probe tests, and tracer tests. The vacuum test subjects the tank to a slight vacuum, enough to counteract the fluid head within the tank. When a leak is encountered, bubbles form at the leak, separate at the tank, and undergo a volume pulsation of constant frequency that can be used to determine leak size.
- (2) The methods currently available for nonvolumetric tank testing use either a type of vapor monitoring or conduct the test under a vacuum. Neither method will provide an exact leak rate. However, each method will provide an analysis of the system in relation to the 0.1 gallons per minute (gpm) leak rate at a probability of detection of 0.95 and a probability of false alarm of 0.05. When selecting a nonvolumetric test method, make sure the method is approved for the entire volume of the tank and not just for the volume containing liquid on the day the tank is tested.

c. Performance. The performance of a leak-detection test method is measured by the accuracy and reliability of that test method in determining whether or not a tank is leaking. The best performance test methods are able to discriminate between the volume changes produced by a leak (signal) and other volume changes that normally occur in both nonleaking and leaking tanks (noise). This noise can often be confused with the leak by masking or mimicking the signal of the leak.

d. Results. A leak-detection test has five possible outcomes:

- (1) Correctly identified leak: an accurate test result where the measured condition reflects actual conditions.
- (2) Correctly identified tight tank: an accurate test result where the integrity of a nonleaking tank is confirmed.
- (3) A false alarm: an erroneous test result where the test mistakenly indicates a leak.
- (4) A missed detection: an erroneous test result where the test mistakenly indicates that the tank is tight when it is leaking.

- (5) An inconclusive test that does not provide either positive or negative evidence of a leak. Also, a positive result may or may not indicate whether the leak is in the tank or the associated piping.

3-3. Regulations. 40 CFR 280 Subpart D specifies the following general release detection requirements for all UST systems in § 280.40:

- a. Release Detection. "Owners and operators of new and existing UST systems must provide a method, or combination of methods, of release detection that:
 - (1) Can detect a release from any portion of the tank and the connected underground piping that routinely contains product;
 - (2) Is installed, calibrated, operated, and maintained in accordance with the manufacturer's instructions, including routine maintenance and service checks for operability or running condition; and
 - (3) Meets the performance requirements in § 280.43 or 280.44, with any performance claims and their manner of determination described in writing by the equipment manufacturer or installer. In addition, methods used after December 22, 1990, except for methods permanently installed prior to that date, must be capable of detecting the leak rate or quantity specified for that method in § 280.43 (b), (c), and (d) or 280.44 (a) and (b) with a probability of detection of 0.95 and a probability of false alarm of 0.05."
- b. Tank Tightness Testing. Section 280.43(c) specifies the following tank tightness testing performance requirements: "Tank tightness testing (or another test of equivalent performance) must be capable of detecting a 0.1 gallon-per-hour leak rate from any portion of the tank that routinely contains product while accounting for the effects of thermal expansion or contraction of the product, vapor pockets, tank deformation, evaporation or condensation, and the location of the water table."

3-4. Test Procedures. A summary of attributes of reliable integrity tightness testing methods has been developed by the EPA based upon research performed on over 25 commercially available methods. The testing methods are summarized in the following documents:

- *Standard Test Procedures for Evaluating Leak Detection Methods: Volumetric Tank Tightness Testing Methods*, EPA/530/UST-90/004, March 1990.

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- *Standard Test Procedures for Evaluating Leak Detection Methods: Nonvolumetric Tank Tightness Testing Methods*, EPA/530/UST-90/005, March 1990.

- *Standard Test Procedures for Evaluating Leak Detection Methods: Pipeline Leak Detection Systems*, EPA/530/UST-90/101, September 1990.

- *List of Leak Detection Evaluations for Underground Storage Tank (UST) Systems*, EPA/510/B-97/004.

- a. Documentation. Either the manufacturer or an independent third party can perform the demonstration tests. However, some states do not recognize results from demonstration tests performed by the equipment manufacturer. When purchasing release detection equipment or having a tank system tested, the organization providing the service or equipment must provide the owner/operator of the system with the manufacturer's documentation of equipment compliance with performance standards outlined in 40 CFR 280.40(a). This documentation must be retained at the facility to meet the record keeping requirements outlined in 40 CFR 280.34.
- b. Selection. Before selecting a tank tightness test method, check with state and local agencies to make sure the proposed method was adequately evaluated and demonstrated in the performance test report. Some states have additional evaluation methods and standards. They may require third-party testing or limit the release detection method to certain size (capacity) tanks. The standards used to evaluate the release detection method will be in the performance test report. These reports will provide the following information about the test equipment: method description, test results, the product used for testing, techniques used for measuring temperature and level, how data are acquired and recorded, limitation of the test method, and certification of results. From this, a determination can be made about the following:

TABLE 3-3 MAJOR VARIABLES AFFECTING LEAK DETECTION	
Variable	Impact
Temperature Change	Expansion or contraction of a tank and its contents can mask leak and/or leak rate.
Water Table	Hydrostatic head and surface tension forces caused by groundwater may mask tank leaks partially or completely.
Tank Deformation	Changes or distortions of the tank due to changes in pressure or temperature can cause an apparent volume change when none exists.
Vapor Pockets	Vapor pockets formed when the tank must be overfilled for testing can be released during a test or expand or contract from temperature and pressure changes and cause an apparent change in volume.
Product Evaporation	Product evaporation can cause a decrease in volume that must be accounted for during a test.
Piping Leaks	Leaks in piping can cause misleading results during a tank test because many test methods cannot differentiate between piping leaks and tank leaks.
Tank Geometry	Differences between the actual tank specifications and nominal manufacturer's specifications can affect the accuracy of change in liquid volume calculations.
Wind	When fill pipes or vents are left open, wind can cause an irregular fluctuation of pressure on the surface of the liquid and/or a wave on the liquid-free surface that may affect test results.
Vibration	Vibration can cause waves on the free surface of the liquid that can cause inaccurate test results.
Noise	Some nonvolumetric test methods are sound-sensitive and sound vibrations can cause waves to affect volumetric test results.
Equipment Accuracy	Equipment accuracy can change with the environment (e.g., temperature and pressure).
Operator Error	The more complicated a test method, the greater the chance for operator error, such as not adequately sealing the tanks.
Type of Liquid Stored	The physical properties of the liquid (including effects of possible contaminants) can affect the applicability or repeatability of a detection method (e.g., viscosity can affect the sound characteristics of leaks in acoustical leak-detection methods).
Power Vibration	Power vibration can affect instrument readings.
Instrumentation Limitation	Instruments must be operated within their design range or accuracy will decrease.
Atmospheric Pressure	A change in this parameter has the greatest effect when vapor pockets are in the tank, particularly for leak-rate determination.
Tank Inclination	The volume change per unit of level change is different in an inclined tank than in a level one.

Source: USEPA 1986. *Underground Storage Tank Leak Detection Methods: A State of the Art Review*. EPA/600/2-86/001.

- (1) The amount of time required for the tank's contents to stabilize after a delivery of product.
- (2) The required test duration for collecting data to accurately determine the condition of the tank.
- (3) Limitations of the test method (such as tank capacity).
- (4) The actual minimum leak rate the test method can detect to a probability of detection of 0.95 and a probability of false alarm of 0.05.
- (5) Whether a third party or the equipment manufacturer conducted the performance test.

c. Performance. The performance claims for leak-detection devices produced by commercial manufacturers will not be discussed in this document. Refer to EPA/625/9-89/009 *Volumetric Tank Testing: An Overview* and EPA/510/B-97/004 *List of Leak Detection Evaluations for Underground Storage Tank (UST) Systems* and literature from individual manufacturers for additional information on the performance of specific commercially available devices.

3-5. Precautions. Table 3-3 summarizes the variables that can affect leak detection. Three of the major variables are discussed below.

a. Noise. A tank tightness or volumetric test measures the change in the volume of fluid in a tank, accounts for other sources of noise (normally occurring volume changes), and attributes the adjusted volume change (if it is above the threshold level) to a leak. Therefore, it is essential that a test method differentiate between and compensate for nonleak-related volume changes (noise) versus actual leaks. There are five common nonleak-related product-volume (or product-level) changes that are sources of ambient noise, some potentially producing larger errors than others. Precautions are incorporated in most reliable test methods to compensate for those phenomena and to minimize the probability of false alarms.

- (1) Thermal expansion or contraction of the product resulting from product addition or removal during volumetric testing can be a major source of noise and, thus, error in tank tightness testing. Volume changes due to expansion and contraction of the product in a filled tank may be as large as 3.8 L (1 gallon) per

hour. Reliable test methods compensate for this phenomenon by requiring a waiting period following any tank additions prior to measurement collection.

- (2) Vapor pockets commonly occur in tanks and the associated piping that have been filled to capacity. Temperature fluctuations and pressure changes in the tank contents cause the expansion or contraction of vapor pockets. Volume changes of trapped vapors produce product-level changes that may be misinterpreted as leaks. Vapor pockets as small as 38 liters (10 gallons) in a 38,000 liter (10,000-gallon) tank can influence test results. In preparation for tightness testing, if vapor pockets of 40 to 80 liters (10 to 20 gallons) or more are suspected, the tank and lines should be bled as a precaution.
- (3) In addition to level, temperature, and pressure changes associated with a product, the tank itself will exhibit expansion and contraction, or structural deformation. This deformation, in turn, causes the product level to change, which could be mistaken as a leak. Both instantaneous deformation and time-dependent relaxation of a tank occur. Reliable tank testing procedures introduce a waiting period between product addition and measurement collection as a precaution to allow the tank deformation effects to subside.
- (4) Minor volume fluctuations may result from the evaporation of product from the fluid surface or condensation of product on tank walls. This phenomenon is more likely to occur in tanks that are not completely filled and contain air or vapor pockets. Completely filling and bleeding tanks and lines prior to test initiation are precautions that will minimize this type of "noise."
- (5) Surface or internal waves may be caused by mechanical vibrations or temperature boundary layers within a tank. These waves can produce apparent level changes that could be mistaken for volume changes or leaks. Infrequent sampling that does not detect this wave phenomenon, known as biasing, can indicate a false result. To prevent this, use reliable test methods such as frequent sampling and averaging of data during the test. Perform tests

during hours when local traffic, especially trucks, would be less prevalent so the impact on test results would be minimized.

b. Groundwater. The location of the groundwater table at the time of testing is another factor that can interfere with accurate tank tightness testing. Unlike the five factors mentioned previously, the groundwater level does not mimic a leak; however, it may have a direct effect on the apparent size of the leak. Existing site information (boring logs) should be used to estimate the depth to groundwater rather than mobilizing a rig and crew to determine the depth to groundwater. When the groundwater level is above the leak, it can restrict or prevent the flow of product out of a tank, and a leak can go undetected. As a precaution, it is important to monitor the groundwater level with respect to the bottom of the tank each time a tank tightness test is conducted. Best results are obtained when the water table is below the tank. If the tank normally is above the water table and recent precipitation has altered that situation, consider delaying the test until the water table has dropped and this potential interference is removed. If at all possible, a test should not be conducted while the water table is fluctuating. If this situation cannot be avoided, such as in a tidal area, it should be understood that the test results will be less accurate and reliable.

c. Volumetric Methods. Tank tightness testing using volumetric methods should not be conducted through the fill pipe. Volumetric test methods record temperature at various points along the diameter of the tank and require precise measurements for the test to be valid. The fill pipe would mask the true temperatures of these various points along the tank diameter.

3-6. Equipment. Each commercially available leak detection method has two components: equipment and procedures. Both the equipment (physical devices, computer hardware, and instrumentation) and procedures (operator responsibilities, computer software, theoretical and analytical approaches) can vary from one method to another. This can result in variances in method performance for different leak rates and threshold values.

a. Temperature/Volume. The majority of tank tightness test requirements include equipment that measure the temperature and volume of the product in a tank, such as thermistors and height or volume sensors.

Some methods include arrays with multiple sensors that better represent actual conditions vertically within the tank.

- b. Data Measurement. The more sophisticated measurement and data analysis equipment is often used to take frequent measurements that can be statistically analyzed and provide a good representation of actual conditions within the tank. This frequent measurement rate and the resulting statistical analyses are typically facilitated by computer equipment.
- c. Additional Information. The reader is directed to manufacturers' literature for details about specific test methods. EPA/625/9-89/009, *Volumetric Tank Testing: An Overview*, is also recommended as a source of information about a number of different methods that were evaluated by the EPA.

3-7. Materials. Once a tank tightness test method has been selected, the operator will provide the necessary equipment, handling/transferring procedures, and training on material safety data sheets (MSDS) for the liquids to be used. The only material that is typically necessary is additional product to fill the tank.

To ensure an accurate test, use product identical in formulation to that which is already in the tank. The added product should also be approximately the same temperature as the product already in the tank to minimize volume expansion or contraction due to temperature variations. If temperatures are not identical, the required settling time prior to testing should be sufficient to allow the temperatures to equalize.

It should be noted that topping off tanks with product may be difficult. The Defense Fuel Supply Center that contracts for most of the Army's fuel has stated they will not contract to have the tanks topped off. Individuals responsible for performing the integrity testing will provide added fuel to top off the tanks to be tested.

3-8. Operations, Procedures, and Instructions. There are three steps involved in all tank tightness testing: preparation, testing, and analysis. Although operations, procedures, and instructions will vary for each commercial test method selected, the common elements of the methods are described. The procedures for a particular test must be strictly followed to assure the performance cited.

a. Preparation.

- (1) The tank is first filled to the level required for testing with the same product at the same temperature as the tank contents. A waiting period follows to allow temperature variations, wave actions, and structural deformations to subside. If necessary, the tank is bled to reduce vapor pockets.
- (2) The sensor instrumentation is inserted into the tank. In the case of overfilled tests, the tank is topped off by adding or removing small amounts of product to bring the product to the test level. A second waiting period is observed.
- (3) Values are taken to determine the coefficient of thermal expansion and/or the height-to-volume conversion. The water-table level is also measured if it is in the vicinity of the tank and if there is a monitoring well.

b. Testing. The sensors inserted into the tank measure the temperature and the level (or volume) of the product in the tank over time. Often these two measurements are collected at the same rate. The instrument readings are recorded either electronically or manually. The test ends based on the data results. Often this is a function of time, but sometimes the decision to end the test is controlled by other measurements.

c. Analysis.

- (1) Convert the level data to volume data and compensate for temperature changes using procedures defined by the manufacturer. Use these data to calculate a volumetric flow rate of leakage from the tank.
- (2) Compare this calculated volumetric flow rate to the predetermined detection criterion for the test. If the calculated volumetric flow rate exceeds the detection criterion, a leak is suspected. If not, it is assumed that no leak is present.

3-9. Waste Disposal. Typically, no wastes are generated during integrity tightness testing. If any product is spilled as a result of the testing, it should be handled consistently with procedures outlined in Chapter 6.

3-10. Reporting and Documentation.

a. Reporting. Owners and operators of UST systems must report suspected releases based upon tank tightness test results to the implementing agency within 24 hours, or another reasonable time period specified by the implementing agency. This requirement is mandatory unless the monitoring device is found to be defective and is immediately repaired, recalibrated, or replaced, and subsequent monitoring does not confirm the initial result.

b. Documentation.

(1) All UST system owners and operators must maintain records demonstrating compliance with applicable regulations.

(2) The records must include the following:

(a) All written performance claims pertaining to any release detection system used, including the manner in which these claims have been justified or tested by the equipment manufacturer or installer. Claims must be maintained for 5 years, or for another reasonable period of time determined by the implementing agency, from the date of installation.

(b) The results of any sampling, testing, or monitoring must be maintained for at least 1 year, or for another reasonable period of time determined by the implementing agency. The results of tank tightness testing must be retained until the next test is conducted.

(c) Written documentation of all calibration, maintenance, and repair of release detection equipment permanently located onsite must be maintained for at least 1 year after the servicing work is completed, or for another reasonable time period determined by the implementing agency. Retain schedules of required calibration and maintenance provided by the release detection equipment manufacturer for 5 years from the date of installation.

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CHAPTER 4

UNDERGROUND STORAGE TANK (UST) INVESTIGATIVE REQUIREMENTS

4-1. General. This chapter discusses data gathering and investigative techniques to determine where the tank is located and what has been in the tank.

4-2. Tank History/Information. Prior to a UST removal, a history of the tank characteristics should be assembled by the designer. It should be as detailed as possible from readily available sources such as records, reports, and interviews. Data gathering is important because the more information a designer has prior to construction, the less surprises will be encountered during removal. Items of specific interest and associated tasks include:

- a. Existing Drawings. Review engineering drawings, preferably as-built, and interview the site personnel. Determine, if possible, the tank and associated piping location, the dimensions and capacity of the tank, material of construction, depth, corrosion protection systems, presence or absence of ballast pads and tie downs, age, and date tank was last used. In some instances, this information may be on an installation's utility maps. If existing drawings cannot be obtained, refer to later parts of this chapter for investigative procedures to obtain tank information.
- b. Inventory Control Records. Review inventory control records as a source of information to determine the types of liquids stored in the tank and whether the tank system has leaked.
- c. Interviews. Determine from site personnel the location, magnitude, and duration of any environmental releases associated with the UST. Determine how the liquids were placed into and removed from the tank, monitoring procedures followed, and the types of liquids stored in the tank. Determine if abandoned tanks were filled with sand, water or concrete at the time of abandonment. A list of previous employees who may have worked in the area should be obtained from the installation to facilitate this process.
- d. Utilities. Locate all underground utilities including, but not limited to, sanitary sewers, storm sewers, water lines, gas lines, power lines, telephone lines, and all associated piping and

appurtenances associated with the area immediately surrounding the tank.

- e. Site Characteristics. Determine depth, rate, and direction of groundwater and soil characteristics from record searches if possible. This information is not required for all removals, but it is helpful information for the designer. If data is not available and it is determined to be necessary for tank removal, refer to Chapter 5 for investigative procedures.

4-3. Regulatory Issues. Federal, state, and local agencies will need to be contacted well in advance of tank removal (a minimum of 30 days). Preferably, the Environmental Coordinator should contact the applicable agencies. In many cases the regulatory agency may want to have an individual onsite to observe tank removal. Appendix B lists state agencies in charge of UST management. In addition, state regulatory agencies can supply lists of licensed tank removal/disposal firms and provide guidance for waste disposal and other useful information. Tanks storing hazardous waste are regulated under 40 CFR 264/265 and are outside the scope of this document.

4-4. Tank Locations.

- a. As-Built Drawings. One source of information for locating USTs is the construction drawings used to install the tank. In some instances, this information may be on an installation's utility maps. Once the drawings have been obtained, they should be field-verified by the designer, if possible, to determine whether the tank is in the location specified. You should recognize it may be difficult to verify as-built drawings.
- b. Visual Inspection. You may be able to locate tanks by visually locating manholes, variations in concrete or asphalt, vent pipes, fill pipes, and ground depression or elevation. In some instances visual inspection by itself is not reliable. Insert a steel probe into the ground to assist the visual inspection.
- c. Geophysical Methods. In cases where documentation of tank locations is questionable or nonexistent, the application of surface geophysical methods has been a successful means of delineating approximate tank boundaries. These methods can provide information that would be otherwise unavailable without costly, and often dangerous, ground-intrusive activity. In addition, the same types of

geophysical data used to identify tank burials can often supply useful information concerning local hydrogeologic conditions, and in some instances, the extent of any gross contamination associated with an UST system. The success of any single geophysical technique at a given site is dependent on site-specific conditions. Therefore, it is generally recommended that you apply more than one geophysical technique to any single objective to accommodate situations where the data from a particular method are deemed problematic. In such a situation, the questionable data can often be quite useful when they are used as a supplement to more definitive data.

Carefully review all pertinent background information and conduct a site visit before designing any geophysical survey to make prudent selections of techniques and to optimize the efficiency of the survey. Several methods are discussed below and presented in Table 4-1. For more detailed information, the reader should consult EM 1110-1-1802 and ASTM PS78. Also the reader may refer to EPA/625/R-92/007.

- (1) Magnetometer Surveys. One of the most commonly used techniques is magnetometry. Ferromagnetic objects, such as a steel tank, produce variations, or anomalies, in the earth's magnetic field. These aberrations are localized and can be mapped at the surface using one of a variety of magnetometers. Magnetometer surveys are relatively easy to implement, but interpretation of magnetic data alone is not always straightforward. Ferromagnetic objects at the surface (e.g., buildings, fences, automobiles) will produce anomalies that may alter or mask anomalies caused by ferromagnetic items beneath the ground. In addition, the position of magnetic anomalies at the surface does not necessarily mimic the position of their underground sources.

- (2) Terrain Conductivity. Terrain conductivity is a function of the type of subsurface material, its porosity, permeability, and the fluids that fill the pore space. Accordingly, this electromagnetic (EM) technique is applicable to assessment of some natural hydrogeologic conditions as well as to mapping contaminant plumes, trench boundaries and, of course, identifying buried tanks. Similar to magnetic field surveys, conductivity surveys are relatively fast and easy to perform. The conductivity data are also susceptible to the same surficial "interferences" (caused by cultural features) that can plague

**TABLE 4-1
GEOPHYSICAL METHODS**

Method	Depth of Penetration	Resolution	Advantages	Disadvantages
Magnetometer (MAG)	Single 55-gallon drum, up to 6 meters. Massive piles 55-gallon drums, up to 20 meters.	Good ability to locate targets.	Quick, one-man operation. Can readily detect buried ferrous objects (buried drums or pipe lines).	Large masses of ferrous objects can have broad response preventing precise location of individual targets. Susceptible to interference from surface metallic objects such as fences. Will not detect materials with low magnetic susceptibility (i.e., nonferrous objects such as fiber tanks).
Terrain Conductivity	Depth controlled by system coil spacing 0.5 to 60 meters typical.	Excellent lateral resolution. Vertical resolution of two layers. Thin layers may not be detected.	No electrodes required—can be used on surfaces where electrode plants would be impossible. Very fast and efficient. One or two man crew. Can be conducted through fresh water. Two-coil orientations and several intercoil separations available to allow several depths of investigation.	Depth inversion ability very limited. Relatively insensitive to changes in conductivity in highly resistive targets. Highly conductive surface materials limits depth of penetration.
Ground Penetrating Radar (GPR)	One to ten meters typical—highly site-specific. Limited by fluids and soils with high electrical conductivity and by fine-grained materials.	Greatest of all three geophysical methods.	Resolution can be on the order of a few centimeters. Provides a cross-section of subsurface. Can detect buried drums—ferrous or nonferrous. Can detect variations in soil type or moisture. Can detect disturbed soil zones. Can detect water table.	Equipment is cumbersome—usually requires flat surface. Depth of penetration seriously limited by conductive material such as clay or water. Decreasing transmitter frequency to increase penetration decreases resolution.

magnetometer data. However, conductivity meters generally provide much better lateral resolution over a buried target. Further, effective penetration depths and sensitivity (to metal) can be adjusted according to the objectives of the survey. Shallow terrain conductivity data can provide lateral resolution on the order of a few feet, which is usually sufficient for most tank removals.

- (3) Ground Penetrating Radar (GPR). If site conditions preclude the use of magnetic and electromagnetic techniques, ground penetrating radar (GPR) is also a viable, though more expensive, means of identifying buried tanks. In fact, GPR can often provide lateral resolution on the order of a foot or less and thus minimize costly excavation. The GPR technique uses high frequency radio waves to acquire subsurface information. From a small transmitter antenna which is moved slowly across the ground, energy is radiated downward below the surface, then reflected back to a receiver antenna. Variations in the return signal are continuously recorded in the instrument's console, providing a continuous "cross-section" of shallow subsurface conditions. An interface between materials having significantly different electrical properties will be apparent on the radar profile. Buried tanks and other discrete objects can be identified providing they are of sufficient size to overcome the inverse relationship between resolution and depth penetration. The depth of penetration with GPR is highly site-specific and is limited by subsurface attenuation of the radar waves; this attenuation is accelerated in materials that have higher electrical conductivities. Generally, better penetration is achieved in dry, sandy, or rocky areas while poor results are obtained in moist, clayey, or conductive soils.

4-5. Site Reconnaissance. During efforts to locate the tank, the following items should also be noted by the designer:

- a. Cover. Identify whether the tank is covered by grass, concrete, asphalt, etc. If possible, determine thickness of cover by reviewing as-built drawings or inserting a steel rod through the soil. This information will be used in preparation of excavation requirements.
- b. Building Proximity. Note where the tank is located with respect to buildings. If the tank is located too close to a building to remove safely, the option to close the tank in place must be evaluated. A tank should be far enough away from buildings to allow the excavation to be safely completed within the excavation criteria specified in

Chapter 7. Note whether any subsurface structures, such as basements, sewers, and other utilities are present where vapors can collect.

- c. Evidence of Leakage or Spillage. Visually inspect the area above and surrounding the tank. Note whether there is any surface contamination indicated by dark soil or stressed vegetation. Evidence of leakage can sometimes be found in sanitary and storm water manholes near USTs, in basement sumps, and in nearby surface waters or groundwater seeps or springs.
- d. Utilities. Verify the utility drawings or obtain verification from the utility as to the exact location of underground or overhead utilities. Note any deviations from the drawings. Evaluate any effects of utility location on construction activities.

4-6. Tank Contents Sampling. The determination of the chemical composition of the tank contents and an estimate of the volume of these contents is crucial in the decision-making process to be performed by the USACE. This task may be performed by USACE or a contractor. The objective of tank sampling is to characterize tank contents and to separately identify those tanks that contain only fuel oils, petroleum products, or related materials from those that contain PCBs, contaminated oils, solvents, or other hazardous waste constituents as defined in 40 CFR 260.10 and listed in 40 CFR 261 Appendix VIII.

If hazardous substances are found during design or predesign activities, ensure adequate lead-time to plan appropriate construction activities. Also, the USACE may recommend limiting subsequent chemical investigations at this site to include only those analytes found in the UST. The results of these analyses can also simply be used to determine the proper method of disposal, including recycling for beneficial use. Many USACE Districts utilize Indefinite Delivery/Indefinite Quantity (ID/IQ) UST Removal Contracts, which include the sampling as a part of the removal process. These contracts make assumptions based on information provided by the USACE District in a scope of work and a site visit conducted jointly by the contractor and the USACE. Refer to paragraph 4-2 regarding site investigative activities.

- a. Typical properties exhibited by petroleum products are discussed below. Petroleum products can be divided into the following general groups:
 - Gasolines.
 - Middle distillates.
 - Heavier fuel oils and lubricating oils.

- (1) Gasolines are blends of petroleum-derived chemicals plus additives that improve fuel performance and engine longevity. Gasolines range in density from 0.72 to 0.78 g/cm³ and are less viscous than water. Gasoline is immiscible in water; however, there are many components of gasoline that readily dissolve upon contact with water.
 - (2) The middle distillate group includes diesel fuel, kerosene, jet fuel, and lighter fuel oils. These fuels may contain as many as 500 individual compounds; however, these compounds tend to be more dense, less volatile, less mobile, and less water soluble than gasoline materials.
 - (3) Heavier fuel oils are similar in composition and characteristics to the middle distillates. These types of fuels are relatively viscous and insoluble in groundwater and are relatively immobile in the subsurface. See Table 4-2 for properties of six common petroleum products.
- b. High Concentration Hazard. Until the identity of UST contents is known, all UST contents should be classified and treated as high-concentration waste for purposes of sample handling.
- c. Overview. As a general guideline, the volume of liquid and sludge content in the UST should be estimated before any sampling is done. The USACE Contracting Officer's Representative (COR) can make a decision regarding sampling once these quantities are known. The USACE may have the option (depending on state and local regulations) not to sample a layer and treat the entire layer as hazardous waste. If this option is not exercised, the following sampling plan should be employed.
- (1) Only one liquid layer present: Collect subsamples at two depths: near the surface (20 percent depth) and near the bottom (80 percent depth). These two subsamples should be composited to form a single sample for analysis.
 - (2) Two liquid layers present: Sample each liquid layer and treat as a separate sample.
 - (3) Empty tanks: Do not sample tanks found to be free of any liquid phase. If there is reason to believe that an empty tank may have held chemicals other than petroleum, oils, and lubricants (POLs), consult the Center of Expertise (HTRW-CX) for guidance.

**TABLE 4-2
PHYSICO-CHEMICAL PROPERTIES OF SIX COMMON HYDROCARBON MIXTURES**

Product	Liquid Density (g/cm ³)	Liquid Viscosity (cPoise)	Water solubility (mg/L)	Vapor Pressure (mm Hg)	Vapor Density (g/m ³)	Flashpoint (°C)
Automotive Gasoline	(0.73) 0.72-0.76 [15.6]	(0.45) 0.36-0.49 [15.6]	(158) 131-185 [13-25]	(469) 263-675 [38]	1,950	<2
No. 2 Fuel Oil	(0.91) 0.81-0.92 [15]	(1.56) 1.15-1.97 [21]	3.2	(14.3) 2.12-26.4 [21]	109	>38
No. 6 Fuel Oil	(0.96) 0.93-1.06 [15]	(254) 14.5-493.5 [38]	~5	(14.3) 2.12-26.4 [21]	105	>38
Jet Fuel (JP-4)	0.75	0.829 [21]	<300	91	400	-23
Jet Fuel (JP-8)	0.80	1.98	Negligible	50	N/A	46
Mineral Base Crankcase Oil	0.84-0.96 [15]	275 [38]	Negligible	N/A	N/A	>38

N/A = Not Available

Note: All values are approximate. Tank contents may be mixtures with varying characteristics.

Note: Values for 20°C unless otherwise indicated. Brackets [] indicate a different temperature in °C.

Note: Values in parentheses are typical of the parameter.

Note: Density of fuel vapors is greater than air so vapors will tend to collect in low places.

Source: Compiled from various published and unpublished sources.

- d. Strategy for the Analysis of UST Contents. There are only a few categories of liquids likely to be present in underground storage tanks at most sites: (1) fuel oil/diesel (2) gasoline (3) jet fuel (4) kerosene (5) heating oil (6) oily water (7) chlorinated solvents (8) waste oil (9) herbicides and/or pesticide/PCBs, (10) paint and plating waste/byproducts, and (11) used oil. Sampling strategy will vary depending upon the type of material stored and whether the material is intended for recycle or disposal. Commercial chemicals and fuel products recovered from an UST used for product storage that are still suitable for use can still be used for their intended purpose. They do not have to be disposed of as hazardous waste. For these types of materials, analysis will be confirmatory in nature to determine the product identity and purity. However, fuel water mixtures that must be processed in order to be usable, materials that can not be used for their intended purpose, waste oils, used oils, and spent materials will require analysis to characterize them for recycle or disposal.
- (1) The analyses outlined here are intended to obtain enough information to adequately identify the tank contents for proper recycle/disposal in accordance with applicable federal and state regulations. The analyses should help determine whether the fluid in an UST is a useable product, is expected to become a hazardous waste when removed for disposal, or is just oily water that may be discharged to a nearby publicly owned treatment works (POTW) or an oil-water separator.
 - (2) For used oily wastes, the sampling strategy begins with consideration of EPA's Standards for the Management of Used Oil, 40 CFR 279. To ensure oily waste is not subject to hazardous waste regulation, sample for total halogens. If the result is less than 1,000 mg/L halogens, then additional testing would be limited to parameters listed in Table 4-3. If more than 1,000 mg/L total halogens are detected, the oily waste is presumed to be hazardous waste unless demonstrated otherwise. To pursue a non-hazardous waste demonstration, Methods 8021 or 8260 may be utilized to determine whether significant amounts of halogenated hazardous constituents from Appendix VIII of 40 CFR 261 are present.

The basis for this testing is found in used oil standards in 40 CFR 279. According to these standards, if oily waste contains greater than 1,000 mg/L total halogens, it is presumed that listed hazardous waste was mixed into the oil. The resultant mixture is then regulated as hazardous waste unless it can be demonstrated that the source of the halogens was not hazardous waste. Once the hazardous waste presumption is rebutted, use Table 4-3 to determine

whether the oil is on-specification or off-specification. As can be seen from Table 4-3, used oil can contain up to 4,000 mg/L total halogens and still be considered on-specification used oil provided the hazardous waste presumption has successfully been rebutted.

TABLE 4-3 USED OIL SPECIFICATION	
Constituent/Property	Final Rule Allowable Level
Arsenic	5 ppm maximum
Cadmium	2 ppm maximum
Chromium	10 ppm maximum
Lead	100 ppm maximum
Total Organic Halogens	1,000 ppm rebuttable 4,000 ppm maximum
Flashpoint	100 degree F minimum

On-specification used oil can be burned in any type of burner. Off-specification used oil, on the other hand, is restricted to being burned in devices listed in 40 CFR 279.61. This limits burning to industrial boilers; industrial furnaces; utility boilers used to produce electric power, steam, heated or cooled air, or other gases or fluids for sale; on-site space heaters meeting the criteria of 40 CFR 279.23; and hazardous waste incinerators.

The used oil specification in Table 4-3, however, only applies to used oil. It does not apply to fuel products. For fuel products the sampling strategy will be based primarily on the requirements of the fuel purchaser/user. Additionally, testing may be required to determine the Department of Transportation (DOT) Proper shipping name for the fuel if sufficient knowledge of the material is not available. Generally, testing for flashpoints and boiling points of petroleum products will be sufficient to determine applicable DOT shipping requirements.

For materials that are not petroleum fuels or used oils such as waste waters, paint wastes, pesticides, PCBs, etc., the sampling strategy will be to analyze the material to determine whether there are viable recycling and/or energy recovery options and to determine whether the material is subject to regulation under the Resource Conservation and Recovery Act (RCRA) or the Toxic Substances Control Act (TSCA).

e. Required Analyses.

- (1) Analysis for used oil: Analyze each UST organic liquid sample collected for total arsenic, total cadmium, total chromium, total lead, total organic halogens, and flashpoint. Currently, no EPA method correctly analyzes organolead in a liquid organic matrix. The organic layer is not usually analyzed for total recoverable petroleum hydrocarbons (TRPH) since it is usually 100 percent hydrocarbon (unless required by applicable regulations). Analysis to determine fuel type is more appropriate.
- (2) Analysis for petroleum products: Characterization tests may be provided by the receiving facility in accordance with state and local regulations. Some facilities perform the work at the receiving facility. Others require characterization tests prior to shipment. The ignitability test requires only 2 mL of sample. Ship samples as high concentration wastes. Adhere to the USACE *Sample Handling Protocol* in EM 200-1-3, Appendix F explicitly.
- (3) Analysis for non-petroleum wastes such as waste waters, PCBs, etc.: (NOTE: the scope of this EM does not include hazardous waste tanks; however, hazardous wastes may be encountered incidental to other activities such as when water intrudes into a gasoline product tank. Therefore, this section is intended to address these types of wastes.) Aqueous layers in the tank may be sampled for TRPH; RCRA characteristics including pH, flashpoint, and TCLP constituents reasonably expected to be present such as lead (or RCRA metals); PCBs; and volatile organic compound analytes. VOC analysis requirements are specified in 40 CFR 265.1084. If both organic and aqueous phases are present, the USACE may elect to analyze each phase for certain parameters selected from the complete list to minimize redundancy. The laboratory used for these analyses should be validated to ensure that it is capable of performing these analyses correctly.
- (4) Analysis for compliance with DOT requirements: Unless the material is a known product, analysis will typically include pH, flashpoint, and boiling point.

f. Tank Accessibility.

- (1) Underground storage tanks may not always be easily accessible for testing during preconstruction activities. Tanks and their filler caps may have been paved over or may be under debris. The contractor for sample collection must consult with the Contracting Officer's Representative (COR) before removing soil or debris to gain access to an UST. In cases where UST accessibility is not possible, tank sampling may be deferred until the construction phase. The construction contractor will facilitate access to the tank by removing debris and dirt so that a sampling subcontractor may collect samples during the construction phase. You should recognize that if tank sampling is deferred until construction due to limited accessibility, the lack of information can lead to costly problems if surprises are encountered. These problems may include contractor downtime, contract modifications, and unexpected increases in disposal/treatment costs. The tank should not be moved until the tank contents can be characterized.
- (2) Situations will arise in which UST access is not possible even though the fill pipe is accessible. This may be the result of corrosion. In this event, the field sampling supervisor should contact the project manager for guidance.

- g. UST Contents Sampling Instructions. These instructions provide a reasonable method for sampling USTs and may be modified or replaced with equivalent instructions to allow for site-specific constraints. Sampling devices must be explosion proof. Acceptable sampling devices include: peristaltic pumps, bladder pumps, weighted bottles, Kemmerer samplers, bailers, or COLIWASAs (for small tanks). See EM 200-1-3 for guidance on sampling methods or refer to EPA/540/P-91/005 *Compendium of ERT Surface Water and Sediment Sampling Procedures*, EPA/540/P-91/008 *Compendium of ERT Waste Sampling Procedures*, and EPA/600/2-80/018 *Samplers and Sampling Procedures for Hazardous Waste Streams* for additional information on these type of samplers. The peristaltic pump provides the most convenient method of withdrawing a sample from a tank and makes it easy to sample separate phases. Instructions for sampling liquid layers in a tank are:

- (1) Wear personal protective equipment as specified in the Site Safety and Health Plan.
- (2) Remove the fill pipe cap with use of nonsparking tools.
- (3) Determine depth of tank and depth of tank contents: Lower a wooden stick (1" by 1" by 12') coated with water-indicating paste (e.g., Kolor Kut™) to the bottom of the tank. Record the following:
 - Distance from the bottom of the tank to the soil surface.
 - Total depth of the sludge layer (if this can be determined by inspection of the stick).
 - Total depth of each layer of liquid in the tank.
 - Whether each layer is aqueous or nonaqueous. (Chlorinated solvents are more dense than water; oil, gasoline, etc. are less dense than water.) If the water is on top, the water-indicating paste will **not** indicate the presence of the heavier-than-water organic layer.
- (4) Collect each separate stratified liquid and/or solid phase for chemical analysis.
- (5) To collect a sample using a peristaltic pump:
 - Fasten the tubing to the stick (used for measuring the depth of the product) at the point from which the sample is to be withdrawn.
 - Extend the stick into the tank until it reaches the bottom.
 - Operate the pump to withdraw the sample directly into the sample bottle.
 - Adjust the stick to withdraw a sample from another depth.
 - Other methods of sample collection are detailed below.
 - (a) Weighted Bottle. Carefully remove cork with a short, sharp tug on the chain. Allow adequate time for the bottle to fill. Additional guidance may be found in ASTM Standards D 4057 and E 300.
 - (b) Kemmerer Sampler. Seat the valve at the base of the sampler. Lower the sampler into the tank. Unseat the valve

at the desired depth. Additional guidance may be found in EPA/540/P-91/005 (SOP #2013) and ASTM Standard D 4136.

- (6) Remove the sampling device from the UST.
- (7) Transfer the contents into the sample containers. Preserve as appropriate. If only organic phase is being sampled, no preservation or cooling is required. Samples must be packed and shipped as high-level samples.
- (8) Fasten the covers finger tight.
- (9) Fill out field notebook, sample log sheet, labels, and chain-of-custody forms (See Chapter 8 for details).
- (10) Place in cooler at 4 degrees C. (Follow Chapter 8 for packaging requirements, use of cans for high-hazard wastes, etc.)
- (11) Decontaminate sampling equipment as described in Chapter 9 of this manual.

h. Sludge Sampling.

- (1) Sludge may be present at the bottom of the UST. Since storage of RCRA-regulated waste is limited to 90 days without a permit, it is important to characterize it early. If generator knowledge is lacking, sludge analysis should include flashpoint to determine if it meets the RCRA definition for the characteristic of ignitability and should include TCLP analyses for metals or other suspected TCLP constituents. Generally, perform sludge sampling if:
 - (a) The tank contains no liquid or the liquids have been removed.
 - (b) The tank is being removed and disassembled, and disposal regulations for the sludge require sampling/analysis.
 - (c) Federal, state, and local regulations require sludge analysis.
- (2) Instructions for sampling sludge:

- (a) Wear personal protective equipment as required in the Site Safety and Health Plan.
 - (b) Use an appropriate nonsparking sampling device such as a polyethylene dipper (ASTM D 5358) or teflon COLIWASA (ASTM D 5495).
 - (c) Immediately transfer sludge from the sampling device to fill the pair(s) of bottles required for VOAs. Fill as completely as possible. Fasten the cover finger tight.
 - (d) Transfer the remainder of the sample into a stainless steel mixing bowl. A stainless steel spoon or trowel may be used to assist in this step.
 - (e) Repeat Steps (b) and (d) to obtain the required volume of sludge. Refer to the Quality Control (QC) requirements in Chapter 8. (For some samples it will be necessary to obtain at least 48 oz. of sludge.)
 - (f) Quickly remove all nonsludge materials including stones and vegetation from the mixing bowl.
 - (g) Composite (homogenize) the bowl contents with a stainless steel spoon.
 - (h) Fill the 8-oz. wide-mouth glass bottles at least 3/4 full.
 - (i) Fasten the cover finger tight.
 - (j) Fill out field notebook, sample log sheet, labels, and chain-of-custody forms.
 - (k) Place in cooler at 4 degrees C.
 - (l) Decontaminate sampling equipment as described in Chapter 9.
- (3) QC split/duplicate samples. Refer to Chapter 8 for split sample requirements.

CHAPTER 5

SITE CHARACTERIZATION

5-1. General. This chapter discusses the investigation procedures that can be employed if the contamination at the UST is more widespread than the immediate tank area. Typically these procedures are above and beyond what is required during a UST removal. These activities, if required, should be performed under a separate contract from the UST removal so as not to slow down the tank removal process yet avoid potential UST-removal contractor delays. This chapter is included for guidance and completeness of this manual. Additional guidance on site characterization may be found in EM 200-1-3 and ASTM Standard Guides D 5730 and E 1912.

5-2. Subsurface Soil Gas Survey. Soil gas surveys (also called field hydrocarbon vapor tests) are a proven quick and economical in situ field method for determining the presence of subsurface chemical contamination. The soil-gas survey measures the relative concentration of volatile hydrocarbon components in the vadose zone of the soil. Data obtained from these surveys can be used to measure the relative magnitude of volatile hydrocarbons in the soil and contaminant dispersion or migration trends. Quantitation is accomplished with a gas chromatograph.

This information may help determine the need for quantitative soil sampling and/or the need for monitoring well installation. Two basic types of soil-gas surveys commonly performed during UST site assessments are discussed below.

