

Chapter VI

Low-Temperature Thermal Desorption

Contents

Evaluation Of The Applicability Of LTTD	VI-7
Soil Characteristics	VI-9
Soil Plasticity	VI-9
Particle Size Distribution	VI-10
Moisture Content	VI-10
Heat Capacity	VI-12
Concentration Of Humic Material	VI-12
Metals Concentration	VI-12
Bulk Density	VI-13
Constituent Characteristics	VI-13
Constituent Concentrations	VI-13
Boiling Point Range	VI-15
Vapor Pressure	VI-15
Octanol/Water Partition Coefficient (K_{ow})	VI-16
Aqueous Solubility	VI-16
Thermal Stability	VI-16
Dioxin Formation	VI-16
Process Operating Conditions	VI-16
Types of Low-Temperature Thermal Desorption Systems ..	VI-17
OffGas Treatment	VI-21
Treatment Temperature	VI-22
Residence Time	VI-22
Pilot Testing	VI-22
Determination Of The Practicality Of Using LTTD	VI-23
Vertical And Horizontal Extent Of Contamination	VI-23
Site Layout	VI-25
Adjacent Land Use	VI-25
Other Considerations	VI-25
Evaluation Of The Effectiveness Of LTTD	VI-26
References	VI-28
Checklist: Can LTTD Be Used At This Site?	VI-29

List Of Exhibits

Number	Title	Page
VI-1	Parallel Flow (Co-Current) Rotary Low-Temperature Thermal Desorption System	VI-2
VI-2	Advantages And Disadvantages Of LTTD	VI-3
VI-3	Low-Temperature Thermal Desorption Process Flow Chart	VI-4
VI-4	Recommended Soil Treatment Temperatures For Selected Petroleum Products	VI-8
VI-5	Key Soil And Constituent Characteristics That Influence Applicability Of LTTD	VI-9
VI-6	Energy Demand Versus Soil Moisture Content	VI-11
VI-7	Feed Soil Moisture Content Limits	VI-11
VI-8	Feed Soil TPH Concentration Limits	VI-14
VI-9	Petroleum Product Boiling Ranges	VI-15
VI-10	Thermal Desorption System Schematic Design	VI-18
VI-11	Thermal Desorption Size Versus Amount Of Soil To Be Treated	VI-24
VI-12	Monitoring Recommendations	VI-26

Chapter VI

Low-Temperature Thermal Desorption

Low-Temperature Thermal Desorption (LTTD), also known as low-temperature thermal volatilization, thermal stripping, and soil roasting, is an *ex-situ* remedial technology that uses heat to physically separate petroleum hydrocarbons from excavated soils. Thermal desorbers are designed to heat soils to temperatures sufficient to cause constituents to volatilize and desorb (physically separate) from the soil. Although they are not designed to decompose organic constituents, thermal desorbers can, depending upon the specific organics present and the temperature of the desorber system, cause some of the constituents to completely or partially decompose. The vaporized hydrocarbons are generally treated in a secondary treatment unit (e.g., an afterburner, catalytic oxidation chamber, condenser, or carbon adsorption unit) prior to discharge to the atmosphere. Afterburners and oxidizers destroy the organic constituents. Condensers and carbon adsorption units trap organic compounds for subsequent treatment or disposal.

Some pre- and postprocessing of soil is necessary when using LTTD. Excavated soils are first screened to remove large (> 2 inches in diameter) objects. These may be sized (e.g., crushed or shredded) and then introduced back into the feed material. After leaving the desorber, soils are cooled, re-moistened to control dust, and stabilized (if necessary) to prepare them for disposal/reuse. Treated soil may be redeposited onsite, used as cover in landfills, or incorporated into asphalt.

Thermal desorption systems fall into two general classes -- stationary facilities and mobile units. Contaminated soils are excavated and transported to stationary facilities; mobile units can be operated directly onsite. Desorption units are available in a variety of process configurations including rotary desorbers, asphalt plant aggregate dryers, thermal screws, and conveyor furnaces.

LTTD has proven very effective in reducing concentrations of petroleum products including gasoline, jet fuels, kerosene, diesel fuel, heating oils, and lubricating oils. LTTD is applicable to constituents that are volatile at temperatures as great as 1,200°F. Exhibit VI-1 provides an illustration of a typical LTTD operation. The advantages and disadvantages of LTTD are listed in Exhibit VI-2.