- a. Active soil gas survey. The first type is the active soil-gas survey in which a probe is inserted into the subsurface and a volume of soil gas is pumped out of the vadose zone into a sample collection device for analysis. The gas samples are injected into a gas chromatograph that has been calibrated with one or more of the analytes thought to be present onsite.
- b. Passive Soil Gas Survey. The second type is the passive soil-gas survey in which a collection device is placed in the subsurface or on the surface of the ground, allowing the atmosphere within the device to come into compositional equilibrium with the soil atmosphere.
- c. Comparison of Methods. Active soil-gas surveys can be completed in as little as one day and are most commonly used. Passive soil-gas surveys take several days or weeks to complete. While both methods of soil gas sampling are applicable to sites contaminated by volatile organic compounds (VOCs), passive soil gas sampling may also identify some semivolatile organic compounds (SVOCs)(EPA/510/B-97/001). Detailed guidance on typical soil-gas monitoring may be found in ASTM D 5314.

Soil gas sampling methods also include headspace measurements and flux chamber measurements (EPA/600/8-87/036). Headspace sampling involves placing samples of site soils into a sealed container and measuring the concentrations of organics in the air above the soil (in the headspace) after some equilization period. Flux chamber measurements are obtained by placing an open-bottomed chamber on the soil surface and slowly passing a carrier gas over the soil surface and collecting a sample of the air from the chamber for analysis.

- a. Theory. The presence of VOCs in shallow soil-gas indicates the observed compounds may either be in the vadose zone near the probe or in groundwater below the probe. The soil gas technology is most effective in mapping low molecular weight halogenated solvent chemicals and petroleum hydrocarbons possessing high vapor pressures and low aqueous solubilities. These compounds readily partition out of the groundwater and into the soil as a result of their high gas/liquid partitioning coefficients. Once in the soil gas, VOCs diffuse vertically and horizontally through the soil to the ground surface where they dissipate into the atmosphere. The contamination acts as a source, and the aboveground atmosphere acts as a sink, and typically a concentration gradient develops between the two. The concentration gradient in soil gas between the source and ground surface may be locally distorted by hydrologic and geologic conditions (e.g., clays, perched water). However, soil gas mapping generally remains effective because distribution of the contamination is usually broader in areal extent than the local geologic barriers and is defined using a large database. The presence of geologic obstructions on a small scale tends to create anomalies in the soil-gas- groundwater correlation but generally does not obscure the broader areal picture of the contaminant distribution. A soil-gas survey may be performed in the vicinity of each UST. Typically 5 to 10 ground probes are driven to depths similar to that of the bottom of the UST or passive samples are placed around the UST location.
- b. Limitations. Soil-gas methods do have limitations, as discussed below:
 - (1) Soil probing is more difficult if the UST is under a large concrete pad.
 - (2) A positive result indicating site impacts are present in the soil which could be related to contamination from other nearby sources or from a recent spill.
 - (3) A positive result could occur (indicating soil contamination when none exists at the location) if volatile hydrocarbons from another source are migrating with and being released from the groundwater.

- (4) Plant matter can cause false positive results.
 - (5) A false negative result, incorrectly indicating that the tank has not leaked, may result if the UST leaked many years ago and the volatile contaminants have largely degraded or dissipated or if the leak involved nonvolatile liquids.
 - (6) Active soil gas may yield a false negative if rainfall or snowmelt occurs just prior to the sampling. The infiltrating water can drive contaminant vapors ahead of the infiltration front and draw clean atmospheric air into the zone to be sampled.
 - (7) Headspace methods may not yield samples representative of in-situ vadose zone atmospheres. Large percentages of vapor phase and moderate percentages of solute and sorbed phase contaminants can be lost in the act of soil sampling.
 - (8) Driven probes tend to degrade natural soil permeability around the body of the probe due to soil compaction concurrent with insertion. This can be a severe limitation to active soil gas extraction in moist, heavy clay soils.
 - (9) Soil characteristics such as high water saturation, soil cements, clay content and organic matter content will negatively impact results of surface flux chamber measurements by restricting the rate of contaminant flux to the chamber.
 - (10) Humidity can affect the collection efficiency of the adsorbent media in the sorbent samplers. Soil gas, even in the drier climates, will be at a relatively high humidity condition.
 - (11) It is not possible to measure the efficiency of passive-sorbent monitoring devices because the bulk volume of soil gas affected by the sorbent trap cannot be measured.
 - (12) Sample collection by pumping soil gas from collection cans or ground probes may disturb the equilibrium between the soil gas and the gas sorbed on soil particles. This may cause dilution and/or contamination of the sample by ambient air.
 - (13) High background concentrations may interfere with obtaining accurate measurements when sampling with sorbents.
- c. Field Equipment. A portable gas chromatograph with a photoionization detector (PID) is sensitive to benzene, toluene, ethylbenzene, and xylenes (BTEX) and decreasingly sensitive to nonaromatic hydrocarbons (octane, etc.) and chlorinated hydrocarbons. The gas chromatograph may also be equipped with a flame ionization detector (FID), which is

also sensitive to hydrocarbons. The user should be aware of the advantages and disadvantages of each type of detector. Each type of detector has limitations related to the environment. The FID is sensitive to severe changes in temperature, and the PID will not function under conditions of high humidity.

- d. Procedure for Conducting a Soil-Gas Survey with a Ground Probe. Use these instructions as a general guide in conducting a soil-gas survey using a ground probe near an UST.
 - (1) Site calibration for a portable gas chromatograph. Ideally, use commercially available vapor standards (low pressure, bottled, standard calibration gas) for instrument calibration. Inject the gas standard into the instrument with a gas-tight syringe. (If commercial gas standards are not available, vapor standards may be prepared in Tedlar bags filled with ultra-pure air. Inject the analyte of interest into the Tedlar bags from vapor obtained with a gas-tight syringe from the headspace above a neat [pure, 100 percent] standard stored in a 40 mL VOA vial with a septum cap. Prepare a new calibration standard daily. It is generally preferable to use commercially available calibration standard gases.)

More than one analyte may be of interest for the gas survey. Any compound that may have been stored in the UST (e.g., gasoline or other volatile fuels; organic solvents such as dichloroethane, trichloroethane, benzene, toluene, xylene, methylene chloride, acetone; etc.) may be used to calibrate the instrument so that quantitative results are obtained for that analyte.

- (2) Typically, a hydraulic mechanism is used to drive and withdraw sampling probes 1.5 to 3 m (5 to 10 feet) long. In unusually hard soil, a hydraulic hammer may also be used. These probes are typically fitted with detachable drive tips (see Figure 5-1).
- (3) Extract gas through the probe via a vacuum pump connected to the tubing. Five sample probe volumes should be extracted prior to sampling.
- (4) Remove a gas sample with the gas-tight syringe inserted into the flexible tubing between the pump and the probe.
- (5) Inject the gas sample into the gas chromatograph.

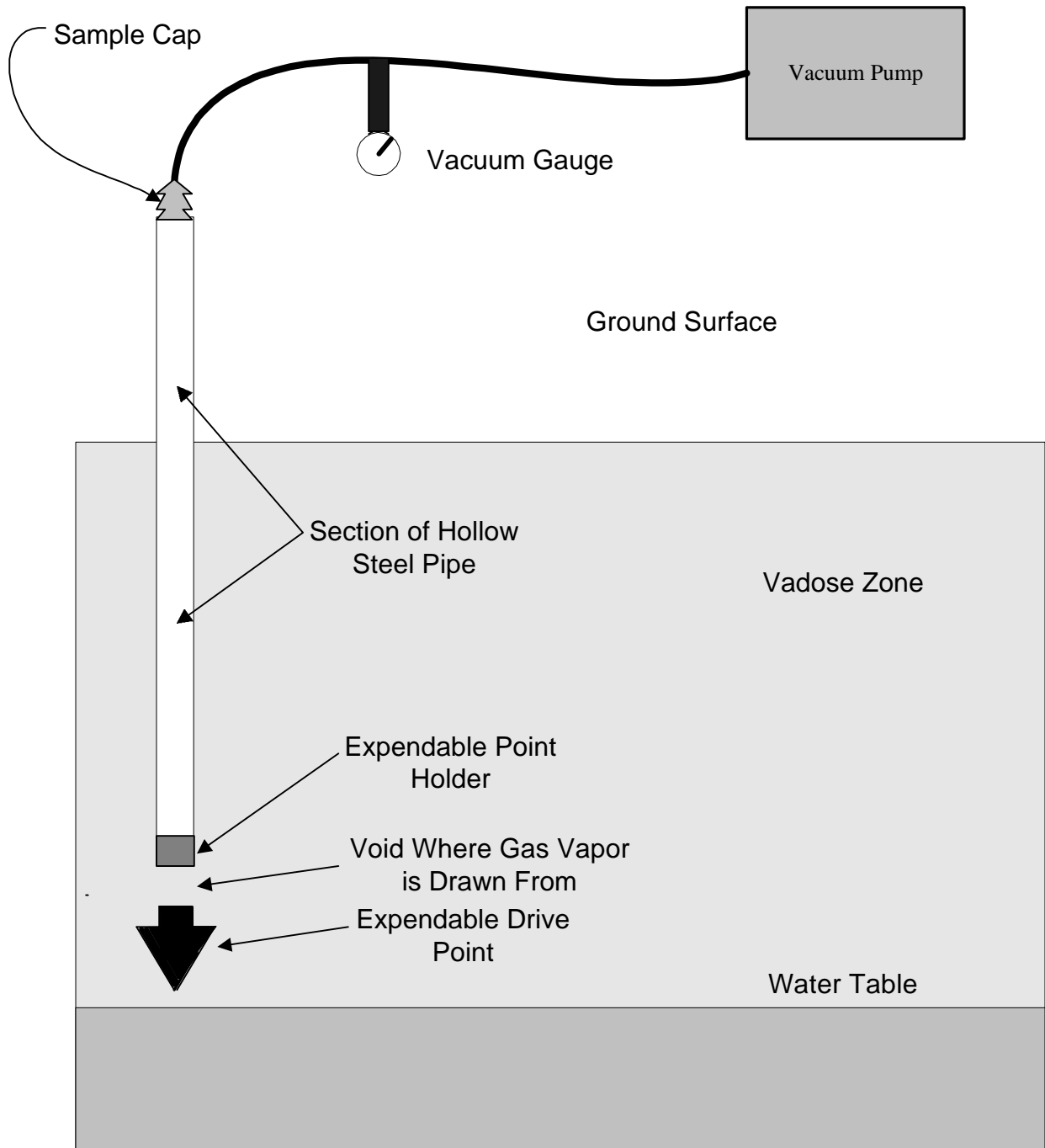


Figure 5-1 Typical Soil-Gas Apparatus

- (6) Record the results in the field notebook. Note all identifiable chemicals along with the concentration of each. Also note significant unidentifiable peaks from each chromatogram. Save the chromatograms as part of the field documentation.
- e. Decontamination. Dedicated sampling probes may be used in lieu of field decontamination during the soil-gas survey. These probes may then be cleaned (as described in Chapter 9) after the sampling event but before leaving the site.

If dedicated probes are not used, the following decontamination procedure should be followed.

- (1) Decontaminate the probe between sample holes by removing visible soil.
- (2) Do not clean with water or any liquid because this will have an effect on the gas chromatograph.
- (3) Draw ambient air blanks through the probe and analyze by gas chromatography to establish that cross-contamination is not occurring.
- (4) Another method that may be used for decontamination is baking the volatiles off the probe using a portable heater.

5-3. Borehole Drilling/Soil Sampling. Soil borings and monitoring wells are the primary means of assessing the extent of contamination from any hydrocarbon phase. Borehole drilling is a method for collecting subsurface soil samples and for subsequent well installation (discussed below). Boreholes are completed to determine the nature and extent of contamination at an UST site.

- a. Methods. It is important to recognize that, while the primary focus on drilling boreholes is for soil sample collection, borings are also required for in-situ testing of subsurface materials and groundwater. Table 5-1 presents types of drilling methods.

TABLE 5-1
DRILLING METHODS

Method	Drilling Principle	Depth Limit meters (Ft.)	Advantages	Disadvantages
Direct-Push	Advancing a sampling device into the subsurface by applying static pressure, impacts, or vibration or any combination thereof to the above ground portion of the sampler extensions until the sampler has been advanced its full length into the desired soil strata.	30 (100)	<p>Avoids use of drilling fluids and lubricants during drilling.</p> <p>Equipment highly mobile.</p> <p>Disturbance of geochemical conditions during installation is minimized.</p> <p>Drilling and well screen installation is fast, considerably less labor intensive.</p> <p>Does not produce drill cuttings, reduction of IDW.</p>	<p>Limited to fairly soft materials such as clay, silt, sand, and gravel. Compact, gravelly materials may be hard to penetrate.</p> <p>Small diameter well screen may be hard to develop. Screen may become clogged if thick clays are penetrated.</p> <p>The small diameter drive pipe generally precludes conventional borehole geophysical logging.</p> <p>The drive points yield relatively low rates of water.</p>

TABLE 5-1
DRILLING METHODS

Method	Drilling Principle	Depth Limit meters (Ft.)	Advantages	Disadvantages
Auger, Hollow- and Solid-Stem	Successive 1.5-m (5-ft) flights of spiral-shaped drill stem are rotated into the ground to create a hole. Cuttings are brought to the surface by the turning action of the auger.	45 (150)	<p>Fairly inexpensive. Fairly simple and moderately fast operation. Small rigs can get to difficult-to-reach areas. Quick setup time.</p> <p>Can quickly construct shallow wells in firm, nonclayey materials.</p> <p>No drilling fluid or lubricants required.</p> <p>Use of hollow-stem augers greatly facilitates collection of split-spoon samples, and continuous sampling is possible.</p> <p>Small-diameter wells can be built inside hollow-stem flights when geologic materials are cavey.</p>	<p>Depth of penetration limited, especially in cavey materials.</p> <p>Cannot be used in rock or well-cemented formations. Difficult to drill in cobbles or boulders.</p> <p>Log of well is difficult to interpret without collection of split spoons due to the lag time for cuttings to reach ground surface.</p> <p>Soil samples returned by auger flight are disturbed making it difficult to determine the precise depth from which the sample came.</p> <p>Vertical leakage of water through borehole during drilling is likely to occur. Solid-stem limited to fine-grained, unconsolidated materials that will not collapse when unsupported. Borehole wall can be smeared by previously-drilled clay.</p> <p>With hollow-stem flights, heaving materials can present a problem. May need to add water down auger to control heaving or wash materials from auger before completing well.</p>

TABLE 5-1

DRILLING METHODS

Method	Drilling Principle	Depth Limit meters (Ft.)	Advantages	Disadvantages
Jetting	Washing action of water forced out of the bottom of the drill rod clears hole to allow penetration. Cuttings brought to surface by water flowing up the outside of the drill rod.	15 (50)	<p>Relatively fast and inexpensive. Driller often not needed for shallow holes.</p> <p>In firm, noncavey deposits where hole will stand open, well construction fairly simple. Minimal equipment required.</p> <p>Equipment highly mobile.</p>	<p>Somewhat slow with increasing depth. Limited to drilling relatively shallow depth, small diameter boreholes.</p> <p>Extremely difficult to use in very coarse materials, i.e., cobbles and boulders.</p> <p>Large quantities of water required during drilling process. A water supply is needed that is under enough pressure to penetrate the geologic materials present.</p> <p>Use of water can affect groundwater quality in aquifer.</p> <p>Difficult-to-interpret sequence of geologic materials from cuttings.</p> <p>Presence of gravel or larger materials can limit drilling.</p> <p>Borehole can collapse before setting monitoring well if borehole uncased.</p>

TABLE 5-1				
DRILLING METHODS				
Method	Drilling Principle	Depth Limit meters (Ft.)	Advantages	Disadvantages
Cable-tool (percussion)	<p>Hole created by dropping a heavy "string" of drill tools into well bore, crushing materials at bottom.</p> <p>Cuttings are removed occasionally by bailer. Generally, casing is driven just ahead of the bottom of the hole; a hole greater than 150 mm (6 inches) in diameter is usually made.</p>	300+ (1,000 +)	<p>Can be used in rock formations as well as unconsolidated formations. Can drill through cobbles and boulders and highly cavernous or fractured rock. Fairly accurate logs can be prepared from cuttings if collected often enough. Driving a casing ahead of hole minimizes cross-contamination by vertical leakage of formation waters and maintains borehole stability. Recovery of borehole fluid samples excellent throughout the entire depth of the borehole. Excellent method for detecting thin water-bearing zones. Excellent method for estimating yield of water-bearing zones. Excellent method for drilling in soil and rock where lost circulation of drilling fluid is possible. Core samples can be easily obtained. Excellent for development of a well.</p>	<p>The potential for cross-contaminated samples is very high.</p> <p>Decontamination can be difficult.</p> <p>Heavy steel drive pipe used to keep hole open and drilling "tools" can limit accessibility. Cannot run some geophysical logs due to presence of drive pipe.</p> <p>Relatively slow drilling method.</p> <p>Heavier wall, larger diameter casing than that used for other drilling methods normally used.</p> <p>Temporary casing can cause problems with emplacement of effective filter pack and grout seal.</p> <p>Heaving of unconsolidated sediment into bottom of casing can be a problem.</p>

TABLE 5-1

DRILLING METHODS

Method	Drilling Principle	Depth Limit meters (Ft.)	Advantages	Disadvantages
Mud Rotary	<p>Rotating bit breaks formation; cuttings are brought to the surface by a circulating fluid (mud). Mud is forced down the interior of the drill stem, out the bit, and up the annulus between the drill stem and hole wall.</p> <p>Cuttings are removed by settling in a "mud pit" at the ground surface and the mud is circulated back down the drill stem.</p>	1,500+ (5,000 +)	<p>Drilling is fairly quick in all types of geologic materials, hard and soft.</p> <p>Borehole will stay open from formation of a mud wall on sides of borehole by the circulating drilling mud. Eases geophysical logging and well construction.</p> <p>Geologic cores can be collected.</p> <p>Can use casing-advancement drilling method.</p> <p>Borehole can readily be gravel packed and grouted.</p> <p>Virtually unlimited depths possible.</p>	<p>Expensive, requires experienced driller and fair amount of peripheral equipment.</p> <p>Completed well may be difficult to develop, especially small diameter wells, because of mud or filtercake on wall of borehole.</p> <p>Lubricants used during drilling can contaminate the borehole fluid and soil/rock samples.</p> <p>Geologic logging by visual inspection of cuttings is fair due to presence of drilling mud. Thus beds of sand, gravel, or clay may be missed.</p> <p>Location of water-bearing zones during drilling can be difficult to detect. Drilling fluid circulation is often lost or difficult to maintain in fractured rock, root zones, or in gravels and cobbles.</p> <p>Difficult drilling in boulders and cobbles.</p> <p>Presence of drilling mud can contaminate water samples, especially the organic, biodegradable muds.</p> <p>Overburden casing usually required. Circulation of drilling fluid through a contaminated zone can create a hazard at the ground surface with the mud pit and cross-contaminate clean zones during circulation.</p>

5-11

TABLE 5-1
DRILLING METHODS

Method	Drilling Principle	Depth Limit meters (Ft.)	Advantages	Disadvantages
Reverse Rotary	Similar to hydraulic rotary method except the drilling fluid is circulated down the borehole outside the drill stem and is pumped up the inside, just the reverse of the normal rotary method. Water is used as the drilling fluid, rather than a mud, and the hole is kept open by the hydrostatic pressure of the water standing in the borehole.	1500+ (5,000 +)	<p>Drilling readily accomplished in soils and most hard rock. Drilling is relatively fast and for drilling large diameter boreholes. Borehole is accessible for geophysical logging prior to installation of well.</p> <p>Creates a very "clean" hole, not dirtied with drilling mud.</p> <p>Large diameter of borehole permits relatively easy installation of monitoring well.</p> <p>Can be used in all geologic formations.</p> <p>Very deep penetrations possible.</p> <p>Split-spoon sampling possible.</p>	<p>Drilling through cobbles and boulders may be difficult.</p> <p>Use of drilling fluids, polymeric additives, and lubricants can affect the borehole chemistry.</p> <p>A large water supply is needed to maintain hydrostatic pressure in deep holes and when highly conductive formations are encountered.</p> <p>Expensive - experienced driller and much peripheral equipment required. Hole diameters are usually large, commonly 450 mm (18 inches) or greater.</p> <p>Cross-contamination from circulating water likely.</p> <p>Geologic samples brought to surface are generally poor; circulating water will "wash" finer materials from sample.</p>

TABLE 5-1

DRILLING METHODS

Method	Drilling Principle	Depth Limit meters (Ft.)	Advantages	Disadvantages
Air Rotary	Very similar to hydraulic rotary, the main difference is that air is used as the primary drilling fluid as opposed to mud or water.	1,500+ (5,000 +)	<p>Can be used in all geologic formations; most successful in highly fractured environments.</p> <p>Useful at most any depth. Drilling in rock and soil is relatively fast.</p> <p>Can use casing-advancement method.</p> <p>Drilling mud or water not required.</p> <p>Borehole is accessible for geophysical logging prior to monitoring well installation.</p> <p>Well development relatively easy.</p>	<p>Relatively expensive.</p> <p>Cross-contamination from vertical communication possible.</p> <p>Air will be mixed with the water in the hole and blown from the hole, potentially creating unwanted reactions with contaminants; may affect "representative" samples.</p> <p>Air, cuttings and water blown from the hole can pose a hazard to crew and surrounding environment if toxic compounds encountered.</p> <p>Compressor discharge air may contain hydrocarbons.</p> <p>Organic foam additives to aid cuttings' removal may contaminate samples.</p> <p>Overburden casing usually required.</p>
Sonic (vibratory)	Employs the use of high-frequency mechanical vibration to take continuous core samples of overburden soils and most hard rock.	150 (500)	<p>Can obtain large diameter, continuous and relatively undisturbed cores of almost any soil material without the use of drilling fluids.</p> <p>Can drill through boulders, wood, concrete, and other construction debris.</p> <p>Can drill and sample most softer rock with high percentage of core recovery.</p> <p>Drilling is faster than most other methods.</p> <p>Reduction of IDW.</p>	<p>Rock drilling requires the addition of water or air or both to remove drill cuttings.</p> <p>Extraction of casing can cause smearing of borehole wall with silt or clay.</p> <p>Extraction of casing can damage well screen.</p> <p>Equipment is not readily available and is expensive.</p>

5-13

TABLE 5-1				
DRILLING METHODS				
Method	Drilling Principle	Depth Limit meters (Ft.)	Advantages	Disadvantages
Air-Percussion Rotary or Down-the-Hole-Hammer	Air rotary with a reciprocating hammer connected to the bit to fracture rock.	600 (2,000)	<p>Very fast penetrations. Useful in all geologic formations.</p> <p>Only small amounts of water needed for dust and bit temperature control.</p> <p>Cross-contamination potential can be reduced by driving casing.</p> <p>Can use casing-advancement method.</p> <p>Well development relatively easy.</p>	<p>Relatively expensive.</p> <p>As with most hydraulic rotary methods, the rig is fairly heavy, limiting accessibility.</p> <p>Overburden casing usually required.</p> <p>Vertical mixing of water and air creates cross-contamination potential.</p> <p>Hazard posed to surface environment if toxic compounds encountered.</p> <p>DTH hammer drilling can cause hydraulic fracturing of borehole wall. The DTH hammer requires lubrication during drilling.</p> <p>Organic foam additives for cuttings' removal may contaminate samples.</p>

- (1) Selection of the most appropriate method or combination of methods must be dictated by the special considerations imposed by multipurpose borings. For example, although the best apparent method for well installation at a particular site may be direct air rotary with driven casing, most air rotary equipment allows sampling only by cuttings. If, in this case, soil sampling is required, pilot (or separate) borings done with equipment capable of providing adequate undisturbed samples may be necessary. In addition, if drilling is to be conducted in an area of perched or multiple aquifer systems, auger techniques should not be used because of the possibility of cross-contamination; borings must be advanced using multiple casing techniques that allow isolation of each aquifer encountered. Additional guidance on drilling methods may be found in EM 1110-1-4000 and the following ASTM Standards:

D 2113 Practice for Rock Core Drilling and Sampling of Rock for Site Investigation

D 5781 Guide for the Use of Dual Wall Reverse-Circulation Drilling

D 5782 Guide for the Use of Direct Air Rotary Drilling

D 5783 Guide for the Use of Direct Rotary Drilling With Water-Based Drilling Fluid

D 5784 Guide for the Use of Hollow-Stem Augers

D 5872 Guide for the Use of Casing Advancement Drilling Methods

D 5875 Guide for the Use of Cable-Tool Drilling and Sampling Methods

D 5876 Guide for the Use of Direct Rotary Wireline Casing Advancement Drilling Methods

D 6286 Guide for Selection of Drilling Methods for Environmental Site Characterization

- (2) The planning, selection, and implementation of any drilling program requires careful consideration by qualified, experienced

personnel. At a minimum, the following general steps are required:

- (a) Review existing site, area, and regional subsurface; geologic; and hydrogeologic information including physical and chemical characteristics.
 - (b) Develop project DQOs and a SAP. See EM 200-1-2 and EM 200-1-3 for additional guidance.
 - (c) Develop a site-specific safety and health program.
 - (d) Define the purpose of the drilling and sampling, select drilling methods and general site layout, and prepare and execute the drilling contract.
 - (e) Field implementation and decontamination includes continuous inspection by qualified, experienced personnel.
- (3) Selection and implementation of soil drilling and sampling methods requires that specific consideration be given to the following issues:
- (a) Prevention of contamination migration.
 - (b) Maintenance of sample integrity.
 - (c) Minimization of disruption of existing conditions.
 - (d) Minimization of long-term impacts.
- b. Equipment. Guidance on sampling equipment may be found in EM 200-1-3 and EM 1110-1-1906. Additional guidance may be found in ASTM D 6169. Hollow stem auger drilling is frequently used and may include the following:
- (1) Hollow-stem auger and drill rig.
 - (2) Sampling tubes. Sampling systems may consist of either of the following:
 - (a) Continuous sampling tube systems consisting of 1.5m (5-foot) long split or solid sampling tubes. Tubes can be used with or without liners of various metallic and nonmetallic

materials. Continuous samplers advance with the auger flights.

(b) Split-spoon sampling consisting of 0.5m (18-inch) long split spoons with basket-retainer shoe. Split spoons are driven into the soil ahead of the auger using a drive hammer.

- (3) Stainless steel knives, spoons, and bowls.
- (4) Sample containers (see Chapter 8).
- (5) Ice.
- (6) Shipping coolers and supplies.
- (7) Decontamination equipment (see Chapter 9).
- (8) Logbook.

c. Procedures.

- (1) Obtain any federal, state, or local permits required for constructing wells or clearing the site for work or access. Contact regulatory agencies to obtain their regulations concerning submission of boring/well logs and samples.
- (2) At each borehole the geologist must maintain a log that contains at a minimum the following information:
 - (a) Name of the project and site.
 - (b) Hole number.
 - (c) Location of the boring.
 - (d) Type of drill rig and method of drilling.
 - (e) Size and type of bit used.
 - (f) Depth of each change of stratum.
 - (g) Thickness of each stratum.

- (h) Identification of the material composing each stratum according to the Unified Soil Classification System, or standard rock nomenclature, as necessary.
 - (i) Depth interval from which each formation sample was taken.
 - (j) Hole diameter and depth at which hole diameter (bit size) changes.
 - (k) Depth at which groundwater is first encountered.
 - (l) Depth to the static water level and changes in static water level with hole depth.
 - (m) Total depth of hole.
 - (n) Depth or location of any loss of drill water circulation, loss of tools or equipment, and any other problems encountered.
 - (o) Location of any fractures, joints, faults, cavities, or weathered zones.
 - (p) Reference elevation for all depth measurements.
 - (q) Name of driller and geologist.
 - (r) Standard Penetration Test blow counts, if applicable.
 - (s) Date(s) of drilling, including depths where work shifts begin and end.
- (3) To take a subsurface soil sample (after the sampler is retrieved from the borehole), follow these steps:
- (a) Set up decontamination, sampling preparation, and support areas at borehole location.
 - (b) Decontaminate all equipment, samplers, and tools that will come in contact with sample media (see Chapter 9 for decontamination procedures). Record decontamination process in logbook.

- (c) Inform driller of sample interval(s) for borehole and oversee sampling process.
- (d) Prepare and label all sample containers. If any volatiles are analytes, have the volatiles containers available first. Label containers with location, depth, analyte, date, and time of sampling.
- (e) Have the driller prepare the sampler for opening, but do not allow the driller to completely open the sampler.
- (f) With the sampler lying on a clean sheet of plastic, the onsite geologist should open the sampler slowly. As the sampler is being opened, the surface of the core should be "sniffed" with a PID/FID. Position the probe of the instrument approximately 25 mm (one inch) from the sample. Record instrument readings in the logbook. If the PID/FID reading is above background, a soil sample should be collected from the anomalous interval. Consult with the site manager to determine whether to submit for chemical analyses.
- (g) For those locations in which VOCs are analytes, VOC samples must be collected immediately after the sampler is opened. Using a sampling knife, cut off solid piece(s) (nominal 25 mm [one inch] in size) of sample and place piece(s) into the container. Immediately close container and place on ice. The container must not have any headspace if the sample is to be analyzed for VOCs.
- (h) Log the core, recording percent recovery, color, texture, clay, sand, gravel content, and other notable characteristics in the logbook.
- (i) After logging, transfer sample to mixing bowl and thoroughly homogenate the sample.
- (j) Fill remaining sample jars.
- (k) Prepare necessary QA/QC samples.
- (l) Log all samples in field notebook; Include borehole ID sample number, analyte(s), date, time, and collector signatures.

- (m) Pack samples for shipment, prepare chain-of-custody records and shipping documentation (see Chapter 8).
 - (n) Ship samples as specified in Chapter 8.
- (4) If the borehole is to be used for a well installation, follow procedures outlined in Paragraph 5-4 below, otherwise grout the borehole. The grout mixture should be composed of Portland cement mixed to a ratio of 27 liters (7 gallons) of water per sack of cement with a 3-percent bentonite powder additive. Grout must be pumped into the borehole via a tremie pipe.

5-4. Well Installation.

- a. Purpose. The purpose of a monitoring well is to provide an access point for measuring groundwater levels and to collect groundwater samples that accurately represent in-situ groundwater conditions at the specific point of sampling. Consult EM 1110-1-4000 for guidance on monitoring well installation.

To procure accurate samples, follow these criteria:

- (1) Construct the well with minimum disturbance to the formation.
 - (2) Construct the well of materials that are compatible with the anticipated geochemical and chemical environment.
 - (3) Complete the well properly in the desired zone.
 - (4) Seal the well adequately with materials that will not interfere with the collection of representative water-quality samples.
 - (5) Develop the well sufficiently to remove any additives associated with drilling and provide unobstructed flow through the well.
- b. Groundwater Sampling. Prior to well sampling, the task manager/field team leader is responsible for collecting and reviewing information about the well. This information should include: well construction methods and materials, well logs, well size, well depth, screen interval(s), and purpose of well (monitoring, water supply, etc.). This information should accompany the field crew during sampling. The following procedures should be followed during a groundwater sampling event:

- (1) Set up decontamination, sample preparation, and support area at wellhead. (This may be at the rear of a truck/van.)
- (2) Decontaminate all equipment/instruments that will be placed into well casing or come in contact with water samples. Record decontamination process in logbook.
- (3) Review well log for construction, size, and well depth. Record information in logbook. *Do not measure the total depth of the well prior to sampling.* Measuring to the bottom of the well casing may cause re-suspension of settled solids from the formation materials and require longer purging times for turbidity equilibration. Measure the well depth after sampling is complete.
- (4) Using water-level probe, determine water level (ASTM D 4750). Record in logbook.
- (5) Calculate purge volume. **NOTE:** USACE well-purging procedures specify including the volume of water in the filter (sand) pack in purge-volume calculations. To prevent purging an unnecessarily large volume of water, calculate height of water column using water level and construction data. Also using construction data, calculate volume of one casing plus filter-pack volume (i.e., one purge volume) using the following formula:

$$\text{Volume (gallons)} = \mathbf{B}r^2h \text{ (cu. ft).} \times 7.48 \text{ (gallons/cu. ft).}$$

r = radius in feet (of either auger borehole or well casing as described below).

h = height of water column in feet.

Because the water contained in the sand pack will be used in the calculations, follow these steps:

- (a) Calculate the total volume of the saturated portion of the borehole. Use the radius of the overall borehole (sand pack plus well casing) for the calculation. This is Volume A.
- (b) Calculate the total volume of the well casing. Use the radius of the well casing for the calculation. This is Volume B.

- (c) Determine the volume of the saturated portion of the sand (filter) pack. This is done by subtracting Volume B from A and multiplying the result by a porosity factor of 0.35. This will be Volume C, the sand-pack volume, as shown here:

$$(\text{Volume A} - \text{Volume B}) \cdot 0.35 = \text{Volume C (sand-pack volume)}$$

- (d) Add Volumes B and C to produce volume of water for one filter (sand) pack and well casing. That is:

$$\text{Volume B} + \text{Volume C} = \text{Volume D, (filter-pack and casing volume)}$$

Record calculations and the purge volume (Volume D) in logbook.

- (6) The well should be purged of at least three casing and sand (filter) pack volumes or until pH, temperature, specific conductance, oxidation-reduction potential (ORP), dissolved oxygen (DO), and turbidity are each at equilibrium. Equilibrium is established when three successive readings are within:

- ± 0.2 pH units.
- ± 1 degree Celsius for temperature.
- ± 3 percent for specific conductance.
- ± 10 mV for oxidation-reduction potential (ORP).
- ± 10 percent for DO.
- ± 10 percent turbidity.

Equilibrium will be established by three consecutive readings, where one casing volume is pumped between each reading. Multiply the filter-pack and casing volume by three to produce the minimum purge volume. If well is purged dry before three purge volumes, allow well to recover and then sample. See EM 200-1-3 for more guidance on well purging.

- (7) Begin purging well using either bailer, submersible pump, or in-place pump.
- (8) Collect all purge water in 55-gallon drums until the disposal method can be determined based on water quality results. **NOTE:** In some instances, purging rates must be kept below 500 mL/min to avoid over pumping or pumping the well to dryness. Ideally, wells should never be pumped to dryness.

- (9) Initiate sampling after purging has been completed. Label all sample containers with well ID, date, and time of sampling, analytes, and preservative. See Table 8-3 for sample bottle requirements. If bioremediation is a potential treatment option, samples should be collected for testing for nitrates, sulfates, ferrous iron, and methane.
 - (10) Collect sample with a freshly decontaminated bailer. Lower bailer carefully into well to prevent aeration of well.
 - (11) Fill VOA containers first (add two drops HCl acid preservative to containers prior to filling). Overfill container, put on cap, and invert container to check for bubbles. If bubbles are present, discard sample and refill. Place samples on ice.
 - (12) Fill other organic analyte bottles next. Do not completely fill the container. Leave approximately 10-percent volume as head space. Mark the volume on the container with a grease pen. Preserve as specified in preservation table. Place samples on ice.
 - (13) Fill remaining inorganic analyte containers.
 - (14) Log all samples in field logbook; include well number, identifier, analyte(s), date, time, and collector signatures. Record time of purge, purge volume, and water quality parameters in logbook.
 - (15) Pack samples for shipment; prepare chain-of-custody records and shipping documentation.
 - (16) Ship samples as specified in Chapter 8.
- c. Free Product. Properly installed and constructed monitoring wells can be used both to delineate the extent of free product and monitor temporal changes in free product accumulations. However, it is also important to realize that monitoring wells are subject to significant limitations in their ability to provide accurate measurements of the thickness of free product in the surrounding soil. Free product can accumulate in a well only if the well is open (i.e., screened) across the zone of free product. Within a well with a properly positioned screen, the thickness of free product typically fluctuates in response to changes in water table elevation. Where wells are initially installed with short screens (1.5 m [5 ft] or less),

changes in the water table elevation may result in a dry well (declining water table) or in a well that is screened below the zone of free product (rising water table). Even in properly constructed wells, the absence of free product may not necessarily indicate that petroleum hydrocarbons are not present in the soil. Similarly to the observation that water may take days or weeks to enter some monitoring wells constructed in clayey soil, free product may not initially appear in monitoring wells. Such a condition indicates that the relative permeability with respect to free product is very low; hence the mobility of the free product is also low. This may also result in a lower calculated volume of free product.

- (1) Record the thickness of free product, if encountered. Three methods are commonly used to measure free product thickness in a well: steel tape and paste, interface probes, and bailers.

The pastes used with the steel tape are sensitive to hydrocarbons and water. Commercially available interface probes sense the presence of both oil and water. The first two methods are accurate to within about 3 mm (0.01 ft) and are convenient for determining the elevation of the air/free product and oil/water interfaces. Whenever possible, measurements should be taken using either steel tape and paste or an interface probe. A bailer is a transparent cylinder with a check valve at its base. The bailer methods can significantly under- or over-estimate the thickness of free product in the well and **should not** be used for determining the elevations of air/free product and free product/water interfaces. Disposable bailers, which are commonly dedicated to monitoring wells containing free product, typically collect an unrealistically small product thickness because of the small size of the intake holes. The use of bailers should be limited to verification of the presence of free product in a well or collection of a small sample of it. Bailers can be used to remove liquids from monitoring wells during baildown tests that are designed to determine the rate of free product recovery into wells. For more information on free product measurement and recovery see EPA/510/R-96/001.

5-5. Aquifer Testing. After completion and development of all monitoring wells, perform slug tests at each well to provide data to contribute to the hydrogeologic characterization of the site. Slug tests provide data to approximate hydraulic conductivity and transmissivity of the aquifer. The slug test is a useful tool for estimating the areal variability of these parameters within a given unit and does not require that any water be

discharged from the tested well. Also, the test does not artificially induce contaminant flow and can be performed on wells within known or suspected groundwater contamination plumes. Further information on aquifer testing may be found in *EPA Groundwater Issue on Suggested Operating Procedures for Aquifer Pumping Tests*, EPA/540/S-93/503. Guidance for measuring well discharge may be found in ASTM D 5737.

- a. Procedure. To perform a slug test, a solid slug is introduced into the well and changing water levels are measured with a transducer. Water level and elapsed-time data can be recorded with a data logger and pressure transducer. Both "rising heads" and "falling heads" are recorded. Additional guidance on conducting a slug test may be found in EPA/540/P-91/007 and ASTM D 4044.
- b. Data. Data from the slug tests can be input from the strip logs into a computer spreadsheet for review. After these data are checked for accuracy, the data file can be transferred into a commercially available program that calculates hydraulic conductivity (m/day [gal/day/ft²]) and transmissivity (m²/day [gals/day/ft]) for the aquifer.

5-6. Soil Testing. To determine an appropriate corrective action for contaminated soil and/or groundwater, site-specific information relating to the hydrologic and geologic characteristics of the site, as well as soil chemistry, is needed. These characteristics include depth to groundwater, soil temperature, moisture content, soil water field capacity in accordance with ASTM D-2325, or ASTM D-3152, particle-size distribution, bulk density, saturated and unsaturated hydraulic conductivity, dissolved oxygen, carbon dioxide, total organic carbon, and total volatile hydrocarbons.

An example of the importance of these parameters is: a soil's hydraulic conductivity directly affects a contaminant's mobility, while soil air conductivity affects the mobility of the contaminant vapors. Air and hydraulic conductivity varies from formation to formation in much the same way, with formations of low hydraulic conductivity generally having low air conductivity as well.

The procedures for collecting field samples for soil parameters are covered extensively in many other publications and are not discussed in this manual. Soil characterization data needs for different remedial technologies can be found in EM 200-1-2.

5-7. Survey. When there is a release from an underground storage tank, the horizontal and vertical extent of the contamination must be determined. To make an accurate determination of contamination extent, verify borehole and monitoring well locations as well as the elevations of the monitoring wells. Designers use this information to develop a site-specific groundwater contour map, for calculating the groundwater gradient and flow rate, and a three-dimensional model of the soil contamination. Coordinates and elevations should be established for each well and boring location to a minimum of third order survey. Elevations should be provided for each well casing to the closest 5 mm (0.01 foot).

5-8. Waste Disposal.

- a. Disposal of Drill Cuttings. Cuttings must be tested using a PID/FID to help determine contaminant status. Potentially contaminated cuttings must be handled as described in "b. Collection and Testing of Potentially Hazardous Materials" (below). Potentially contaminated drill cuttings and/or vapors are defined as those substances with PID/FID readings in excess of 5 ppm above background levels. This assumes that the tanks being pulled are POL tanks and that the primary contamination is from volatile contaminants. If this is not the case, analytical results of actual soil samples must be used. The implementing agency should provide guidance values for soil disposal. Additional guidance may be found in EPA/540/G-91/009.
- b. Collection and Testing of Potentially Hazardous Materials. Materials generated during field activities must be placed in properly labeled drums that are Department of Transportation (DOT)-approved for transport of hazardous materials. Follow these guidelines:
 - (1) Segregate all materials in separate drums (i.e., soil, water, tyvek, and other similar materials).
 - (2) Secure drums at a designated staging area on wooden pallets, pending receipt of analytical results.
 - (3) Label all drums adequately prior to moving them to the staging area. Label drums in a permanent, waterproof manner in accordance with the IA requirements. Drums must not be labeled on the top. At a minimum, label drums as to type of material contained, site number, and location boring numbers.

The eventual disposal of the contents of these drums is determined by the results of the associated analytical tests for the project. Local regulations may preclude the use of drill cuttings as backfill. Check with the local IA to determine if non-contaminated drill cuttings need to be containerized and disposed of offsite.

CHAPTER 6

SAMPLING DURING UST REMOVAL PROCEDURE

6-1. General. The purpose of this chapter is to recommend sampling procedures for the excavation of soils from UST sites and free-product sampling procedures for spills or leaks that have occurred at UST sites. The objectives of the sampling are:

- (1) To obtain soil, and water if present, from the surface and known depths in the vicinity of the UST excavation for evaluation of site characteristics.
- (2) To detect the presence of any contaminants.
- (3) To evaluate the potential for pollutant migration.

The contractor should be responsible for assessing specific situations for the most appropriate response. Upon removal of USTs, pools of free product may exist in the ground cavity. The origin of these pools is usually seepage from the tank or spills associated with removal. Free-product pools should be sampled to possibly determine the nature and source of these liquids. Guidance for preparation of sampling plans can be found in EM 200-1-3.

6-2. Field Screening for Soil Samples. An organic vapor analyzer may be used as a cost-effective screening device for soil samples. When this instrument is equipped with a sampling probe and a flame ionization detector (FID) or a photoionization detector (PID), it is capable of detecting volatile hydrocarbons in the 1 to 1,000 ppm range. The results obtained are not quantitative, however. The results from several soil samples are relative and will allow the sampling team to select samples that are the most contaminated with hydrocarbons. The presence of little or no organic vapor is possibly indicative of noncontaminated soils. The USACE may use FID/PID results as the criteria for deciding which soil samples should be analyzed by the more expensive gas chromatography (GC) techniques (Method 8021 or Modified 8015). Other screening methods such as immunoassay may also be used for soil tests.

- a. Purpose. Field screening is done for a variety of reasons. The technique is frequently used to screen soil samples for measurable levels of volatile organics. For example, the results can be used to select the most contaminated sample from a soil boring for complete analysis by Method 8021. Field screening is often used as a predesign activity to construct an effective sampling plan. The FID/PID is also used during construction to delineate the extent of excavation.
- b. Field Equipment. A pint jar with metal ring-type lid is frequently used for this screen. The sample is placed in the bottle and covered with aluminum foil. The ring lid secures the foil. An organic vapor

analyzer (such as the Century OVA) is used to measure volatile organics.

- c. Instructions for Headspace Analysis by FID/PID. This procedure is used in categorizing soil based on the quantity of organic vapor present and may be modified slightly.
- (1) Stabilize and calibrate the FID/PID. Follow the manufacturer's instructions. Some models are factory calibrated to methane and should not be recalibrated. Other models require the use of a calibration gas; follow the manufacturer's recommendations for calibration (called "spanning") of the instrument (see Chapter 11).
 - (2) Place soil from the soil sampling equipment into the jar. Cover with foil and secure ring cap. The pint jar should be at least 3/4 full.
 - (3) Place the jar in hot tap water (30 degrees C.) for 5 minutes. An alternate method is to place the jar on the dashboard of a vehicle with the defrost cycle on.
 - (4) Remove the jar from the water or dashboard.
 - (5) Immediately insert the sampling probe through the foil and into the headspace above the soil.
 - (6) Take the reading and record the value in the field logbook along with the other particulars of the sampling point.
 - (7) Verify that the FID/PID is reading background before exposing the probe to another sample.

6-3. Sampling. Guidance for soil and water sampling may be found in EM 200-1-3.

- a. Soil Sampling. Conduct soil sampling at the ground surface, including the exposed walls and bottom of the excavation or within the mound of excavated soil. Surface soil sampling typically refers to samples collected between 0 and 300 mm (0 and 12 inches) from the surface. Surface soil sampling may be accomplished with a trowel, a push tube, a hand auger, or a backhoe. Soil samples may provide two types of soil contaminant representation: grab and composite. These samples may be collected in random locations from a grid pattern or in selected areas believed to be contaminated (as evidenced by staining or measurable volatile organic readings).

- (1) A grab sample is a discrete aliquot representative of a specific location at a given point in time. The sample is collected at one time and at one particular sampling point and depth.
 - (2) A composite sample is a nondiscrete sample composed of more than one specific aliquot that may be collected at various sampling locations, depths, and/or different points in time. The aliquots are thoroughly mixed together, and the mixture homogenized.
- b. Water Sampling. If water is present in the excavation, and has not been determined to be groundwater, completely evacuate and dispose of it in accordance with all applicable regulations. If within 24 hours, the water recharges into the excavation to a level sufficient for sample collection, collect a sediment-free sample as soon as practicable. However, if water exists in the excavation and site conditions warrant immediate backfilling (that is, collapsing side walls or other safety issues), collect a water sample. Water sampled directly from inside an excavation or from a soil boring is not necessarily representative of normal groundwater conditions and should not be evaluated as a groundwater sample. Such samples may, however, be used to document the existence of a release (ASTM E 1599).
- c. Equipment. Surface soil and water sampling require limited equipment including the following:
- HNu or OVA or equivalent monitoring devices (Chapter 11).
 - CGI (see Chapter 10).
 - Backhoe.
 - Hand auger.
 - Stainless steel trowels.
 - Push tube.
 - Stainless steel knives and spoons.
 - Stainless steel mixing bowls.
 - Pond sampler.
 - Sample containers (see requirements in Chapter 8).
 - Decontamination equipment (see Chapter 9).
 - Personal protective equipment (respirator, etc.).
 - Tape measure.
- d. Materials. Supplies required to perform soil sampling include the following:
- Preservation supplies (ice).
 - Sample labels, custody seals, and chain-of-custody forms.
 - Personal protective supplies (gloves, tyvek).
 - Decontamination supplies (see Chapter 9).
 - Logbooks.

e. Operations, Procedures, and Instructions.

- (1) Notify and inform the selected analytical laboratory before sampling of the estimated number of samples to be collected, the analyses required. Special requirements, if any, and expected sample arrival date. This information should be in the project DQOs provided to the laboratory. In addition, many states have developed required sampling patterns for obtaining samples from excavations. Contact the state agency to determine any requirements.
- (2) Discuss (as a field team) the Site Safety and Health Plan (SSHP) prior to initiating field activities. All monitoring and protective equipment should be checked thoroughly at this time. Personal protective equipment and health and safety standards are specified for each activity in the SSHP.
- (3) Set up decontamination, sample preparation, and support area at a central location.
 - (a) Equipment Selection and Preparation. Decontaminate all equipment, samples, and tools that will come in contact with sample media. Record decontamination process in log book. All sampling equipment must be made of inert and nonreactive material (i.e., stainless steel, PTFE, glass), and if not disposable, must be decontaminated before and between sampling points. Disposable sampling equipment may be thrown in the trash if not contaminated or drummed up and disposed with the soil. The decontamination procedure may vary depending on site and contaminant conditions. Chapters 7 and 9 outline decontamination procedures.
 - (b) Carry sampling equipment to sample location. Be sure all equipment rests on plastic sheeting next to sample location. Utilize an HNu or Organic Vapor Analyzer (OVA) or similar instrument to detect any organic vapors being emitted during excavation and sampling and a Combustible Gas Indicator (CGI) to monitor oxygen levels.
- (4) Sample Container Preparation. Prepare and label all sample containers to be collected that day (sample containers are discussed in Chapter 8). Label should identify sample location ID, sample ID, depth, analyte, date, time of sampling, and any preservatives added (preservatives are not usually required for soil samples although some jurisdictions may require them, especially for volatile analytes). Time of sampling and depth should be added after sample is collected.

- (5) Selection of Sampling Location. Sampling locations and depths required within the excavation are often selected to obtain the most contaminated sample. Consult the Implementing Agency (IA) to determine sample locations and depths. Soil samples should be taken from the surface down to approximately 300 mm (12 inches) in depth. *Under no circumstances is anyone to enter a hole for the purpose of sampling.* Soil samples are to be taken from the bucket of the backhoe or other implement being used for excavation. Samples should be collected from the native soil, not any surrounding backfill. All backfill should be removed during soil excavation.
- (a) Worst-case locations include:
- Areas around the tanks and piping locations that record the highest reading with the vapor monitoring equipment or that look stained or discolored.
 - The lowest point of the tank cavity, if this can be determined, where the tank meets the piping.
 - Beneath the fill lines. At least two surface soil samples—one from either end of each tank—should be collected when the tank(s) are removed.
- (b) Samples collected may consist of random grid grab samples, random grid composite samples, composite or grab of stained soils, offsite clean soil, or grabs or composites from runoff areas. Consult the Implementing Agency for further guidance on excavation sampling as well as sampling from the mound of excavated soil.
- (c) If possible, an offsite sample should also be collected to compare with the excavation samples. This "background" sample should be collected in an undisturbed area. This may be difficult to obtain in an industrialized area.
- (6) Soil Sample Collection. Collect a sample using a stainless steel trowel or spoon, hand auger, or similar device.
- (a) Collect samples for volatile organic analysis (VOA) first to minimize loss of the soil contaminants.
- (b) Fill VOA containers directly from a trowel. Do not homogenize VOA samples.
- (c) For samples subject to other than volatile analyses, place a sufficient amount of soil in a stainless steel mixing bowl or tray for homogenization. This includes composite samples. Prior to homogenization, remove all twigs, stones,

and other debris from the soil. With a stainless steel spoon, the sample is scraped from the sides, corners, and bottom of the tray; rolled to the middle of the tray; and initially mixed. The sample should then be quartered and moved to the four corners of the mixing vessel. Each quarter of the sample should be mixed individually, then rolled to the center of the container, and the entire sample mixed again.

- (d) Since excavation pits should not be entered, samples should be collected by the use of a backhoe. The backhoe is to scoop a bucket full of soil from the desired sampling location. The sampler then collects a sample from the center of the bucket.
 - (e) Local requirements may indicate the need to sample groundwater if present in the excavation. If this is required, sampling should be accomplished without entering the excavation. A long handled dipper should be used to collect the water sample.
- (7) Sample Packaging. Place the sample in a sample container appropriate for the type of analysis to be performed. Container requirements are described in Chapter 8 and EM 200-1-3. The latest version of SW-846, referenced in Chapter 8, should be used to meet analytical requirements.
- (a) Wipe the outside of the sample container to prevent the spread of contamination. The sample container must not contain any headspace. This no headspace requirement applies to samples collected for volatile organic analyses only. Log all samples in field logbook or on field sheets; include sample location, sample ID number, analytes, date, time, and signatures of samplers.
 - (b) As the samples are collected, place them in a Ziplock® bag in an ice chest containing an ice substitute or regular ice that has been double wrapped in plastic. Samples are kept on ice to maintain their integrity. Each sample should be individually wrapped to prevent possible cross-contamination. Highly contaminated soil samples must be placed in metal cans (see Chapter 8). Sample temperature should be maintained at 4 ± 2 degrees C.
- (8) Decontamination. Refer to Chapter 9 for more information on decontamination procedures.
- (9) Sample Shipping. Refer to Chapter 8 for shipping requirements.

6-4. Free-Product Sampling. This section applies to the sampling of residual free-product pools in an UST excavation. Limit sampling to liquid free product. Saturated soils or sludges should be sampled according to guidelines described previously. Further guidance on the characterization of free product may be found in EPA/510/R-96/001.

- a. Precautions. Specific hazards in the excavation area include the danger of subsidence both in the pit and of the sidewalls. It is recommended that personnel never enter an excavation pit. Extreme caution also must be exercised when approaching a pit to sample from above, as sidewall subsidence occurs frequently and with no warning.
- b. Equipment. Free-product sampling is an activity that requires limited equipment, including the following:
 - HNu, OVA, or equivalent monitoring devices (see Chapter 11).
 - Backhoe (if needed).
 - Liquid sampling equipment.
 - Narrow-mouthed glass bottles.
 - Sample containers (see requirements in Chapter 8).
 - Decontamination equipment (see Chapter 9).
 - Personal protective equipment (respirator, etc.).
 - Tape measure.
- c. Materials. In addition to the equipment listed in the preceding section, the supplies required to perform free-product sampling include the following:
 - Sample containers.
 - Preservative supplies (ice).
 - Sample labels, custody seals, and chain-of-custody forms.
 - Personal protective supplies (gloves, Tyvek®).
 - Decontamination supplies (see Chapter 9).
 - Logbook.
- d. Operations, Procedures, and Instructions.
 - (1) Notify the selected analytical laboratory before sampling of the estimated number of samples to be collected, the analyses that will be required, special requirements (if any) and when it should expect to receive the samples.
 - (2) Discuss (as a field team) the SSHP and the procedures outlined by it prior to initiating field activities. All monitoring and protective equipment should be checked thoroughly at this time. Personal protective equipment and safety and health standards are specified for each activity in the SSHP.

- (3) Set up decontamination, sample preparation, and support area at a central location.
- (4) Equipment Selection and Preparation. Decontaminate all equipment, samples, and tools that will come in contact with sample media. Record the decontamination process in logbook. All sampling equipment must be made of inert and nonreactive material (i.e., stainless steel, PTFE, glass), and if not disposable, must be decontaminated before and between sampling points. The decontamination procedure may vary depending on site and contaminant conditions. Chapters 7 and 9 outline decontamination procedures.
- (5) Carry sampling equipment to sample location. Be sure all equipment rests on plastic sheeting next to sample location. Utilize an HNu, OVA, or similar instrument to detect any organic vapors being emitted during excavation and sampling and a CGI to monitor oxygen levels.
- (6) Sample Container Preparation. Prepare and label all sample containers (sample containers are discussed in Chapter 8). Label should identify sample location ID, sample ID, depth, analyte, date, time of sampling, and any preservatives added.
- (7) Selection of Sampling Location. Sampling locations are often selected based on equipment availability and proximity to the sides of the excavation pit. Samples should be taken from each pool occurring in an excavation pit. If only one large pool is present, at least two samples should be taken from separate locations within that pool.
- (8) Sample Collection.
 - (a) Tools: Collect samples using clean, stainless steel/glass/aluminum combination subsurface grab or COLIWASA samplers. Equipment instructions are supplied by the manufacturers.
 - (b) Containers: Samples collected with these types of equipment must be transferred to sample bottles for shipment. Metal containers with inner cap seals are preferable, but glass may also be used.
 - (c) Methods: When necessary, a backhoe may be used to transport a pool and surrounding soil to the surface for collection of the free-product sample. Another technique is to pump out the free product from the excavation into the sample jars using a peristaltic pump. After water separation, samples

should be transferred to metal or glass containers with inner cap seals for transport.

(d) Separating free product: Often, free product will occur in pools mixed with water from precipitation or ground seepage. In these cases, attempts should be made in the field to separate free product from the water to obtain an adequate quantity for analysis. Generally, 250 mL (8oz) of product is a sufficient amount for most analyses required. To achieve separation, liquid in a narrow-mouthed glass bottle must be allowed to settle until the water has clearly dropped to the bottom section. Cap the opening and tilt the bottle sideways until the floating phase portion floats clear of the mouth. Much of the water can then be drained away by simply uncapping the opening while tilting the bottle. Repeat this procedure until the desired amount of free-product sample is recovered. The residual water must be disposed of according to individual facility guidelines.

(9) Sample Packaging. Place the sample in a sample container appropriate for the type of analysis to be performed. Container requirements are described in Chapter 8. The latest version of SW-846, referenced in Chapter 8, should be used to meet analytical requirements. Wipe the outside of the sample container to prevent the spread of contamination. The sample container must not contain any headspace. This applies to the collection of organic samples for VOCs only. Log all samples in the logbook; include sample location, sample ID number, analytes, date, time, and signatures of samplers.

(10) Chain-of-Custody. Chain-of-custody procedures are described in Chapter 8.

(11) Decontamination. Decontaminate sampling equipment before and after sampling. First clean equipment of gross contamination then wash it with Alconox soap and distilled water. Rinse it using deionized water and allow it to dry. Refer to Chapters 7 and 9 for more information on decontamination procedures.

(12) Sample Shipping. Ship samples via an overnight carrier and pack according to the DOT or International Air Transport Association (IATA) procedures for the transport of samples. Refer to Chapter 8 for more information on sample shipment.

6-5. Waste Disposal. Waste that is generated during sampling in and around the UST(s) must be containerized and labeled according to its contents. The waste must be packaged in DOT-approved containers for subsequent treatment or disposal as outlined in Chapter 5.

6-6. Reporting and Documentation Requirement.

a. Use a field logbook to record:

- All activities performed, including names of samplers.
- Location and depths of samples.
- Dates and times when these activities were performed.
- Personnel contacted.
- Field conditions.
- Times of site arrival and departure.
- Soil color and texture.
- Instrument calibration information.
- Any unusual circumstances. Information should be factual, as it will be required for preparation of the Closure Report discussed in Chapter 1. If logbook corrections are necessary, draw a single line through the original entry, write the corrected entry alongside it, and initial and date the correction.

b. Information not recorded in the logbook must be recorded on field forms. In either case the following information must be recorded:

- Site identification.
- Type of samples.
- Sample identification numbers.
- Date and time collected.
- Collector's name.
- Field observations.
- Measurements.

Record safety and health monitoring information in the field logbook or on field data forms. Record everything so that events can be reconstructed at a later date. This logbook, combined with copies of the custody forms submitted to the laboratory with the samples, will serve to document sampling activities.

c. Photographs are suggested. If photos are taken they need to be labeled with the date, name of photographer, roll number, site name, camera type and lens size, sequential number of photo, and general direction. See EM 200-1-3 for additional information. Telephoto or wide-angle shots cannot be used in enforcement proceedings because they can distort the view.

6-7. Department of Transportation Sample Shipping Requirements

- a. Special consideration must be given to shipment of samples that are regulated as hazardous materials by the Department of Transportation. The following types of samples commonly encountered during UST removal activities are potentially DOT-regulated hazardous materials:

- Tank contents.
- Saturated soil samples.
- Free product samples.
- Water samples preserved with acid.
- Decontamination fluids.
- Sample preservatives such as methanol.

b. Definition of DOT Hazardous Material. Samples generated during UST removal activities are regulated by DOT as hazardous materials most commonly because they either meet the definition of a combustible liquid, a flammable liquid, a corrosive liquid, or because they are RCRA hazardous wastes. For example, samples of tank contents, free-product, or saturated soils having a flashpoint between 60.5°C (141°F) and 93°C (200°F) are regulated as combustible liquids. Materials having a flashpoint of less than 60.5 degrees C (141 degrees F) are regulated as flammable liquids. Water samples, which have been acidified for preservation purposes, may meet the definition of a DOT corrosive liquid. Spent decontamination fluids utilizing nitric acid, methanol, or hexane may be regulated by DOT because they are RCRA hazardous wastes. See Chapter 8 for sample packaging, marking, and shipping requirements. See 49 CFR, Subchapter C for details on Hazardous Materials Regulations.

CHAPTER 7

SITE SAFETY AND HEALTH PLAN REQUIREMENTS

7-1. General. A written site-specific safety and health plan is required to protect onsite personnel, the environment, and potential offsite receptors from the chemical and physical hazards particular to the UST site. The site safety and health plan (SSHP) must address all potential hazards and must present a plan of immediate action to protect all contractor's employees and USACE personnel and/or property. The SSHP must be followed during investigations, testing, repair/upgrade, removal, and all other UST-associated work. The contractor must be required to provide to the USACE, or an authorized representative, an SSHP before any work is initiated onsite in fulfillment of the contract or subcontract for UST work as directed by USACE. The contractor must utilize the services of a certified industrial hygienist (CIH) or a certified safety professional (CSP) experienced in hazardous waste site operations to oversee the development and implementation of the safety and health documents required by this section.

- a. References. All site investigation and UST removal activities and safety and health documents must, at a minimum, comply with the following regulations:
 - (1) Federal Acquisition Regulation (FAR) Clause 52.236-13: Accident Prevention.
 - (2) USACE, *Safety and Health Requirements Manual*; EM 385-1-1 (latest revision).
 - (3) OSHA *Construction Industry Standards*, 29 CFR 1926, and *General Industry Standards*, 29 CFR 1910; including but not limited to 29 CFR 1926.65 - *Hazardous Waste Operations and Emergency Response*.
 - (4) NIOSH/OSHA/USCG/EPA, *Occupational Safety and Health Guidance Manual for Hazardous Waste Site Activities*, October 1985.
 - (5) USACE, Guide Specification, CEGS-01350, *Safety, Health, and Emergency Response* (HTRW).
 - (6) Other applicable federal, state, and local safety and health requirements.
- b. Personnel. The SSHP must include but not be limited to:
 - Phone numbers of all emergency response personnel associated with evacuation routes and assembly areas.

- Phone numbers and names of persons in the areas adjoining the UST site.
- A roster of all contractor's personnel onsite.
- Detailed directions and a map to the nearest medical facility.
- Other inclusions deemed necessary to ensure that all safety requirements are addressed.

Because of the nature of the flammable or combustible liquids that are stored in these tanks, hazardous conditions may arise in the work area during removal and subsequent handling of tanks. For this reason, all personnel involved onsite must be familiar with the potential hazards and know appropriate safety and health measures to ensure a safe working environment.

7-2. Submittals. The following safety and health documents are required for UST activities delineated in this manual. Avoid providing material of a general nature that is not related to the UST project or site. Information readily available in standard texts should be repeated only to the extent necessary to meet the requirements of this scope. The Safety and Health Program (SHP) should contain general information required by the referenced OSHA standard and EM 385-1-1. By comparison, the SSHP should be a brief document addressing site-specific safety and health requirements and procedures based upon site-specific conditions. Reiteration of general information contained in the SHP should be avoided in the SSHP.

- a. Safety and Health Program. The contractor must submit a copy of the SHP required by OSHA Standard 29 CFR 1926.65(b)(1) through (b)(4) with the initial SSHP. Information contained in this written program must be used by reference in the SSHP, as appropriate, to fulfill site-specific plan detail requirements.
- b. Site Safety and Health Plan. The contractor's SSHP required by 29 CFR 1926.65(b)(4) must be prepared by the contractor and submitted to the contracting officer for review and approval prior to the commencement of any onsite work by the contractor and/or subcontractors. The level of detail provided in the SSHP should be tailored to the type of work, complexity of site activities, and anticipated hazards. All topics required by OSHA 29 CFR 1926.65(b)(4) and those described below must be addressed in the SSHP. Where the use of a specific topic is not applicable to the project, a negative declaration supported by a brief justification must be given.
 - (1) Site Description and Contamination Characterization. Describe the location, topography, and approximate size of the site; the onsite jobs/tasks to be performed; and the duration of planned site activities. Compile a complete list of the contaminants found or known to be present in site areas. This listing should be based on results of previous studies; or, if not available, select the likely contaminants based on site history and prior

site uses/activities. Include chemical names, concentration ranges, media where found, locations onsite, and estimated quantities/volumes to be impacted by site work, if known. In addition, information should also be included for any other chemicals brought onsite to complete any tank removal or site characterization activities.

- (2) Hazard/Risk Analysis. Identify the chemical, physical, biological, and safety hazards of concern for each site task and/or operation to be performed. Analyze these hazards and develop procedures for their control. Selection of chemicals as indicators of hazard must be based on media concentrations, toxicity, volatility or potential for air entrainment at hazardous levels, and frequency of detection.

Describe chemical and physical properties of selected contaminants, sources and pathways of employee exposures, anticipated onsite and offsite exposure-level potentials, and regulatory (including federal, state, and local) or recommended protective exposure standards. Specify and justify "action levels" based upon airborne exposure hazards and direct skin-contact potentials for upgrades/downgrades in levels of personnel protection; for implementation of engineering and/or work practice controls; for emergency evacuation of onsite personnel; and for the prevention and/or minimization of public exposures to hazards created by site activities.

Perform exposure monitoring/sampling as well as personnel monitoring in accordance with paragraph 7-6 titled *Exposure Monitoring/Air Sampling Program*. Compare the resulting data with established "action levels." Initiate the appropriate corrective actions as necessary.

- (3) Accident Prevention. The contractor's SSHP will serve as the Accident Prevention Plan (APP) and activity hazard analyses (phase plans) as required by FAR Clause 52.236-13 and USACE EM 385-1-1. Thus, a separate APP is not necessary. Any additional topics required by EM 385-1-1 must be addressed in an accident prevention section of the contractor's SSHP. Daily safety and health inspections must be conducted by the SSHA to determine if operations are being performed in accordance with the contractor's SSHP, USACE and OSHA regulations, and contract requirements. In the event of an accident/incident, the contractor must immediately notify the contracting officer's representative (COR). Within two working days of any reportable accident, the contractor must complete and submit to the contracting officer (CO) an Accident Report on ENG Form 3394 in

accordance with AR 385-40 and USACE supplements to that regulation.

- (4) Staff Organization, Qualifications, and Responsibilities. The organizational structure must be discussed, including lines of authority (chain of command) and overall responsibilities of the contractor and all subcontractors for site activities, including supervisor/employee relationships. Summarize the operational and safety and health responsibilities and qualifications of each key person identified. Specifically:
- (a) A CIH or CSP with experience in hazardous waste site operations must be responsible for the development, implementation, and oversight of the contractor's SSHP and SHP. The SHP and SSHP must be signed and dated by the CIH or CSP prior to submittal.
 - (b) A fully trained and experienced SSHO, responsible to the contractor and the CIH or CSP, may be delegated to implement and continually enforce the safety and health program and site-specific plan elements onsite.
 - (c) At least one person certified in First Aid/CPR by the Red Cross, or equivalent agency, must be continuously present onsite during site operations.

7-3. Medical Surveillance. All personnel performing onsite activities must be participants in an ongoing medical surveillance program, meeting the requirements of 29 CFR 1926.65(f) and ANSI Z-88.2. A description of the general medical surveillance program is to be included in the contractor's SHP. All medical surveillance protocols and examination results must be reviewed, signed, and dated by a licensed physician who is certified in Occupational Medicine by the American Board of Preventative Medicine, or who, by necessary training and experience, is board eligible. The contractor's SHP may only describe the content and frequencies of any additional medical tests/examinations/ consultations determined necessary by the physician due to probable site-specific conditions, potential occupational exposures, and required protective equipment. Certification of participation in the medical surveillance program, the date of last examination, and name of reviewing occupational physician must also be included for each affected employee. The written medical opinion from the attending physician required by 29 CFR 1926.65(f)(7) must be made available upon request to the COR for any site employee.

7-4. Safety and Health Training. All personnel performing onsite activities must have completed applicable training in accordance and compliance with 29 CFR 1926.65(e) and EM 385-1-1. In addition, site-specific training covering site hazards, procedures, and all contents of the approved contractor SSHP must be conducted by the SSHO for onsite employees and visitors prior to

commencement of work or entering the site. The type, duration, and dates of all employee training performed must be listed by employee name and certified in the contractor SSHP. The following training information is general in nature but should be included in the SSHP.

a. Basic, Refresher, Supervisory, and Site Training.

- (1) No employee should be put into a hazardous field situation without training that includes an opportunity to practice job assignments in a nonhazardous situation. This section describes training requirements.
- (2) Before starting work on the site, an employee or subcontractor must complete a 40-hour basic hazardous waste safety and health training course that meets the requirements of 29 CFR 1926.65(e), the *OSHA Standard for Hazardous Waste Operations and Emergency Response*. The training is to be documented with a certificate signed by the course director. Basic training also includes at least three additional days of field or operations training under supervision. Supervisors are required to complete eight additional hours of hazardous waste management training.
- (3) On an annual basis, employees are required to complete eight hours of refresher training thereby meeting the requirements of 29 CFR 1926.65(e)(8).
- (4) Employees should complete a site-specific safety training/orientation that emphasizes:
 - Names of personnel responsible for site safety and health.
 - A discussion of the SSHP.
 - Site-specific safety and health hazards.
 - Exposure monitoring/personal exposure guidelines (e.g., PEL, TLV, IDHL, odor threshold, etc.).
 - Fire extinguishers.
 - Designated work zones.
 - Phase safety plans.
 - The nature of site hazards.
 - Use of personal protective equipment (PPE).
 - Decontamination facilities and procedures.
 - Work practices by which employees can minimize risks from hazards.
 - Site rules and regulations, including vehicle use.
 - Medical surveillance requirements, including recognition of symptoms and signs of exposure.
 - Confined space entry procedures.
 - Emergency and fire response.

- Material safety data sheets (MSDSs).
- Procedures for reporting hazardous conditions and practices.
- Safety and Health training requirements.

b. Training for Subcontractors.

- (1) Subcontractors are required to submit certification that they have met OSHA requirements for basic, refresher, and supervisory training before working on the site.
- (2) The SSHO should be responsible for conducting a task-or assignment-specific briefing for subcontractors seeking access to the site to perform work.
- (3) Training should be specific to the assignment or task and may include the same topics discussed in the previous section.
- (4) Subcontractors or authorized visitors may enter the site after completing this orientation, providing that in addition to meeting the training requirements, they possess appropriate medical and respirator certifications.

c. Visitor Training. Visitors and other individuals seeking access to the site must receive a briefing conducted by the SSHO as to their safety-related responsibilities. This briefing (typically 5 to 10 minutes in length) should include:

- Areas of site restriction.
- Discussion of the site evacuation warning signal.
- Discussion of the emergency egress route.
- Other topics as deemed necessary by the nature of the visit.

7-5. Personal Protective Equipment (PPE). The contractor's SSHP should include a written PPE Program that in accordance with 29 CFR 1926.65 (g) (5) and the respiratory protection program requirements of 29 CFR 1926.103. The contractor SSHP must detail the minimum PPE ensembles (including respirators) and specific PPE construction materials for each site-specific task/operation to be performed based upon hazard/risk analysis. Components of levels of protection (A, B, C, D, and modifications) must be relevant to site-specific conditions, including heat and cold stress potential and safety hazards. Site-specific procedures for onsite PPE use, limitations, training, fit testing, cleaning, maintenance, inspection, and storage and disposal should be included also.

- a. Level of Protection. The level of protection for the majority of site work tasks described in this UST Manual is anticipated to be Modified Level D as described in Table 7-1. However, the SSHO may upgrade to Level C if the "action levels" discussed in this plan are exceeded. Work must cease pending a complete reevaluation of the

site conditions by the CIH/CSP and SSHO should Level A and B conditions be anticipated or required once onsite.

- (1) Modified Level D. Employees and subcontractors will be required to wear the PPE designated in Table 7-1 for tasks that the SSHO determines to be Modified Level D. The SSHO is responsible for determining if liquid contaminant exposure could occur. These conditions may require taping of the joints at the wrist and ankle.

See Table 7-1 for PPE descriptions for Levels A, B, and C. Employees and subcontractors will be required to wear PPE as dictated by task according to the SSHO.

b. Respiratory Protection Program.

- (1) Employees and subcontractors are required to conform to the respiratory protection requirements of OSHA 29 CFR 1926.103 and EM 385-1-1. A written respiratory program as required by 29 CFR 1926.103(b)(1) should be incorporated as a part of the contractor's/subcontractor's written SSHP and provided with the SSHP to the contracting officer.
- (2) Employees and subcontractors must be required to submit evidence of respirator fit testing to the SSHO prior to performing tasks with the potential for upgrade to Level C or Level B. The documentation of qualitative and/or quantitative fit testing for survey personnel wearing respirators must include the following items for each individual: the manufacturer; the model; the size; the NIOSH Testing and Certification Number; the test results; the signature of the individual being tested; and the signature of the staff member who performed the fit test.
- (3) Before using a respirator, employees and subcontractors are required to perform an inspection and checkout in accordance with the manufacturer's instructions. All respirator users will conduct positive- and negative-pressure leak testing each time the respirator is worn to ensure satisfactory fit and valve function. The user will perform the following tests:
 - (a) Positive-pressure test: The user places the palm of his/her hand over the exhalation valve and exhales gently. If the respirator fits properly, the face piece should swell slightly.
 - (b) Negative-pressure test: The user covers both cartridges with his/her hands and inhales gently. If the respirator fits properly, the face piece should collapse on his/her face.

**TABLE 7-1
 PERSONAL PROTECTIVE EQUIPMENT**

Level D	<p>Work clothing, as dictated by the weather Safety (steel toe/shank) shoes or boots Chemical goggles or face shield Hard hat Nitrile, neoprene, or natural rubber gloves (use when handling or contact may occur with contaminated soils or similar incidents)</p>
Modified Level D	<p>Work clothing as dictated by the weather Safety (steel toe/shank) shoes or boots Hard hat Face shield (for pumping operations) Chemical goggles (for tank interior decontamination operations) Saranex or polyethylene-coated tyvek (or equivalent) Coveralls with hood (use when handling or contact may occur with contaminated soils or material, tank contents, tank interior decon, or other similar incidents) Nitrile, neoprene, or natural rubber overboots (use when handling or contact may occur with contaminated soils or similar incidents) Nitrile, neoprene or natural rubber gloves (use when handling or contact may occur with contaminated soils or similar incidents)</p>
Level C	<p>Same as for Modified Level D except for the addition of: Full-face, air-purifying respirator equipped with organic vapor cartridges</p>
Level B	<p>Same as for Modified Level D except for the addition of: Pressure-demand, full-face SCBA or pressure-demand supplied air respirator with escape SCBA</p>
Level A	<p>Pressure-demand, full-face SCBA or pressure-demand supplied air respirator with escape SCBA Fully encapsulating suit Inner gloves</p>

- (4) Facial hair (beards, sideburns, etc.) that interferes with the sealing surface of a respirator or interferes with its valve function is not permitted. A "one-day" growth of beard is considered to be interference.
- (5) Contact lenses must not be worn onsite. Each individual who requires visual correction must be provided with the appropriate corrective lenses that are made to be mounted inside a full face piece.
- (6) Employees and subcontractors are required to clean and disinfect their respirators thoroughly after each use or at the end of the day's activities. Respirator wipes may be used in the intervals.
- (7) Respirators must be stored away from dust, sunlight, heat, extreme cold, excessive moisture, damaging chemicals, and sources of mechanical damage.

7-6. Exposure Monitoring/Air Sampling Program (Personal and Environmental). Where there may be employee exposures to, and/or offsite migration potentials of, hazardous airborne concentrations of hazardous substances, then appropriate direct-reading (real-time) air monitoring and integrated time-weighted average (TWA) air sampling must be conducted in accordance with applicable regulations (OSHA, EPA, state). Both air monitoring and air sampling must accurately represent concentrations of air contaminants encountered on and leaving the site's exclusion/contamination reduction or support zones as deemed appropriate for the type of monitoring performed. Follow these guidelines for monitoring:

- (1) Utilize sampling and analytical methods following NIOSH (for onsite personnel and site perimeter locations) and/or EPA (for site perimeter or offsite locations) criteria.
- (2) Use laboratories successfully participating in and meeting the requirements of the American Industrial Hygiene Association's (AIHA) Proficiency Analytical Testing (PAT) or Laboratory Accreditation programs for personnel sample analysis.
- (3) Perform meteorological monitoring onsite as needed and use it as an adjunct in determining perimeter and any offsite monitoring/sampling locations. Where perimeter monitoring/sampling is not deemed necessary, provide a suitable justification for its exclusion.
- (4) Conduct noise monitoring as needed, depending on the site hazard assessment.

- (5) Compare all monitoring/sampling results to "action levels" established pursuant to "Hazard/Risk Analysis," in paragraph 7-2 above to determine acceptability and need for corrective action. As a minimum, develop action levels by taking into account the PELs, TLVs, odor thresholds, explosive limits of and monitoring instrument responses to the contaminants where this information is available.

Minimum action levels for benzene and gasoline (where applicable) and percent oxygen and lower explosive limits (LELs) must be as follows:

Benzene

0-1 ppm	Level D/Modified Level D
1-25 ppm	Level C/Modified Level C
> 25 ppm	Shut down operations and ventilate the area

Gasoline

0-30 ppm	Level D/Modified Level D
30-1,000 ppm	Level C/Modified Level C
> 1,000 ppm	Shut down operations and ventilate the area

Oxygen Monitoring

19.5%-22%	Normal operations
< 19.5%	Level B, shut down operations and ventilate the area
>22%	Shut down operations and ventilate the area

LEL

≤ 10%	Normal operations with monitoring
> 10%	Shut down operations and ventilate the area

a. Exposure Monitoring.

- (1) The SSHO should perform exposure monitoring to ensure that employees and subcontractors are not exposed to chemical contaminants above established exposure limits.
- (2) Conduct personal monitoring by taking breathing zone and general area measurements using direct reading instruments during work tasks that have the potential for exposure. When personnel are working on or near tanks or within trenches/excavations, the contractor should implement routine personnel air surveillance for the presence of air contaminants (gasoline, benzene, oxygen level, LEL, etc.). Air monitoring will be required whenever personnel enter a confined space or continuously during tank vapor purging/inerting. (For the purposes of this manual, purging means any method employed by the contractor to reduce the atmosphere in the tanks to less than 10 percent of the LEL. Inerting refers to methods used to reduce the oxygen content in

the tank to less than or equal to 8 percent.) Air monitoring will ensure that personnel are not exposed above OSHA PELs or ACGIH TLVs, whichever is more stringent.

- (3) Follow these guidelines for environmental monitoring:
 - (a) Conduct environmental monitoring by taking general area measurements using direct reading instruments during work tasks that have the potential to produce airborne contaminants that may migrate offsite.
 - (b) Conduct confined space monitoring for all excavations greater than five feet in depth and continuously during the time workers are present in excavations.
 - (c) Conduct air monitoring in storage tanks to ensure the tank has been adequately purged. The contractor must test all areas (top, middle, bottom) of the tanks in the event stratification has occurred.

When monitoring to ensure personnel safety, both oxygen content and LEL readings are required. When obtaining LEL readings, first verify the oxygen content of the space to provide for proper operation of combustible gas indicators. Oxygen levels less than 19.5 percent constitute IDLH conditions. (If the inerted nature of the tank is to be determined, only oxygen readings are required. Forced fresh air ventilation will be required when appropriate.)

Whenever air monitoring within the exclusion zone indicates Level C, PPE is required, as well as routine air monitoring at the boundary of the exclusion zone. The SSHO must expand the exclusion zone as necessary to ensure air concentrations do not exceed Level D action levels at the exclusion zone boundary.

- (4) Cold climates present special problems for monitoring instruments and monitoring in general. Instruments must be calibrated frequently and must be allowed time to warm up. Meters must be calibrated for the conditions of the vapor mixture to be measured and calibrated at the temperatures to be used. A rise in temperature of 10 degrees requires a calibration recheck and area resampling.

b. Exposure Monitoring Equipment.

- (1) The presence of organic vapors throughout the site area and in breathing zones must be determined using a real-time vapor monitoring instrument such as a PID or FID.

(2) Equipment used for real-time environmental monitoring include Photoionization Detectors (PID), Flame Ionization Detectors (FID), and Combustible Gas Indicators (CGI). Many CGIs are also equipped to monitor oxygen and hydrogen sulfide levels in the atmosphere. This type of instrument is recommended for environmental monitoring and required for confined space work. Other monitoring equipment that may be necessary (depending on site conditions) is direct-reading colorimetric indicator/detector tube systems for measuring benzene. All instruments should be maintained and calibrated according to manufacturers' guidelines.

c. Phase Safety Plans. The following sections contain phase safety plans and are indicative of activities encountered in UST work. Each site will be different and, therefore, will contain different hazards. Each specific task will require separate descriptions. The following are examples of typical task descriptions:

(1) Surveying.

- (a) Task Description. Workers survey various sites for surface features and locations and elevations of all new monitoring wells.
- (b) Physical Hazards. Uneven terrain. Unsure footing, especially in wet conditions. Tick and snake bites. Rodents. Debris. Poisonous plants. Vegetation in some areas can hide hazards. Vehicle traffic. Overhead obstructions in buildings.
- (c) Exposure Hazards. Refer to the hazard analysis paragraphs (7-14) of this chapter for exposure hazards relative to UST work.
- (d) Level of Protection. Refer to the action levels discussed previously for the applicable action level for PPE.
- (e) Standard Procedures. The SSHO is required to measure the ambient air concentrations, check the site for physical hazards, and authorize the surveyor to begin surveying. The appropriate protective clothing is worn in accordance with the action levels specified. In some cases, Level C may be required, particularly in areas of significant contamination.

(2) Soil-Gas Survey.

- (a) Task Description. A soil-gas survey may be performed to investigate underground contamination from volatile chemicals (such as industrial solvents, cleaning fluids, and petroleum products) by looking for their vapors in the shallow soil.
- (b) Physical Hazards. Uneven terrain. Unsure footing, especially in wet conditions. Tick and snake bites. Rodents. Debris. Vegetation in some areas can hide hazards. Poisonous plants. Vehicle traffic. Heavy equipment is involved (i.e., medium-sized vehicle with lab equipment, sampling equipment, and a moderate-sized hydraulic press to drive sampler into soil). General safety precautions around heavy equipment should be observed.
- (c) Exposure Hazards. Refer to the appropriate portions (7-14) of this chapter for the exposure hazards. The borehole provides a conduit for hazardous vapors or fluids to reach the surface.
- (d) Level of Protection. Refer to the action levels discussed previously to determine the action level for PPE.
- (e) Standard Procedures.
 - Wear the appropriate protective clothing in accordance with the action levels specified. In some cases, Level C may be required, particularly in areas of significant contamination.
 - Wear leather gloves during activities that involve handling drill rig components and samples.
 - Know the location of underground and overhead utilities (electric lines, gas lines, and so forth). An installation representative, who is knowledgeable about the location of buried utilities, must approve all drilling and/or soil sampling locations.
 - Do not wear loose fitting clothing or jewelry.
 - Constrain long hair.
 - Do not touch or go near moving parts.

- Know the location of "Emergency Shut Off" switches. Should field maintenance on the drill rig be required, follow lockout/tagout procedures appropriate to the equipment and established in accordance with 29 CFR 1910.147.
- Stay away from operating equipment, particularly if the rig is located on unstable terrain.
- Minimize exposure time if close observation is required to complete an inspection.
- Allow properly equipped and protected personnel to respond in the event of an accident (hitting a gas line or drilling into heavy contamination). Immediately leave the area.
- Do not smoke or use spark-producing equipment around drilling operations, because flammable gasses may be released from the subsurface environment.
- Do not work during a rain storm because lightning could strike the rig. Heavy rain can increase the risk of sliding and falling, decrease visibility, and may make the equipment more hazardous to operate.

(3) Well Installation.

- (a) Task Description. Monitoring wells are one method that may be used to provide an access point for measuring groundwater levels and to collect groundwater samples that accurately represent in-situ groundwater conditions at the specific point of sampling.
- (b) Physical Hazards. Uneven terrain. Unsure footing, especially in wet conditions. Tick and snake bites. Rodents. Debris. Vegetation in some areas can hide hazards. Vehicle traffic. In addition, the following physical hazards may exist:
 - A major hazard of air rotary drilling can occur if the air compressor hose breaks loose and flies around uncontrollably, causing damage to equipment, serious injury, or death.
 - Explosion potential. Use of hollow-stem auger in methane- or gasoline-soaked soils represents a potential explosion.

- Stacked pipes can pose a hazard if one pipe falls and the stack collapses.
- Heavy equipment is involved (i.e., drill rig, compressor, water truck, flat-bed for drill rods). General safety precautions around heavy equipment should be observed.
- Hoisting the rope with a windlass during sampling provides a potential for injury if something slips or breaks.
- The weight used to drive the split-spoon is located overhead where disintegrating metal can fly anywhere if something breaks.
- Other physical dangers include: heavy rotating components, hoisting heavy materials overhead, material falling from the mast, and exposure to hot engine parts.

(c) Exposure Hazards. Refer to paragraphs 7-14 of this chapter for information on exposure hazards. In addition:

- Cuttings, drilling liquids, and groundwater may be contaminated. The presence of hazardous constituents should be evaluated, and the fluids managed accordingly. Avoid direct contact with these materials.
- The borehole provides a conduit for hazardous vapors or fluids to reach the surface. For example, methane in a landfill, vapors from buried drums, and contaminated groundwater can all be conveyed up the borehole. Respiratory and dermal protection may be needed.
- Rotary drilling with air can cause stripping of hazardous volatiles that may be present in the soil, and these vapors will be concentrated at the wellhead. For this reason, rotary air drilling may present a more serious inhalation hazard than drilling with other fluids.

(d) Level of Protection. Refer to the action levels discussed previously for the appropriate PPE.

(e) Standard Procedures.