Exhibit VI-1
Parallel Flow (Co-Current) Rotary Low-Temperature Thermal Desorption System

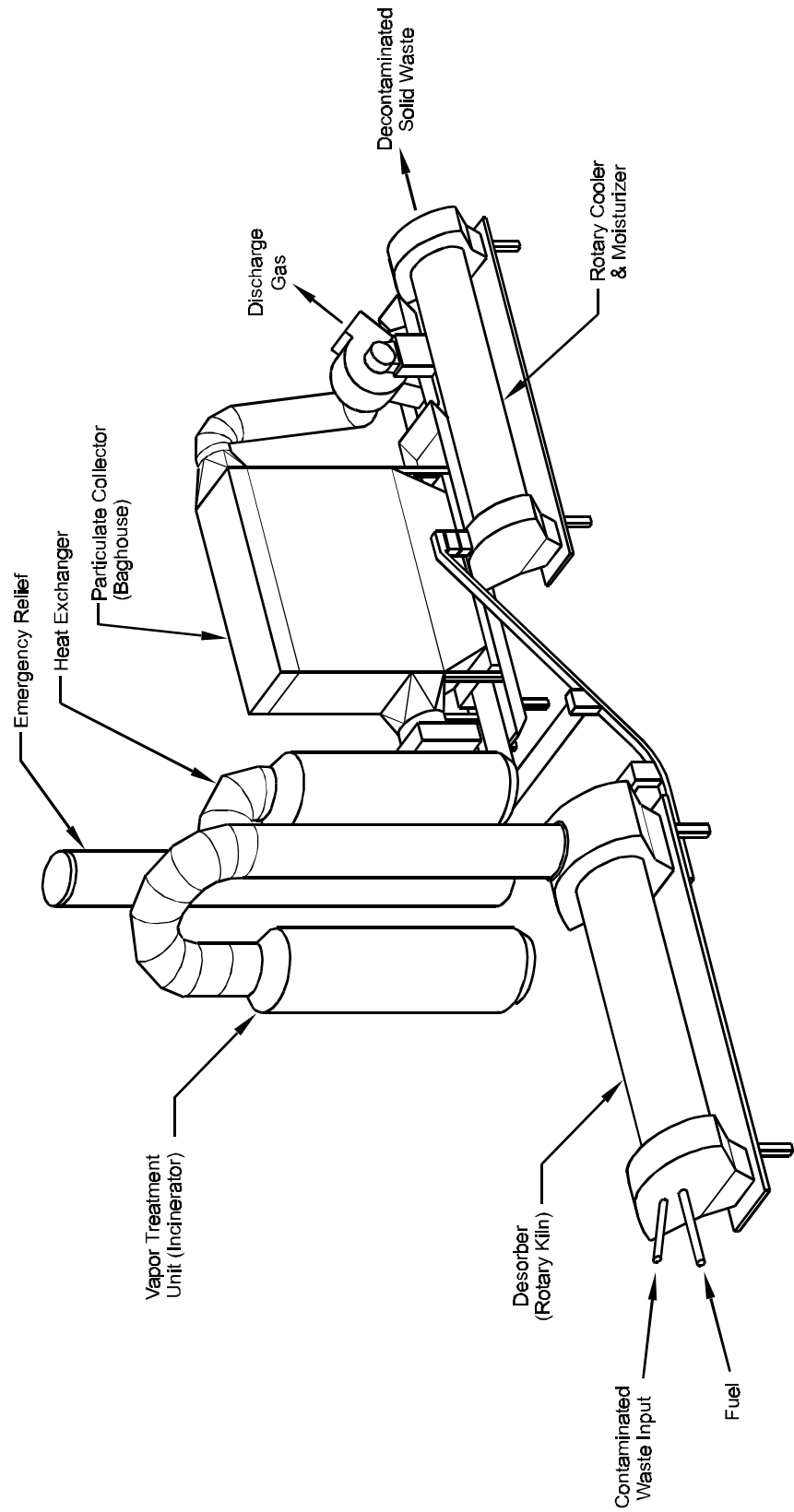
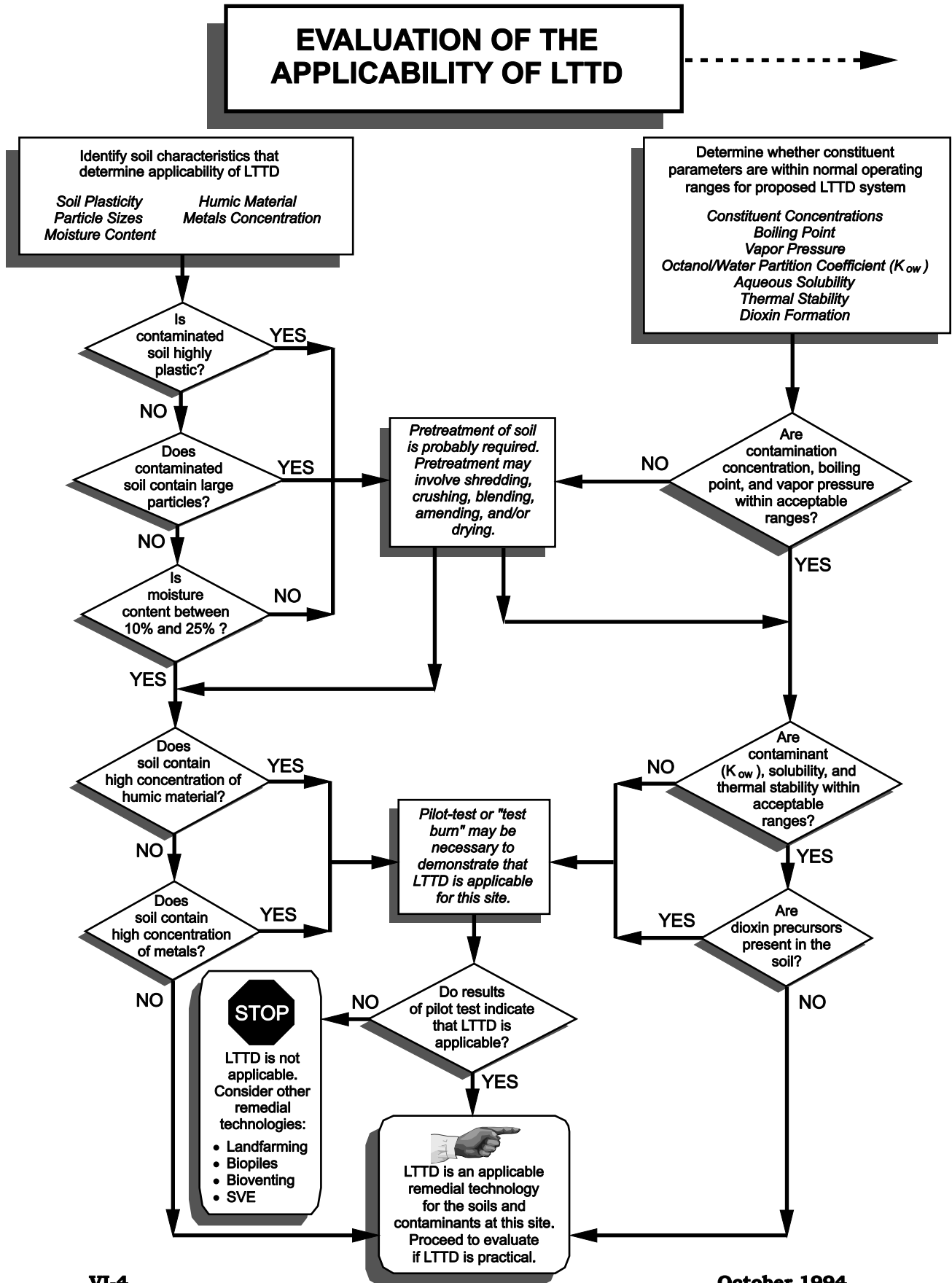