- Wear the appropriate protective clothing in accordance with the action levels specified. Wear gloves during activities that involve handling drill rig components and samples. In some cases, Level C may be required, particularly in areas of significant contamination.
- Monitor all drilling activities with a CGI for explosive gases. Readings should be collected in the borehole whenever a sample is collected or drilling is stopped.
- Use common sense. Drill rigs are heavy equipment and should be respected as such.
- Know the location of underground and overhead utilities (electric lines, gas lines, and so forth).
- Walk completely around the rig before raising the drill rig mast in the vicinity of power lines. Determine the minimum distance from any point on the drill rig to where the nearest power line will be when the mast is raised and/or being raised. Do not raise the mast or operate the drill rig if this distance is less than 6 meters (20 feet).
- Minimum protective gear includes steel-toed shoes, hearing protection, hard hats, and eye protection.
- Do not wear loose-fitting clothing or jewelry.
- Constrain long hair.
- Do not touch or go near moving parts.
- Know the location of "Emergency Shut Off" switches. The driller and the SSHO must check the emergency kill-switch operation prior to commencing a drilling and/or sampling study and during the daily maintenance check. All malfunctions must be documented and reported to the project manager. All malfunctions must be repaired before drilling and/or sampling operations are permitted.
- Stay away from operating equipment, particularly if the rig is located on unstable terrain. If close observation is required to complete an inspection, minimize exposure time.

- In the event of an accident (hitting a gas line or drilling into heavy contamination), allow properly equipped and protected personnel to respond. Immediately leave the area.
- Do not smoke or use spark-producing equipment around drilling operations because flammable gases may be released from the subsurface environment.
- Do not work around a drill rig during a thunderstorm because lightning could strike the rig. Heavy rain can increase the risk of sliding and falling, decrease visibility, and may make the equipment more hazardous to operate by decreasing friction on the rope around the windlass.
- Wear the appropriate respiratory and dermal protection if exposure to hazardous vapors or contaminated cuttings and fluids is a possibility.

(4) Groundwater Sampling.

- (a) Task Description. Groundwater wells at various sites are developed, sampled, and the water level measured.
- (b) Physical Hazards. Metallic well parts can cut hands. Uneven terrain. Unsure footing, especially in wet conditions. Tick and snake bites. Rodents. Debris. Vegetation in some areas can hide hazards. Vehicle traffic.
- (c) Exposure Hazards. Refer to the appropriate portion of this chapter for exposure hazards. (See paragraphs 7-14.)
- (d) Level of Protection. Refer to the action levels discussed previously for the appropriate PPE at the specific site.
- (e) Standard Procedures. Refer to Appendix C for the procedure for opening and sampling wells. Wear the appropriate protective clothing in accordance with the action levels specified. In some cases, Level C may be required, particularly in areas of significant contamination.

(5) Soil Sampling.

- (a) Task Description. Collect soil samples at intervals during well installation, and collect soil borings at specified locations.

- (b) Physical Hazards. Refer to above for the hazards of drilling rigs. Uneven terrain. Unsure footing, especially in wet conditions. Tick and snake bites. Rodents. Debris. Vegetation in some areas can hide hazards. Vehicle traffic.
- (c) Exposure Hazards. Refer to the appropriate portion of this chapter for exposure hazards. (See paragraphs 7-14.)
- (d) Level of Protection. Refer to the action levels discussed previously to select the proper action level for PPE.
- (e) Standard Procedures. Wear the appropriate protective clothing in accordance with the action levels specified. Gloves are worn during sampling activities. In some cases, Level C may be required, particularly in areas of significant contamination.

7-7. Heat/Cold Stress Monitoring. Implement heat-and/or cold-stress monitoring protocols as appropriate. Determine work/rest schedules based upon ambient temperature, humidity, wind speed (wind chill), solar radiation intensity, duration and intensity of work, and protective equipment ensembles. Develop minimum required physiological monitoring protocols that will affect work schedules. In cases where impervious clothing is worn (full body), follow the NIOSH/OSHA/USCG/EPA *Occupational Safety and Health Guidance Manual for Hazardous Waste Site Activities* protocol for prevention of heat stress. Commence heat-stress monitoring at temperatures of 70 degrees F. and above. Where impervious clothing is not worn, the most current published ACGIH heat-stress standard threshold limit values (TLV) must be used. To help prevent frostbite and hypothermia, reference and follow the most current published ACGIH cold-stress standard as a minimum. See Appendix D for heat- and cold-stress procedures.

7-8. Standard Operating Safety Procedures, Engineering Controls, and Work Practices. The elements outlined below must be addressed in the SSHP as a minimum.

a. Site Rules/Prohibitions.

(1) Buddy System.

- (a) USACE safety and health policy requires each employee entering a hazardous waste operation to be accompanied by a "buddy." A buddy provides co-worker/partner with assistance; observes partner for signs of exposure; periodically checks the integrity of partner's PPE; and notifies the SSHO if help is needed.

- (b) Because the buddy must provide help, the buddy must be in sight or hearing of the employee, and be prepared to enter any area the employee enters. Thus, the buddy must be fully certified to work in the level of protection that the employee is working in, and must have the appropriate PPE available. Personnel should not enter any area to assist their buddy unless another backup is available in the case of an emergency.
 - (c) Personnel who can provide emergency assistance in the event of injury or illness can serve as a buddy. Persons able to serve as buddies include: USACE personnel; subcontractor employees; federal, state, and local regulatory agency employees; and facility operators and their employees.
 - (d) Persons not able to serve as buddies include: members of the general public or reporters, clerical staff, persons not wearing the level of protection used in the work area, and persons not certified to wear the level of protection used in the work area.
 - (e) The use of buddies other than USACE personnel is approved only on a case-by-case basis by the CIH/CSP or the SSHO. The buddy must agree to, and be aware of, the responsibilities of a buddy as defined above.
- (2) General Safety and Health Rules.
- (a) All USACE and subcontractor personnel assigned to work on the site must be provided with a copy of the SSHP and must attend a daily safety briefing before commencing work.
 - (b) MSDSs for all chemicals brought to the site must be filed onsite. All project personnel will be informed of their location and availability.
 - (c) No one will be permitted to work alone on the site—the buddy system will be followed.
 - (d) Eating, drinking, chewing gum or tobacco, smoking, or any practice that increases the probability of hand-to-mouth transfer and ingestion of material is prohibited in any investigation area.
 - (e) Hands and faces must be thoroughly washed upon leaving the work area and before eating, drinking, or other activities.

- (f) Whenever decontamination procedures for protective clothing are in effect, the entire body must be thoroughly washed as soon as possible after the protective clothing is removed.
 - (g) Medicine and alcohol can increase the effects of exposure to toxic chemicals. Personnel using prescription drugs must inform the doctor prescribing the medicine of potential contact with toxic materials. Field employees taking over-the-counter drugs within a day before work on a site must inform a physician of intentions to perform hazardous waste operations while using the drug.
 - (h) Alcoholic beverage intake will be prohibited during the work day. Personnel under the influence of recreational or illegal drugs will not be allowed onsite and may face disciplinary action.
 - (i) Wearing of contact lenses onsite is prohibited.
 - (j) Wearing of beards by individuals assigned to tasks that require or may require respirators will be prohibited. A one-day growth of facial hair that interferes with respirator-to-face seal is considered to be a beard.
 - (k) All personnel working in exclusion zones must process through decontamination before eating, drinking, and/or smoking.
 - (l) Before initiating any nonroutine operation, personnel must consult SSHO about safety and health requirements for the operation.
- (3) Site Safety Practices. Historically, one of the major causes of physical injuries at sites is slips and falls. To prevent this hazard, pick up tools, parts, and other equipment. Grease droppings, oils, and sludge must be cleaned up as soon as possible. Use warning signs, railings, and in-place covers to protect against low piping, open tanks, and open manholes or hatches. The simple knowledge of proper lifting techniques can save many strained or injured backs. There are a host of general practices that require training to ensure personnel safety during operation of the site. A few are detailed below:
- (a) Do not run except in emergencies.
 - (b) Do not operate moving equipment unless instruction in its use has been given, and use is authorized by the SSHO. Only properly licensed personnel will be authorized to move heavy equipment.

- (c) Do not perform onsite equipment maintenance unless specific lockout/tagout instructions are given by the SSHO and specific lockout/tagout procedures for the equipment are established and followed.
- (d) Observe driving regulations within the site. These include wearing seat belts at all times when the vehicle is in motion and maintaining speeds under 15 miles per hour.
- (e) Remove safety equipment or supplies from their normal location after SSHO authorization.
- (f) Position safety devices, safety guards, and chains in place before equipment operation.
- (g) Improvised staging and structures are not permitted.
- (h) Carry a portable two-way radio for emergency and related use (applies to all USACE personnel). The SSHO should always carry a two-way radio.
- (i) Keep hand tools and special tools clean and in good repair.
- (j) Have the SSHO mark and inspect temporary lines, power cords, and outlets prior to use.
- (k) Locate buried cables and underground utilities prior to intrusive activities (such as excavation).
- (l) Use the correct tool for the particular job in the proper manner.
- (m) Carry materials and tools with concern for overloads and balance; these items must be securely held.
- (n) Avoid movement with obscured vision.
- (o) Practice good housekeeping at all times.
- (p) Use solvents and volatile liquids for periodic cleaning, etc., with SSHO authorization. Follow proper storage and disposal guidelines.
- (q) Do not practice "horseplay:" any frivolous behavior that increases the probability of an accident.

b. Material Lifting.

- (1) Many types of objects are handled in normal operation and maintenance at sites. Care should be taken in handling heavy or bulky items because they are the cause of a considerable number of accidents. Be certain employees know the following fundamentals of proper lifting to avoid back injuries:
 - (a) Consider the size, shape, and weight of the object. A worker should not lift more than one person can handle comfortably.
 - (b) Place the feet far enough apart for good balance and stability. *THE FOOTING SHOULD BE SOLID.*
 - (c) Get as close to the load as possible. The legs should be bent at the knees.
 - (d) Keep the back as straight as possible.
 - (e) Grip the object firmly.
 - (f) Straighten the legs from their bend to lift the object.
 - (g) Never carry a load you cannot see over or around.
 - (h) Set the object down by positioning yourself like you lifted; the legs are bent at the knees and the object lowered.

- (2) When two or more workers are required to handle an object, coordination is essential to ensure that the load is lifted uniformly and that the weight is equally divided between workers. Each worker, if possible, should face the direction in which the object is being carried. In handling bulky or heavy items, the following guidelines should be followed to avoid injury to the hands and fingers:
 - (a) Have a firm grip on the object.
 - (b) Make sure the hands and object are free of oil, grease, or water that might prevent a firm grip.
 - (c) Inspect the item for metal slivers, jagged edges, burrs, and rough or slippery surfaces.
 - (d) Wear gloves when possible.
 - (e) Keep fingers away from any points that may cause the fingers to be pinched or crushed, especially when setting the object down.

c. Fall Protection.

- (1) Falls are the second largest cause of physical injuries. Besides the fall hazards within the site, ladders and platforms present an accident hazard. Refer to procedures specified in the USACE *Safety and Health Requirements Manual* (EM 385 1-1) for the use of ladders.
- (2) Platforms and scaffolds must be inspected before use, so that they comply with the USACE *Safety and Health Requirements Manual* (EM 385 1-1).

d. Hand Tools.

- (1) Refer to USACE *Safety and Health Requirements Manual* (EM 385-1-1) for guidance in the use of hand tools. Only use tools that are in good condition. Improper and defective tools contribute to accidents. Observe the following safe practices:
- (2) Use tools in the manner for which they were designed to prevent injuries.
- (3) Be sure of footing before using any tool.
- (4) Do not use tools that have split handles, mushroom heads, worn jaws, or other defects.
- (5) Do not use makeshift tools or improper tools.
- (6) Make sure that tools cannot fall on someone below when working overhead. Tie the tools to a line, if necessary.
- (7) Use non-sparking tools where there is a possibility of explosive vapors or gases.

e. Hoses. Observe the following rules when using hoses:

- (1) Inspect hoses for defects, cuts, loose clamps, improper fittings, etc., before use.
- (2) Never apply air from an air hose to any part of the body or clothing.
- (3) Use only standard fittings for all hoses.
- (4) All quick makeup connections must be secured.

f. Electrical Safety.

- (1) Guidance for electrical safety appears in the USACE *Safety and Health Requirements Manual* (EM 385-1-1). Most equipment at the site uses electricity as the power source. Only use equipment designed and installed in compliance with the National Electrical Code Fire Code No. 70 (1985), NFPA, on the site. Maintaining field equipment requires exposure to electrical hazards that may result in shock or death unless safe practices are strictly followed. When working with electricity, it must always be assumed that there is sufficient voltage and current present to cause injury.
- (2) All lockout and tagging of circuits must comply with the provisions of 29 CFR 1926.417 and EM 385-1-1. No work will be performed on any energized electrical circuits. De-energize electrical circuits by opening the circuit breaker or disconnecting the switch feeding them. Where no circuit breaker or disconnect switch exists, employ other methods to de-energize the circuit. After the circuit has been de-energized, test it with a voltage tester to make sure there is no voltage present. Before work starts on the circuit, lock the disconnect switch or circuit breaker in the open position with the worker's safety lock. Attach a warning tag to the switch or breaker with the worker's name on it.
- (3) When work is to be performed on electrically driven equipment, lock the motor disconnect switch or circuit breaker to that equipment in the open position with the worker's safety lock. Attach a warning tag to the switch breaker with the worker's name on it. Before work starts on the equipment, the worker must attempt to operate the equipment to make sure it is inoperative. Adhere to applicable lockout/tagout procedures in compliance with 29 CFR 1910.147 and EM 385-1-1.
- (4) Workers will adhere to the following general rules:
 - (a) Survey the work area to determine whether any part of an electrical power circuit, either exposed or concealed, is located such that the performance of work could bring any person, tool, or machine into physical or electrical contact with it.
 - (b) Acquire the SSHO's permission to open an electrical control panel.
 - (c) Do not use a part of the body to test a circuit.

- (d) Avoid contact with grounding conductors like water, pipes, drains, or metal objects when working on electrical equipment or wiring.
- (e) Wear an electrical protection ensemble specified by the SSHO when performing electrical work near grounding conductors.
- (f) Do not bypass or disconnect electrical safety devices.
- (g) Use only approved extension cords.
- (h) Use only tools with insulated handles.
- (i) Use only portable electrical devices with ground fault circuit interruption (GFCI) protection when utilizing temporary electrical systems.
- (j) Do not use metal-cased flashlights.
- (k) Do not wear jewelry.
- (l) Use grounded or double-insulated electric tools.
- (m) Keep all electric motors, switches, and control boxes clean at all times.

g. Mechanical Equipment Safety.

- (1) The SSHO must inspect all mechanical equipment before it is allowed on the site.
- (2) Accidents in using machinery and mechanical devices can be kept to a minimum by designing each job to prevent accidents. When any mechanical equipment is purchased, consider all points that affect safety; past accident experience with the kind of equipment should serve as a guide, and desirable safety features should be specified and included in the original design.
- (3) The SSHO should ensure that rules and safety practices in the use of mechanical devices are regularly followed and that the equipment is in proper working order, in keeping with all the safeguards that have been adopted.
- (4) Safety guards are furnished for protection. The following regulations must be followed:
 - (a) Remove guards only after equipment has been shut down, tagged, and locked out of service in accordance with 29 CFR

1910.147 and EM 385-1-1. Replace guards as soon as work is completed.

- (b) Make sure guards are in place and operative when using machinery.
- (c) Be thoroughly familiar with equipment before attempting to operate it.
- (d) Do not stand on moving equipment while it is in operation.

h. Equipment Startup and Operation. Rules for safe operation of mechanical equipment may be summarized as follows:

- (1) No machine will be lubricated or adjusted while in motion, unless its manufacturer specifies this practice, and it is deemed prudent by the SSHO.
- (2) Belts, ropes, or other moving parts of equipment must not be guided or controlled by hand or foot.
- (3) Do not operate machines unless they are in good working condition. The mechanical equipment operators should perform daily maintenance checks. All malfunctions must be documented and reported to the SSHO and the project manager. All malfunctions will be repaired before operations are permitted.
- (4) Operators of mechanical equipment must place themselves in a "safe" position before putting the equipment into operation.
- (5) Shut off power and lock the equipment securely against all motion prior to repairs or adjustments. A warning sign must also be attached to the lock.
- (6) Never oil line shafting while in motion, unless its manufacturer specifies this practice.
- (7) The SSHO must authorize machine and apparatus operation.
- (8) No person should use equipment without prior instruction or experience.
- (9) Provide adequate clearance at machine installation; passageways must be kept free of stumbling hazards.
- (10) Illuminate machines adequately.
- (11) Keep steps, handrails, and floors free from grease and debris.

i. Excavations and Trenching. All site excavations and trenching must comply with the provisions of EM 385-1-1 and 29 CFR 1926 Subpart P, *Excavations*.

(1) Excavations.

- (a) To prevent injury and property damage during excavation work, pre-excavation conditions (superimposed loads, soil structure, and hydrostatic pressure, etc.) study to evaluate changes that might occur or situations that might develop, and plan the job ahead. Conduct all excavating work in conformance with EM 385-1-1 and 29 CFR 1926.650 through 1926.653, including requirements for shoring or continuously sloping excavations in which employees are exposed to danger from moving ground.
- (b) The presence of underground facilities, such as utility lines (water, electricity, gas, or telephone), tanks, process piping, and sewers is a major hazard. If these are dug into, undercut, or damaged in any way, there may be injury or death to workers, interruption of service, contamination of water, disruption of processes, and expensive delays. Before excavation, the location of various utilities and their approximate depth below ground must be coordinated through the installation or local private utility district and marked by stakes in the ground. Contents of buried tanks and piping should be indicated on the location markings. If the contents are flammable or toxic, have proper protective equipment readily available in case of rupture. Indicate the bottom depth of the tank.

Make sure clearance to adjacent overhead transmission and distribution electrical lines is sufficient for the movement of vehicles and operation of construction equipment. The requirements stated in EM 385-1-1, 29 CFR 1926 and the National Electric Safety Code must be followed by the contractor.

- (c) Excavated, stockpiled materials or tank and equipment must not be placed closer to the edge of the excavation than a distance equivalent to one-half the maximum depth of excavation. Tarpaulins, sheeted barricades, or low built-up board barricades must be used to confine material to the immediate area.
- (d) Barricade excavations to prevent employees and others from falling into it. When an excavation must remain open for duration of the construction work, use barricades, fences,

horses, and warning signs. If the excavation must remain open during periods when the work site is unoccupied (i.e., overnight, over a weekend, and other similar off periods), place lighted barricades around the excavation to alert personnel and prevent them from falling into the trench. See EM 385-1-1 for safe access requirements.

- (e) Any excavation greater than or equal to 1.2 meters (4 feet) deep must be provided with two means of access to facilitate safe entrance and exit. Space the means of access so that no worker in the excavation will be more than 7.5 meters (25 feet) from one of them. Make accesses extend from the bottom of the trench to at least 1 meter (3 feet) above the surface of the ground.

j. Explosive Atmospheres, Ignition Sources, and Hot Work.

- (1) Some potential causes of explosions and fires include:
 - (a) Chemical reactions that produce explosion, fire, or heat.
 - (b) Ignition of explosive or flammable chemicals.
 - (c) Ignition of materials due to oxygen enrichment.
 - (d) Agitation of shock- or friction-sensitive compounds.
 - (e) Sudden release of materials under pressure.
- (2) Explosions and fires may also arise spontaneously. However, more commonly, they result from site activities, such as moving drums, accidentally mixing incompatible chemicals, or introducing an ignition source (such as a spark from equipment) into an explosive or flammable environment. Explosions and fires not only pose the obvious hazards of intense heat, open flame, smoke inhalation, and flying objects, but may also cause the release of toxic chemicals into the environment. Such releases can threaten both personnel onsite and members of the general public living or working nearby.

To protect against these hazards, the following should be done:

- Conduct initial entry and periodic monitoring in accordance with 29 CFR 1926.65(h).
- Monitor for explosive atmospheres and flammable vapor using a CGI.

- Keep all potential ignition sources away from an explosive or flammable environment.
- Use nonsparking, explosion-proof, intrinsically-safe equipment.
- Follow safe practices when performing any task that might result in the agitation or release of chemicals. Action levels for CGI monitoring appear in Table 7-2.

**TABLE 7-2
ACTION LEVELS FOR CGI MONITORING**

EXPLOSION HAZARD

<u>Limit</u>	<u>Action Guide</u>
0 - 10%	No explosion hazard; work proceeds
>10%	Explosion hazard; evacuate, vent

OXYGEN DEFICIENCY HAZARD

<u>Limit</u>	<u>Action Guide</u>
<19.5% Oxygen	Oxygen deficient; use supplied air
19.5 - 22% Oxygen	No oxygen deficiency hazard; work proceeds
>22% Oxygen	Potential explosion hazard; evacuate, vent

Reference: EM 385-1-1

- (3) No ignition sources (e.g., cigarette lighters, matches, or other flame-producing items) other than those required for the completion of the project, will be permitted in the exclusion- or the contamination-reduction zones. To eliminate potential ignition sources, follow these guidelines:
- (a) Barricade and post work zones before any work is done that might release vapors.
 - (b) Stop burning or other work that might be a source of ignition.
 - (c) Eliminate all ignition sources from the area where flammable vapors may be present or may travel.
 - (d) Keep work zones free of all ignition sources from the time tank removal starts until the tank(s) is/are inerted, residues have been removed, and the tanks' interiors have been decontaminated.
 - (e) Post signs warning vehicles and other ignition sources to be kept out of the area.
 - (f) Do not perform work if the wind direction carries vapors into areas outside the work zones where they might produce a hazardous condition, nor perform work when an electrical storm is threatening the work site. Sparks caused by friction or electrostatic effects may also be an ignition source in flammable atmospheres, especially at low humidity. Proper grounding of metal objects and/or electrical equipment, together with the use of sparkless tools and localized humidity adjustment, may reduce this hazard.
- (4) Hot work on the tanks may be conducted only:
- (a) When inerted and
 - (b) To the extent necessary to begin dismantling the tanks.

After decontamination of the tanks' interiors, hot work must not be performed unless combustible gas/oxygen monitoring indicates atmospheres within and immediately surrounding the tanks are noncombustible as defined in this chapter and Chapter 13. The hot-work prohibition includes welding, grinding, sawing, or other similar operations that could be expected to potentially generate combustion-producing temperatures or sparks, or that could produce potentially hazardous fumes or vapors. If hot work is to be conducted, the contractor must obtain a permit from the contracting officer prior to

conducting such work and will designate an individual at each hot-work site as a fire watch. This person's sole responsibility will be to monitor the hot work and have immediate access to the fire extinguisher located at each hot-work site. The contractor must obtain a new permit at the start of each work shift during which hot work will be conducted.

- k. Illumination. The SSHO should ensure that all work areas will be lighted to not less than the illumination intensities listed in 29 CFR 1926.65(m) and EM 385-1-1. To ensure this, work activities must be restricted to daylight hours.
- l. Confined Space Entry Program. The confined space procedures detailed in Appendix E must be adhered to where applicable.
- m. Drug-Free Work Environment. All UST projects shall comply with the Drug-Free Workplace Act requirements.

7-9. Site Control Measures. Personnel not directly involved with the project will not be permitted to enter the work zones.

- a. Work Zones. The exclusion zones should include an area 7.5 meters (25 feet) from the storage tank location and excavations. At the exclusion zone perimeter, the contractor must establish a contamination-reduction zone. Within the contamination-reduction zone, equipment and personnel should be cleaned following the guidelines provided in this chapter and Chapter 9. The contractor's site office, parking area, and other support facilities must be located outside the exclusion zone and the contamination-reduction zone, in the support zone. The minimum level of personal protection must be indicated in the SSHP. The boundaries of the work zones must be clearly demarcated and posted by the contractor. A site map must be included in the SSHP outlining the extent of work zones and support facilities. The contractor must maintain a register of all personnel visiting, entering, or working on the site.
- b. Signs. Warning zones should be posted at the exclusion zone perimeter stating:

Hazardous Area - Keep Out Danger - No Smoking Authorized Personnel Only

The signs must be printed in large, bold letters on contrasting backgrounds. Signs should be visible from all points where entry might occur and at such distances from the restricted areas that

employees may read the signs and take the necessary protective steps before entering.

- c. OSHA Jobsite Posters. OSHA jobsite posters must be posted at each site.
- d. Vehicle Operation. Site personnel are expected to comply with all relevant traffic safety laws. They must obey the applicable speed limits. Whenever operating a moving vehicle, personnel must wear the seat belts provided.

7-10. Personal Hygiene and Decontamination.

a. Decontamination.

- (1) Decontaminate personnel who have come in contact with contaminated materials; they must not exit the work zones without first being decontaminated. Contaminated materials include soils that show visible evidence of being discolored or contaminated, decontamination fluids, and equipment that has come in contact with these types of soils or decontamination fluids.
- (2) Use suitable detergent as the decontamination solution and rinse. Items should be rinsed with clean water after washing. When temperatures fall to 32° F. or below, mix an additive into the decontamination solutions to prevent freezing.
- (3) Personnel who inadvertently become contaminated should immediately wash all contaminated areas. Clothing that is to be reused should be processed through the wash/rinse cycle three times and should be visually inspected by the SSHO to ensure no contamination remains. Any clothing that cannot be decontaminated in this manner must be discarded with the disposable clothing.
- (4) Containerize and dispose of used wash and rinse solutions as contaminated fluids.

b. Sanitation. In accordance with 29 CFR 1926.65(n), sanitary facilities must be provided to include drinking (potable) water, washing facilities, fire-fighting water, and toilet facilities. In addition, employees should be provided a clean area for food handling, as appropriate.

- (1) Potable Water. The SSHO must identify the closest source of potable water. If not sufficiently close, potable water should

be provided in tightly closed containers equipped with a tap. Sanitary, disposable cups should be provided, with a container to dispose used cups.

- (2) Washing Facilities. The SSHO must identify washing facilities located at the site that will allow workers to wash after decontamination, prior to leaving the site. Soap and disposable towels, with a container to collect the towels, should also be provided.

c. Toilet Facilities. The SSHO must identify toilet facilities to be located onsite for workers.

7-11. Equipment Decontamination. Refer to Chapter 9 for decontamination procedures.

7-12. Emergency Equipment and First-Aid Requirements.

a. Equipment. The following items, as appropriate, must be immediately available for onsite use:

- (1) Fire Extinguisher. Select and size fire protection based on site hazards; at the minimum, a Class 20A/20BC extinguisher shall be readily available onsite during all site activities. The fire extinguisher must be kept with the field crew during any drilling activity.
- (2) First-Aid Kit. Keep 16-unit first-aid kits in the support zone. Additionally, a minimum of two First-Aid/CPR-qualified employees must be onsite during project operations.
- (3) Portable Eye Wash. Portable eye-wash stations must be readily available onsite.
- (4) Portable Radios. If deemed necessary, portable two-way radios should be used as the communication link between each active site and the SSHO in case of emergency or related matters.

b. Communications and Notification Protocols.

- (1) Include emergency telephone numbers in the SSHP. Post these numbers and keep them readily available to members of the field crew. Discuss emergency communication in the safety meeting prior to initiating the field work. Each member of the field crew should know the location of the closest telephone.

- (2) Site notification protocols are listed below. Mitigate the emergency, then notify the appropriate emergency response service.
 - (a) In the case of a fire or explosion, call the local fire department.
 - (b) In the case of an accident or injury, the nearest hospital should be used.

c. Evacuation Procedures.

- (1) Withdrawal From Immediate Work Area. Withdrawal to a safe, upwind location will be required if any of the following occur:
 - (a) If concentrations of volatile organics, combustibles, or toxic gases exceed the action levels.
 - (b) Occurrence of a minor incident. Field operations should resume after first-aid and/or decontamination procedures have been administered.
 - (c) Heavy equipment or monitoring instrument malfunctions.
- (2) Withdrawal From Specific Site. The specific site will be evacuated in the following cases:
 - (a) Explosive levels of combustible gases exceed 10 percent of the LEL.
 - (b) A major accident or injury occurs.
 - (c) Fire and/or explosion occurs.
- (3) The SSHO should establish a safe refuge point and announce its location in the daily meeting.
- (4) Drill evacuation procedures on a periodic basis.

d. Contingency Procedures.

- (1) If an employee working in a contaminated area is injured or exposed:
 - (a) Move the employee to a clean area (on a stretcher, if needed).

- (b) Call for the necessary emergency medical response services (ambulance, fire, hospital, or poison control center) as detailed in the SSHP.
 - (c) Remove evidently contaminated clothing (if possible).
 - (d) Administer first aid, if you are qualified, and the situation warrants it.
 - (e) Evacuate other persons threatened by the condition.
 - (f) Arrange transportation to local emergency medical facility.
- (2) Emergency first-aid treatment is administered only by trained individuals and only to prevent further injury until professional treatment can be obtained.
- (3) If the injury to the worker is chemical in nature (e.g., overexposure), institute the following first-aid procedures as soon as possible:

Injury	Treatment
Eye Exposure	If contaminated solid or liquid gets into the eyes, wash eyes immediately at one of the emergency eyewash stations using large amounts of water and lifting the lower and upper eyelids occasionally. Obtain medical attention immediately.
Skin Exposure	If contaminated solid or liquid gets on the skin, remove contaminated clothing and wash the contaminated skin promptly using soap or mild detergent and water. Obtain medical attention immediately if there are any symptoms of exposure.
Breathing	If a person inhales large amounts of a gas or vapor, move individual to fresh air at once. If the person cannot breathe, provide artificial respiration. Keep the affected person warm and at rest. Obtain medical attention immediately.
Swallowing	If contaminated solid or liquid has been swallowed, contact the poison control center. Obtain medical attention immediately.

Provide the emergency medical facilities established for the site with a copy of the SSHP.

- (4) In the event of an emergency situation requiring evacuation of field personnel working within an exclusion zone, the following procedures should be followed:
 - (a) The SSHO should evacuate all personnel using a prearranged air-horn signal.
 - (b) Personnel leaving exclusion zones should exit through the contamination reduction zone unless that brings them closer to the hazard. They will decontaminate as planned unless the delay would pose an unreasonable risk to their safety.
 - (c) The SSHP identifies a signal for site evacuation. Equipment necessary to give that signal must be onsite. Practice a streamlined decontamination procedure to be used in the event of an evacuation. Practice evacuation procedures.

- (5) In the event of an explosion or fire at the site, the SSHO will take the following minimum actions:
 - (a) Evacuate all unnecessary personnel to a prearranged reassembly point (the safe refuge point).
 - (b) Request emergency response assistance from the fire department and from hospitals, poison control centers, etc.
 - (c) Notify the appropriate personnel.

7-13. Emergency Response and Contingency Procedures (Onsite and Offsite).

The contractor SSHP shall contain an emergency response plan in compliance with 29 CFR 1926.65(p), which addresses the following elements, as a minimum:

- Pre-emergency planning and procedures for reporting incidents to appropriate government agencies for potential chemical exposures, personal injuries, fires/explosions, environmental spills and releases, discovery of radioactive materials.
- Personnel roles, lines of authority and communications.
- Posted instructions and a list of emergency contacts: physician, nearby medical facility, fire and police departments, ambulance service, federal/state/local environmental agencies, CIH/CSP, Contracting Officer.
- Emergency recognition and prevention.
- Site topography, layout, and prevailing weather conditions.

- Criteria and procedures for site evacuation including emergency alerting procedures/employee alarm system, emergency PPE and equipment, safe distances, places of refuge, evacuation routes, site security and control.
- Specific procedures for decontamination and medical treatment of injured personnel.
- Route maps to nearest pre-notified medical facility.
- Criteria for initiating community alert program, contacts, and responsibilities.
- Critique of emergency responses and follow-up.

7-14. Occupational Safety and Health Hazards Associated With Tank Removal Processes. Workers should be aware of appropriate health precautions. When high concentrations of petroleum hydrocarbon vapors are inhaled, symptoms of intoxication, ranging from simple dizziness to excitement or unconsciousness, may result, and are similar to those produced by alcohol or anesthetic gases. If such effects occur, move the individual to fresh air. For minor effects of exposure, breathing fresh air or oxygen results in rapid recovery. If breathing has stopped, apply artificial respiration promptly, and obtain medical attention as soon as possible.

Subparagraphs b. and c. below contain special toxicity considerations for benzene and tetraethyl lead, which may be present in petroleum products or wastes found in underground storage tanks. Exercise care to minimize exposure to these substances during the handling of underground petroleum-storage tanks.

- a. Precautions. Tests have shown that prolonged or repeated exposure to some petroleum substances, in liquid or vapor form, may cause serious illness, including cancer, in laboratory animals. Although the significance of these test results to human health is not fully understood, exposure to petroleum substances should be minimized. The following health precautions are suggested:
 - (1) Avoid skin contact and inhalation of vapors.
 - (2) Keep petroleum liquids away from eyes, skin, and mouth; they can be harmful or fatal if inhaled, absorbed through the skin, or ingested.
 - (3) Use soap and water or waterless hand cleaner to remove any petroleum product that contacts skin. Do not use gasoline or similar solvents to remove oil and grease from skin.

- (4) Promptly wash petroleum-soaked clothes and avoid using soaked leather goods. Properly dispose of rags.
- (5) Keep work areas clean and well-ventilated.
- (6) Clean up spills promptly.

b. Benzene.

- (1) High occupational exposures to benzene have been associated with various human blood disorders, including an increased risk of leukemia. Very high levels have also been known to affect the central nervous system. Benzene administered by mouth has induced cancer in laboratory animals in long-term tests. Benzene is rapidly absorbed through the skin.
- (2) The OSHA imposes limits on occupational exposure. See 29 CFR 1926.1128.

c. Tetraethyl Lead. This organic form of lead can cause diseases of the central and peripheral nervous systems, the kidney, and the blood. Skin absorption of this compound is a major route of entry into the body. The ACGIH time-weighted average is 0.1 milligrams per cubic meter for general room air. The permissible exposure level (PEL) in OSHA's *Occupational Safety and Health Standards* (29 CFR 1910.1000, Table Z-1) is 0.075 milligrams per cubic meter.

d. Flammability and Combustibility Considerations.

- (1) Flammable or combustible vapors are likely to be present in the work area. The concentration of vapors in the tank, the excavation, or the work area may reach the flammable (explosive) range before venting is completed and a safe atmosphere is reached. Therefore, precautions must be taken to:
 - (a) Eliminate all potential sources of ignition from the area (for example, smoking materials, nonexplosion-proof electrical and internal combustion equipment).
 - (b) Prevent the discharge of static electricity during venting of flammable vapors.
 - (c) Prevent the accumulation of vapors at ground level. Refer to American Petroleum Institute (API) Publication 2015 and Recommended Practice 2003 for general precautionary measures to follow during tank sampling, product removal, vapor purging, inerting, excavating, and tank decontamination.

- (2) A CGI should be used to check for hazardous vapor concentrations (see Chapter 10, *Combustible Gas Monitoring Procedures*). All open-flame and spark-producing equipment within the vapor hazard area should be shut down. Electrical equipment (for example, pumps and portable hand tools) used in the area must be explosion-proof in accordance with NFPA 70B Class I, Division I, Group D or otherwise approved for use in potentially explosive atmospheres.
- e. Tank Safety and Health Work Practices and Procedures. Task-specific safety and health practices and procedures should be followed during the project in conformance with OSHA, USACE, and other applicable standards such as API Publications and Practices, and the following considerations:
- (1) Tank Contents Sampling. Personnel accomplishing this activity will initially wear Level D PPE as a minimum.
 - (2) Transfer of Materials out of Storage Tank(s). Use the following guidelines for material removal:
 - (a) Wear, minimally, Modified Level D PPE if you are engaged in material transfer activities or are within 7.5 meters (25 feet).
 - (b) Remove liquids and residues from the tank(s) following the procedures outlined in Chapter 12 titled *Product Removal Procedures* using explosion-proof or air-driven pumps.
 - (c) Ground and bond all pumps, motors, and hoses to prevent electrostatic-ignition hazards.
 - (d) It may be necessary to use a hand pump to remove the last few millimeters of liquid from the bottom of the tanks.
 - (e) If a vacuumtruck is used for removal of liquids or residues, the area of operation for the vacuum truck must be vapor-free. Locate the truck upwind from the tank and outside the path of probable vapor travel. API Publication 2219 and these guidelines will govern the vacuum truck operation and safety practices.
 - (f) Collect tank residues in drums, tanks, or tank trucks labeled according to DOT Standard 49 CFR Part 171 and Parts 1 and 2 and then dispose of them properly (Chapter 14).

- (3) Inerting Procedures. Following the removal of the tank's contents BUT PRIOR TO EXCAVATION OF THE TANKS AND TANK PREPARATION ACTIVITIES, insert the tanks in accordance with the tank inerting procedures presented in Chapter 13 of this manual. If dry ice is used, it should be introduced in the amount of at least 1.36 Kg (3 pounds) per 378 liters (100 gallons) of tank capacity. Skin contact with dry ice must be prevented by wearing heavy cloth gloves. Inerting must be sufficient to lower the oxygen content to less than or equal to 8 percent. *The contractor must confirm that the oxygen content of the tank is less than 8 percent before proceeding with additional activities on the tank (e.g., excavation).*
- (4) Excavating. Initially Level D PPE will be required for all personnel involved in tank excavation or within 15 meters (50 feet) of such operations. Modified Level D PPE will be used by personnel who may come into contact with the tank's contents or materials/soils that are contaminated with the tank's contents. Excavation of the tank including tank preparation, removal, decontamination, demolition, and disposal should be in accordance with the guidelines listed in Chapter 13 of this manual.
- (5) Decontamination of Tank Interior. Use API Publication 2015 to govern safety practices and procedures for the cleaning of the tanks. At a minimum, Modified Level D PPE should be used by personnel conducting decontamination operations.

7-15. Logs, Reports, and Recordkeeping. Develop, maintain, and submit the following logs, reports, and records to the COR at the conclusion of the site work.

a. Safety Inspection Reports.

- (1) Daily Safety Checklist. Conduct job-site safety inspections on a daily basis by the SSHO.
- (2) Weekly Safety Report. The SSHO should submit a cumulative daily safety checklist to the CIH/CSP for the preceding week. The SSHO should prepare a short cover memorandum describing any problems and/or deficiencies and how they were corrected.

b. Injury/Illness/Accident Reports. Injuries, illnesses, and accidents involving employees and subcontractors will be reported to the USACE using ENG FORM 3394.

c. Medical, Respirator Fit Test, and Training Certifications.

- (1) Medical, respirator fit test, and training certifications for USACE employees who work on the site should appear in Appendix A of the SSHP.
 - (2) If additional employees work on the site, their certifications should be forwarded to the USACE by the CIH/CSP.
 - (3) Medical, respirator fit test, and training certifications for subcontractors should be forwarded to the USACE by the CIH/CSP as they are contracted to work on the site.
- d. Training Logs. Document site-specific training, including subcontractor, "tool box," and visitor training.
- e. Monitoring Results. Document direct reading instrument (DRI) monitoring results in the logbook.
- f. Visitor's Log. An employee, subcontractor, and visitor log should be maintained by the SSHO.
- g. Phase Out Reports. Upon completion of the project, the CIH/CSP should prepare a phase-out report to include:
- (1) Summary of air monitoring data.
 - (2) Decontamination certification.
 - (3) Summary of accidents/injuries/illnesses.
 - (4) Other appropriate information.

CHAPTER 8

SAMPLING AND ANALYSIS PLAN REQUIREMENTS

8-1. General. Read this chapter for preparation guidelines for the Sampling and Analysis Plan (SAP). The SAP includes a Field Sampling Plan (FSP) and Quality Assurance Project Plan (QAPP). The FSP describes field activities, and the QAPP describes the laboratory-related activities of analysis, laboratory quality control and reporting. See EM 200-1-2 and EM 200-1-3 for additional guidance.

Plan requirements apply to all projects whether at active installations, through the Installation Restoration Program (IRP), Formerly Used Defense Sites (FUDS), or at Civil Works facilities. The plan's objective is to assure quality data in order to classify an UST as one that has not produced chemical contamination allowing removal by the local district or, as an UST that has caused soil or groundwater chemical contamination requiring further evaluation³ or remediation.

8-2. Plan Contents. The SAP must include the following items:

- a. Title Page. The title page must contain the project name, project location, contract number, phase, date, and contractor's name and address, if applicable.
- b. Table of Contents.
- c. Project Description. The scope of work and relevant background material, as applied to the collection of chemical data, must be briefly described. Any description of toxic or hazardous substances that may be encountered at the site should be included, if known. In addition, a brief description of the site conditions, such as geology and surface water, should be included.
- d. Chemical Data Quality Objectives. Briefly describe the level and extent of chemical data required to support decisions during the project. EM 200-1-2 has guidance concerning preparation of Data Quality Objectives. The data must provide a basis for decision making related to the tank, its contents, and any releases to the environment. The data must allow decisions to be made regarding future site remediation, determination of whether contamination is a result of Department of Defense (DOD) activities, and determination of disposal methods for all wastes generated onsite. Finally, the results must be determined in a manner that complies with all applicable federal, state, and local regulations governing USTs.
- e. Project Organization and Functional Area Responsibility. The following functions must be fulfilled. In smaller projects, one person may have multiple responsibilities.

- (1) Contracting Officer's Representative (COR) represents the USACE and serves as liaison between the USACE and the contractor.
- (2) Contractor's Project Manager reviews and approves field operations procedures, assures that these procedures meet quality control (QC) objectives, and provides technical insight.
- (3) Contractor's Field Sampling Supervisor is responsible for the management of the field sampling team during onsite activities.
- (4) Field Technician/Project Chemist is responsible for collecting, packaging, and shipping samples.
- (5) QC Program Manager is responsible for maintaining all aspects of QC during field operations.
- (6) Site Safety and Health Officer (SSHO) is responsible for the safety of all site personnel and for ensuring that all field operations are in compliance with the Site Safety and Health Plan (See Chapter 7).

f. Field Activities. Include discussion of the proposed field activities in the SAP document, along with the following information, as applicable:

- List of field equipment, containers, and supplies.
- Sampling locations.
- Sampling procedures.
- Field screening.
- Quality control samples.
- Quality assurance samples.
- Sample documentation.
- Spill reporting requirements.

g. Chain-of-Custody and Transportation. Include discussion of the documentation and shipping requirements. See paragraph 8-3 below for details.

h. Laboratory Activities. Discuss the laboratory procedures and methods followed in the SAP. See Paragraph 8-4 for details.

8-3. Sample Packaging, Shipping, and Chain-of-Custody. The USACE furnishes detailed guidance regarding sample handling in *Sample Documentation and Shipment Instructions* (Appendix F of EM 200-1-3). It must be provided by the COR. Follow this protocol explicitly with the exception of those details in which the protocol disagrees with more stringent state or local regulations. The fundamental details of sample handling as they pertain to UST actions are summarized in this section.

- a. Low-, Medium-, and High-Concentration Samples. All nonaqueous samples taken from the tank contents must be considered as high-concentration samples and handled accordingly. All aqueous samples exhibiting evidence of contamination (appearance, odor, OVA results) must be treated as medium-concentration samples. All other nonaqueous and aqueous samples should be considered as low-concentration samples unless there is reason to believe otherwise.
- b. Receipt for Samples. The current site owner, operator, or agent-in-charge is legally entitled to the following:
 - (1) A receipt describing the samples obtained from the site.
 - (2) A portion of each sample equal in weight or volume to the portion retained, (i.e. split sample) if requested. If the samples are refused, refusal should be noted on the receipt for samples. The samples should then be disposed as investigation-derived waste.
- c. Sample Labeling. Each sample bottle must be labeled. Write the sample number on the can lid. The label must not soak off or become illegible if exposed to water for the time it takes to ship the samples to the laboratory. Use indelible ink to mark the labels. Include the following on each label:
 - Date.
 - Time of collection.
 - Site name.
 - A brief description of the sample.
 - Type of sample (grab, composite).
 - Preservatives used.
 - Analyses required.
 - Sample number as assigned in the field.
 - Sampler's signature.

See Figure 8.1 for appropriate label or tag formats. Create local forms that meet your specific needs.

Special consideration must be given to DOT labeling requirements for any sample suspected to exhibit a DOT hazard class. For example, nitric acid containing mixtures exhibiting a DOT corrosive characteristic at the packing group I or II level are required to be labeled with a "cargo aircraft only" label as well as a "corrosive" label.

- d. Sample Packaging. Proper sample packaging assures that samples will arrive at the laboratories in acceptable condition and that sample

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Designate <hr/> Comp. Grab		Preservative: Yes No	
		ANALYSIS	
Time		BOD Anions Solids (TSS) (TDS) (SS)	
Month Day Year	Sampler (Signature)	COD TOC Nutrients Phenolics Mercury	
		Metals Cyanide Oil & Grease	
		Organics GCC/MS	
Project Code Station Code	Location Station	Priority Pollutants	
		Volatile Organics	
		Pesticides	
		Mutagenicity	
		Bacteriology	
		Remarks:	
Tag No.		Lab Sample No.	

FIGURE 8-1. EXAMPLE OF SAMPLE TAG OR LABEL

validity and integrity have not been compromised. This section provides guidelines for sample packaging activities. Give special

consideration to DOT packaging requirements for samples exhibiting or suspected to exhibit a DOT hazard class.

- (1) Tape all sample bottles shut with strapping tape. The only exception to this rule applies to samples for volatile organic analysis. The string from the numbered tag, if used, should be secured around the lid. Mark the level of all liquid samples on the bottle with a grease pencil to provide a reference level that could be used to identify a leaking container.
- (2) Place each bottle in a clear plastic bag (Ziploc® or equivalent) through which the sample tag and label are visible and seal the bags.
- (3) Ship samples of medium- and high-concentration wastes in metal cans inside the cooler. More than one bottle may be placed in each can as long as they do not touch one another.

For packages containing materials suspected to meet a DOT hazard class, the package (bottle, can, and cooler) must meet DOT performance-oriented packaging requirements for combination packaging (or must meet conditions for an applicable limited quantity exception). Also, to comply with DOT regulations (unless specifically excepted by regulation) mark outer packages with "This Side Up" (along with an orientation arrow); the DOT proper shipping name and hazard class for the material such as "Flammable Liquid N.O.S. UN 1993" or "Corrosive Liquid N.O.S. UN 1760;" and the shipper's or consignee's name and address.

Place an appropriate hazard class label and a "cargo aircraft only" label, if applicable, on the package.

Refer to EM 200-1-3, *Appendix F, Sample Documentation and Shipment Instructions* for further details regarding the shipping of high-concentration samples.

- (4) Place the samples in steel or reinforced plastic coolers for shipment to the laboratories. Line coolers with about 75 mm (3 inches) of cushioning material (only 25 mm (1 inch) under cans) such as Styrofoam peanuts. Place the sample bottles, contained in plastic bags, in such a fashion that they will not touch during shipment. Cover sample bottles with additional packing material to at least halfway up. Place sealed bags of ice (or ice substitute) near, *but not touching*, the samples. Ice should also be placed above the samples.

- (5) Before closing the cooler, place a chain-of-custody record (see Figure 8-2 for example format) in a waterproof plastic bag and tape it to the inside of the cooler lid. Create local forms that meet your specific needs. Appropriate additional documentation may be sent along with the chain-of-custody forms to the laboratory. Chain-of-custody procedures are discussed in detail later in the chapter.
- (6) Shut the cooler and secure it by wrapping strapping tape completely around the cooler at a minimum of two locations. Tape the drain shut.

e. Sample Shipping.

- (1) Attach shipping labels to the top of the cooler.
- (2) Number and sign custody seals and affix on the front right and back left of cooler. Cover custody seals with wide, clear tape.
- (3) Affix labels "This Side Up" (with appropriate arrow) on all four sides and "Fragile" labels on at least two sides.
- (4) Place the proper shipping name and identification number (i.e., "Flammable Liquid N.O.S., UN 1993") on all sides of the cooler, as appropriate.
- (5) Inform the shipper of the nature of the contents to determine applicable DOT requirements. Complete hazardous material shipping documents, also known as bill of ladings, for all shipments of medium and high concentration samples.
- (6) If the samples are shipped using a limited quantity exception indicate on the bill of lading (i.e., "Ltd Qty" or "limited quantity").
- (7) The shipper must ensure that the samples will arrive at the laboratory by the next day.
- (8) Include additional information with sample shipments utilizing the RCRA sample exclusion, in 40 CFR 261.4(d) or equivalent state regulation. This would apply, for example, to ignitable waste samples. The following must accompany the sample: (1) the sample collector's name, address, and telephone number; (2) the lab's name, address and telephone number; (3) the quantity of the sample; (4) the date of shipment; and (5) a description of the sample.

- (9) Consider maximum weight restrictions applicable to some shippers when filling coolers.
 - (10) It is acceptable for personnel from the contractor's sampling team or from the analytical laboratory to transport samples from the field to the analytical laboratory as long as the delivery time is comparable to that available from commercial carriers. If this option is exercised, the SAP must explain in sufficient detail how and when sample custody will be transferred.
 - (11) QA samples must be shipped by a commercial carrier that provides overnight delivery from the field to the QA laboratory or delivered personally.
 - (12) The field sampling supervisor must notify (by telephone) the sample custodians at the contractor's analytical laboratory and the QA laboratory of the intended sample arrival time. Make this notification least 2 working days in advance of delivery. Avoid weekend deliveries unless prearranged.
 - (13) For more information on regulations regarding shipping of hazardous materials, refer to *Title 49, Subchapter C, of the Code of Federal Regulations*.
- f. Chain-of-Custody. A custody form is used to track samples from the field to the laboratory and through the course of the analytical work.
- (1) Chain-of-custody is initiated in the field when samples are first placed in coolers for shipping. The custody forms are filled out by the contractor's sampling team. Custody is maintained during shipping with the custody seal. The chain-of-custody is continued in the laboratory from the time of sample receipt to the time the sample is discarded.
 - (2) List only one site per custody form. If the contractor is sampling at two or more different UST sites, each site must be tracked with an independent custody form. Ship the original with the samples and keep a copy for the sampling contractor's files.
 - (3) In the laboratory, a record of sample custody is maintained as follows:

Chain of Custody (COC) Record

Chain of Custody No.		Project No./Title			Analyses						Project Point of Contact		Phone Number
											Scope of Work Document(s):		
Date	Time	Sample Identification	# of Bottles							Matrix	Comments		
Samples Preserved?				Yes ⁽¹⁾						No			
Date	Time	Relinquished by		Date						Time	Received by		
Date	Time	Relinquished by		Date						Time	Received by		
Date	Time	Relinquished by		Date						Time	Received by		

FIGURE 8.2. Example Chain-of-Custody Record

- (a) All incoming samples are received by a sample custodian who shall indicate receipt by signing the accompanying custody forms. The sample custodian files these forms with the project file as a permanent record.
 - (b) The laboratory manager is notified of receipt of samples and notifies the various analytical groups of the required analytical work. Individuals from each analytical group maintain the chain-of-custody while checking out samples, performing the extractions and analyses, and returning the samples to the sample custodian.
- (4) See Figure 8-2 for an example format of a chain-of-custody record. Create local forms that meet your specific needs; be sure to include the name and location of the company or laboratory.

8-4. Sample Analysis and Data Reporting. Describe planned sample analysis activities in the SAP. Include required analyses, methods, the analytical laboratory selected, and the vague particulars of data reporting.

This section provides general requirements regarding approved methods, data reporting, and laboratory validation. The contractor is bound to follow all site-specific requirements as set forth in the Scope of Work (SOW) and should use this section only as a guide to fill in details not explicitly stated in the SOW.

- a. **Methods for Sample Analysis.** Perform all sample analyses of water or soils using standard EPA methods as listed in Tables 8-1 and 8-2. All procedures specified must be followed exactly with no deviations unless modifications are specifically authorized by the designated project QA laboratory. All method QC requirements will be followed explicitly. The running of QC duplicates, spike samples, and method blanks must be in accordance with the laboratory QA/QC plan as set forth in the Laboratory Quality Management Manual (LQMM), or at least the rate specified in the method. At a minimum, this rate will be 1 in 20, but at least 1 per batch. The laboratory is required to report internal QC data (instrument blanks, method blanks, spike matrix recoveries, and internal duplicates, etc.) for a minimum of 5 percent of the project samples.

The USACE **encourages** the use of their samples for internal QC checks (matrix spike recovery or internal duplicate). If a USACE sample is selected for an internal QC check for a batch that

**TABLE 8-1 METHODS FOR DETERMINATION OF METALS
(RCRA and Priority Pollutants) by Atomic Absorption and Inductively Coupled
Plasma**

Metal	Technique ¹	Digestion and Analysis Method ⁴		
		Soil/Sediment	Groundwater ²	Surface Water ²
Arsenic (As)	GF	3050/7060	Inc ³ /7060	206.2
	H	Inc ³ /7061	Inc ³ /7061	206.3
Barium (Ba)	DA	3050/7080	3005/7080	208.2
	GF	-	-	208.2
	ICP	3050/6010	3005/6010	200.7
Cadmium (Cd)	DA	3050/7130	3005/7130	213.1
	GF	3050/7131	3020/7131	213.2
	ICP	3050/6010	3005/6010	200.7
Chromium (Cr)	DA	3050/7190	3005/7190	218.1
	GF	3050/7191	3020/7191	218.2
	ICP	3050/6010	3005/6010	200.7
Iron (Fe)	DA	3050/7380	3005/7380	236.1
	GF	-	-	236.2
	ICP	3050/6010	3005/6010	200.7
Lead (Pb)	DA	3050/7420	3005/7420	239.1
	GF	3050/7421	3020/7421	239.2
	ICP	3050/6010	3005/6010	200.7
Manganese (Mn)	DA	3050/7460	3050/7460	243.1
	GF	-	-	243.2
	ICP	3050/6010	3050/6010	200.7
Mercury (Hg)	CV	Inc ³ /7471	Inc ³ /7470	245.1
Selenium (Se)	GF	3050/7740	Inc ³ /7740	270.2
	H	Inc ³ /7741	Inc ³ /7741	270.3
Silver (Ag)	DA	Inc ³ /7760	Inc ³ /7760	272.1
	GF	-	-	272.2
	ICP	3050/6010	3005/6010	200.7
Sodium (Na)	DA	3050/7770	3005/7770	273.1
	GF	-	-	273.2
	ICP	3050/6010	3005/6010	200.7

NOTES:

¹Abbreviations: CV = Cold Vapor; DA = Direct Aspiration; GF = Graphite Furnace; H = Hydride; ICP = Inductively Coupled Plasma

²(a) Any water sample may be analyzed by SW-846 methods. Groundwater samples must be analyzed by the SW-846 methods. Surface water and other water samples (drinking, silo, leachate, etc.) may be analyzed by the 200-series or the SW-846 series methods.

(b) Other extraction procedures may be appropriate instead of those listed. Methods 3010 (for flame and ICP) and 3020 (for graphite furnace) are used as extraction procedures for Total Metals and are used in EP TOX or TCLP extractions. Method 3040 is used to extract metals from oily wastes (greases, waxes, etc.).

(c) All 200 series methods are from EPA 600/4-79-020 (1983) Methods for Chemical Analysis of Water and Wastes; all other methods are from SW-846 (1986), Test Methods for Evaluation of Solid Waste (including all promulgated updates).

³Method-specific extraction procedure is incorporated into method. For arsenic this involves digestion by 3050 followed by additional digestion in the method. For silver, digestion by 3050 is used with modification: approximately twice as much HCl is used. ⁴Latest promulgated versions of referenced methods should be used.

TABLE 8-2 METHODS FOR DETERMINATION OF NONMETALLIC ANALYTES

Part 1. Organic Analytes⁸				
Organic Analytes	Technique ¹	Extraction and Analysis Methods		
		Soil/Sediment	Groundwater ²	Surface Water ²
Halogenated Volatile Organics	GC	5030/8021	5030/8021 ³	6013
Aromatic Volatile Organics (or BTEX)	GC	5030/8021	5030/8021 ³	6023
PCBs	GC	3540/8082 3550/8082	3510/8082 3520/8082	608
Volatile Organics	GC/MS	Inc ⁴ /8260	Inc ⁴ /8260	624
Part 2. Miscellaneous Analytes⁸				
Misc. Analytes	Technique ¹	Preparation and Analysis Methods		
		Soil/Sediment	Groundwater ²	Surface Water ²
TRPH ⁵	IR	9071/418.1 ⁵	418.1	418.1
Fuel Constituents	GC	Modified EPA Method 8015		
Ignitability		1010 or 1020		
Corrosivity		9045	9040/1110	9040/1110
Reactivity		(Sections 7.3.3 and 7.3.4 of SW-846)		
EP Toxicity-Metals		13106	13106	
TCLP-Metals		Federal Register ^{6,7}		
pH		9045	9040	

NOTES:

¹Abbreviations: DA = Direct Aspiration; GC = Gas Chromatograph; GC/MS = Gas Chromatograph/Mass Spectroscopy; IR = Infrared Spectroscopy.

²(a) Any water sample may be analyzed by SW-846 methods. Groundwater samples must be analyzed by the SW-846 methods. Surface water and other water samples (drinking, silo, leachate, etc.) may be analyzed by the 200-series or the SW-846 series methods.

(b) All 300-600 series methods are from EPA 600/4-79-020 (1983) *Methods for Chemical Analysis of Water and Wastes*; all other methods are from SW-846 (1986), *Test Methods for Evaluation of Solid Waste (including all promulgated updates)*.

³Direct injection may be used for high concentrations of contaminants in water. It is preferable to use Method 8260. If Method 8015, 8021, 601, or 602 is used, it is necessary to confirm results with a dual-column injection or a validation by GC/MS.

⁴Method-specific extraction procedure is incorporated into method.

⁵Some states require specific methods other than those cited here for the determination of petroleum hydrocarbons. In these cases, the state-required methods should be used. If the cited method for Total Recoverable Petroleum Hydrocarbons is used, follow extraction through Step 7.11 and then dilute with Freon-113 to 100 mL.

⁶Extraction procedure only. Analysis (Table 8-1) must follow.

⁷Federal Register March 29, 1990 (SW-846, 3rd Ed. 1311). TCLP leachates are analyzed by one or more of the following methods: 6010, 7060, 7470 and 7740. Scope must specify which analyses are to be performed on TCLP leachate extracts.

- Internal Quality Control: The number and types of internal QC checks shall be defined clearly in the SAP. The USACE requirements are basically the same as those given in the EPA method. The only significant difference is that the USACE encourages (Section 5.1) that its samples be treated as an independent set so that all applicable QC checks are applied to the set of USACE samples even though the USACE sample size may be small. A list of all applicable checks must be enumerated in the SOW and SAP in order to assure the USACE that the analytical laboratory is aware of these requirements for internal QC checks. These include:
 - Limits of data acceptability and corrective action to be taken when these limits are exceeded must be described.
 - Corrective Action: The feedback system in place to deal with problems identified by these internal QC checks must be described. Personnel responsible for executing this corrective action must be identified.
 - The methods for determining precision, accuracy, and instrument sensitivity (detection and quantitation limits) must be described.
 - Procedures for calibration and the frequency of calibration checks for laboratory instrumentation shall be described.

⁸Latest promulgated versions of referenced methods should be used.

contains samples from another client, the USACE requests a copy of the results obtained.

The detection limits stated in the SOW (or by the nominal values given for each method) must be met by the contractor's laboratory. All samples must be extracted (or digested) and analyzed within the specific holding times specified by each method. All analyses must be performed by the designated laboratory (or laboratories) and may not be subcontracted.

b. QA and QC Frequency. Normally for most smaller USTs, the number of QA/QC field check samples is limited to the following:

- (1) For the tank water samples: Collect one sample in triplicate. One sample set may be collected for rinsate verification and sent to the contractor's laboratory and QA laboratory. Provide one pair of trip blanks for each cooler that contains aqueous samples for VOA.
- (2) For the high-concentration organic samples and sludge samples: Collect one sample in triplicate.

c. Data Reporting. The USACE requirements for reporting the analytical data were established to effectively report analytical results along with the appropriate QC information needed to assess reliability. These requirements are based on simplified contract laboratory program (CLP) or EPA SW-846 or other performance-based methods deliverables package. See EM 200-1-3 and EM 200-1-6 for general information.

- (1) General Requirements. The contractor and the analytical laboratory must concur on how certain data reporting requirements are to be handled. Details describing each of the following data reporting requirements must be given in the SAP and approved prior to the start of work.
 - (a) Data computations. All units of expression and equations required to calculate concentrations or the values of measured parameters must be provided.
 - (b) Unusual results. Plans for treating outliers or other results that appear unusual or questionable.
 - (c) Loss of control. Plans for treating data and reanalysis of samples that have been handled during periods of loss of analytical control.
 - (d) Data handling. Description of the data management systems: collection of raw data, data storage and conversion, data and calculations review, and data quality assurance documentation.

- (e) Personnel. Identify all personnel that will be involved in the data reporting sequence for this specific project.
 - (f) Precision, Accuracy, and Completeness. Procedures to assess these parameters of the analytical data must be described. The laboratory must maintain appropriate control charts.
- (2) Sample Description. The laboratory is asked to supply a brief physical description of the sample. The following guidelines should be used.
- (a) Water Samples. Coloration and clarity.
 - (b) Soil/Sediment/Sludge Samples. Coloration, texture, and artifacts.
 - (c) Recommended Descriptive Terms.
 - Coloration: red, orange, yellow, green, blue, violet, black, grey, brown, white, colorless, etc; dark or light.
 - Clarity: clear, cloudy, opaque.
 - Texture: fine (powdery), medium (sand), coarse (large crystals or rocks).
- (3) Data Qualifications. These symbols are used to qualify the analytical results, as necessary. They should be used in place of or adjacent to the appropriate analytical result.
- U = Analyte not detected at the laboratory reporting limit
 - J = Analyte detected below the laboratory reporting limit, concentration is estimated
 - B = Analyte detected in the method blank
 - NA = Not analyzed
 - NR = Not reported
 - BDL = Analyte not detected at the laboratory reporting limit
- (4) Internal Quality Control Reporting. The laboratory should report the results for the following quality control samples:
- (a) Laboratory Method Blanks
 - (b) Surrogate Spike Recovery
 - (c) Matrix Spike Samples
 - (d) Lab Duplicates
 - (e) Lab Control (Blank Spike) Samples.

- d. Holding Times. Table 8-3 summarizes the maximum holding times, preservation requirements, and bottles (containers) for various analytes. All of the bottles must be obtained precleaned from an EPA-approved supplier. These values are established by the EPA. Exceeding the maximum holding time would jeopardize the validity of the analytical results. During construction, the SOW may require very short turnaround times for analysis because of the nature of the project phase. The analytical laboratory selected as a contractor must agree to abide by these analysis turnaround times.
- e. Detection and Quantitation Limits. The SOW may specify required detection or quantitation limits based on state and local requirements and on a Record of Decision. If these limits are not specified, it is to be assumed that the nominal values provided by SW-846 or the CLP User's Guide apply.

8-5. Commercial Analytical Laboratory. USACE validation of the project laboratory is optional for UST work. The project manager may request validation by the HTRW-CX or accept state validations at his or her discretion. If the project involves HTRW factors the project manager should request validation by the HTRW-CX. The laboratory validation process takes several weeks with the time required depending primarily on how promptly the laboratory responds. The USACE laboratory validation process for UST projects is described in a memo from CEMP-RT dated 14 September 1993, titled "Hazardous, Toxic & Radioactive Waste (HTRW) - Policy Guidance on Validation of Commercial Analytical Chemistry Laboratories".

8-6. Government Analytical Laboratories. Chemical analyses may be performed by USACE laboratories when sampling is performed by government personnel.

8-7. Quality Assurance Laboratory. The USACE Design District responsible for the UST action will propose the use of a USACE or other referee laboratory as the project's quality assurance laboratory if QA samples are to be collected.

8-8. Sample Numbering System. UST samples collected under contract with the USACE must be numbered using a USACE numbering system as described below:

aaaa-bbbb-cccc

aaaa = Four-character designation of the project name

bbbb = Four-character designation of the sampling subsite

cccc = Four-number character sequential numerical designation starting with '0001' for the first sample and incrementing by one for each subsequent sample.

**TABLE 8-3
SUMMARY OF SAMPLE CONTAINER, PRESERVATION, AND MAXIMUM HOLDING TIMES**

Matrix	Parameter ¹	Container ²	Preservation ³	Maximum Holding Times	
				Extraction ⁴	Analysis
Water	Volatiles	2 X 40 mL G, Septa vials	Ice to 4 °C HCl to pH<2	-	14 d
Water	PCBs	2 X 1 L ⁵ amber G	Ice to 4 °C	7 d	40 d
Water	Metals ⁶	1 X 1 L P	HNO ₃ to pH<2	-	6 mo ⁶
Water	TRPH	2 X 1 L G	Ice to 4 °C HCl to pH<2	-	28 d
Soils	Volatiles	2 X 4 oz (or 2 X 120 mL) G, Septa lids	Ice to 4 °C	-	14 d
Soils/Sediments	PCBs	1 X 8 oz G (or 1 X 240 mL)	Ice to 4 °C	7 d	40 d
Soils/Sediments	Metals/ TRPH	1 X 8 oz G (or 1 X 240 mL)	Ice to 4 °C (TRPH only)	-	6 mo ⁶ (TRPH: 28 d)
High Concentration Wastes	Volatiles	2 X 40 mL G, Septa vials	Ice to 4 °C	-	14 d
High Concentration Wastes	PCBs	1 X 40 mL G, Septa vial	Ice to 4 °C	-	
Product	All	1 X 250 mL G ⁷		-	

NOTES:

¹Abbreviation: TRPH = Total Recoverable Petroleum Hydrocarbon.

²All containers must have Teflon-lined seals (Teflon-lined septa for VOA vials). G = Glass; P = High-density polyethylene. Samples for analysis for volatiles must have septa lids.

³Sample preservation will be done in the field immediately upon sample collection.

⁴When only one holding time is given, it implies total holding time from sampling until analysis.

⁵Triplicate sample sets are required on at least 5 to 10 percent (but at least one) sample so that the laboratory can perform all method QC checks for SW-846 methods.

⁶Total Recoverable Metals for water samples. Holding time for Hg is 28 days in glass.

⁷Collect only one 250 mL sample.

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The following abbreviations should be used to designate the nature of each sample:

TK - Tank
SS - Surface Soil Boring
SW - Surface Water
SL - Sludge
SB - Subsurface Soil
MW - Monitoring Well
SD - Sediment

8-9. Sample Documentation. Each sampling team or individual performing a particular sampling activity is required to record pertinent information in a bound field logbook with prenumbered pages. All entries shall be made with indelible ink. Mistakes must be crossed out with a single line, corrected, initialed, and dated.

CHAPTER 9

GENERAL EQUIPMENT DECONTAMINATION PROCEDURES

9-1. General. This chapter describes the procedures for the decontamination of field equipment potentially contaminated in conjunction with UST removal. This process recommends but does not necessarily dictate the proper decontamination methods for any given situation. The contractor will be responsible for assessing specific situations for the most appropriate response. Decontamination is performed as a QA measure and a safety precaution. It prevents cross-contamination among samples and helps maintain a clean working environment for the safety of all field personnel and any others who may be affected.

Decontamination is mainly achieved by rinsing with liquids that include detergent solutions, potable water, deionized water, nitric acid, methanol, and hexane. Equipment is allowed to air-dry after being cleaned or is wiped dry with paper towels. Equipment can then be reused immediately. Steam cleaning should be used whenever visible contamination exists and for large machinery/vehicles. The reader should refer to EM 200-1-3 for additional guidance on decontamination. Also, guidance may be found in ASTM Standard Practices D 5088 and D 5608.

9-2. Precautions. It is important to ensure that investigation-derived wastes are not being generated as a result of decontamination chemicals.

9-3. Equipment. Materials used for decontamination may include but are not limited to:

- Wash basins (approximately 75 liters [20 gallons]).
- Buckets (10 to 20 liters [3 to 5 gallon]).
- Brushes.
- Squeeze bottles/spray cans.
- Alconox or equivalent detergent.
- Methanol.
- Nitric acid.
- Hexane.
- Potable water of known quality.
- Deionized water.
- Aluminum foil.

9-4. Operations, Procedures, and Instructions. Field personnel responsible for equipment decontamination should be familiar with all safety rules and regulations, the use of equipment and procedures for decontamination of equipment, and the standard practices governing equipment decontamination.

a. Operations.

- (1) Decontaminate all equipment prior to field use.

- (2) Clean the equipment on the assumption that it is highly contaminated until enough data are available to allow an accurate assessment of the level of contamination.
 - (3) Have an adequate supply of rinsing liquids and all materials. Perform decontamination in the same level of protective clothing as sampling activities unless a different level of protection is specified by the project manager.
 - (4) Collect and hold all decontamination liquids until they can be properly disposed. The procedure for full field decontamination must be followed without deviation unless specified by the project manager.
- b. Decontamination Staging Area. A staging area may be required for decontamination of drilling rigs and heavy equipment. The staging area must be constructed to:
- (1) Allow easy access for equipment to move in and out of the staging area.
 - (2) Contain all wash waters and any spray.
 - (3) Allow collection of all wash water into 55- gallon drums or tanks.
 - (4) Minimize cross-contamination.

Typically, a decontamination area consists of a plastic-lined area that drains to a sump where a submersible pump can remove the decontamination water and deposit it in drums, tanks, or in the sanitary sewer.

c. Decontamination Steps.

- (1) The purpose of the initial decontamination step is to remove gross contamination. Remove any solid particles from the equipment or material by brushing and then rinsing with available potable water. Use only water that is known to be contaminant-free. Record the source of the water in the field logbook and collect a sample for analysis if the source has not been analyzed. For drilling equipment, steam cleaning is necessary.
- (2) Wash equipment with soap or detergent solution.
- (3) Rinse with potable water by submerging or spraying.

- (4) Use an optional rinse with a solvent (methanol) to dissolve and remove soluble organic contaminants. Hexane may be used to dissolve waste lubricating oils, tars, and bunker fuels.
- (5) Use an optional rinse with a diluted nitric acid solution to dissolve and remove soluble inorganic metals.
- (6) Rinse thoroughly with distilled water.
- (7) Air-dry equipment or rinse with nanograde methanol to expedite drying.
- (8) Samples of drippings from the last rinse in Step 6 may be collected and analyzed to verify and document the effectiveness of the decontamination procedure. This type of sample is called an equipment/rinsate blank. The results of these analyses are not usually available for at least one week after they arrive in the laboratory. It is, therefore, important to thoroughly decontaminate all equipment to prevent cross-contamination of samples and prevent the detection of contaminants in the rinsate blank.
- (9) Allow item to completely air-dry prior to any use. Cover item if it is not intended for immediate use. Place large items on a clean sheet of plastic.
- (10) Wrap the item in aluminum foil if it is not going to be used immediately. Larger items should be wrapped in clean plastic sheets until they are ready for use.

d. Post-Operation Procedures-Field.

- (1) Decontaminate as much sampling equipment as possible and properly discard expendable items that cannot be decontaminated. Proper disposal shall include onsite drumming of liquids and solids in approved 55-gallon drums for temporary storage prior to subsequent disposal.
- (2) Prepare the rinsate blank sample and transport it according to all federal, state, local, and USACE regulations and/or requirements.
- (3) Store drums of rinse water/solids after decontamination in a secure area.

e. Post-Operation Procedures-Office.

- (1) Inventory equipment and supplies. Repair or replace all broken or damaged equipment. Replace expendable items. Return

equipment to the equipment manager and report incidents of malfunction or damage.

- (2) Contact the analytical laboratory to ensure the samples arrived safely and that instructions for analyses are clearly understood.
- (3) After receiving the results of the laboratory analyses, arrange for the disposal of wastes generated during the investigation.

9-5. Waste Disposal and Recycling.

a. Waste that is generated during equipment decontamination will likely consist of wastewater. Package wastewater in DOT-approved 55-gallon containers for shipment to a disposal facility.

b. Occasionally, solvents such as hexane are utilized in the decontamination process. Hexane decontamination fluid, which is ignitable, is ordinarily regulated as a RCRA hazardous waste; however, opportunities for recycling do exist. Federal regulation allow RCRA characteristic waste, such as hexane, to be mixed with used oil and burned as used oil fuel provided the resultant mixture does not exhibit any RCRA hazardous characteristic. In other words, hexane containing decontamination fluid can be mixed into used oil provided the flashpoint of the resultant mixture is greater than 60 degrees C (140 degrees F) and the mixture does not exceed threshold concentrations for TCLP constituents. This is permissible according to federal regulation, but may be prohibited by individual states. Alternatively, the hexane can be disposed of by burning for energy recovery at a permitted RCRA TSDF.

c. Occasionally, methanol is used for decontamination. Minimize use of methanol because it is regulated as a listed hazardous waste.

9-6 Waste Minimization During Decontamination Operations. To prevent the generation of excessive volumes of decontamination fluids, implement an active waste minimization policy to circumvent the generation of large quantities of decontamination fluid. Activities that could be implemented to reduce wastewater volume include the use of low flow water applicators during decontamination.

CHAPTER 10

COMBUSTIBLE GAS MONITORING PROCEDURES

10-1. General. This chapter describes combustible gas indicators (CGIs), their operation, and correct monitoring procedures.

- a. Purpose. Combustible gas indicators (or explosimeters) are used to determine the potential for the combustion or explosion of unknown atmospheres. Combustible gas monitoring is performed to determine when an explosion hazard exists in the UST work environment. A typical CGI determines the level of organic vapors and gases present in an atmosphere as a percentage of the lower explosive limit (LEL) or the upper explosive limit (UEL) by measuring the change in electrical resistance in a Wheatstone bridge circuit. A Wheatstone bridge circuit is a four-arm bridge circuit used to measure the electrical resistance of an unknown resistor by comparing it with a known standard resistance.
- b. Units. CGIs provide readouts in units of percent LEL, in parts per million (ppm) combustible gases by volume, or both. The more explosive the calibration gas (the lower the LEL), the more sensitive the indication of explosivity, resulting in a greater margin of safety. The operator should be familiar with the LEL concentrations for specific gases to effectively use instruments that provide data only in ppm combustible gases (by volume).
- c. Calibration. Instruments can be purchased that are factory-calibrated for gases like butane, pentane, methane, or petroleum vapors, (methane calibration is the most common). The LEL of methane is 5 percent methane by volume in air; therefore, an air mixture containing 5 percent methane will be read as 100-percent LEL and is explosive. When combustible gases other than methane are sampled, the relative response of the detector must be considered.

Recalibration to other gases may be possible (see the manufacturer's recommendations). National Institute of Standards Technology (NIST) traceable calibration gases should be used. The relative sensitivity of the detector and the differences in LEL for different gases will produce varying meter responses. *When possible, the gas used for calibration should be as similar as possible to the gas that will be*

measured. Calibrate or at least do zeroing checks under field conditions.

10-2. Precautions. During the course of UST activities, workers may be exposed to petroleum hydrocarbon liquids, vapors, and possibly other hazardous wastes. Personnel involved in combustible gas monitoring should be familiar with the potential hazards and appropriate safety and health measures. This is accomplished by reading the SSHP, consulting with the project manager, and observing good safety practices.

All analyzers and testing equipment used in locations that may have flammable atmospheres must be approved, per NFPA 70, for the hazardous location (by Class and Division) and the hazardous substance (by Group) in that location. It is important that manufacturers' recommendations be followed, including calibration procedures.

10-3. Operations, Procedures, and Instructions. Site personnel responsible for combustible gas monitoring should be familiar with all safety rules and regulations as detailed in the SSHP and the use of equipment and procedures for monitoring combustible gas.

a. Instrument Requirements. Guidelines for instrument use include the following:

- (1) Use only those instruments that are certified safe for use in atmospheres containing vapors or gases in concentrations greater than 25 percent of the LEL. Some are not certified safe for operation in the atmospheres they can detect. The instrument manufacturer's operating manual should be consulted to determine safety certification in specific atmospheres.
- (2) CGIs do not indicate if a given atmosphere contains hazardous or toxic compounds nor do they indicate whether an atmosphere is oxygen deficient.
- (3) Do not use the CGI in atmospheres containing silicanes, silicones, or other compounds containing silicon because these substances seriously impair the instrument response.
- (4) If the detector has a platinum filament, its sensitivity may be reduced by exposure to gases like leaded gasoline vapors (tetraethyl lead), sulfur compounds (mercaptans and hydrogen

sulfide), and sulfide compounds. An inhibitor filament that will nullify the effect of leaded gasoline vapors is available on some commercial units. Consult the instrument manufacturer's operating manual to determine the instrument's ability to function in leaded gasoline atmospheres.

- (5) Use an oxygen detector in conjunction with a CGI. Select a unit with this feature and follow the operating manual to use the oxygen detector. This is especially important when atmospheres are monitored within enclosed spaces or where oxygen-deficient atmospheres (< 19.5 percent) may exist. A CGI may give a false "safe" reading in an oxygen-deficient atmosphere.
- (6) Calibrate CGI instruments frequently using a NIST traceable calibration gas. Unusually high concentrations of sulfur dioxide, fluorine, chlorine, bromine, iodine, and oxides of nitrogen interfere with measurement. Consult the manufacturer's operating manual for calibration frequency. Also, frequent calibration will be necessary if several known organic species are present. Maximum accuracy requires a recalibration for each gas.
- (7) Do calibration and zeroing checks under field conditions.

b. Instrument Preparation. Assemble the equipment and supplies listed in Table 10-1. Perform a minimal check of the CGI in the office to ensure that it is functioning properly. Obtain the CGI, its operating manual, and a supply of NIST traceable gas. Methane is the factory calibration gas, but other gases may be used for specific requirements.

Perform the equipment checks below.

- (1) Make sure the instrument is clean and serviceable, especially sample lines and detector surfaces.
- (2) Check the battery charge level. If in doubt, charge the battery as described in the operating manual. Some units have charge-level meters, while others have only low-charge alarms.
- (3) Turn the unit to the "on" position and allow the instrument sufficient warmup time.

- (4) Verify that the sample pump is operable when the analyzer is on. The pump can usually be heard when operating.

TABLE 10-1 COMBUSTIBLE GAS INDICATOR (CGI) EQUIPMENT AND SUPPLIES CHECKLIST	
	CGI
	Battery Charger for CGI
	Oxygen Sensor
	Battery Charger for Oxygen Sensor
	Spare Gas-Detector Filaments
	Spare Batteries for CGI
	Jeweler's Screwdrivers for Internal Adjustment
	Calibration Kit A) Spare gas cylinder (NIST traceable calibration gas) B) Valve attachment C) Flexible tubing (tygon) D) Cylinder to encapsulate sensor probe
	Probe Extensions

- (5) With the intake assembly in combustible gas-free ambient air, zero the meter by rotating the zero control until the meter reads 0 percent LEL. For instruments with an additional oxygen meter, adjust the dial to 21 percent oxygen in nonhazardous locations.
- (6) Calibrate the unit against a known concentration of a calibration gas, like methane, by rotating the calibration control (span or gain) until the meter reads the same concentration as the known standard.

- (7) Some instruments require internal calibrating with a small screwdriver. Consult the operating manual before calibration. With this model, it is also necessary to maintain the proper flow rate during calibration. Connect a flow meter between the CGI and the calibration gas cylinder to monitor the flow rate.
- (8) Most models are equipped with three meters that read percent oxygen, percent LEL, and ppm. The ppm dial is often not used in the field unless a photoionization detector (PID) or flame ionization detector (FID) is not available, as the PID/FID instruments are considered to be more accurate.

c. Documentation Preparation.

- (1) Obtain a logbook.
- (2) Record results of the equipment check in the logbook.

d. Field Preparation.

- (1) Instrument Check. Before using the CGI in the field, follow the procedures described in the instrument preparation section. You may need to make additional adjustments. If necessary, adjust the alarm setting to the appropriate combustibility limit. The action level or the point when activities are halted and personnel are removed from the immediate vicinity, as detailed in the SSHP, is usually less than 25 percent of the LEL for the gases that are present.
- (2) Record necessary calibration data in the logbook and include the information listed below:

- Date and time of arrival at the site.
- Site identification.
- Instrument, model number, and serial number.
- Date/time calibrated.
- Calibration gas used, including manufacturer and lot number.
- Calibration location.
- Operator's signature.

e. Field Measurements.

- (1) Calibrate the CGI daily before use in the field. See the manufacturer's manual for calibration procedures.
- (2) Position the CGI intake assembly close to the area in question to get an accurate reading. For readings taken downhole during drilling, there will be a slight delay between positioning the intake tubing downhole and registering accurate meter readings because of the time required for the sample to travel the length of the tube.
- (3) Interpret CGI meter readings according to one of three typical instrument responses:
 - (a) The meter indicates 0.5 LEL (50 percent). This means that 50 percent of the concentration of combustible gas required to reach an unstable combustible situation is present.
 - (b) The meter needle stays above 1.0 LEL (100 percent). This means that the concentration of combustible gas is greater than the LEL and less than the UEL. Therefore, the concentration is immediately combustible and explosive.
 - (c) The meter needle rises above the 1.0 LEL (100 percent) mark and then returns to zero. This response indicates that the ambient atmosphere has a combustible gas concentration greater than the UEL.
- (4) Evacuate the area if any of the following events occur:
 - (a) Sounding of the GCI alarm
 - (b) Readings that reach the action levels designated in the SSHP
 - (c) Malfunctioning of the CGI
 - (d) Condition encountered or suspected that indicates oxygen enrichment or depletion of the atmosphere (specially designed units are available for operation in those atmospheres).
- (5) Keep in mind these important factors during CGI use:

- (a) Slow, sweeping motions of intake or cell assembly will help ensure that problem atmospheres are not bypassed. Cover an area from the ground to the breathing zone and areas where maximum concentrations may be expected (for example, downhole during drilling).
- (b) Operating the unit in temperatures outside the recommended operating range may compromise the accuracy of readings or damage the instrument. Check the operating manual for the temperature limitations of each particular model.
- (c) Many CGIs are not designed for use in oxygen-enriched or -depleted atmospheres.
- (d) Calibrate the equipment and charge the battery after each field use. See the operating manual for details.
- (e) The operator should fully understand the operating principles and procedures for the specific CGI in use.

f. Post Operations.

(1) Field.

- (a) Carefully clean the outside of the CGI with a damp disposable towel to remove any visible dirt when the activity is completed or at the end of the day. Return the CGI to a secure area and place on charge.
- (b) Ensure that all equipment is accounted for, decontaminated, and ready for shipment.

(2) Documentation.

- (a) Record any uncompleted work (such as additional monitoring) in the logbook.
- (b) Complete logbook entries, verify the accuracy of entries, and sign/initial all pages.
- (c) Review data collection forms for completeness.

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(3) Office.

- (a) Deliver original forms and logbooks to the document control officer (with copies to the project manager and files).
- (b) Inventory equipment and supplies. Repair or replace all broken or damaged equipment. Replace expendable items. Return equipment and report incidents of malfunction or damage.

CHAPTER 11

ORGANIC VAPOR MONITORING PROCEDURES

11-1. General. This chapter describes monitoring of organic vapors using a portable PID and FID in the UST work environment. Both PIDs and FIDs are useful as general survey instruments at UST sites. A PID is capable of detecting and measuring real-time concentrations of many organic vapors in the air. A PID is similar to a FID in application. Equipment calibration should be done at the frequency and in accordance with the written manufacturer's instructions. Table 11-1 describes the application comparisons between a PID and an FID. Other types of measuring devices such as colorimetric or immunoassay can be used, but they do not provide the continuous readout of the PID or FID instruments.

- a. PID. A PID responds to most vapors that have an ionization potential less than or equal to that supplied by the ionizing ultraviolet (UV) lamp in the detector. Several lamps are available for the PID, each having a different source wave length and subsequent different ionization potential. For this reason, the selection of the appropriate lamp is essential in obtaining useful field results. Although it can be calibrated to a particular compound, the instrument cannot distinguish between detectable compounds in a mixture of gases. Therefore, it indicates an integrated response to the mixture.
- b. FID. An FID is useful as a general screening tool to detect the presence of most organic vapors. It can detect pockets of gaseous hydrocarbons in depressions or confined spaces and can screen an area for the presence of elevated levels of vapor-phase organics. The FID will respond to most organic vapors as they form positively charged ions when burned in a hydrogen flame. The magnitude of the response is a function of the detector sensitivity and the ionization properties and concentration of the particular compound. As a result, the response must be compared with the response generated by a known concentration of a standard gas. The sample concentration is then reported as the ppm-equivalent of the standard gas. Most units are calibrated with methane; however, almost any gaseous hydrocarbon that produces a response can be used. Many models also have built-in calibration circuits to ensure that the electronic response remains constant in all ranges.

11-2. Precautions. Personnel involved in the procedures outlined in this chapter should be familiar with the potential hazards and know in the appropriate safety and health measures needed to ensure a safe working environment. During the course of UST activities, workers may be exposed to petroleum hydrocarbon liquids and vapors and other hazardous wastes. Good safety practices should be observed by all individuals using this procedure.