Exhibit VI-2
Advantages And Disadvantages Of LTTD

Advantages	Disadvantages
<ul style="list-style-type: none"> ○ Readily available equipment for onsite or offsite treatment. ○ Very rapid treatment time; most commercial systems capable of over 25 tons per hour throughput. ○ Cost competitive for large volumes (> 1,000 yd³) of soils: \$30-70/ton of contaminated soil, exclusive of excavation and transportation costs. ○ Can be used to mitigate "hot spot" source areas with very high concentrations of petroleum hydrocarbons. ○ Easily combinable with other technologies, such as air sparging or groundwater extraction. ○ Treated soil can be redeposited onsite or used for landfill cover (if permitted by a regulatory agency). ○ Can consistently reduce TPH to below 10 ppm and BTEX below 100 ppb (and sometimes lower). 	<ul style="list-style-type: none"> ○ Requires excavation of soils; generally limited to 25 feet below land surface. ○ Onsite treatment will require significant area (> ½ acre) to locate LTTD unit and store process soils. ○ Offsite treatment will require costly transportation of soils and possibly manifesting. ○ Soils excavated from below the groundwater table require dewatering prior to treatment because of high moisture content.

This chapter will assist you in evaluating a corrective action plan (CAP) which proposes LTTD as a remedy for petroleum-contaminated soil. It is not intended to serve as a guide for designing, operating, monitoring, or permitting thermal desorption systems. Further, LTTD processes generate additional waste streams (e.g., gaseous and/or liquid) that require treatment and typically come under the authority of different regulatory agencies. Desorption units are permitted by these other agencies and must comply with monitoring and treatment requirements that are beyond the purview of most UST programs. The evaluation process is summarized in a flow diagram shown on Exhibit VI-3 and will serve as a roadmap for the decisions you will make during your evaluation. A checklist has also been provided at the end of this chapter to be used as a tool to evaluate the completeness of the CAP

**Exhibit VI-3
Low-Temperature Thermal Desorption Process Flow Chart**



**Exhibit VI-3
Low-Temperature Thermal Desorption Process Flow Chart**

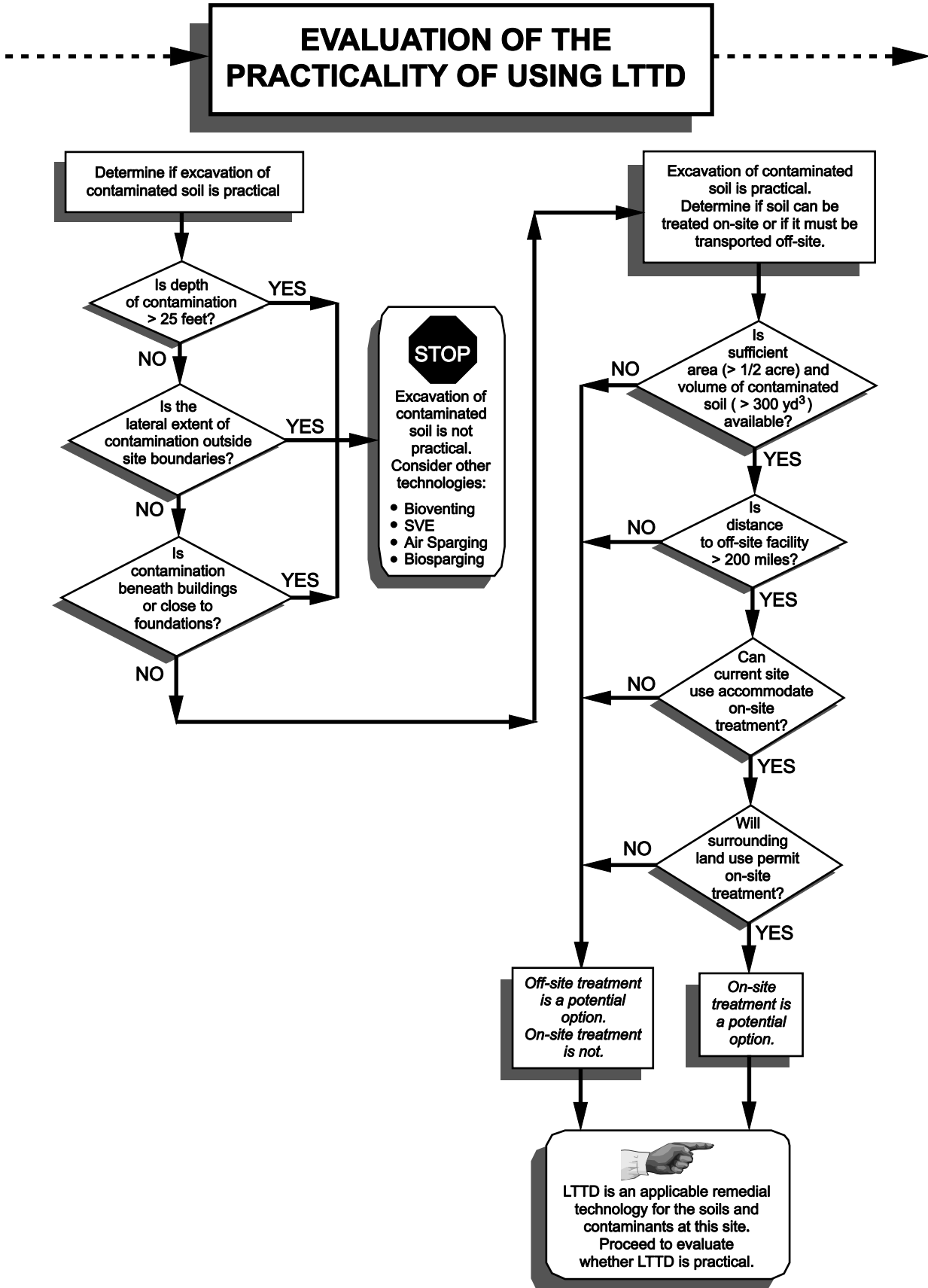
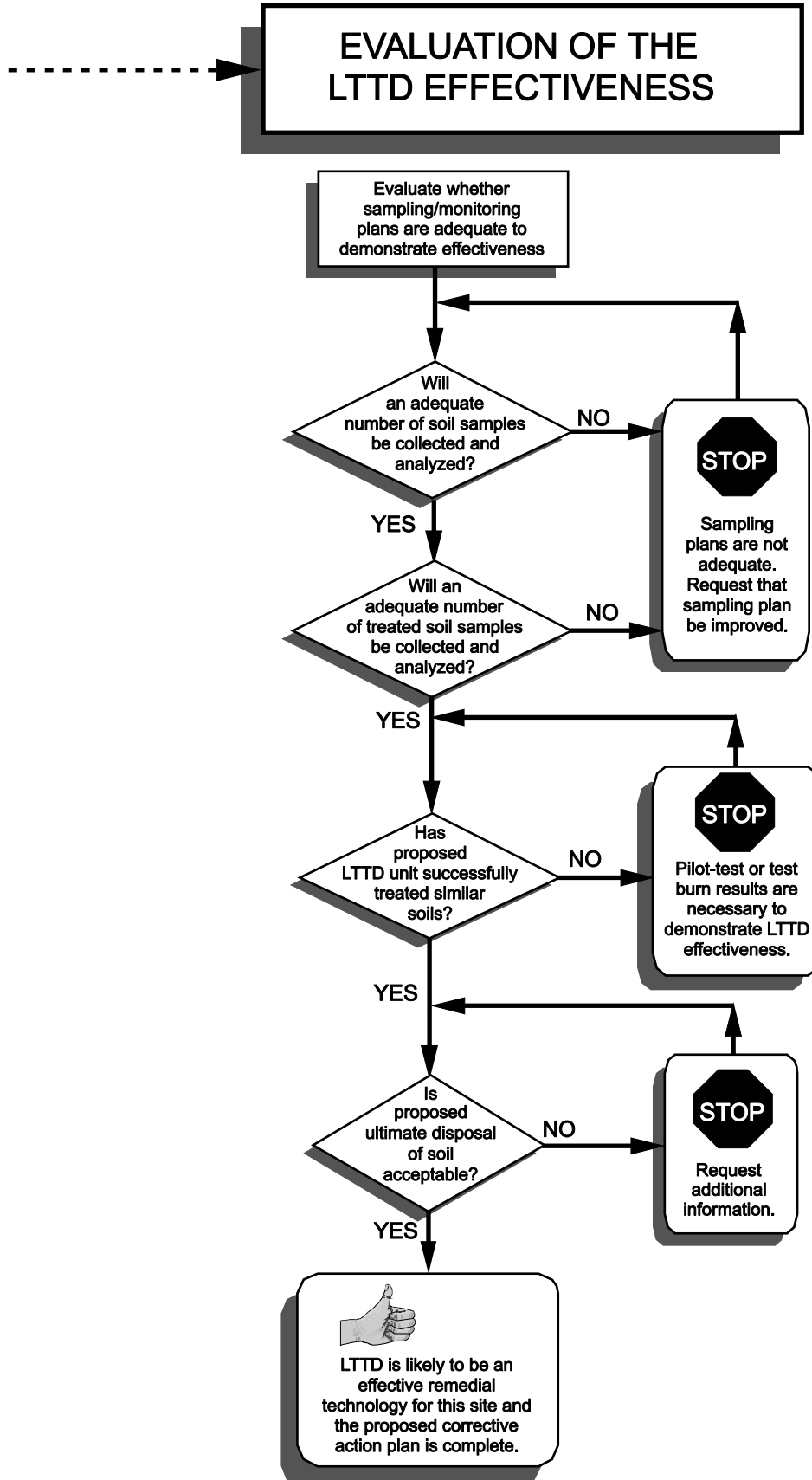


Exhibit VI-3
Low-Temperature Thermal Desorption Process Flow Chart



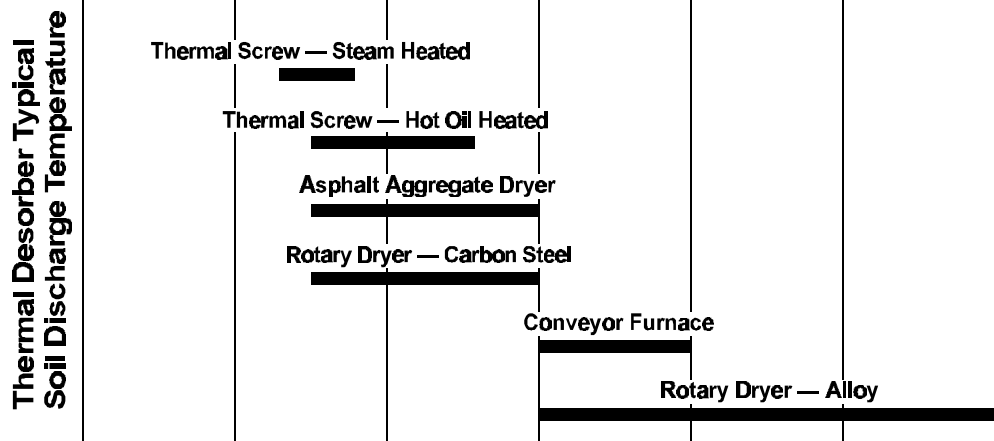
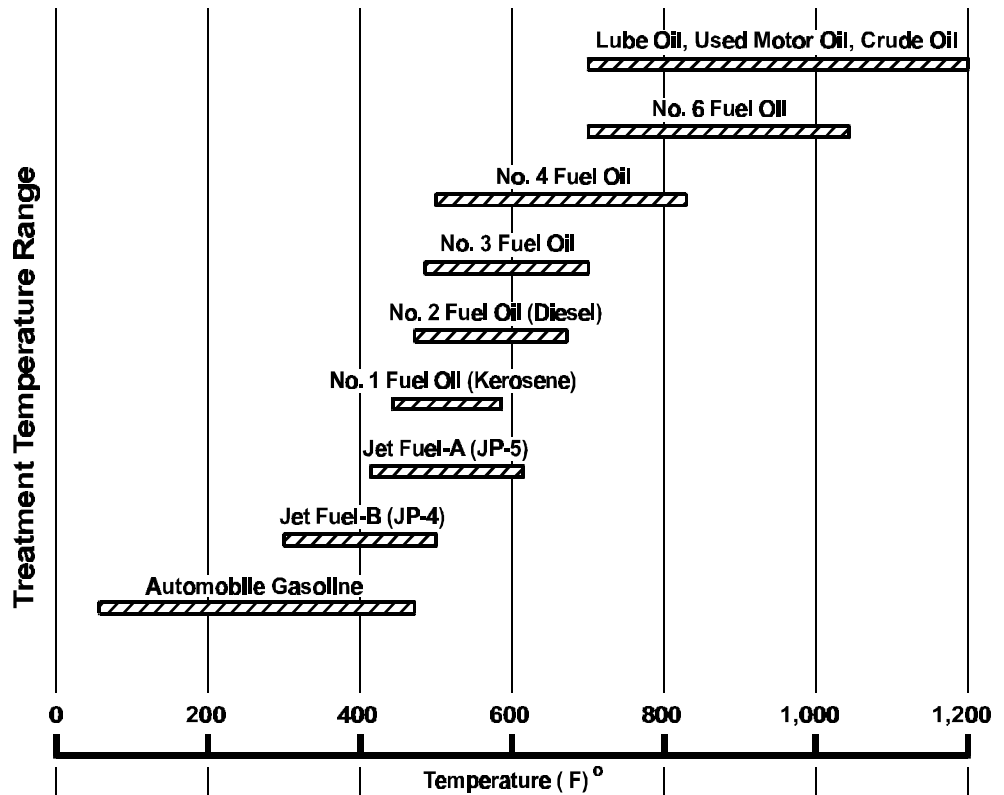
and to help focus attention on areas where additional information may be needed. The evaluation process is divided into the following three steps:

- **Step 1: An evaluation of the applicability of LTTD.** Factors that influence the applicability of thermal desorption include physical and chemical properties of the soil and constituents present at the site, and the process operating conditions of the desorption system. To complete the evaluation, you will need to verify that these properties are within the range of LTTD effectiveness. Pre- and post-treatment of the soil should also be considered. If factors are outside the demonstrated range of LTTD effectiveness, then pilot studies (e.g. test burns) may be appropriate to verify that LTTD will be effective.
- **Step 2: An evaluation of the practicality of using LTTD.** Determination of the practicality of using thermal desorption depends upon site-specific factors such as volume of contaminated soil, horizontal and vertical extent of contamination, site area, site usage and surrounding land use. In addition, desorption process parameters (e.g., soil processing rate, mobile vs stationary unit) and target residual levels should also be considered. Other considerations include economic factors and disposition of treated soils.
- **Step 3: An evaluation of LTTD effectiveness.** The effectiveness of LTTD treatment systems may be evaluated by either (1) calculating the percent reduction in constituent concentrations by comparing the pre- and post-treatment levels in the soil or, (2) determining if residual contaminant levels are at or below regulatory limits. Monitoring plans should specify an adequate number of samples of treated soil to be analyzed.