**TABLE 11-1
COMPARISON OF THE FID AND PID**

	FID	PID
Response	Responds to many organic gases and vapors, especially low molecular weight hydrocarbons.	Responds to many organic and some inorganic gases and vapors, especially heavy hydrocarbons.
Application	In survey mode, detects total concentrations of gases and vapors. In GC mode, identifies compounds.	In survey mode, detects total concentrations of gases and vapors. Some compounds possible if GC column and standards are used.
Limitations	Does not respond to inorganic gases and vapors with a higher ionization potential than the flame detector. No temperature control.	Does not respond to methane or inorganic aliphatic chlorinated solvents. Does not respond properly in presence of water vapor (high humidity). Does not detect a compound if probe (lamp) has a lower energy than compound's ionization potential.
Calibration Gas	Methane and others.	Benzene (1,3-butadiene) and others.
Ease of Operation	Requires experience to interpret correctly, especially in GC mode.	Fairly easy to use and interpret. More difficult in the GC mode.
Detection Limits	0.1 ppm (methane).	0.1 ppm (benzene), depends on lamp voltage.
Response Time	2-3 sec (survey mode).	3 sec for 90 percent of total concentration.
Maintenance	Periodically clean and inspect particle filters, valve rings, and burner chamber. Check calibration and pumping system for leaks. Recharge battery after each use.	Clean UV lamp frequently. Check calibration regularly. Recharge battery after each use.
Useful Range	0-1,000 ppm.	0-2,000 ppm.
Service Life	8 hours; 3 hours with strip-chart recorder.	10 hours; 5 hours with strip-chart recorder.

Monitor potentially toxic or potentially explosive vapors to determine when an explosive or toxic hazard exists in the work environment.

11-3. PID Operations, Procedures, and Instructions. Site personnel responsible for organic vapor monitoring should be familiar with all safety rules and regulations and the procedures for operating equipment.

a. Limitations.

- (1) The PID is a nonspecific total vapor detector. It cannot be used to identify substances; it can only quantify substances.
- (2) The PID must be calibrated to a specific compound.
- (3) The PID does not respond to certain low molecular weight hydrocarbons such as methane and ethane.
- (4) Certain models of PID instruments are not intrinsically safe. Refer to the manufacturer's operating manual for use in potentially flammable or combustible atmospheres.
- (5) A PID should be used in conjunction with a CGI.
- (6) Electrical power lines or power transformers close to the PID instrument may cause measurement errors. Under these circumstances, refer to the operating manual for proper procedures.
- (7) High winds and high humidity will affect measurement readings. Certain models of PID instruments become unusable under foggy or high humidity conditions.
- (8) The lamp must be periodically cleaned to ensure ionization of the air contaminants.
- (9) Consult the manufacturer's operating manual to determine the instrument's response to various chemicals.

b. Calibration. Transport of calibration gas cylinders by passenger and cargo aircraft is guided by the U. S. Code of Federal Regulations, 49 CFR Parts 100-177. Benzene is a typical calibration gas included with a PID. Benzene is classified as a nonflammable gas, UN1556, and the proper shipping name is "compressed gas." It must be shipped in cargo aircraft only.

c. Instrument Preparation. Assemble the PID equipment and supplies listed in Table 11-2. Perform the startup procedures and operational checks described below.

- (1) Assemble the instrument and check battery according to manufacturer's instructions. Turn on the PID.
- (2) Zero the instrument using zero-calibration air or ambient air.
- (3) Calibrate the instrument according to the manufacturer's specifications. At a minimum, instruments should be calibrated daily at field conditions.
- (4) Contact the carrier that will transport equipment and hazardous materials to obtain information on regulations and specifications.

TABLE 11-2 PHOTOIONIZATION DETECTOR (PID) EQUIPMENT AND SUPPLIES CHECKLIST	
	Photoionization Detector (PID)
	Operating Manual
	Probes: 9.5eV_____, 10.2eV_____, and 11.7eV_____
	Battery Charger for PID
	Spare Batteries
	Jeweler's Screwdriver for Adjustments
	Tygon Tubing
	NIST Traceable Calibration Gas (type: _____)
	"T" Valve for Calibration
	Intake Assembly Extension
	Strap for Carrying PID
	Teflon Tubing for Downhole Measurements
	Plastic Bags for Protecting the PID from Moisture and Dirt

d. Documentation Preparation.

- (1) Obtain a logbook.
- (2) Record results of the equipment check in the logbook.

e. Field Preparation.

- (1) Follow the startup procedures and operational check as described in Section 11.3. Check the calibration of the instrument against a known sample of calibration gas. If the calibration is outside manufacturer's specifications, recalibrate the instrument.
- (2) Follow the instructions in the operating manual explicitly to obtain accurate results. As with any field instrument, accurate results depend on the operator's knowledge of the manual.
- (3) Position the PID intake assembly close to the monitoring area because the low sampling rate allows for only very localized readings. Do not immerse the intake assembly in fluid under any circumstances.
- (4) Monitor the work activity as specified in the SSHP while taking care not to permit the PID to be exposed to excessive moisture, dirt, or contamination. Conduct the PID survey at a slow-to-moderate rate of speed and slowly sweep the intake assembly (the probe) from side to side.
- (5) Evacuate the area if the preset alarm sounds. Operators using supplied air systems may not need to evacuate the work area, but they should frequently observe the levels indicated by the instrument.
- (6) Static voltage sources like power lines, radio transmissions, or transformers may interfere with measurements. See the operator's manual for a discussion of necessary considerations.

f. Post Operation.

- (1) Field.
 - (a) Carefully clean the outside of the PID with a damp disposable towel to remove any visible dirt when the

activity is completed or at the end of the day. Return the PID to a secure area and place on charge.

- (b) Ensure that all equipment is accounted for and decontaminated.

(2) Documentation.

- (a) Record any uncompleted work (such as additional monitoring) in the logbook.
- (b) Complete logbook entries, verify the accuracy of entries, and sign/initial all pages.
- (c) Review data collection forms for completeness.

(3) Office.

- (a) Deliver original forms and logbooks to the document control officer with copies to the project manager and files.
- (b) Inventory equipment and supplies. Repair or replace all broken or damaged equipment and charge the batteries. Replace expendable items. Return equipment and report incidents of malfunction or damage. If necessary, replenish supplies of the NBS traceable calibration gas.

11-4. FID Operations, Procedures, and Instructions. Site personnel should be familiar with all safety rules and regulations and procedures for operating equipment.

a. Limitations.

- (1) The FID does not respond to nongaseous organic compounds such as some pesticides, polynuclear aromatic hydrocarbons (PAHs), and polychlorinated biphenyls (PCBs).
- (2) Most portable FIDs use the sample gas as combustion air for the detector flame and are designed to operate in ambient atmospheres with oxygen concentrations of approximately 21 percent. This design precludes the sampling of process vents, poorly ventilated or sealed containers, or any sample gas with a hydrocarbon concentration sufficient to reduce the available oxygen or saturate the detector. Optional equipment is available to supply oxygen from a compressed gas cylinder or

introduce sample gas through a dilution system with a known dilution factor.

- (3) Concentrations beyond the greatest scale factor of the instrument or in excess of 30 percent of the LEL of the sample component require system modification. If system modifications are required, consult the manufacturer's operating manual.
- b. Calibration. FID instruments usually have a negligible response to carbon monoxide (CO) and carbon dioxide (CO₂). Their structures preclude the production of appreciable ions in the detector flame so other organic materials may be analyzed in the presence of CO; and, as with the PID, the FID responds differently to different compounds. Because the instrument is factory-calibrated to methane, all relative responses are given in percentages with methane at 100. Therefore, the identity of the chemical of interest must be ascertained before its concentration can be determined.

In addition, the FID unit requires a trained individual to maintain and operate the unit. Department of Transportation regulations prohibit the carrying of compressed hydrogen gas on passenger aircraft. When the FID instrument is transported on a passenger aircraft, the hydrogen gas contained in the instrument must be emptied before loading. Transport of an FID or extra cylinders of hydrogen gas or calibration gas by cargo aircraft must comply with the regulations stipulated in 49 CFR Parts 100-177. Consult the shipper for any recent changes in this procedure.

- c. Instrument Preparation. Assemble the equipment and supplies listed in Table 11-3. Perform the startup procedures and functional checks described below. The purpose of these checks is to verify that an instrument will function properly (for example, the batteries are serviceable, and the instrument can be zeroed and calibrated) in the field. If problems develop, obtain a replacement unit and perform the same functional checks.
- (1) Turn the instrument on and allow adequate warmup time.
 - (2) Check the battery charge level indicator. If it is not fully charged, recharge the battery as described in the manual.
 - (3) Turn on the pump and check for leaks by covering the sample inlet and observing the rotameter. The indicator ball should drop to zero.

- (4) With the pump operating, open the hydrogen gas storage tank valve and the supply regulator to allow fuel gas to flow into the detector chamber.
- (5) Depress the igniter switch, observe the indicator needle for positive response, and listen for a pop. If the flame fails to light, depress the igniter switch again. Once the detector flame is lit, the unit is ready for use. Before lighting the detector flame, always be sure that the combustion gas flow (usually sample gas) is started. If the detector fails to light, check over the instrument battery and gas levels and start again at Step 1. If the instrument still does not light, contact the project manager.

TABLE 11-3 FLAME IONIZATION DETECTOR (FID) EQUIPMENT AND SUPPLIES CHECKLIST	
	Flame Ionization Detector (FID)
	Probe Extension
	Operating Manual
	Battery Charger
	Spare Batteries
	Jeweler's Screwdriver for Adjustments and Calibration
	Refueling Hose for Hydrogen Cylinder
	NIST Traceable Calibration Gas (type: _____)

- (6) If the instrument has internal calibration capability, perform the instrument calibration according to the procedures described in the operating manual.

d. Documentation Preparation.

- (1) Obtain a logbook.
- (2) Record equipment checking results in the field logbook.

- (3) Obtain a sufficient number of the appropriate data collection forms.
- e. Field Preparation. Before using the FID in the field, perform the following instrument checks to ensure that the equipment was not damaged during transport.
- (1) Follow the instrument checkout procedures described above in office preparation.
 - (2) If calibration to a specific hydrocarbon species is desired, complete this procedure according to the manufacturer's operating instructions.
 - (3) Calibrate the FID daily before each use in the field.
 - (4) Hold the sample probe in the area in question. The low sample rate allows for only very localized readings.
 - (5) A slow sweeping motion should help prevent the bypassing of problem areas. Make sure the batteries are recharged within the time frame specified in the operator's manual. The usual length of operating time between charges is 8 to 12 hours.
 - (6) Perform FID monitoring at 1.5-meter (5-foot) intervals downhole, at the headspace, and in the breathing zone during drilling activities. In addition, where elevated organic vapor levels are encountered, monitoring may be performed in the breathing zone during actual drilling. When the activity does not require drilling (like surface sampling), only record readings in the breathing zone. Consult the SSHP for the specific monitoring instructions.
 - (7) Check for an alarm on the unit that signals the operator if the detector flame goes out. If the alarm sounds, evacuate the work area, relight the flame in a known safe area, and reenter the site.
 - (8) Monitor fuel and combustion air supply gauges regularly to ensure sufficient gas supplies.
 - (9) Clean sample probe or in-line filters (in front of the detector), when high background readings occur or after prolonged use. Use pipe cleaners to clean the probe and apply clean air blown backwards through the probe to clean the filters. Do not use organic solvents because the detector may become saturated by the solvent.

- (10) Perform the routine maintenance described in the operating manual. Because the FID unit contains pressurized gas supplies, leak-check procedures must be regularly performed. Leaking hydrogen gas is explosive.
 - (11) Modify the system if concentrations beyond the maximum full-scale capability of the instrument or in excess of 30-percent LEL of the sample component occur. Similar modification may be necessary for sampling in oxygen-deficient atmospheres. This usually entails increasing the combustion air to the detector by sample dilution or by an independent air supply. A dilution system apparatus is required to supply a filtered, controlled air supply for analyzers that use the sample gas stream as the source of combustion air. A dilution system can dilute a gas stream by ratios up to 100:1 through the selection of various critical orifices.
- f. Post Operations. See paragraph 11-3f. The same post-operations process applies to both FIDs and PIDs.

CHAPTER 12

PRODUCT REMOVAL PROCEDURES

12-1. General. This chapter describes the procedures that should be followed for removal of product from an UST after the tank's contents have been characterized by reviewing records and/or by chemical analysis. Sampling is usually recommended for tanks that are no longer in use or that have experienced a change in use over their lifetimes. The only time when a UST would not be sampled is when the tank is currently in service, and the contents stored over its service life are well-documented.

12-2. Operations, Procedures, and Instructions.

a. Precautions. During the course of product removal, workers may be exposed to petroleum hydrocarbon liquids, vapors, or wastes. All precautions should be observed by all individuals using this procedure for product removal from USTs. Site personnel responsible for product removal should be familiar with:

- (1) All safety rules and regulations (consult the SSHP for specific safety instructions).
- (2) The use of equipment and procedures for removing product from tanks.
- (3) The handling and disposal of the types of products likely to be encountered.
- (4) API Publications: 1604, 2003, 2015, 2217, 2219, and NFPA 327.
- (5) Transportation of fuel and fuel products.

b. Documentation.

- (1) Obtain a field logbook to record all activities performed, personnel contacted, time and dates when these activities were performed, field conditions, and any unusual circumstances.
- (2) Keep information factual and objective.
- (3) Enter information not recorded in the logbook on field forms. In either case, record the following information:
 - Site identification
 - Date and time specific activities took place
 - Personnel names
 - Field observations.

Photographs are suggested; if photos are taken, records must indicate the name of photographer, site name, camera type and lens size, and general direction. This information will be included in the Tank Closure Report discussed in Chapter 1 of this manual.

c. Procedures.

- (1) Observe any special precautions.
- (2) Perform limited excavation (per requirements in EM 385-1-1) to access the piping. Flush and drain piping into the tank, being careful to avoid any spillage to the surrounding area. Disconnect piping (except the vent line) from the tank and cap or remove the piping.
- (3) Take a sample for offsite analysis if tank contents are unknown. Generally, the contents of an active tank are known. See Chapter 6 for sampling of tank contents.
- (4) Vent the tank properly by ensuring all vent pipes are open to the atmosphere, then pump or drain residual product to the lowest possible level through the water-draw or pumpout connection.

12-3. Equipment. Vacuum tank trucks, along with explosion-proof or air-driven pumps, provide a fast and efficient method for removing and hauling product from USTs.

a. Precautions

- (1) The vacuum truck operator should be trained to identify or recognize hazards connected with truck operations including spills, hose failures, and discharges of flammable and toxic vapor.
- (2) The truck operator should be provided with and trained in the use of all required personal protective equipment. In addition, the tank operator should be trained in recognition of potentially flammable conditions and fire prevention, first aid, and the proper use of portable fire extinguishers and other fire extinguishing techniques.
- (3) Department of Transportation regulations in 49 CFR 172 Subpart H require the truck operator to be trained and tested on the hazardous materials regulations. Training must include general awareness of the hazardous materials regulations, safety training, driver training, and function specific training. The truck operator should be knowledgeable in and compliant with applicable state and local hazardous material regulations as

well as the following portions of the *Code of Federal Regulations*:

- (a) 49 CFR Parts 170-178 and 390-397 Transportation. (This material has been compiled by National Tank Truck Carriers in their publication: *Cargo Tank Hazardous Material Regulations*.)
 - (b) 40 CFR 263 Standards Applicable to Transporters of Hazardous Waste.
 - (c) 40 CFR 279 Standards Applicable to the Management of Used Oil (when applicable).
- b. Truck Inspection and Operating Procedures. The truck operator should complete this inspection checklist before the truck is operated:
- (1) All valves are operating freely.
 - (2) Floats for liquid-level indicators are working properly.
 - (3) Rubber stoppers on scrubber shutoffs are in good condition and seated properly.
 - (4) Dome gaskets are in good condition and seated tightly when the domes are closed (this can be checked by applying pressure to the tank).
 - (5) Hoses, connections, and fittings are in good condition, and the materials of construction are appropriate for the application.
 - (6) All connections and other equipment are leak-free and in good working order.
- c. Internal Valves. Internal valves are not required on tanks that have been specifically exempted by the U. S. Department of Transportation; however, a copy of the exemption must be carried on the truck.
- d. Operating Environment.
- (1) Because truck engines are an ignition source, they should be operated upwind of any pickup point and outside path of vapor travel.
 - (2) If there is any question whether the area is gas-free, a gas test should be performed using a CGI before any operation is started. The area must be vapor free.

- (3) A vacuum truck should be permitted into a diked tank area only after the area has been tested and found to be gas free.
 - (4) In the area where product will be discharged from the vacuum truck, vapor travel and sources of ignition must be considered.
- e. Static Electricity. With nonconductive hose, any exposed metal, such as a hose flange, can accumulate static electricity and act as an ignition source if the metal touches or comes close to ground. Therefore, if nonconductive hose is used to discharge a flammable liquid into an open area (such as a pit or an open tank) or discharged where any source of flammable material is present near the hose's exposed metal parts, the metal parts shall be bonded, the hose and the tank or receiving vessel shall be bonded, and the bonding system shall be grounded. (Refer to NFPA 30, Flammable and Combustible Liquids Code).

As it is difficult to distinguish between conductive and nonconductive hose and both may be used, it is recommended that all exposed metal on any hose be grounded. Exception to this would be a closed system with tight connections at both ends of the hose. An alternative to grounding in such cases is verifying, by means of electrical testing, that the hose is conductive.

- f. Cargo Tank Vacuum Loading. The truck operator should utilize the following procedure when loading a cargo tank:
- (1) Attach the suction hose from the inlet valve to the load source.
 - (2) Close all valves.
 - (3) Start the vacuum pump.
 - (4) Position the four-way valve to pull a vacuum on the cargo tank.

WARNING: When volatile flammable or toxic liquids are loaded, the vacuum pump exhaust should be extended downwind by attaching a length of hose sufficient to allow venting to a hazard-free area away from people, ignition sources, and so forth.

- (5) When the tank is full, close the inlet valve.
- (6) Bleed off the vacuum by opening the bleeder valve, equalizing the tank pressure.
- (7) Close and cap the bleeder valve. Open the inside and outside scrubber (liquid entry preventer); drain valves. Catch any liquid for proper disposal.

CAUTION: To prevent liquids and solids from entering the vacuum pump, neither the inside nor the outside scrubber drain valves should be opened while the unit is under vacuum.

12-4. Waste Disposal and Recycling. Two types of waste associated with product-removal operations include product and contaminated water from rinsing activities.

a. Product Disposal. (*Note: The scope of this EM is limited to petroleum, oil, and lubricant tanks; therefore, this discussion does not include other types of products*). In many instances, product removed from tanks can be reused onsite if the fuel characteristics meet the facility's specifications. If the fuel does not meet the specifications, (e.g., because of excessive amounts of water or sludge in the fuel), it can be shipped to a recycler for reclamation. Prior to shipment, a determination on the regulatory status of the material must be made. It may be regulated as a hazardous waste if it is ignitable, fails TCLP, or meets criteria for a state-regulated waste. On the other hand, it may be excluded from regulation if it can still be used as a fuel or if recycled in a manner that excludes it from regulation as a hazardous waste.

- (1) When the petroleum, oil, lubricant (POL) is not subject to regulation as a hazardous waste, options for recycling include:
 - (a) Use for its intended purpose directly. For example it can be burned as a fuel in a boiler, in an industrial furnace, or in a space heater. It could also be burned in an engine used to operate a free-product recovery system.
 - (b) Use for its intended purpose after being re-processed. For example, fuel/water mixtures can be physically separated on site to recover the fuel. Since it is not regulated as hazardous waste, processing does not require an RCRA Part B permit.
 - (c) Use as an additive for paving or roofing asphalt. Whereas hazardous wastes are prohibited from being used as ingredients for products placed on the land (unless specific conditions are met), this prohibition does not apply to non-hazardous wastes.
 - (d) Use as a substitute for a commercial product. For example, it could be used as form release agent for concrete production.
- (2) When the POL is ignitable or fails TCLP, the following options for disposal and/or recycling should be considered:

- (a) Use for its intended purpose without first processing. Fuel that can still be used for its intended purpose is not subject to RCRA regardless of whether or not it exhibits a hazardous characteristic.
 - (b) Process it to become a useable fuel. However, the facility that processes the waste must be a permitted RCRA treatment, storage, and disposal (TSD) facility.
 - (c) Mix with used oil and burn as used oil provided the mixture does not exhibit any RCRA hazardous characteristic. Note, however, that this is permissible according to federal regulation, but may be prohibited by individual states.
 - (d) Burn for energy recovery at a permitted TSD facility.
 - (e) Use as an effective substitute for an ingredient in a commercial chemical product provided the resultant product is not applied to the land or burned for energy recovery. However, it can be recycled into a product applied to the land if the following three criteria are met:
 - (1) The recyclable material has undergone a chemical reaction in the course of producing the product so as to become inseparable by physical means;
 - (2) the product meets land disposal restriction treatment standards; and
 - (3) the product is produced for the general public's use.
- b. Contaminated Water. Contaminated water can be disposed of in several different ways. Some DOD facilities may discharge to an oil/water separator. A second method is to discharge it to the local publicly owned treatment works (POTW) or an industrial wastewater treatment facility. Contact the facility environmental coordinator and the local POTW to determine discharge requirements for the facility. Another method of disposal is to ship the water/product mixture to a recycler. The reader should recognize that this may be a more expensive option due to shipping costs. Any method of disposal needs careful and precise documentation, including laboratory analytical results, disposal facility approval and certification, and the proper paperwork to track the removal and disposal of the waste.

CHAPTER 13

UNDERGROUND STORAGE TANK REMOVAL PROCEDURES

13-1. General. This chapter recommends procedures for the removal, storage, and offsite disposal of UST systems that have contained flammable or combustible fluids. All such work must be accomplished in accordance with federal, state, and local requirements as well as accepted safety standards. Before initiating work, the appropriate government agencies should be consulted concerning applicable regulatory and permit requirements. *This chapter is not considered to be all inclusive due to the differences in state regulatory requirements.* USACE Guide Specifications and other helpful guidance references are included in Chapter 1.

13-2. Removal of Underground Tanks.

a. Preparation.

- (1) Observe the safety precautions as described in Chapter 7.
- (2) Notify the Implementing Agency a minimum of 30 days prior to tank removal. Obtain a tank removal permit from the local fire chief or proper authorities and notify the environmental coordinator of the day and time when work will begin at least 3 days in advance. Typically, local regulations require a local fire official representative to be onsite before work may begin. Notify proper fire authorities as they require.
- (3) Remove all liquids from the tank following the procedures outlined in Chapter 12.

b. Purging Tanks. Purging or ventilating a tank replaces or dilutes the flammable vapors in the tank with air. The goal of tank purging is to reduce the flammable vapors in the tank to below one percent of the LEL. Tanks shall be purged for confined space entry but not for removal purposes. However, it is important to recognize that the tank may continue to be a source of flammable vapors even after following the purging procedures.

Confined space entry into the tanks should not be attempted unless absolutely necessary, but it may be required to effectively remove sludge from the tank. Consult NFPA 326, *Safe Entry into Underground Storage Tanks*, for tank entry and Table 13-1, which summarize the procedures for tank purging as well as associated advantages and disadvantages.

TABLE 13-1
 PROCEDURES FOR PURGING TANKS

Procedure	Advantage	Disadvantage
<ul style="list-style-type: none"> • Venting vapors This must be done at least 3.7 m (12 feet) above grade and 1 m (3 feet) above roof lines. 	<ul style="list-style-type: none"> • Ventilation is usually the first method of choice for removing flammable atmospheres since it can be accomplished with the least cost. 	<ul style="list-style-type: none"> • The work area must be free from sources of ignition. • All venting of flammable vapors must be into a safe location and should be monitored to ensure that a vapor buildup does not occur. • Ventilation must be ongoing to maintain flammable vapors below 10 percent LEL. • It may not be possible to adequately ventilate a tank that contains residuals of highly flammable liquids or sludge. • Venting without forced flammable vapor removal will not work unless the access to the tank is located on the top of the tank. • Venting is time consuming. • Purging is a temporary procedure. Product trapped in bottom sludge and wall scale regenerates flammable vapors inside the tank. • Venting cannot be used for tank removal purposes.

TABLE 13-1 (continued)
PROCEDURES FOR PURGING TANKS

Procedure	Advantage	Disadvantage
<ul style="list-style-type: none"> Ventilation via an eductor-type air mover usually driven by compressed air 	<ul style="list-style-type: none"> Tanks equipped with fill (drop) tubes that are not removable can be purged efficiently by this method. 	<ul style="list-style-type: none"> Vapors must be discharged at a minimum of 3.7 m (12 feet) above grade. All precautions must be taken to minimize the hazards of ignitability and static electricity. Air movers must be inherently bonded to the vessel being ventilated. Exhaust fumes will need to be vented at a minimum height of 3.7 m (12 feet) above grade and 1 m (3 feet) above any adjacent rooflines. To avoid rupturing the tank, air pressure in the tank must not exceed 34.5 KPa (5 psi) so the size of vent openings as well as the air pumping rate must be considered.

TABLE 13-1 (continued)
PROCEDURES FOR PURGING TANKS

Procedure	Advantage	Disadvantage
<ul style="list-style-type: none"> • Ventilation via a diffused air blower 	<ul style="list-style-type: none"> • Generally, blowing into the tank rather than exhausting from the tank is more effective. • Ventilation via diffused air blower is relatively inexpensive. 	<ul style="list-style-type: none"> • Irregular-shaped containers may not be thoroughly purged by this method if the airstream leaves pockets that cannot be effectively reached with the uncontaminated air. • All precautions must be taken to minimize the hazards of ignition by static electricity. Air movers must be inherently bonded to the vessel being ventilated. • Fill (drop) tubes must be removed to allow proper diffusion of the air in the tank. • Air supply must come from a compressor that has been checked to ensure a clean air supply that is free from volatile vapors. • To avoid rupturing the tank, air pressure in the tank must not exceed 34.5 KPa (5 psi). • Exhaust fumes will need to be vented at a minimum height of 3.7 m (12 feet) above grade and 1 m (3 feet) above any adjacent rooflines.

TABLE 13-1 (continued)
PROCEDURES FOR PURGING TANKS

Procedure	Advantage	Disadvantage
<ul style="list-style-type: none"> ● Use of commercial emulsifiers 	<ul style="list-style-type: none"> ● Completely miscible in water. ● Aids in the elimination of flammable vapors. ● Biodegradable. 	<ul style="list-style-type: none"> ● Regulatory requirements for treatment and disposal of the water must be determined. ● Biosolve is an expensive material to purchase.
<ul style="list-style-type: none"> ● Displacement of vapors with water 	<ul style="list-style-type: none"> ● One of the safest and simplest methods. 	<ul style="list-style-type: none"> ● Regulatory requirements for treatment/disposal of water used in the vapor-freeing process may make this method cost-prohibitive. ● The liquid previously contained in the tank must be readily displaced by or be soluble in water. ● In accordance with USACE guide specifications, purging methods utilizing liquids shall not be allowed.

- (1) Exhaust flammable vapors from the tank by one of two methods of tank ventilation listed below.
 - (a) One method is ventilation using an eductor-type air mover, usually driven by compressed air. However, the USACE does not approve this method. Therefore, it is presented in this manual only for completeness of information. The eductor-type air mover must be properly bonded to prevent the generation and discharge of static electricity. When using this method, the fill (drop) tube should remain in place to ensure ventilation at the bottom of the tank. Tanks equipped with fill (drop) tubes that are not removable are purged by this method. An eductor extension is used to discharge vapors a minimum of 3.7 meters (12 feet) above grade or 1 meter (3 feet) above adjacent roof lines, whichever is greater.
 - (b) Ventilation with a diffused air blower is a second method. When using this purging method, it is imperative that the air-diffusing pipe is properly bonded to prevent the discharge of a spark. Fill (drop) tubes must be removed to allow proper diffusion of the air in the tank. Air supply should be from a compressor that has been checked to ensure a clean air supply that is free from volatile vapors. Air pressure in the tank must not exceed 34.5 KPa (5 psi) gauge to avoid tank failure.
- (2) One of the safest and simplest methods for purging a tank is to fill the tank with water. However, in certain areas, regulatory requirements for treatment/disposal of water used in the vapor-freeing process may make this method cost-prohibitive. Purging methods using liquids will not be used on USACE projects due to generation of excessive volumes of waste. *The method is presented here for completeness.* Before employing the method described below, consult local regulations.
 - (a) Fill the tank with water until the floating product nears the fill opening. Remove the floating product and place it in a suitable container for proper disposal. Care should be exercised to ensure that neither product nor water is spilled into the tank excavation.

- (b) Observe normal safety precautions filling the tank with water because flammable vapors will be expelled through both the vent and fill openings, but primarily at the fill opening. To minimize this escape of vapor through the fill opening, temporarily cap the opening.
 - (c) Pump out the water and dispose of it in accordance with local regulations when the tank is free of vapor.
- (3) Another purging method that has been used with success and is an approved method in some states is the use of commercial emulsifiers and volatile fuel encapsulators. These products are completely miscible in water, aid in the elimination of flammable vapors, and are biodegradable. Regulatory requirements for treatment and disposal of the water must be determined prior to using this method.
- (a) Standing outside the tank, rinse the tank with a three- to six- percent solution of the product using a pressure sprayer through a manway opening.
 - (b) Measure explosive concentrations at several levels within the tank. If readings are greater than 20 percent of the LEL, rinse the tank again.
 - (c) When LEL readings are acceptable, pump out the water in the tank for disposal.
- c. Inerting Tanks. Inerting displaces the flammable atmosphere of the tank with an inert or nonreactive gas such as nitrogen or carbon dioxide. Inerting is achieved when the oxygen content is lowered to below 8 percent oxygen by volume, which is the amount of oxygen needed by most petroleum products to support combustion. Table 13-2 summarizes the procedures and advantages/disadvantages for tank inerting. Inerting is the only option available when removing tanks from the ground.

Always exercise caution when handling or working around tanks that have stored flammable or combustible liquids. Before initiating work in the tank area or on the tank, a Combustible Gas Indicator (CGI) should be used to assess vapor concentrations in the tank and work area. CGI operation is detailed in Chapter 10.

TABLE 13-2
 PROCEDURES FOR INERTING TANKS

Procedure	Advantage	Disadvantage
<ul style="list-style-type: none"> Displacement of vapors with dry ice, carbon dioxide gas 	<ul style="list-style-type: none"> When inerting with dry ice, the static electrical problems that are encountered with gas cylinder inerting are not encountered. Dry ice is readily available and relatively inexpensive. 	<ul style="list-style-type: none"> This method cannot be used if the tank is to be entered for any reason as the tank atmosphere will be oxygen-deficient. The dry ice vaporization releases flammable vapors. Exhaust fumes from inerting should be vented at a minimum height of 3.7 m (12 feet) above grade and 1 m (3 feet) above any adjacent roof lines. Air pressure in the tank must not exceed 34.5 KPa (5 psi) gauge. There is no momentum for vapors in the tank to move toward the vent so inerting takes longer and may be less effective than inerting with compressed gas. Pockets of vapors can be trapped in the tank if distribution of the inert gas in the tank is incomplete. Oxygen may be re-introduced into the tank unless all holes are effectively plugged, except for the vent line.

TABLE 13-2 (continued)
PROCEDURES FOR INERTING TANKS

Procedure	Advantage	Disadvantage
<ul style="list-style-type: none"> ● Inerting with an inert gas such as CO₂ or N₂ <p>The concentration of oxygen in the tank can be reduced to a level insufficient to support combustion by replacing the oxygen with an inert gas.</p> <p>CO₂ is generally the gas of choice since its density is greater than air causing it to settle to the tank bottom pushing oxygen up and out of the tank.</p>	<ul style="list-style-type: none"> ● Inert gases may be used to remove the flammable vapors from containers under certain conditions without the hazards incidental to having the vapor-air mixture in the tank space pass through the flammable range. ● Inerting with CO₂ or nitrogen from cylinders is generally faster than dry ice due to better distribution of the inert gas. ● Inerting can be completed in a short period of time. 	<ul style="list-style-type: none"> ● This method cannot be utilized if the tank is to be entered for any reason, as the tank atmosphere will be oxygen-deficient. ● The gas must be introduced through a single tank opening and under low pressure < 34.5 KPa (5 psi). ● Compressed gases may create a potential ignition hazard as the result of the development of static electrical charges. The discharge device must, therefore, be grounded. ● Exhaust fumes from inerting should be vented at a minimum height of 3.7 m (12 feet) above grade and 1 m (3 feet) above any adjacent roof lines. ● Inerting with gas can be expensive. ● Compressed CO₂ has a much larger temperature difference with the outside atmosphere than bottled nitrogen. This difference leads to condensation, which increases the generation of static electricity. ● Oxygen may be re-introduced into the tank unless all holes are completely plugged, except for the vent line.

- (1) Flammable and combustible vapors may be inerted with an inert gas such as CO₂ or N₂. This method should not be utilized if the tank is to be entered for any reason, as the tank atmosphere will be oxygen deficient. The inert gas should be introduced through a single tank opening at a point near the bottom of the tank, at the end of the tank opposite the vent. If necessary, excavate around the vicinity of the tank to access the connection. When inert gases are used, they should be introduced under low pressure to avoid the generation of static electricity. When using CO₂ or N₂, pressures in the tank should not exceed 5 psi gauge. The process of introducing compressed gases into the tank may create a potential ignition hazard as the result of the development of static electrical charges. The discharging device must, therefore, be grounded. CO₂ extinguishers should not be used for inerting flammable atmospheres because explosions have resulted from the discharging of CO₂ fire extinguishers into tanks containing a flammable vapor-air mixture.

- (2) If the method described above is not practical, the vapors in the tank may be displaced by adding solid carbon dioxide (dry ice) to the tank in the amount of at least 1.36 Kg (3 pounds) per 378 liters(100 gallons) of tank capacity. The dry ice should be crushed and distributed evenly over the greatest possible area in the tank to promote rapid evaporation. As the dry ice vaporizes, flammable vapors will flow out of the tank and may surround the area. Therefore, where practical, plug all tank openings except the vent after introducing the solid CO₂ and continue to observe all normal safety precautions regarding flammable or combustible vapors.

- (3) Monitoring of oxygen concentrations within the tank should be done during the inerting operation. Inerting has been satisfactorily accomplished when the oxygen content is less than 8 percent. If vapor reduction is not occurring satisfactorily and the onsite official allows, pour water down each pipe to which dry ice was added. This will distribute the dry ice and release more CO₂. If vapor reduction is not adequate after the above procedures have been followed, repeat dry ice application using half of the original dry ice quantity per volume.

d. Testing.

- (1) The tank atmosphere and the excavation area should be continuously tested for percent oxygen and combustible gas during the tank excavation and removal operations. Follow these guidelines to test:
 - (a) Take such tests with a CGI with an oxygen meter that is properly calibrated according to the manufacturer's instructions (typically on pentane or hexane in air) and which is thoroughly checked and maintained in accordance with the manufacturer's instructions.
 - (b) Use a person completely familiar with the use of the instrument and the interpretation of the instrument's readings to do the test.
 - (c) Take readings at the bottom, middle, and upper portions of the tank and clear the instrument after each reading. If the tank is equipped with a nonremovable fill tube, readings should be taken through another opening.
- (2) Follow these procedures to ensure the tanks remain properly inerted:
 - (a) Test the tank vapor space by placing the indicator probe into the fill opening with the drop tube removed. Liquid product must not enter the probe.
 - (b) Readings of less than 8 percent oxygen must be obtained before the tank is considered safe for removal from the ground. Oxygen readings that rise above 8 percent during removal activities will require additional tank inerting before removal activities can continue.

e. Associated Piping Inerting. In preparation for tank removal, the type of tank appurtenances must be evaluated. Different types of tank configurations include those with removable extractor valves, angle check valves, nonextractor angle check valves, direct connect lines, and other connecting lines. Remove any check valves to prevent backflushing of the pipe lines. All piping must be inerted before tank removal begins. These lines may have a manhole that

allows access from the surface without excavation, or excavation may be required for access. Confined space precautions will be followed if employees are required to enter tanks, manholes, or excavations.

- (1) Removable Extractor Valves. Procedures for inerting different types of tank configurations are discussed first followed by procedures common to all.
 - (a) Access tank connections via manhole or by excavation.
 - (b) Remove each extractor valve riser cap and remove the extractor valve using the proper tool.
 - (c) Recap and tighten each extractor valve riser cap.
- (2) Nonextractor Angle Check Valves, Direct Connections and Other Connecting Lines.
 - (a) Access connections via manhole or by excavation.
 - (b) Inert all piping before tank removal begins.
 - (c) Disconnect the fuel line from the angle check valve and disconnect other lines from the tank.
 - (d) Catch any liquids from the lines in a container and properly dispose of liquids.
 - (e) Attach a reducing bell to the suction or connecting line to reduce the line diameter to 20 mm (3/4-inch).
 - (f) Remove angle check valve or appurtenance from the tank, if possible.
 - (g) Attach a 20 mm (3/4-inch) gasoline-rated hose to the 20 mm (3/4-inch) end of the bell reducer and insert the free end of the hose into the nearest bung opening in the tank.
- (3) Common Pipe Inerting Procedures. Use N₂ or CO₂ for the following steps.
 - (a) Disconnect the piping at the dispenser or building.

- (b) Make connections such that the piping system may be backflushed with the selected inert substance.
- (c) Pressurize the line with the substance so that the fluid in the pipeline will be backflushed into the UST. If the tank connections are of the extractor-valve type, repeat the backflushing process with each line that is connected to the UST. If the lines are of the direct-connect type, continue until the hose discharge is observed to be exhausting clean inert substance. The procedures must be repeated for each additional line.

f. Tank Removal.

- (1) Remove liquids and residues from the tank as detailed in Chapter 12.
- (2) If excavation has not already been performed for piping access, remove concrete or asphalt cover. Excavate underlying soils down to the top of the tank. Segregate these soils from those underlying the tank to reduce disposal volumes if these upper soils have no visual or odor contamination. Excavation should be deep and wide enough to allow access to all associated piping and appurtenance tank connections.
- (3) Remove the fill pipe, gauge pipe, vapor recovery truck connection, submersible pumps, and other tank fixtures. Remove the drop tube, except when it is planned to purge the tank by using an eductor as described previously. Cap or remove all nonproduct lines, such as vapor recovery lines, except the vent line. The vent line should remain connected until the tank is purged. Temporarily plug all other tank openings so that all vapors will exit through the vent line during the inerting process.
- (4) After the tank has been inerted and before it is removed from the excavation, cap or plug all pipes or bungs at or as near as possible to the tank. Cut any tank hold-down straps. Use a nonsparking cutter, such as pipe cutters, to avoid the generation of any sparks during pipe cutting.

The plug or cap sealing the vent tube must have a 3-mm (1/8-inch) hole drilled through the tube. This hole will allow expansion and contraction of the gases contained within the tank due to temperature variations without subjecting the tank to excessive differential pressure caused by temperature changes. The tank should always be positioned with this vent plug on top of the tank during subsequent transport and storage.

- (5) To remove the tank:
 - (a) Attach pulling chain to the tank eyelets or any secure hooks or rungs, or use nylon slings that will support the tank weight.
 - (b) Remove tank from excavation, using appropriate lifting device in accordance with requirements of EM 385-1-1. Front-end loaders and backhoes cannot be used for lifting unless they are equipped with a factory attached hook designed with adequate lift capacity for the tank, and the tank does not exceed the published lifting capacity for the equipment.
 - (c) Set tank on the ground and stabilize with wooden blocks. Keep the ventilation cap with the 3-mm (1/8-inch) hole on top.
- (6) Visually inspect the outside of the tank and use screwed (boiler) plugs to plug any and all corrosion holes in the tank shell.
- (7) Recheck the oxygen content within the tank as before and reinitiate inerting procedures, if required. It is vital that the internal tank atmosphere be insufficient to support ignition as sparks are possible, and a tank above ground can cause great damage to life and property if ignition occurs.
- (8) Remove external scale and attached soil from the tank.
Nonsparking tools must be used at all times in the vicinity of the tank until such time as the tank interior and exterior surfaces are decontaminated.

- (9) See Chapter 15 (Soil and Free-Product Removal Procedures) for further excavation procedures concerning soil samples and contamination soil excavation.
 - (10) Contain spills or drips during removal using absorbent booms or other methods required by the Implementing Agency. If you observe contamination (i.e., saturated soil or free product) from previous operation or removal, consult local environmental officials, the fire marshal, or the EPA for assistance and requirements. See API Bulletin 1628 for further information.
- g. Sludge Removal. Remove sludge and decontaminate the interior and exterior of the tank prior to tank removal from the work site. The contractor should submit in the SSHP plans and procedures, including materials and supplies, for safely and effectively opening the tanks, cleaning all surfaces of the interior of the tanks, and disposing of the sludge and decontamination fluids.

Restrictions include the following:

- (1) No volatile organic solvents should be permitted for decontamination procedures.
- (2) The Implementing Agency must be consulted to determine if any requirements exist for determining when the tank is considered clean.
- (3) No personnel should be permitted to enter any of the storage tanks at any time except by following the confined space guidelines as provided in Appendix E of this manual or unless the tank ends have been removed.

Refer to Chapter 14 for sludge removal and tank cleaning procedures. Collect and dispose of decontamination fluids as outlined in Chapter 9.

- h. Free-Product Removal. Many times during tank removals, the excavation area fills up with free product and/or water. Remove this product and water prior to tank removal or soil excavation. Refer to Chapter 5 for installation of monitoring wells in free product, Chapter 6 for sampling free product, and Chapter 15 for free product procedures.

- i. Tank Ballast Pads. Concrete ballast pads and associated hold down straps are installed to counteract buoyant forces in high groundwater areas. Ballast pads are difficult and expensive to remove. Concrete ballast pads may be left in place under most circumstances unless significant contamination is present and it cannot be remediated by in-situ methods, or the user requires the pads removal.

13-3. Tank Disposal.

a. Tank Storage.

- (1) Label tanks if they will be stored prior to disposal. Label after removal from the ground but prior to removal from the site.

Label requirements include the following:

- (a) Regardless of the condition of the tank, the label should contain a warning against certain types of reuse.
- (b) The former contents and present vapor state of each tank, including vapor-freeing treatment and date should be indicated.
- (c) The label should be similar to the following in legible letters at least two (2) inches high:

TANK HAS CONTAINED LEADED GASOLINE* NOT VAPOR FREE NOT SUITABLE FOR STORAGE OF FOOD OR LIQUIDS INTENDED FOR HUMAN OR ANIMAL CONSUMPTION DATE OF REMOVAL: MONTH/DAY/YEAR
--

*Or other flammable/combustible liquid. Use the applicable designation, for example, DIESEL.

- (2) Tanks that have held leaded motor fuels (or whose service history is unknown) should also be clearly labeled with the following information (see API Publication 2015A for additional guidelines):

TANK HAS CONTAINED LEADED GASOLINE
LEAD VAPORS MAY BE RELEASED IF HEAT
IS APPLIED TO THE TANK SHELL

- (3) Remove tanks from the excavation site as promptly as possible after vapor-freeing and sludge removal procedures have been completed, preferably on the day of tank removal from the excavation. If a tank remains at the excavation site overnight or longer, additional vapor may be released from any liquid absorbed in the tank walls or residues remaining in the tank.
- (4) Decontaminate the tank as indicated in Paragraph 13-2e and Chapter 14 prior to removal from the excavation site. Check with a CGI to ensure that the LEL does not exceed 10 percent of the LEL and the oxygen content of the tank atmosphere is not greater than 8 percent.
- (5) Secure the tank on a truck for transportation to the storage or disposal site with the 1/8-inch vent hole located at the uppermost point on the tank. Tanks should be transported in accordance with all applicable federal, state, and local regulations.
- (6) Store tanks in secured areas on the premises of persons familiar with any attendant hazards and where the general public will not have access. A fenced yard, separate from other facilities, is preferred.

b. Disposal Criteria.

- (1) Tanks should not be reused. Whether sold to a scrap dealer or disposed of at an approved facility, tanks must be cut into small pieces smaller than 1.5m² (16 ft²). The dissection can occur at the excavation site, at a centrally located contractor staging area, or at a licensed tank decommissioning/disposal facility. The contractor should submit the dissection method and location as part of the work plan.
- (2) Tanks that have been lined internally or coated externally with epoxy-based or similar materials may not be accepted by scrap

processors. Prior inquiries should be made as to the requirements of the scrap processor.

c. Disposal Procedures.

- (1) After a tank has been vapor-freed, render it unsuitable for future use as a storage tank by puncturing or cutting with nonspark-producing methods. The USACE-recommended practice is cutting tanks into sections no larger than 1.5 m² (16 ft²). Recycle or landfill only if scrap processors refuse to accept the tank sections.
- (2) Assign all tanks a unique identifier for all records and reporting.
- (3) Use a bill of sale to transfer tank ownership. This bill of sale should be submitted with the Tank Closure Report discussed in Chapter 1.
- (4) Consult current federal, state, and local regulations prior to disposal to determine if special procedures or preparations are required.
- (5) Physically clean metal tanks that are going to be sold as scrap metal after they are inerted and cut open. Cleaning can consist of high pressure or steam rinse, triple rinse, or scraping/scrubbing. Methods are detailed in Chapter 14.

13-4. Waste Disposal and Recycling. Free product, sludge, and rinse waters are typical wastes generated during tank removal. Federal, state, and local requirements must be followed for proper disposal. Options for managing wastes generated during tank removal will be similar to those discussed in section 12-4 regarding tank contents.

13-5. Tank Coating Issues. The exterior of metal USTs are frequently coated with coal-tar type coatings. Historical data indicates that the coating materials occasionally contain hazardous substances such as asbestos, polychlorinated biphenyls, lead, and cadmium. The presence of PCBs and asbestos make it difficult to recycle the tanks as scrap metal. If the coating contains PCBs and/or asbestos that cannot be easily removed because of regulatory constraints or safety issues, it may be more cost effective to dispose of the tanks within a chemical waste landfill.

CHAPTER 14

SLUDGE REMOVAL PROCEDURES

14-1. General. This chapter describes the removal procedure for any remaining sludge in the underground storage tank (UST). This chapter recommends but does not necessarily dictate the proper procedure for sludge removal in any given situation. Typically, the contractor is responsible for assessing specific situations for the most appropriate response.

14-2. Operations, Procedures, and Instructions.

- a. Contractors, subcontractors, and employees responsible for sludge removal should be familiar with:
 - (1) Confined space entry (confined space should be avoided if at all possible).
 - (2) All safety rules and regulations (consult SSHP for specific instruction/requirements).
 - (3) Use of equipment and procedures for removing tanks.
 - (4) Handling and disposal of the sludge likely to be encountered.
 - (5) API Publications: 2003, 2015, 2217, and 2219.
- b. Documentation.
 - (1) Use field logbook to record all activities performed, personnel contacted, dates and times when these activities were performed, field conditions, and any unusual circumstances.
 - (2) Keep information factual and objective.
 - (3) Enter information not recorded in the logbook on field forms. In either case, record the following information:
 - Site identification
 - Date and time specific activities took place
 - Personnel names
 - Field observations

Photographs are suggested. If photos are taken, record name of photographer, site name, camera type and lens size, and general direction for enclosure in the Tank Closure Report.
- c. Procedures. Minimize activities requiring personnel entry into tanks. However, when such entry is necessary, follow safety and

health precautions for tank entry as outlined in Chapter 7 and Appendix E, Confined Space Entry, including the additional precautions necessary for tanks that have stored leaded gasoline.

- (1) Remove sludge by various methods or by a combination of methods, depending on the construction of the tank and the number and size of shell openings. These methods are summarized in Table 14-1 and are discussed below. If at all possible, use procedures that do not require tank entry.
 - (a) The preferred method of sludge removal is to remove the end walls of the tank. Remove the sludge by flushing it from the tank with a high-pressure, low-volume water stream, collect, and containerize it. This method eliminates problems with confined space entry, explosive atmospheres, and allows easier cleaning of the tank. Any method of removing residual material that minimizes the time that workers must spend inside the tank contributes to the safety of the operation.
 - (b) The tank may be swept and washed down with a water-hose stream.
 - (c) The sludge may be washed or swept into piles and removed from the tank with buckets or wheelbarrows.
 - (d) If necessary, any remaining liquids may be removed from the tank with an absorbent, such as sawdust or spent clay, and may be disposed of as a solid waste.
 - (e) Vacuum tank trucks provide a fast and efficient method for removing and hauling sludge from tanks. Follow these guidelines when using vacuum trucks:
 - Be sure the area in which the vacuum tank truck operates is vapor-free.
 - Locate the truck upwind from the tank and outside the path of probable vapor travel.
 - Consider vapor travel and sources of ignition where sludge will be discharged from the vacuum truck

For specifics of vacuum truck safety precautions and operation, refer to Chapter 12.

14-3. Waste Disposal and Recycling. Sludges that cannot be vacuumed should be transferred to a lined, 55-gallon drum or another suitable container. Small quantities of water may be added to the tank to facilitate removal.

TABLE 14-1 PROCEDURES FOR SLUDGE REMOVAL		
Procedure	Advantage	Disadvantage
Flushing with high air pressure.	Minimizes confined space activities. Not labor intensive.	Requires an outlet at the bottom of the tank, or self-priming pumps, or steam- or water-operated eductor. Increases potential for static charge buildup in the nozzle, which could trigger an explosion.
Flushing with water.	Same as above. No special equipment is required.	Same as above, with the potential for creation of even larger waste quantities.
Mechanically sweeping or scraping into piles and removing with buckets.	Minimizes waste quantity. No special equipment is required.	Labor-intensive in a confined space environment.
Application of an absorbent such as sawdust or spent clay.	Can be disposed as a solid waste.	Effective for small quantities or residuals. Increases waste quantity. Material still has to be mechanically removed.
Vacuum truck.	Minimizes waste quantity. Minimizes confined space activities. Not labor-intensive.	Area of truck operation must be vapor-free.

Test tank sludge for hazardous characteristics outlined in 40 CFR 261 Subpart C. The test results determine the requirements for the final disposal. At some installations, disposal services may be available through the local Defense Reutilization and Marketing Office (DRMO). This typically involves completion of a turn-in document for each container of hazardous waste as well as coordination either directly with the DRMO Contracting Officer Representative or coordination via the installation environmental office. Suggested disposal methods include cement kilns, incineration, solidification, landfill disposal, or shipment to a temporary storage and disposal facility.

Options for recycling of petroleum tank sludges are similar to those discussed in Section 12-4.

14-4. Reporting and Documentation Requirements-Hazardous Waste.

- a. Notification and Application. All facilities that generate, store, transport, treat, or dispose of hazardous wastes must file a form notifying the EPA. Unless notification has been given to EPA, waste may not be stored, transported, treated, or disposed. All facilities that store, treat, or dispose of sludge must apply for an EPA permit.
- b. Development of a Plan. Each facility that generates sludge must develop a plan for the storage, treatment, and disposal of its sludge. If storage, treatment, or disposal is to occur onsite, the facility is then considered to be the operator of a hazardous-waste-management facility and must obtain a permit to operate such a facility. A plan must, therefore, be developed to operate the facility. If the facility decides to dispose of the sludge offsite, no permit is required as long as the facility stores the material in appropriate containers and ships it offsite within 90 days of generation; however, 40 CFR 262.34 specifies storage requirements before shipment.
- c. Shipping Hazardous Waste. Before shipping RCRA hazardous waste to an offsite facility, the facility that generated the waste is required to prepare and sign a manifest that identifies the facility, identifies the waste by its EPA and DOT hazardous waste number and name, identifies the offsite facility that will handle the material, and specifies the total quantity in the shipment. The facility should be certain that the transporter and the selected facility have EPA identification numbers and permits to engage in hazardous-waste-management activities.
- d. Documentation. The regulations impose extensive recordkeeping and reporting requirements. Facilities that generate sludge must maintain copies of all manifest documents and records and must also

- submit annual reports. Additional reporting requirements are detailed in 40 CFR 262, Subpart D and 40 CFR 268.7.
- e. Requirements for Transporters. Persons engaged in the offsite transportation of the sludge must comply with EPA's specific regulations for the transportation of hazardous wastes, which govern notification, manifest, and recordkeeping. Persons transporting the sludge must also comply with the DOT regulations set forth in 49 CFR.
 - f. State Programs. RCRA authorizes the states to conduct their own hazardous-waste programs in lieu of the federal RCRA program. Any state whose program has been approved by EPA may itself carry out the functions delegated to EPA under the act and may specify additional and more rigorous requirements. Consequently, facilities that generate sludge and who plan to dispose of sludge should have their plans reviewed by their state's environmental agency to ensure compliance.
 - g. Specific Facility Standards. Specific requirements governing storage, treatment, and disposal of hazardous wastes are updated continually by EPA, and operators should consult the most up-to-date publications for details about items such as security, monitoring, contingency plans, and emergency procedures.

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CHAPTER 15

SOIL REMOVAL, FREE-PRODUCT REMOVAL, AND BACKFILLING PROCEDURES

15-1. General. This chapter discusses the procedures for excavation of soils and any associated free product when small quantities of hydrocarbon-contaminated soils require treatment or disposal. An example is removal of soils when small releases have occurred and are confined to the tank excavation; these soils can be removed or treated onsite. The amount of soil to be removed is dictated by the volume of released hydrocarbon, the depth and area of liquid hydrocarbon penetration, the ease with which the soil can be removed and properly treated, available funding, and the state or local regulatory requirements.

This guidance is only intended for removing small, reasonable amounts of contaminated soil and free product in the excavation. Refer to Chapter 5 for the definition of contaminated soil. If it appears that extensive contamination is present that cannot be cleaned up by the provisions described in this EM, the reader should proceed with corrective action plan procedures.

15-2. Precautions. Keep the following precautions in mind:

- a. Petroleum-contaminated soil may be flammable or combustible and can be a source of potentially explosive vapor. Care must be taken, both during and following excavation, that vapor or liquid from the soil is not allowed to accumulate in a confined area and pose a fire or explosion hazard.
- b. Digging should be done with extreme care to avoid sparking from stones and igniting the product.
- c. Equipment should operate slowly, with due regard for the danger of explosion. In certain circumstances, moving the earth may ventilate the saturation area sufficiently to relieve the vapor concentration, allowing movement and activity to proceed safely.
- d. If the soil is to be stored onsite after excavation, cover or store in a bermed or otherwise contained area (such as stored on and covered by polyethylene sheets) so that leached petroleum product cannot be released into surrounding soil, surface water, or groundwater.
- e. The contractor should have spill response materials available as required by guide spec 02120 referenced in paragraph 1-4.
- f. Offsite transport and disposal of contaminated soil must be in accordance with state and local regulations. Excavation of

contaminated soil creates increased exposure potential for site personnel, the public, and the environment.

- g. In confined spaces, air-vapor concentrations should be monitored to ensure that hazardous levels are not reached.

15-3. Equipment.

- a. Soil. Transportation of contaminated soil requires conventional earth-moving equipment.

Many types of equipment are available for excavation, loading, and removal of soils. Standard construction equipment is typically employed, but consider factors such as safety, depth of contamination, and soil stability. Backhoes with 0.38 m³ (0.5 CY) capacity have a maximum reach of 8 meters (26 feet) and a maximum excavation depth of 5 meters (16 feet). Larger backhoes with 2.7 m³ (3.5 CY capacity) have the ability to remove soils at depths of up to 14 meters (45 feet) at maximum digging angles of 45 degrees.

The major hauling cost factor is the distance to the disposal facility. Site-specific conditions, community and interstate relations, and regulatory measures affect disposal costs. In some states the contaminated soils are considered a special hazardous waste and must be handled, hauled, and disposed of accordingly.

- b. Free Product. Free product may be removed using positive displacement pumps or vacuum trucks. In some instances, if the amount of free product is small, absorbent booms may be used to collect the product. Additional guidance on the recovery of free product may be found in EPA/510/R-96/001.

15-4. Soil Removal. Excavation guidelines include the following:

- a. Excavate the hole downward and outward in consultation with the governing agency or Environmental Coordinator.
- b. Proceed until all the soils contaminated above regulatory limits have been removed or until a reasonable amount of excavation has occurred. The designer should specify a maximum cubic yardage of contaminated soil excavation from each tank area without prior approval from the contracting officer's representative (COR). If a minimum additional amount of contaminated soil requires removal to result in a clean closure, the contractor will obtain approval from the COR to perform the additional excavation. The bid form can identify a minimum quantity of soil to be removed with a second quantity of soil to cover a worst-case scenario.

- c. Perform appropriate verification testing in accordance with the IA requirements if widespread contamination is present.
- d. Backfill the excavation with clean fill. Clean fill is typically defined as fill that has no evidence of contamination, or has contamination levels below regulatory limits. The IA must be consulted to define the requirements of clean fill.
- e. See Chapter 16 for more details. These excavations will be done safely according to the local codes and regulations governing safe excavations and EM 385-1-1 and 40 CFR 1926.650-1926.653. Table 15-1 provides an estimated quantity of soil that is typically removed from an UST excavation based on tank size.
- f. Contaminated Soil. If the soil in the excavation is contaminated, follow these steps:
 - (1) Prepare an area to store the excavated soil. This can be achieved by placing 6-mil or heavier polyethylene sheeting on the ground and placing excavated soil on top. This prevents contaminants in the excavated soils from migrating into the uncontaminated soils.
 - (2) Cover this stockpile after work each day by a similar sheet of polyethylene to protect the excavated soils from infiltration due to precipitation and to help contain vapors released.
 - (3) Make provisions to divert surface runoff from soil stockpiles, as well as surface runoff, to reduce the amount of contaminated water.
 - (4) An alternative method, and in some areas a requirement, is to place the excavated soils directly into 55-gallon drums. Coordinate with the local implementing agency regarding approved stockpiling procedures.
- g. Sampling. After tank removal has been completed, the soil in the bottom of the excavation should be sampled according to federal and state requirements.
 - (1) Take these samples, at a minimum, from the bottom of the excavation from the end locations of the tanks (see Chapter 6).

TABLE 15-1					
Estimated Quantity of Soil to be Removed by Tank Size (Average)					
Tank Size liters (gallons)	Tank Diameters meters (feet)	Tank Length meters (feet)	Excavation Size cubic meters (Bank CY)	Volume of Tank CM (CY)	Estimated Soil Excavated CM (Bank CY)
1,890 (500)	1.22 (4.00)	1.83 (6.00)	31 (40)	2.13 (2.79)	28.5 (40)
3,780 (1,000)	1.22 (4.00)	3.50 (11.50)	46 (60)	11.41 (5.35)	40.5 (55)
7,570 (2,000)	1.93 (6.33)	2.80 (9.17)	61 (80)	8.18 (10.70)	52.0 (70)
11,350 (3,000)	1.93 (6.33)	4.17 (13.67)	76 (100)	12.18 (15.93)	65.5 (85)
15,140 (4,000)	1.93 (6.33)	5.18 (17.00)	92 (120)	15.15 (19.81)	76.0 (100)
18,925 (5,000)	2.44 (8.00)	4.32 (14.17)	103 (135)	20.16 (26.37)	84.0 (110)
22,700 (6,000)	2.44 (8.00)	5.05 (16.58)	115 (150)	23.60 (30.87)	93.0 (120)
30,280 (8,000)	2.44 (8.00)	6.73 (22.08)	145 (190)	31.43 (41.11)	113.0 (150)
37,850 (10,000)	2.90 (9.50)	6.02 (19.75)	165 (215)	39.64 (51.85)	124.0 (160)
45,420 (12,000)	2.90 (9.50)	6.91 (22.67)	183 (240)	45.50 (59.51)	137.0 (180)
56,780 (15,000)	2.90 (9.50)	9.07 (29.75)	230 (300)	59.71 (78.10)	168.0 (220)
75,700 (20,000)	2.90 (9.50)	11.51 (37.75)	279 (365)	75.77 (99.10)	202.5 (265)

Assumptions:

1. Amount of fill over tank is 1 meter (3 feet).
2. Soil around perimeter of tank to be excavated is 1 meter (3 feet) (the width of a backhoe bucket).
3. Stained soil under tank extends down 0.7 meters (2 feet).
4. Tank volume calculation does not account for domed ends.
5. Formula for excavation size:

$$((\text{tank diameter} + 5\text{ft}) * (\text{tank length} + 6\text{ft}) * (\text{tank diameter} + 6\text{ft})) / 27 \text{ CF/CY}$$
 (Conversion from CY to CM is 0.76455).
6. Formula for tank volume:

$$(\text{Tank length} * \pi * \text{tank diameter}^2 / 4) / 27 \text{ CF/CY}$$
 (Conversion from CY to CM is 0.76455).

- (2) Take samples with a backhoe and containerize in small vessels, such as a plastic bag or jar for field testing as detailed in Chapter 6. These tests will characterize the extent of contamination and subsequent excavation and help in the segregation of clean and uncontaminated soils. It must be noted that these field tests are not a substitute for the laboratory analytic tests that must be done. Field tests are used to differentiate between clean soils and those that are suspected to be contaminated.
 - (3) Submit samples for analytic tests. Laboratory confirmation based on samples collected from excavation bottoms and soil stockpiles is necessary in most states to confirm clean closure. Check with the IA for specific requirements.
- h. Landfilling Requirements. A common remedial action for excavated soils has been disposal in landfills. Varying interpretations exist regarding classification of hydrocarbon-contaminated soils as hazardous or nonhazardous. Levels of contaminants allowable for landfilling under applicable regulations must be determined in developing a sound disposal strategy.
- i. Onsite Treatment. Various treatment and disposal options for excavated soil containing petroleum hydrocarbons are available but decisions must be based on and in accordance with state and local regulations. Treatment of soils may require an air permit for volatile organic compounds from the state agency that has jurisdiction. The methods of onsite treatment and soil replacement discussed below can be viable if approved by the regulatory agencies. Refer to EPA/530/UST-88/001 for additional information.
- (1) Land treatment (landfarming). Land treatment is a process by which contaminated soils are removed and spread over an area to enhance naturally occurring processes such as biodegradation and volatilization. A centralized location, such as a landfill, airfield, or other isolated location should be used for land treatment.
 - (2) Aeration/enhanced volatilization. Soil aeration by mixing and exposure to air can reduce hydrocarbon concentrations to acceptable levels. This process may be as simple as overturning the soils with excavation equipment, tillers, or shakers to increase volatilization or enhancing vapor removal by forced or passive venting with an engineered venting system.

- (3) Thermal treatment. Incineration and high temperature stripping of residual hydrocarbons are methods employed in some circumstances for the onsite treatment of soils. Treatment costs and local air quality regulations are major factors controlling the use of these techniques. Examples of thermal treatment technologies include low-temperature thermal desorption or asphalt kilns. When an asphalt kiln is used, the unit should be proven clean prior to processing any soil.
 - (4) Isolation/containment. Isolation/containment is a process in which the impacted soils are isolated through the use of caps, slurry walls, grout curtains, or cutoff walls.
 - (5) Soil slurry bioreactor. The soil-slurry-bioreactor process entails mixing a variety of agents into the soil to encourage microbial activity.
- j. Asphalt Incorporation. Asphalt incorporation is a process whereby soils containing residual hydrocarbons are incorporated into hot asphalt mixes as a partial substitute for aggregates. During the heating of the mixture, the more volatile components are vaporized, and the remaining compounds are incorporated into the asphalt mixture. This alternative is normally a viable disposal option only when an asphaltic paving project is ongoing within the project area. An active project is normally necessary to lead to a demand for the contaminated soil material as an asphalt admixture.
- k. Excavation Liner. In some instances, a 6-mil liner is placed in the excavation and then the contaminated soil is placed back in the excavation. Check with the IA prior to using this method.

15-5. Free-Product Removal. Free product should be removed, not for remediation purposes, but to prevent further damage to the environment. If possible, the excavation should be sloped to allow pooling of the free product. A pump or vacuum truck can then be used to remove the free product from the excavation. Refer to Chapter 12 for operation of product removal equipment and waste disposal.

15-6. Backfill, Compaction, and Testing.

- a. Backfilling.
 - (1) Coordinate with the customer concerning the option of leaving excavations open pending the return of laboratory test results. Laboratory turn-around time plays a critical role in the duration that an excavation must be left open. If field analysis is allowed by the regulatory authority, this will reduce or eliminate turn-around time concerns.

- (2) Secure open excavations and stockpile areas while awaiting confirmation test results.
 - (3) Backfill excavations immediately after confirmation test results have been approved. If contaminated material removal is part of a larger project, suitable backfill material, as well as topsoil and grading requirements are specified in CEGS 02221-*Excavating, Filling, and Backfilling for Buildings* or CEGS 02222-*Excavating, Filling and Backfilling for Utility Systems*. In situations that involve only tank removal, grading, backfill, and compaction should be addressed in CEGS 02115-*Removal of Underground Storage Tanks*. Special information concerning allowable contaminant levels should be included in those specifications if used.
- b. Backfill Material. In many cases, the degree of engineering control of the materials used as backfill may not need to be as stringent as described below. In other cases, such as under pavements, special compaction and material requirements may apply, and the specifications will need to be revised to address these special requirements or another specification section should be referenced.
- (1) Obtain backfill material from a location defined by the user or if using an off-site source, verify through analytical testing to ensure contamination is not present above regulatory levels for suitable backfill.
 - (2) Test off-site backfill for contamination in accordance with CEGS 01450-Chemical Data Quality Control. Backfill should be classified in accordance with ASTM D 2487 as GW, GP, GM, GC, SW, SP, SM, SC, MH, CL, or CH and should be free from roots and other organic matter, trash, debris, snow, ice or frozen materials. If off-site backfill is used, soil classification test results should be approved prior to bringing the material on-site.
 - (3) Test backfill material for Atterberg limits ASTM D 4318, grain-size distribution, and compaction characteristics ASTM D 698, ASTM D 1557 at a frequency of once per 3,000 cubic meters (3,000 cubic yards) or a minimum of one test per borrow source. *Off-site backfill should not be used until chemical and physical test results have been submitted and approved.*
- c. Compaction.
- (1) Place approved backfill in developed areas in lifts with a maximum loose thickness of 200 mm (8 inches), compacted to 90 percent maximum dry density for cohesive soils, or 95 percent

maximum dry density for cohesionless soils in accordance with ASTM D 698 or D 1557.

- (2) Perform density tests at a frequency of once per 930 square meters (10,000 square feet) per lift. A minimum of one density test should be performed on each lift of backfill placed. In open areas without special compaction requirements, a maximum density of 85 percent using 300-mm (12-inch) lifts will be acceptable. A method specification is also frequently used in which a prescribed number of passes using a specified piece of equipment is required.

- d. Density Testing. Determine field in-place dry density in accordance with ASTM D 1556, ASTM D 2167, or ASTM D 2922. If ASTM D 2922 is used, a minimum of one in ten tests must be checked using ASTM D 1556 or ASTM D 2167.

15-7. Special Waste Requirements. Though petroleum-contaminated soils that do not exhibit a RCRA hazardous waste characteristic are not subject to hazardous waste regulation, many states may still regulate them as "special wastes." Typically, these soils are either placed in special waste management units or are treated to below certain concentration levels before final disposal. Implementing agencies may also be able to assist in identifying any special handling requirements. Consult individual state regulations. A list of contacts is provided in Appendix B.

CHAPTER 16

SITE RESTORATION PROCEDURES

16-1. General. This chapter identifies procedures and sources of information you will find helpful when selecting the appropriate corrective action for a particular UST site. Both soil and water contamination are addressed using in-situ and ex-situ remediation options. Contact the facility coordinator to determine unique site-specific requirements.

16-2. Soil Remediation Processes. Studies in the literature use different nomenclature to describe remediation methods. A recent EPA study classified the primary technologies into five categories.

- a. In-Situ Treatment. In-situ treatment includes technologies such as vapor extraction, volatilization, air/vacuum extraction, in-situ soil venting, in-situ bioremediation, isolation/containment, and passive remediation.
- b. Landfilling. This method includes all options using landfill disposal.
- c. Land Treatment. Land treatment includes landfarming, ex-situ bioremediation, land application, land spreading, passive aeration, aeration, and ex-situ soil venting.
- d. Thermal Treatment. Thermal treatment includes incineration, low-temperature thermal stripping, and treatment in asphalt plants.
- e. Other. This category encompasses all other technologies such as soil washing, solidification/stabilization, or other technologies that do not fit into the other categories listed.
- f. Selected references are as follows:

(1) Pope and Matthews. *Bioremediation Using the Land Treatment Concept*, EPA 600/R-93/164. August 1993.

(2) *Bioventing Performance and Cost Summary*. Air Force Center for Environmental Excellence. July 1994.

(3) *Guide for Conducting Treatability Studies Under CERCLA: Biodegradation Remedy Selection*, EPA/540/R-93/519a. August 1994.

(4) "Quick Reference Fact Sheet." *Guide for Conducting Treatability Studies Under CERCLA: Biodegradation Remedy Selection*, EPA/540/R-93/519b. August 1994.

(5) Leeson, A. and Hinchee, R.E., et al. "Principles and Practices of Bioventing." *Volume 1: Bioventing Principles* EPA/540/R-95/534a
Columbus: Battelle Memorial Institute.

(6) Leeson, A. and Hinchee, R.E., et al. "Principles and Practices of Bioventing." *Volume 2: Bioventing Design* EPA/540/R-95/534b.
Columbus: Battelle Memorial Institute.

(7) *Technologies and Options for UST Corrective Actions: Overview of Current Practice*, EPA/542/R-92/010. August 1992.

(8) *U. S. Air Force Remediation Handbook for POL-Contaminated Sites*, U. S. Air Force. December 1993.

(9) Soil Vapor Extraction and Bioventing, EM 1110-1-4001.

- g. Survey of Remediation Practices. The findings from a 1992 22-state survey (EPA/542/R-92/010) of petroleum-contaminated soil treatment/disposal practices revealed landfilling as the primary corrective action method used at 55 percent of the sites surveyed, followed by in-situ treatment at 19 percent, thermal treatment at 13 percent, land treatment at 11 percent, and other technologies at 2 percent.

Thermal treatment using asphalt plants was used at 61 percent of the sites, followed by low-temperature thermal treatment at 39 percent and incineration at less than 1 percent of the sites.

Land treatment corrective action sites most often used aeration (50 percent), followed by land farming (36 percent), and land application (13 percent).

Approximately 37 percent of the corrective action sites reported required some sort of groundwater corrective action as well. Information addressing remediation of groundwater sources is included in paragraph 16-4.

16-3. Backfill. Begin backfilling only after authorization from the Environmental Coordinator or IA and after the excavation area contaminants are determined to be below the remediation concentrations. This authorization should be issued within 24 to 48 hours after excavating is complete to allow time for laboratory analysis of the soils. Some exceptions should be noted, such as IA regulations and proximity to residential areas or other areas with restricted access.

a. Methods. Individual site conditions will determine the methods of backfill. Some of the options are detailed below.

- (1) Backfill clean holes (as determined by lab analyses) with clean fill.
- (2) Leave potentially contaminated holes open until confirmation sampling results have been obtained.
- (3) Backfill potentially contaminated holes with granular backfill while awaiting analytical results in areas where safety is a concern.
- (4) Place polyethylene liner in contaminated holes prior to backfilling.
- (5) Backfill all holes with granular backfill regardless of contamination.
- (6) Leave heavily contaminated holes open. The IA and the Environmental Coordinator must be contacted to determine the best option for the site.

b. Backfill.

- (1) Use backfill as specified in CEGS Section 02315-*Excavation, Filling, and Backfilling for Buildings* or Section 02316-*Excavation, Filling, and Backfilling for Utilities Systems*.
- (2) Perform density tests by an approved commercial testing laboratory or by facilities furnished by the contractor.
- (3) Determine moisture density relations in laboratory tests in accordance with ASTM D 1557, Method B, C, or D or ASTM D 3017.
- (4) Determine field in-place density in accordance with ASTM D 1556, ASTM D 2167, or ASTM D 2922.
- (5) Material. The source of backfill material must be determined to be free of contamination through chemical analysis prior to placement of clean fill in the excavated area.
- (6) Exceptions. If the soil excavation sample results indicate the site is not remediated, yet the limits of practical excavation have been reached, place a 6-mil or heavier polyethylene sheeting in the hole prior to backfilling. This polyethylene

sheeting will allow clean backfill placed in the hole to remain free of contamination.

- c. Grading. All areas disturbed by construction must be uniformly smooth graded. The finished surface should be reasonably smooth, compacted, free from irregular surface changes, and maintained free of trash. Prepare surface for seeding or asphalt/concrete as required and specified in applicable USACE guide specifications.

16-4. Groundwater Remediation Processes. This section presents corrective action technologies for the removal of free product and for remediation of petroleum-contaminated groundwater.

- a. Free-Product Recovery. There are typically two approaches for recovery of free product: trench systems and wells. The choice is usually based on site specific conditions. After collection, the free product is separated from the groundwater and disposed of or recycled. The remaining petroleum-contaminated groundwater is treated using a variety of methods and discharged to a publicly owned treatment works (POTW) or discharged to the environment. Specific technologies include skimmers, oleophilic-hydrophobic separators, free-product recovery with water table depression, vapor extraction/groundwater extraction, dual phase (liquid and vapor) recovery, and oil-water separation. Whichever option is selected, a permit to discharge must be negotiated with the IA.
- b. Groundwater Remediation. Groundwater remediation can be accomplished either in-situ or ex-situ depending on the site characteristics. In-situ methods are preferred, if possible, and include such methods as air sparging, intrinsic remediation, and introduction of oxygen or nutrients.

The second, more conventional ex-situ methods include conventional pump-and-treat processes such as granular activated carbon (GAC) and air stripping, which are easily mobilized and readily available from a variety of suppliers in close proximity to most sites. Many times air stripping and GAC are used together to prolong the life of the carbon. Other options for ex-situ treatment include ultraviolet oxidation, biological treatment, or simply discharging to a POTW.

- c. Selected references are as follows:

(1) *Cleanup of Releases From Petroleum USTs: Selected Technologies*, EPA/530/UST-88/001. April, 1988.

(2) *Diagnostic Evaluation of In-Situ SVE-Based System Performance*, EPA/600/R-96/041, NTIS PB96-163537. March, 1996.

- (3) *Engineer Design of Free-Product Recovery Systems*, EPA/600/R-96/031, NTIS PB96-153556. 1996.
- (4) *How to Effectively Recover Free Product of Leaking UST Sites*, EPA/510/R-96/001. September, 1996.
- (5) *In-situ Air Sparging*, EM 1110-1-4005
- (6) *In-Situ Air Sparging: Evaluation of Petroleum Industry Sites and Considerations for Applicability, Design and Operation*, API Publication Number 4609. American Petroleum Institute. April, 1995.
- (7) *In-Situ SVE-Based Systems for Free-Product Recovery and Residual Hydrocarbon Removal*, EPA/600/R-96/042, NTIS PB96-163605. 1996.
- (8) *Remediation Technologies Screening Matrix and Reference Guide*, EPA/542/B-94/013, NTIS PB95-104782. October, 1994.
- (9) Rifai, H.S. "Modeling Natural Attenuation Using Bioplume II/III Model," Presentation at the U.S. Air Force Center for Environmental Excellence, Environmental Restoration Technology Transfer Symposium. November, 1994.
- (10) *Standard Guide for Corrective Action for Petroleum Releases*, ASTM E 1599. 1994.
- (11) *Standard Guide for Risk Based Corrective Action Applied at Petroleum Release Sites*, ASTM E 1739. 1995.
- (12) *Test Plan and Technical Protocol for Bioslurping*. AFCEE, Technology Transfer Division. Draft copy. January 30, 1994.
- (13) *Technical Protocol for Implementing the Intrinsic Remediation with Long-Term Monitoring Option for Natural Attenuation of Dissolved-Phase Fuel Contamination in Groundwater*. AFCEE. 1994.
- (14) *Soil Bentonite Slurry Trench Cutoff*, Corps of Engineers Civil Works Guide Specification (CWGS) 02214.
- (15) *Chemical Feed Systems*, Corps of Engineers Guide Specification (CEGS) 11242.
- (16) *Water Softeners, Cation Exchange (Sodium Cycle)*, CEGS 11250.
- (17) *Air Stripping Systems*, CEGS 11301.

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- (18) *Prefabricated Biochemical Wastewater Treatment Plant*, CEGS 11390.
- (19) *Low Permeability Clay Layer*, CEGS 02377.
- (20) *Soil-Bentonite Slurry Trench for HTRW Projects*, CEGS 02260.
- (21) *Solidification/Stabilization of Contaminated Material*, CEGS 02160.
- (22) *Groundwater Monitoring Wells*, CEGS 02522.
- (23) *Piping; Off-Gas*, CEGS 02150.
- (24) *Fans/Blowers/Pumps; Off-Gas*, CEGS 11215.
- (25) *Downflow Liquid Activated Carbon Adsorption Units*, CEGS 11225.
- (26) *Chemical Feed Systems*, CEGS 11242.
- (27) *Air Stripping Systems*, CEGS 11301.
- (28) *Plate and Frame Filter Press System*, CEGS 11360.
- (29) *Filtration System*, CEGS 11393.
- (30) *Vapor Phase Activated Carbon Adsorption Units*, CEGS 11226.
- (31) *Advanced Oxidation Processes (AOP)*, CEGS 11377.
- (32) *Thermal (Catalytic) Oxidation Unit*, CEGS 11378.

16-5. Waste Disposal. Disposal requirements are identified in Chapters 12 and 14.

APPENDIX A

REFERENCES

a. Required Publications.

FAR 52.236-13	Accident Prevention
<u>Code of Federal Regulations</u>	
29 CFR 1910	General Industry Standards
29 CFR 1910.120	Hazardous Waste Site Operations and Emergency Response
29 CFR 1926	Construction Industry Standards
40 CFR 260	Hazardous Waste Management System: General
40 CFR 261	Identification and Listing of Hazardous Waste
40 CFR 262	Standards Applicable to Generators of Hazardous Waste
40 CFR 263	Standards Applicable to Transporters of Hazardous Waste
40 CFR 266	Standards for the Management of Specific Hazardous Wastes and Specific Types of Hazardous Waste Management Facilities
40 CFR 268	Land Disposal Restrictions
40 CFR 280	Technical Standards and Corrective Action Requirements for Owners and Operators of Underground Storage Tanks (UST)
49 CFR Subtitle B	Chapter I Research and Special Programs Administration, Department of Transportation (Parts 100-199)

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49 CFR Subtitle B Chapter III Federal Highway Administration,
Department of Transportation (Parts 390-399)

Environmental Protection Agency (EPA)

EPA QA/G-5	EPA Guidance for Quality Assurance Project Plans
EPA QA/R-5	EPA Requirements for Quality Assurance Project Plans for Environmental Data Operations
EPA/510/B-97/001	Expedited Site Assessment Tools for Underground Storage Tank Sites
EPA/510/B-97/004	List of Leak Detection Evaluations for UST Systems
EPA/510/R-96/001	How to Effectively Recover Free Product At Leaking Underground Storage Tank Sites
EPA/530/UST-88/001	Cleanup of Releases from Petroleum USTs: Selected Technologies
EPA/530/UST-90/004	Standard Test Procedures for Evaluating Leak Detection Methods: Volumetric Tank Tightness Testing Methods
EPA/530/UST-90/005	Standard Test Procedures for Evaluating Leak Detection Methods: Nonvolumetric Tank Tightness Testing Methods
EPA/530/UST-90/101	Standard Test Procedures for Evaluating Leak Detection Methods: Pipeline Leak Detection Systems
EPA/530/SW-89-031	RCRA Facility Investigation (RFI) Guidance
EPA/540/G-91/009	Management of Investigation-Derived Wastes During Site Inspections
EPA/540/P-87/001	A Compendium of Superfund Field Operations Methods
EPA/540/P-91/005	Compendium of ERT Surface Water and Sediment Sampling Procedures

EPA/540/P-91/007	Compendium of ERT Groundwater Sampling Procedures
EPA/540/P-91/008	Compendium of ERT Waste Sampling Procedures
EPA/540/R-93/519	Guide for Conducting Treatability Studies Under CERCLA: Biodegradation Remedy Selection
EPA/540/R-95/534	Principles and Practices of Bioventing
EPA/540/S-93/503	Groundwater Issue (Feb. 93); Suggested Operating Procedures for Aquifer Pumping Tests
EPA/540/2-91/003	Soil Vapor Extraction Technology Reference Handbook
EPA/542/B-94/013	Remediation Technologies Screening Matrix and Reference Guide
EPA/542/R-92/010	Technologies and Options for UST Corrective Actions: Overview of Current Practice
EPA/600/2-80/018	Samplers and Sampling Procedures for Hazardous Waste Streams
EPA/600/7-84/064	Geophysical Techniques for Sensing Buried Wastes and Waste Migration
EPA/600/2-86/001	Underground Tank Leak Detection Methods: A State-of-the-Art Review
EPA/600/2-90/011	Assessing UST Corrective Action Technologies: Site Assessment and Selection of Unsaturated Zone Treatment Technologies
EPA/600/4-84/076	Characterization of Hazardous Waste Sites-A Methods Manual: Volume II. Available Sampling Methods
EPA/600/8-87/036	Soil Gas Sensing for Detection and Mapping of Volatile Organics
EPA/600/R-96/031	UST Corrective Action Technologies: Engineering Design of Free-Product Recovery Systems

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EPA/600/R-96/041 Assessing UST Corrective Action Technologies:
 Diagnostic Evaluation of In-Situ SVE-Based System
 Performance

EPA/600/R-96/042 In-Situ SVE-Based Systems for Free-Product Recovery
 and Residual Hydrocarbon Removal

EPA/625/9-89/009 Volumetric Tank Testing: An Overview

EPA/625/R-92/007 Use of Airborne, Surface, and Borehole Geophysical
 Techniques at Contaminated Sites: A Reference
 Guide

EPA/600/R-93/164 Bioremediation Using the Land Treatment Concept

EPA 600/4-79-020 Methods for Chemical Analysis of Water and Waste
 (1983)

EPA SW-846 Test Methods for Evaluation of Solid Waste (1986)
 (including all promulgated updates)

Department of the Air Force

Air Force Institute (AFI) 32-4002 Hazardous Material Emergency Planning
and Response Compliance

Air Force Institute (AFI) 32-7002 Environmental Information Management
System

Remediation Handbook for POL-Contaminated Sites (December 1993)

Technical Protocol for Implementing the Intrinsic Remediation with
Long-Term Monitoring Option for Natural Attenuation of Dissolved-Phase
Fuel Contamination in Groundwater, AFCEE (1994)

Test Plan and Technical Protocol for Bioslurping, AFCEE

Bioventing Performance and Cost Summary, AFCEE

Department of the Army

AR 200-1 Environmental Protection and Enhancement

AR 385-40	Accident Reporting and Records
ER 200-2-3	Environmental Compliance Policies
ER 385-1-92	Safety and Occupational Health Document Requirements for Hazardous, Toxic, and Radioactive Waste (HTRW) and Ordnance and Explosive Waste (OEW) Activities
ER 1110-1-263	Chemical Data Quality Management for Hazardous, Toxic, and Radioactive Waste Remedial Activities
ER 1180-1-6	Construction Quality Management
EP 200-2-3	Environmental Compliance Operations and Maintenance Procedures
EP 415-1-260	Resident Engineer's Management Guide
EP 415-1-261	Quality Assurance Representatives Guide
EP 415-1-266	Resident Engineer's Management Guide for HTRW Projects
EM 200-1-1	Validation of Analytical Chemistry Laboratories
EM 200-1-2	Technical Project Planning (TPP) Process
EM 200-1-3	Requirements for the Preparation of Sampling and Analysis Plans
EM 200-1-6	Chemical Quality Assurance for HTRW Projects
EM 385-1-1	Safety and Health Requirements Manual
EM 1110-1-1802	Geophysical Exploration for Engineering and Environmental Investigations
EM 1110-1-1906	Soil Sampling

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EM 1110-1-4000	Monitoring Well Design, Installation, and Documentation at Hazardous, Toxic and/or Radioactive Waste Sites
EM 1110-1-4001	Soil Vapor Extraction and Bioventing
EM 1110-1-4005	In-Situ Air Sparging
CEGS 01351	Safety, Health, and Emergency Response (HTRW/UST)
CEGS 01450	Chemical Data Quality Control
CEGS 02115	Underground Storage Tank Removal
CEGS 02120	Transportation and Disposal of Hazardous Materials
CEGS 02150	Piping; Off-Gas
CEGS 02160	Solidification/Stabilization of Contaminated Material
CWGS 02214	Soil Bentonite Slurry Trench Cutoff
CEGS 02260	Soil-Bentonite Slurry Trench for HTRW Projects
CEGS 02315	Excavation, Filling, and Backfilling for Buildings
CEGS 02316	Excavation, Filling, and Backfilling for Utilities Systems
CEGS 02377	Low-Permeability Clay Layer
CEGS 02522	Ground-water Monitoring Wells
CEGS 11215	Fans/Blowers/Pumps; Off-Gas
CEGS 11225	Downflow Liquid-Activated Carbon Adsorption Units
CEGS 11226	Vapor Phase Activated Carbon Adsorption Units
CEGS 11242	Chemical Feed Systems

CEGS 11250 Water Softeners, Cation Exchange (Sodium Cycle)

CEGS 11301 Air Stripping Systems

CEGS 11360 Plate and Frame Filter Press System

CEGS 11377 Advanced Oxidation Processes (AOP)

CEGS 11378 Thermal (Catalytic) Oxidation Unit

CEGS 11390 Prefabricated Biochemical Wastewater Treatment
 Plant

CEGS 11393 Filtration System

CEMP-RF
Memorandum Policy Guide for Underground Storage Tanks (USTs)
 on Formerly Used Defense Sites (FUDS), July 31,
 1990

NIOSH/OSHA/
USCG/EPA Occupational Safety and Health Guidance Manual for
 Hazardous Waste Site Activities, October 1985

American National Standards Institute (ANSI)

ANSI Z-88.2 Respiratory Protection

American Petroleum Institute (API)

Publication 1628 A Guide to the Assessment and Remediation of
 Underground Petroleum Releases

Publication 2015 Cleaning Petroleum Storage Tanks

Publication 2217 Guidelines for Confined Space Work in the Petroleum
 Industry

Publication 2219 Safe Operation of Vacuum Trucks in Petroleum Service

Publication 4609 In-Situ Air Sparging: Evaluation of Petroleum
 Industry Sites and Considerations for
 Applicability, Design, and Operation

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Recommended Practice 1604	Removal and Disposal of Used Underground Petroleum Tanks
Recommended Practice 1631	Interior Lining of Underground Storage Tanks
Recommended Practice 2003	Protection Against Ignitions Arising out of Static, Lightning, and Stray Currents

American Society for Testing and Materials (ASTM), Annual Book of ASTM
Standards, 100 Barr Harbor Dr., West Conshohocken, PA 19428-2959

D698	Standard Test Method for Laboratory Compaction Characteristics of Soil Using Standard Effort (12,400 ft-lbf/ft ³ (600 kN-m/m ³))
D1556	Standard Test Method for Density and Unit Weight of Soil in Place by the Sand-Cone Method
D1557	Standard Test Method for Laboratory Compaction Characteristics of Soil Using Modified Effort (56,000 ft-lbf/ft ³ (2,700 kN-m/m ³))
D2113	Practice for Diamond Core Drilling for Site Investigation
D2167	Standard Test Method for Density and Unit Weight of Soil in Place by the Rubber Balloon Method
D2325	Standard Test Method for Capillary-Moisture Relationships for Coarse- and Medium-Textured Soils by Porous-Plate Apparatus
D2487	Standard Test Method for Classification of Soils for Engineering Purposes
D2922	Standard Test Methods for Density of Soil and Soil- Aggregate in Place by Nuclear Methods (Shallow Depth)
D3017	Standard Test Method for Water Content of Soil and

- Rock in Place by Nuclear Methods (Shallow Depth)
- D3152 Standard Test Method for Capillary-Moisture Relationships for Fine-Textured Soils by Pressure-Membrane Apparatus
- D4044 Standard Test Method (Field Procedures) for Instantaneous Change in Head (Slug Tests) for Determining Hydraulic Properties of Aquifers
- D4057 Standard Practice for Manual Sampling of Petroleum Products
- D4136 Standard Practice for Sampling Phytoplankton With Water-Sampling Bottles
- D4318 Standard Test Method for Liquid Limit, Plastic Limit, and Plasticity Index of Soils
- D4750 Standard Test Method for Determining Subsurface Liquid Levels in a Borehole or Monitoring Well
- D5088 Standard Practice for Decontamination of Field Equipment Used at Nonradioactive Waste Sites
- D5126 Standard Guide for Comparison of Field Methods for Determining Hydraulic Conductivity in the Vadose Zone
- D5314 Standard Guide for Soil Gas Monitoring in the Vadose Zone
- D5358 Standard Practice for Sampling With a Dipper or Pond Sampler
- D5495 Standard Practice for Sampling With a Composite Liquid Waste Sampler (COLIWASA)
- D5608 Standard Practice for the Decontamination of Field Equipment Used at Low-Level Radioactive Waste Sites

- D5730 Standard Guide to Site Characterization for Environmental Purposes With Emphasis on Soil, Rock, Vadose Zone, and Groundwater
- D5737 Standard Guide for Methods for Measuring Well Discharge
- D5743 Standard Practice for Sampling Single or Multi-layered Liquids, With or Without Solids, in Drums or Similar Containers
- D5781 Guide for the Use of Dual Wall Reverse-Circulation Drilling
- D5782 Guide for the Use of Direct Air Rotary Drilling
- D5783 Guide for the Use of Direct Rotary Drilling With Water-Based Drilling Fluid
- D5784 Guide for the Use of Hollow-Stem Augers
- D5831 Standard Test Method for Screening Fuels in Soils
- D5872 Guide for the Use of Casing Advancement Drilling Methods
- D5875 Guide for the Use of Cable-Tool Drilling and Sampling Methods
- D5876 Guide for the Use of Direct Rotary Wireline Casing Advancement Drilling Methods
- D6001 Standard Guide for Direct Push Water Sampling for Geoenvironmental Investigations
- D6169 Standard Guide for Selection of Soil and Rock Sampling Devices Used With Drill Rigs for Environmental Investigations
- D6286 Standard Guide for Selection of Drilling Methods for Environmental Site Characterization

E300	Standard Practice for Sampling Industrial Chemicals
E1599	Standard Guide for Corrective Action for Petroleum Releases
E1739	Standard Guide for Risk-Based Corrective Action Applied at Petroleum Release Sites
E1912	Standard Guide for Accelerated Site Characterization for Confirmed or Suspected Petroleum Releases
PS78	Provisonal Standard Guide for Selecting Surface Geophysical Methods

National Fire Protection Association (NFPA), Batterymarch Park,
Quincy, MA 02269

30	Flammable and Combustible Liquids Code
70	National Electrical Code
70B	Electrical Equipment Maintenance
326	Procedure for Safe Entry of Underground Storage Tanks
327	Standard Procedure for Cleaning or Safeguarding Small Trucks and Containers

b. Related Publications.