Evaluation Of The Applicability Of LTTD

This section defines the key parameters that should be used to decide whether LTTD will be a viable remedy for a particular site. In order to determine if LTTD is an applicable remedial alternative, factors to be considered include the characteristics of the soil and constituents present at the site, as well as the LTTD process operating conditions. Thermal desorption is applicable to a wide range of organic constituents, including most petroleum hydrocarbon fuels (Exhibit VI-4). Specific soil and constituent characteristics that influence the applicability of LTTD are summarized in Exhibit VI-5.

**Exhibit VI-4
Recommended Treatment Temperatures For Selected Petroleum Products**



Legend

- Recommended Product Treatment Temperature Range
- Typical Thermal Desorber Soil Discharge Temperature

Exhibit VI-5	
Key Soil And Constituent Characteristics That Influence Applicability Of LTTD	
Soil Characteristics	Constituent Characteristics
Soil plasticity	Contaminant concentrations
Particle size distribution	Boiling point range
Moisture content	Vapor pressure
Heat capacity	Octanol/water partition coefficient
Concentration of humic material	Aqueous solubility
Metals concentration	Thermal stability
Bulk density	Dioxin formation

The remainder of this section describes each of these parameters, why each is important to LTTD, how each can be determined, and the range of each parameter considered appropriate for LTTD.

Soil Characteristics

Essentially all soil types are amenable for treatment by LTTD systems. However, different soils may require varying degrees and types of pretreatment. For example, coarse-grained soils (e.g., gravel and cobbles) may require crushing; fine-grained soils that are excessively cohesive (e.g., clay) may require shredding.

Soil Plasticity

The plasticity of the soil is a measure of its ability to deform without shearing and is to some extent a function of water content. Plastic soils tend to stick to screens and other equipment, and agglomerate into large clumps. In addition to slowing down the feed rate, plastic soils are difficult to treat. Heating plastic soils requires higher temperatures because of the low surface area to volume ratio and increased moisture content. Also, because plastic soils tend to be very fine-grained, organic compounds tend to be tightly sorbed. Thermal treatment of highly plastic soils requires pretreatment, such as shredding or blending with more friable soils or other amendments (e.g., gypsum).

Plasticity characteristics are formally measured using a set of parameters known as Atterberg Limits. Atterberg Limits are defined as the moisture contents which define a soil's liquid limit, plastic limit, and sticky limit. The range of water content where the soil is in a plastic state is defined as the plasticity index.

The plasticity index is the difference between the soil's liquid and plastic limits, and indicates the range of water content through which the soil remains plastic. Thus, the greater the plastic index, the more likely the soil will clump. In general, clumping is most likely for silt and clay soils.

From a practical standpoint, formal determination of a soil's plasticity index is unnecessary. One of the first stages in the LTTD treatment train is screening to remove material larger than about 2 inches in diameter. Desorption unit operators will take the steps necessary to ensure that the soils will move freely through the treatment process, whether this requires shredding, blending, or amending. If the soils are to be blended, the characteristics of the blending stock should be determined to ensure that no contaminants are present that could adversely affect treatment of the soils excavated from the UST site.