Hazardous Liquid Pipeline Safety Act of 1979 (49 U.S.C.A. 2001, et
seq.).

Natural Gas Pipeline Safety Act of 1968 (49 U.S.C.A. 1671, et seq.).

Solid Waste Disposal Act, Public Law 89-272, Title II, as added by
Public Law 94-580, *Resource Conservation and Recovery Act*, 42

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U.S.C. 6921 et seq., Oct. 21, 1976, as amended by the *Hazardous and Solid Waste Amendments* (HSWA) of 1984, Public Law 98-616, 42 U.S.C. 6901 et seq.

Heath, Ralph C. and Frank W. Trainer. *Introduction to Groundwater Hydrology*. National Water Well Association, 1988.

Johnson, P.C., C.C. Stanley, M. W. Kemblowski, D. L. Byers, and J. D. Colthart. "A Practical Approach to the Design, Operation, and Monitoring of In-Situ Soil-Venting Systems." *Groundwater Monitoring Review* 10(2) (1990): 159-177.

National Truck Carriers. *Cargo Tank Hazardous Material Regulations*

Rifai, H.S. "Modeling Natural Attenuation Using BioplumeII/III Model," Presentation at the U.S. Air Force Center for Excellence, Environmental Restoration Technology Transfer Symposium, November, 1994.

APPENDIX B

STATE REGULATORY AGENCY CONTACTS

Alabama (EPA Form), Alabama Department of Environmental Management, Ground Water Section/Water Division, 1751 Congressman W.L. Dickinson Drive, Montgomery, Alabama 36130, 205/271-7823

Alaska (EPA Form), Department of Environmental Conservation, Box 0, Juneau, Alaska 99811-1800, 970/465-2653

American Samoa (EPA Form), Executive Secretary, Environmental Quality Commission, Office of the Governor, American Samoan Government, Pago Pago, American Samoa 96799; Attention: UST Notification

Arizona (EPA Form), Attention: UST Coordinator, Arizona Department of Environmental Quality, Environmental Health Services, 2005 N. Central, Phoenix, Arizona 85004

Arkansas (EPA Form), Arkansas Department of Pollution Control and Ecology, P.O. Box 9583, Little Rock, Arkansas 72219, 501/562-7444

California (State Form), Executive Director, State Water Resources Control Board, P.O. Box 100, Sacramento, California 95801, 916/445-1533

Colorado (EPA Form), Section Chief, Colorado Department of Health, Waste Management Division, Underground Tank Program, 4210 East 11th Avenue, Denver, Colorado 80220, 303/320-8333

Connecticut (State Form), Hazardous Materials Management Unit, Department of Environmental Protection, State Office Building, 165 Capitol Avenue, Hartford, Connecticut 06106

Delaware (State Form), Division of Air and Waste Management, Department of Natural Resources and Environmental Control, P.O. Box 1401, 89 Kings Highway, Dover, Delaware 19903, 302/726-5409

District of Columbia (EPA Form), Attention: UST Notification Form, Department of Consumer and Regulatory Affairs, Pesticides and Hazardous Waste Management Branch, Room 114, 5010 Overlook Avenue SW., Washington, DC 20032

Florida (State Form), Florida Department of Environmental Regulation, Solid Waste Section, Twin Towers Office Building, 2600 Blair Stone Road, Tallahassee, Florida 32399, 904/487-4398

Georgia (EPA Form), Georgia Department of Natural Resources, Environmental Protection Division, Underground Storage Tank Program,

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3420 Norman Berry Drive, 7th Floor, Hapeville, Georgia 30354, 404/
656-7404

Guam (State Form), Administrator, Guam Environmental Protection Agency,
P.O. Box 2999, Agana, Guam 96910, Overseas Operator (Commercial call
646-8863)

Hawaii (EPA Form), Administrator, Hazardous Waste Program, 645
Halekauwila Street, Honolulu, Hawaii 96813, 808/548-2270

Idaho (EPA Form), Underground Storage Tank Coordinator, Water Quality
Bureau, Division of Environmental Quality, Idaho Department of Health
and Welfare, 450 W. State Street, Boise, Idaho 83720, 208/334-4251

Illinois (EPA Form), Underground Storage Tank Coordinator,
Division of Fire Prevention, Office of State Fire Marshal, 3150
Executive Park Drive, Springfield, Illinois 62703-4599

Indiana (EPA Form), Underground Storage Tank Program, Office of
Environmental Response, Indiana Department of Environmental Management,
105 South Meridian Street, Indianapolis, Indiana 46225

Iowa (State Form), UST Coordinator, Iowa Department of Natural
Resources, Henry A. Wallace Building, 900 East Grand, Des Moines, Iowa
50219, 512/281-8135

Kansas (EPA Form), Kansas Department of Health and Environment, Forbes
Field, Building 740, Topeka, Kansas 66620, 913/296-1594

Kentucky (State Form), Department of Environmental Protection, Hazardous
Waste Branch, Fort Boone Plaza, Building #2, 18 Reilly Road, Frankfort,
Kentucky 40601, 501/564-6716

Louisiana (State Form), Secretary, Louisiana Department of Environmental
Quality, P.O. Box 44066, Baton Rouge, Louisiana 70804, 501/342-1265

Maine (State Form), Attention: Underground Tanks Program, Bureau of Oil
and Hazardous Material Control, Department of Environmental Protection,
State House—Station 17, Augusta, Maine 04333

Maryland (EPA Form), Science and Health Advisory Group, Office of
Environmental Programs, 201 West Preston Street, Baltimore, Maryland
21201

Massachusetts (EPA Form), UST Registry, Department of Public Safety,
1010 Commonwealth Avenue, Boston, Massachusetts 02215, 617/566-4500

Michigan (EPA Form), Michigan Department of State Police, Fire Marshal Division, General Office Building, 7150 Harris Drive, Lansing, Michigan 48913

Minnesota (State Form), Underground Storage Tank Program, Division of Solid and Hazardous Wastes, Minnesota Pollution Control Agency, 520 West Lafayette Road, St. Paul, Minnesota 55155

Mississippi (State Form), Department of Natural Resources, Bureau of Pollution Control, Underground Storage Tank Section, P.O. Box 10385, Jackson, Mississippi 39209, 601/961-5171

Missouri (EPA Form), UST Coordinator, Missouri Department of Natural Resources, P.O. Box 176, Jefferson City, Missouri 65102, 314/751-7428

Montana (EPA Form), Solid and Hazardous Waste Bureau, Department of Health and Environmental Science, Cogswell Bldg., Room B-201, Helena, Montana 59620

Nebraska (EPA Form), Nebraska State Fire Marshal, P.O. Box 94677, Lincoln, Nebraska 68509-4677, 402/471-9465

Nevada (EPA Form), Attention: UST Coordinator, Division of Environmental Protection, Department of Conservation and Natural Resources, Capitol Complex 201 S. Fall Street, Carson City, Nevada 89710, 800/992-0900, Ext. 4670, 702/885-4670

New Hampshire (EPA Form), NH Dept. of Environmental Services, Water Supply and Pollution Control Division, Hazen Drive, P.O. Box 95, Concord, New Hampshire 03301, Attention: UST Registration

New Jersey (State Form), Underground Storage Tank Coordinator, Department of Environmental Protection, Division of Water Resources (CN-029), Trenton, New Jersey 08625, 609/292-0424

New Mexico (EPA Form), New Mexico Environmental Improvement Division, Groundwater/Hazardous Waste Bureau, P.O. Box 968, Santa Fe, New Mexico 37504, 505/827-2933

New York (EPA Form), Bulk Storage Section, Division of Water, Department of Environmental Conservation, 50 Wolf Road, Room 326, Albany, New York 12233-0001, 518/457-4351

North Carolina (EPA Form), Division of Environmental Management, GroundWater Operations Branch, Department of Natural Resources and Community Development, P.O. Box 27687, Raleigh, North Carolina 27611, 919/733-3221

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North Dakota (State Form), Division of Hazardous Management and Special Studies, North Dakota Department of Health, Box 5520, Bismarck, North Dakota 58502-5520

Northern Mariana Islands (EPA Form), Chief, Division of Environmental Quality, P.O. Box 1304, Commonwealth of Northern Mariana Islands, Saipan, CM 96950, Cable Address: Gov. NMI Saipan, Overseas Operator: 6984

Ohio (State Form), State Fire Marshal's Office, Department of Commerce, 8895 E. Main Street, Reynoldsburg, Ohio 43068, State Hotline: 800/282-1927

Oklahoma (EPA Form), Underground Storage Tank Program, Oklahoma Corporation Comm., Jim Thorpe Building, Oklahoma City, Oklahoma 73105

Oregon (State Form), Underground Storage Tank Program, Hazardous and Solid Waste Division, Department of Environmental Quality, 811 S.W. Sixth Avenue, Portland, Oregon 98204, 503/229-5788

Pennsylvania (EPA Form), PA Department of Environmental Resources, Bureau of Water Quality Management, Ground Water Unit, 9th Floor Fulton Building, P.O. Box 2063, Harrisburg, Pennsylvania 17120

Puerto Rico (EPA Form), Director, Water Quality Control Area, Environmental Quality Board, Commonwealth of Puerto Rico, Santurce, Puerto Rico, 809/725-0717

Rhode Island (EPA Form), UST Registration, Department of Environmental Management, 83 Park Street, Providence, Rhode Island 02903, 401/277-2234

South Carolina (State Form), Ground-Water Protection Division, South Carolina Department of Health and Environmental Control, 2600 Bull Street, Columbia, South Carolina 29201, 803/758-5213

South Dakota (EPA Form), Office of Water Quality, Department of Water and Natural Resources, Joe Foss Building, Pierre, South Dakota 57501,

Tennessee (EPA Form), Tennessee Department of Health and Environment, Division of Superfund Underground Storage Tank Section, 150 Ninth Avenue, North, Nashville, Tennessee 37219-5404, 615/741-0690

Texas (EPA Form), Underground Storage Tank Program, Texas Water Commission, P.O. Box 13087, Austin, Texas 78711

Utah (EPA Form), Division of Environmental Health, P.O. Box 45500, Salt Lake City, Utah 84145-0500

Vermont (State Form), Underground Storage Tank Program, Vermont
AEC/Waste Management Division, State Office Building, Montpelier,
Vermont 05602, 802/828-3395

Virginia (State Form), Virginia Department of Environmental Quality, UST
Program, P. O. Box 10009, Richmond, Virginia 23240-0009, 804/698-4269.

Virgin Islands (EPA Form), 205(J) Coordinator, Division of Natural
Resources Management, 14 F Building 111, Watergut Homes, Christianstead,
St. Croix, Virgin Islands 00820

Washington (State Form), Underground Storage Tank Notification, Solid
and Hazardous Waste Program, Department of Ecology, M/S PV-11, Olympia,
Washington 98504-8711, 206/459-6316

West Virginia (EPA Form), Attention: UST Notification, Solid and
Hazardous Waste, Ground Water Branch, West Virginia Department of
Natural Resources, 1201 Greenbriar Street, Charleston, West Virginia
25311

Wisconsin (State Form), Bureau of Petroleum Inspection, P.O. Box 7969,
Madison, Wisconsin 53707, 608/266-7605

Wyoming (EPA Form), Water Quality Division, Department of Environmental
Quality, Herschler Building, 4th Floor West, 122 West 25th Street,
Cheyenne, Wyoming 82002, 307/777-7781.

APPENDIX C

WELL OPENING PROCEDURES

Volatile organic contaminants (VOCs) tend to accumulate in the vapor space of well casings. These organics can escape the well stem as a "slug" once the cap is removed from the wellhead. Field personnel will follow these procedures for initial opening of all wells in which the water is expected to contain VOCs in greater than trivial concentrations.

- A two-party team will initiate well-opening **PRIOR** to any sampling activity.
- Approach the wells from an upwind direction.
- For initial well-opening, wear a minimum of Level C respiratory protection, e.g., an Ultratwin with a GMC-H cartridge.
- Open wells with unvented casings and threaded caps slowly to avoid sudden release of gases due to over-pressure.
- When the well is open, test the air in the wellhead for the contaminants of concern.
- If the readings indicate a potential health hazard from the venting process, allow the well to vent for 15 to 30 minutes and then test again.
- The field team may perform monitoring or sampling in the level of protection specified in Chapter 7 for the concentrations found.
- Take new exposure readings at least four or five times an hour.
- Many wells can be opened and "sniffed" at one time, which allows the maximum ventilation time.

If field personnel can demonstrate that volatile organics are not a concern, the site safety and health officer may allow them to skip the VOA procedure. Experience with a recent round of groundwater sampling at the same location would provide enough information to show whether this route of exposure is a concern.

APPENDIX D

HEAT/COLD STRESS MONITORING

- D-1. Heat Stress. Heat stress usually is a result of protective clothing decreasing natural body ventilation, although it may occur at any time work is being performed at elevated temperatures.
- a. Symptoms. If the body's physiological processes fail to maintain a normal body temperature because of excessive heat, a number of physical reactions can occur ranging from mild (such as fatigue, irritability, anxiety, and decreased concentration, dexterity, or movement) to fatal. Because heat stress is one of the most common and potentially serious illnesses at hazardous waste sites, regular monitoring and other preventative measures are vital. Site workers must learn to recognize and treat the various forms of heat stress.
 - b. Treatment. The best approach is preventative heat stress management. In general:
 - (1) Urge workers to drink 0.5 liters (16 ounces) of water before beginning work, such as in the morning or after lunch. Provide disposable 120-ml (4-ounce) cups and water that is maintained at 10 degrees to 15 degrees C (50 degrees to 60 degrees F). Urge workers to drink 1 to 2 of these cups of water every 20 minutes, for a total of 3.5 to 7 liters (1 to 2 gallons) per day. Workers must wash hands and face prior to drinking. Provide a cool area for rest breaks.
 - (2) Acclimate workers to site work conditions by slowly increasing workloads, i.e., do not begin site work with extremely demanding activities.
 - (3) Provide cooling devices to aid natural body ventilation. These devices, however, add weight, and their use should be balanced against worker efficiency. An example of a cooling aid is long cotton underwear that acts as a wick to help absorb moisture and protect the skin from direct contact with heat-absorbing protective clothing.
 - (4) Install mobile showers and/or hose-down facilities to reduce body temperature and to cool protective clothing.
 - (5) Conduct field activities in the early morning or evening in hot weather.

- (6) Ensure that adequate shelter is available to protect personnel against heat, cold, rain, or snow, etc., all of which can decrease physical efficiency and increase the probability of both heat and cold stress. If possible, set up the command post in the shade.
- (7) In hot weather, rotate shifts of workers wearing impervious clothing.
- (8) Good hygienic standards must be maintained by frequent changes of clothing and showering. Clothing should be permitted to dry during rest periods. Persons who notice skin problems should immediately consult medical personnel and the site safety and health officer (SSHO).

D-2. Heat Stroke. Heat stroke is a medical emergency, with a high mortality rate. Heat stroke is an acute and dangerous reaction to heat stress caused by a failure of heat-regulating mechanisms of the body - the individual's temperature control system that causes sweating stops working correctly. Body temperature rises so high that brain damage and death will result if the person is not cooled quickly.

- a. Symptoms: Red, hot, dry skin, although person may have been sweating earlier; nausea; dizziness; confusion; extremely high body temperature; rapid respiratory and pulse rates; unconsciousness; or coma.
- b. Treatment: The most important objective in the treatment of heat stroke is the lowering of the victim's body temperature as rapidly as possible. Cool the victim quickly. If the body temperature is not brought down fast, permanent brain damage or death will result. Soak the victim in cool but not cold water, sponge the body with cool water, or pour water on the body to reduce the temperature to below 102 degrees F. Observe the victim and obtain medical help. Do not give coffee, tea, or alcoholic beverages.

D-3. Heat Exhaustion. Heat exhaustion is a state of very definite weakness or exhaustion caused by the loss of fluids from the body. This condition is much less dangerous than heat stroke, but it nonetheless must be treated.

- a. Symptoms: Pale, clammy, moist skin; profuse perspiration; and extreme weakness. Body temperature is normal, pulse is weak and rapid, breathing is shallow. The person may have a headache, may vomit, and may be dizzy.
- b. Treatment: Remove the person to a cool, air conditioned place; loosen clothing; place in a head-low position; and provide bed

rest. Consult physician, especially in severe cases. The normal thirst mechanism is not sensitive enough to ensure body fluid replacement. Have patient drink 1 to 2 cups of water immediately, and every 20 minutes thereafter, until symptoms subside. Total water consumption should be about 3.5 to 7 liters (1 to 2 gallons) per day.

- D-4. Heat Cramps. Heat cramps are caused by perspiration that is not balanced by adequate fluid intake. Heat cramps are often the first sign of a condition that can lead to heat stroke.
- a. Symptoms: Acute painful spasms of voluntary muscles (e.g., abdomen and extremities).
 - b. Treatment: Remove victim to a cool area and loosen clothing. Have patient drink 1 to 2 cups of water immediately, and every 20 minutes thereafter, until symptoms subside. Total water consumption should be 3.5 to 7 liters (1 to 2 gallons) per day. Consult with physician.
- D-5. Heat Rash. Heat rash is caused by continuous exposure to heat and humid air and aggravated by chafing clothes. The condition decreases ability to tolerate heat.
- a. Symptoms: Mild red rash, especially in areas of the body in contact with protective gear.
 - b. Treatment: Decrease amount of time in protective gear and provide powder to help absorb moisture and decrease chafing.
- D-6. Heat Stress Monitoring and Work Cycle Management. For strenuous field activities that are part of ongoing site work activities in hot weather, the following procedures should be used to monitor the body's physiological response to heat and to manage the work cycle, even if workers are not wearing impervious clothing. These procedures are to be instituted when the temperature exceeds 70 degrees F.
- a. Measure Heart Rate (HR). Take a rest period and measure heart rate by the radial pulse for 30 seconds as early as possible, in the resting period. The HR at the beginning of the rest period should not exceed 110 beats/minute. If the HR is higher, shorten the next work period by 33 percent, while the length of the rest period stays the same. If the pulse rate still exceeds 110 beats/minute at the beginning of the next rest period, shorten the following work cycle by another 33 percent. The procedure is continued until the rate is maintained below 110 beats/minute.
 - b. Measure Body Temperature. Body temperature should be measured orally with a clinical thermometer as early as possible in the

resting period. Oral temperature (OT) at the beginning of the rest period should not exceed 99.40 degrees F; if it does, the worker will be prohibited from continuing work until the OT is maintained below 99.4 degrees F (37.4 degrees C).

- c. Manage Work/Rest Schedule. Use the following work/rest schedule as a guideline:

Adjusted Temperature (°F)	Active Work Time (min/hr) Using Level B/C Protective Gear
75 or less	50
80	40
85	30
90	20
95	10
100	0

- d. Measure the air temperature with a standard thermometer. Estimate fraction of sunshine by judging what percent of the sun is out:

- 100-percent sunshine = no cloud cover = 1.0
- 50-percent sunshine = 50-percent cloud cover = 0.5
- 0-percent sunshine = full cloud cover = 0.0

Calculate the adjusted temperature:

$$T \text{ (adjusted)} = T \text{ (actual)} + (13 \times \text{fraction sunshine})$$

- e. Reduce or increase the work cycle according to the guidelines under heart rate and body temperature.

D-7. Cold Stress.

- a. Persons working outdoors in low temperatures, especially at or below freezing are subject to cold stress. Exposure to extreme cold for a short time causes severe injury to the surface of the body or results in profound generalized cooling, causing death. Areas of the body that have high surface area-to-volume ratio such as fingers, toes, and ears are the most susceptible.
- b. Protective clothing. Personal protective clothing and equipment are essential in the prevention of cold stress and injury related to a cold environment. Clothing made of thin cotton fabric is ideal; it helps evaporate sweat by "picking it up" and bringing it

to the surface. Loosely fitted clothing also aids sweat evaporation. Tightly fitted clothing of synthetic fabric interferes with evaporation. Recommended clothing includes the following: cotton undershirt, cotton shorts/underpants, cotton and wool thermal underwear, cotton and wool socks, wool or thermal trousers (quilted or specially lined), waterproof insulated boots, wool shirt, wool sweater over cotton shirt, Anorak or arctic parka, wool knit cap, hard-hat liner, wool mittens, ski mask or scarf, and windproof and waterproof outer layer.

- c. Many factors influence the development of a cold injury: the type and duration of exposure, the ambient temperature, the humidity, and the velocity of the wind. Wind chill is used to describe the chilling effect of moving air in combination with low temperature.
- d. As a general rule, the greatest incremental increase in wind chill occurs when a wind of 5 mph increases to 10 mph. Additionally, water conducts heat 240 times faster than air. Thus, the body cools suddenly when chemical-protective equipment is removed if the clothing underneath is perspiration soaked.

D-8. Frostbite Symptoms. Local injury resulting from cold is included in the generic term frostbite. Frostbite of the extremities can be categorized in three ways:

- Frost nip or incipient frostbite is characterized by sudden blanching or whitening of skin.
- Superficial frostbite is characterized by skin with a waxy or white appearance and is firm to the touch, but tissue beneath is resilient.
- Deep frostbite is characterized by tissues that are cold, pale, and solid.

b. Treatment. To administer first aid for frostbite:

- (1) Take the victim indoors and rewarm the areas **quickly** in water that is between 39 degrees and 41 degrees C (102 degrees and 105 degrees F).
- (2) Give a warm drink—**not** coffee, tea, or alcohol. The victim must not smoke.
- (3) Keep the frozen parts in warm water or covered with warm clothes for 30 minutes, even though the tissue will be very painful as it thaws.

- (4) Elevate the injured area and protect it from injury.
 - (5) Do not allow blisters to be broken.
 - (6) Use sterile, soft, dry material to cover the injured areas.
 - (7) Keep victim warm and get immediate medical care.
- c. Precautions. After thawing, the victim should try to move the injured areas a little, but no more than can be done alone, without help.
- (1) Do *not* rub the frostbitten part (this may cause gangrene).
 - (2) Do *not* use ice, snow, gasoline, or anything cold on the frostbitten area.
 - (3) Do *not* use heat lamps or hot water bottles to rewarm the part.
 - (4) Do *not* place the part near a hot stove.
- D-9. Hypothermia. Systemic hypothermia is caused by exposure to freezing or rapidly dropping temperature.
- a. Symptoms. Its symptoms are usually exhibited in five stages:
- (1) Shivering.
 - (2) Apathy, listlessness, sleepiness, and (sometimes) rapid cooling of the body to less than 95 degrees F.
 - (3) Unconsciousness, glassy stare, slow pulse, and slow respiratory rate.
 - (4) Freezing of the extremities.
 - (5) Death.
- b. Treatment. As a general rule, field activities must be curtailed if equivalent chill temperature (degrees F) as defined in Table D-1 is below zero (0 degrees F).

**TABLE D-1
COOLING POWER ON EXPOSED FLESH EXPRESSED AS AN
EQUIVALENT TEMPERATURE UNDER CALM CONDITIONS***

Actual Temperature Reading (°F)												
Estimated Wind Speed (in mph)	50	40	30	20	10	0	-10	-20	-30	-40	-50	-60
	Equivalent Chill Temperature (°F)											
calm	50	40	30	20	10	0	-10	-20	-30	-40	-50	-60
5	48	37	27	16	6	-5	-15	-26	-36	-47	-57	-68
10	40	28	16	4	-9	-24	-33	-46	-58	-70	-83	-95
15	36	22	9	-5	-18	-32	-45	-58	-72	-85	-99	-112
20	32	18	4	-10	-25	-39	-53	-67	-82	-96	-110	-121
25	30	16	0	-15	-29	-44	-59	-74	-88	-104	-118	-133
30	28	13	-2	-18	-33	-48	-63	-79	-94	-109	-125	-140
35	27	11	-4	-20	-35	-51	-67	-82	-98	-113	-129	-145
40	26	10	-6	-21	-37	-53	-69	-85	-100	-116	-132	-148
Wind Speeds greater than 40 mph have little additional effect.	LITTLE DANGER in <hr with dry skin Maximum danger of false sense of security.				INCREASING DANGER Danger from freezing of exposed flesh within one (1) minute.				GREAT DANGER Flesh may freeze within 30 seconds.			
Trenchfoot and immersion foot may occur at any point on this chart.												
*Developed by U.S. Army Research Institute of Environmental Medicine, Natick, MA SOURCE: ACGIH, Threshold Limit Values for Chemical Substances in the Work Environment for 1984-1985.												

APPENDIX E

CONFINED SPACE ENTRY

- E-1. General. These procedures establish minimum requirements for safe entry into, work in, and exit from confined spaces like tanks, vessels, manholes, pipelines, water transmission lines, tunnels, stilling wells, junction structures, valve and metering vaults, dry wells, and wet wells. These confined spaces are dangerous because gases and vapors accumulate to form oxygen deficient, toxic, or explosive atmospheres.
- E-2. Confined Space Entry Program. No one will enter a confined space unless these procedures (or equivalent procedures established by the subcontractor or client) are followed. The SSHO will determine whether alternate procedures are equivalent. A confined space entry program must include at a minimum:
- a. Responsibilities and duties of personnel associated with confined space entry activities.
 - b. Continuing evaluation and identification (posting) of confined spaces.
 - c. Coordination of confined space entry activities.
 - d. Specific training for confined space entrants.
 - e. Pre-entry review and permit preparation.
 - f. Provision of appropriate safety equipment.
 - g. Adherence to the buddy system.
 - h. Detection of hazardous conditions.
 - i. Ventilation of hazardous gases.
 - j. Written rescue and emergency services and procedures.
 - k. Vessel preparation, isolation, lockout/tagout.
 - l. Atmospheric testing, oxygen, toxicity, and flammability.

m. Communication devices, hand, radio, rope.

E-3. Confined Space Entry Personnel. The roles of confined space entry personnel include:

- Confined Space Entry Coordinator. Personnel at the project trained and authorized in writing by the designated authorities to sign, issue, and revoke entry permits.
 - Person-in-Charge. An entry team member trained and authorized to certify that entry permit conditions have been met.
 - Confined Space Entrants. Entry team member trained to perform actual work in the confined space.
 - Entry Attendant. An individual stationed outside and required to remain outside the confined space while entrants are in the confined space, who monitors the authorized entrants and the confined space activities and, under specified conditions, authorizes evacuation of the confined space.
 - Rescue Personnel. Personnel who are trained, qualified, and authorized to respond to emergencies in confined spaces.
- a. The personnel who fill these roles must have completed training in these procedures and in site-specific confined space hazards identified by the SSHO.
- b. Entry by personnel into any confined space where liquids or gases may have been present, or may occur during the entry, requires at least three persons: one entrant, one attendant, and one rescue worker. The attendant and rescue worker are to remain outside confined space. Rescue workers may perform other tasks during an entry if those tasks will not impede response to an emergency.
- c. Personnel may fill the roles listed above only if they are qualified. All entrants and rescue teams must be trained in their entry-procedure responsibilities. A written record of the length and content of such training must be kept.

E-4. Confined Space Entry Permits.

- a. Written entry permits are required for any entry into, or work in, confined spaces. When a work team plans to enter a confined space, it must complete an entry permit form that contains, at a minimum, the information in Table E-1. Users are directed to create local forms meeting their specific needs. Forms should include the personnel, task, measurements, equipment required, and the emergency contact.
- b. Entry permits may be issued only by the Confined Space Entry Coordinator. Actual entry is authorized when the "Person in Charge" completes the pre-entry checklist on the entry permit and signs the form.
- c. Entry permits will address a single work project in a single confined space, for one work period, not to exceed 8 hours. The coordinator may issue permits for a task involving a group of spaces with a common hazard potential. A permit may allow work over a longer period, if the personnel, the tasks, and the hazards do not change.

E-5. Equipment Required for Confined Space Entry.

- a. USACE personnel may enter a confined space only with the equipment specified in the entry permit. The safety equipment listed below would be adequate for most foreseeable conditions.
- b. Personal Protective Equipment (PPE)
 - (1) Airline respirator or Self-Contained Breathing Apparatus (SCBA)
 - (2) Steel-toe safety shoes
 - (3) Hard hat
 - (4) Surgical PVC inner gloves
 - (5) Neoprene rubber outer gloves

**TABLE E-1
CONFINED SPACE ENTRY PERMIT MINIMUM REQUIREMENTS**

Space to be Entered: _____
 Nature of Task: _____
 Duration of Permit: From: _____ To: _____
 Person In Charge: _____
 Authorized Entrants: _____

 Attendant: _____
 Coordinator Signature: _____

Pre-Entry Check List

Needed? In Place? (To Be Initialed By Person in Charge)

_____	_____	Traffic cones or barriers in place
_____	_____	Safety harness with retrieval tripod in place
_____	_____	SCBA ready for emergency use
_____	_____	Valves tagged out (mark N/A if not applicable)
_____	_____	Electrical equipment disconnected & locked out (or N/A)
_____	_____	Protective clothing & equipment donned appropriately
_____	_____	Rescue worker is within easy reach

Personal Protective Equipment

Needed?	In Place?		Needed?	In Place?	
_____	_____	Airline breathing mask	_____	_____	SCBA
_____	_____	Steel-toe safety shoes	_____	_____	Hard hat
_____	_____	Surgical PVC inner gloves	_____	_____	Rubber outer gloves
_____	_____	Chemical safety goggles	_____	_____	Rubber overboots
_____	_____	PVC rain suit	_____	_____	Duct tape on seams
_____	_____	Forced ventilation blower	_____	_____	5-minute escape packs

Atmospheric Testing

Needed? In Place?

_____	_____	Oxygen deficiency (> 19.5% and < 21.5%)
_____	_____	Flammable gases (< 10% LEL)
_____	_____	Toxic gases (< PELs). (Specify: _____)
_____	_____	Ventilation blower pushing clean air into space
_____	_____	Gas Detector(s) - on the belts or suits of entrants
_____	_____	Atmospheric Testing - after period of ventilation

ENTRY APPROVED: _____
Person-in-Charge
Date

- (6) Chemical safety goggles
 - (7) Rubber overboots or hip waders
 - (8) PVC rain suit
 - (9) Duct tape on the seams
 - (10) Forced ventilation blower
 - (11) Five-minute escape packs
- c. Rescue Equipment
- (1) Parachute-type safety harness
 - (2) Safety lifeline
 - (3) Automatic rescue winch
 - (4) Rescue & retrieval tripod or derrick
 - (5) Two-way radios
 - (6) First-aid kit
- d. Routine confined space entries can be performed in regular work clothes if the entry team has enough information about the atmosphere inside the space. Some circumstances that would change the type of equipment needed include the following:
- Respiratory protection is not necessary if:
- (1) The monitoring equipment reveals no contaminants in the air and
 - (2) There is no potential source of contaminants and
 - (3) The oxygen level is at least 19.5 percent.
- e. If the air and surfaces in the space are free of contaminants, protective clothing is not needed.
- f. If air contaminants in the space can affect the worker by absorption through the skin, a Level A suit is required.
- g. A SCBA, in working order, must be ready for use.

- h. Only intrinsically-safe equipment may be used in confined spaces. Temporary lighting, whether electrically or battery operated, must be low-voltage, double-insulated, and explosion-proof. Tools used in confined spaces must be of a non-sparking type, unless there is no potential for flammable vapors or gases in the space.

E-6. Preparation for Entry.

- a. Inspect the area near the space for tripping hazards, traffic, and ignition sources, like lighted cigarettes. Remove them, if you can. Provide controls if you cannot move them.
- b. Inspect the condition of the entry steps of the confined space. Do not rely on a permanent ladder if the space is often wet. If it appears that the steps will not support your weight or if the confined space contains no steps, then provide a ladder and approved hoist or another form of ready entry and exit. Only one person at a time should ascend or descend a ladder. Personnel must not carry tools or other objects in their hands while climbing in or out of the confined space.
- c. If materials can flow into the space:
 - (1) And valves are motor operated: disconnect them, engage the lockouts, and attach a lockout tag.
 - (2) And valves are manually operated: either station someone at the valve handle or chain and padlock the handle.
 - (3) Install steel blanks in lines with flanged connections.
- d. The potential types of emergency in the spaces vary with the type of confined space. The rescue equipment, including the SCBA, should be inspected and tested prior to space entry.
- e. Coworkers must inspect each other's safety equipment before entry to determine if it is properly adjusted and in the proper position.

E-7. Monitoring.

- a. Combination combustible gas and oxygen indicators must be used to test the atmosphere of the confined space for the presence of combustible gases and adequate oxygen levels before entering. The permit must specify tests for any other dangerous contaminants, such as hydrogen sulfide, which could be present in the space.
- b. Prior to entry, the Person-in-Charge must test the atmosphere within the confined space with the meters as specified below.

- (1) Start up, check voltage, and field check the meters. Do not calibrate the detector with the probe in the confined space.
 - (2) Insert the probe about 12 inches into the space. Read the meters.
 - (3) Drop the probe to the level that workers in the space will occupy. Read it again.
 - (4) Measure for vapor conditions on the assumption that stratification of vapors has occurred in the tank. At a minimum, measure the top, middle, and bottom of the space as well as any identifiable pockets, corners, etc.
- c. Gases and vapors tend to stratify in confined spaces. One entrant must wear or carry the meter throughout the duration of the entry.
- d. If a toxic material is present above its exposure limit, or flammable gas is above 10 percent of the LEL, or oxygen is below 19.5 percent or above 21.5 percent, the team shall provide forced ventilation to eliminate these conditions and shall not make entry until these conditions are eliminated. The LEL must be less than 10 percent and oxygen levels must be between 19.5 percent and 22 percent.
- e. The air monitors must be field tested in accordance with the instructions contained in the instrument manual. If the detector fails the prescribed field tests, it must be recalibrated by the procedures established by the manufacturer. No entry is permitted unless the required measurements have been collected.

E-8. Ventilation.

- a. When monitoring indicates a need for ventilation, it must be provided until the monitor indicates acceptable air levels. Blowers should be coupled with a large-diameter, flexible hose that can direct air into the work area. Blowers used within confined spaces will be intrinsically safe. Gasoline, diesel, or gas-operated equipment used near confined spaces must be oriented so that their exhaust cannot enter the space.
- b. Continuous ventilation is desirable for any confined space entry. It is required for entry into any space where liquids or gases may have been present or could enter during the personnel entry.

E-9. Responsibilities During Confined Space Entry.

- a. The Person-in-Charge of the entry must:

- (1) Assure that the pre-entry checklist on the permit is completed before any employee enters a confined space.
 - (2) Evaluate the pre-entry conditions.
 - (3) Verify that the rescue worker is available and that the means for summoning is operable.
 - (4) Terminate the entry upon becoming aware of a nonpermitted condition.
- b. The Person-in-Charge of entry may serve as an entrant or an attendant in accordance with the sections below.
- c. The Entry Attendant must:
- (1) Remain outside the confined space.
 - (2) Leave only when replaced by an equally qualified individual or to save his/her own life. If the attendant must leave and there is no replacement, order the entrants to exit the confined space.
 - (3) Stay continuously aware of the location and condition of all authorized entrants within the confined space by voice, radio, telephone, visual observation, or other equally effective means.
 - (4) Stay continuously aware of conditions in the space.
 - (5) Order entrants to exit the confined space at the first indication of hazardous condition (such as instrument alarms, visible releases, or unusual behavior by the entrants).
 - (6) Summon immediate emergency assistance, if needed.
 - (7) Warn unauthorized persons not to enter or to exit immediately if they have entered. Advise the authorized entrants and management of entry by unauthorized persons.
 - (8) Assemble and inspect the equipment that the rescue worker would need to enter the space.
 - (9) Keep objects away from the access hole where they can be accidentally knocked, pushed, or dragged into the confined space. Lower tools or supplies to workers inside by a hand line.

- (10) If safety harnesses are worn into the space, secure the safety line to a nearby well-anchored object, never to movable equipment or a vehicle. Monitor the safety line at all times, taking up extra slack as needed. Keep the safety line away from traffic and equipment with moving parts.
- d. Confined space entrants must:
- (1) Remove all jewelry before entering the space.
 - (2) Inspect their own and each other's personal safety gear before entering the confined space.
 - (3) Comply with these procedures and the conditions of the permit.
 - (4) Follow the directions of the Person-in-Charge and the Attendant.
 - (5) Leave the space and report to the Attendant immediately upon feeling the effects of a chemical exposure.
 - (6) While working, avoid looking up.

E-10. Rescue Procedures.

- a. Upon detecting an emergency condition, the personnel in the confined space must:
- (1) Move an incapacitated coworker in close proximity toward the exit. However, do not move towards the hazard, even to save a coworker.
 - (2) Exit the space.
 - (3) Immediately inform the Attendant of the nature of the hazard.
- b. Upon detecting an emergency, the Attendant must:
- (1) Remain outside the confined space to lower necessary rescue equipment into the space and render other necessary assistance.
 - (2) Start to withdraw the worker(s) with the safety line.
 - (3) Notify the rescue worker(s).

- (4) Send someone to notify the emergency service providers specified in the permit. Give the location and any other pertinent information.
 - (5) Remain available to lower necessary rescue equipment into the space, render any other necessary assistance, and guide emergency units to the scene.
- c. Upon detecting an emergency, rescue workers must:
- (1) Report to the confined space as quickly as possible.
 - (2) If appropriate, don a SCBA.
 - (3) Enter to offer assistance and correct the problem.
- d. Protection of employee life and health is the first priority of the rescue worker. No employee may enter the confined space without a SCBA until all causes of the incapacitation have been eliminated.
- e. The rescue team must be trained in:
- (1) The requirements for entrants.
 - (2) The rescue functions assigned to them using the retrieval and rescue equipment furnished.
 - (3) Basic first aid and cardiopulmonary resuscitation.