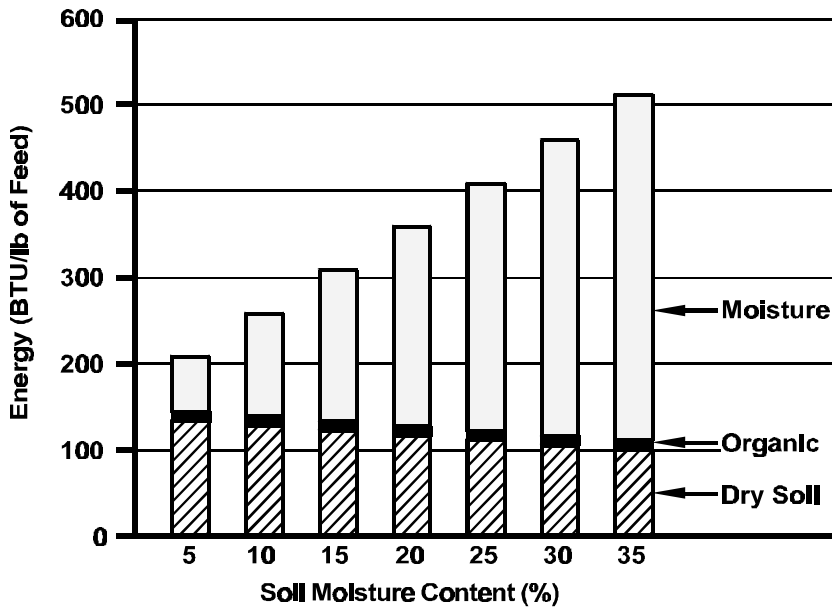
Particle Size Distribution

Particle size distribution is important for proper selection of the type of thermal desorber and pretreatment process to be used. Material larger than 2 inches in diameter will need to be crushed or removed. Crushed material is recycled back into the feed to be processed. Coarser-grained soils tend to be free-flowing and do not agglomerate into clumps. They typically do not retain excessive moisture, therefore, contaminants are easily desorbed. Finer-grained soils tend to retain soil moisture and agglomerate into clumps. When dry, they may yield large amounts of particulates that may require recycling after being intercepted in the baghouse. Other consequences of fine-grained soils are discussed under Soil Plasticity and Moisture Content.

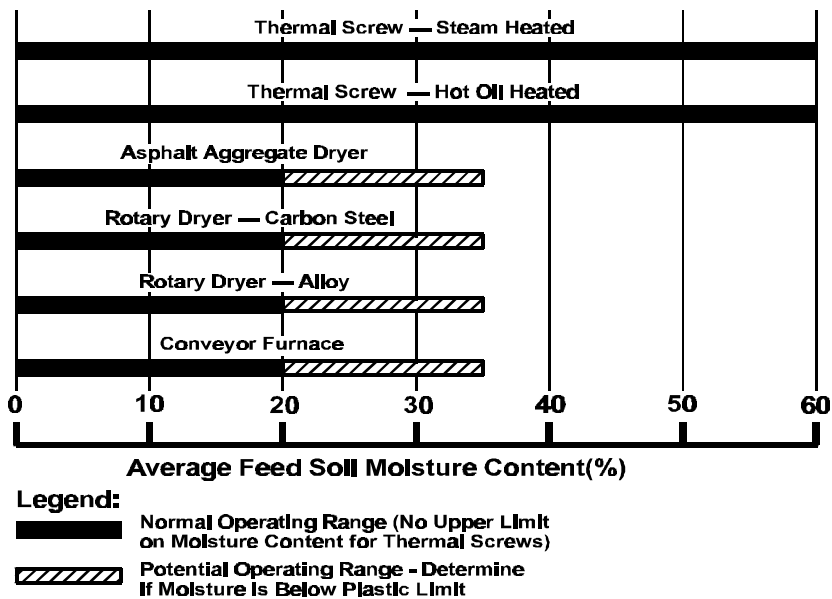
Moisture Content

The solids processing capacity of a thermal desorption system is inversely proportional to the moisture content of the feed material. The presence of moisture in the excavated soils to be treated in the LTTD unit will determine the residence time required and heating requirements for effective removal of contaminants. In order for desorption of petroleum constituents to occur, most of the soil moisture must be evaporated in the desorber. This process can require significant additional thermal input to the desorber and excessive residence time for the soil in the desorber (Exhibit VI-6). In general, soil moisture content ranges from 5 to 35 percent. Exhibit VI-7 shows the applicability of various LTTD system configurations for various soil moisture ranges. For LTTD treatment, the optimal soil moisture range is from 10 to 25 percent. For moisture content above 10 percent by weight,

**Exhibit VI-6
Energy Demand Versus Soil Moisture Content**



**Exhibit VI-7
Feed Soil Moisture Content Limits**



moisture is the major heat sink in the system. Moisture content also influences plasticity which affects handling of the soil. Soils with excessive moisture content (> 20 percent) must be dewatered. Typical dewatering methods include air drying (if storage space is available to spread the soils), mixing with drier soils, or mechanical dewatering. For example, if 10 feet of soil will be excavated, including 1 foot in the capillary fringe, and 9 feet of drier soil, the excavated soils when mixed would likely be suitable for LTTD.

If soils located beneath the water table or those with moisture contents greater than 20 to 35 percent are proposed for treatment by LTTD, you should verify that dewatering is planned. If the soil is to be mixed with drier soils there needs to be a sufficient volume of this material available to produce a mixture with an acceptable moisture level.

Heat Capacity

Heat capacity of soil partially determines the amount of heat that must be transferred to raise the temperature of the soil sufficiently to volatilize the organic contaminants. However, since the typical range in heat capacity values of various soils is relatively small, variations are not likely to have a major impact on application of thermal desorption processes.

Concentration Of Humic Material

Humic material is composed of organic material formed by the decay of vegetation. Humic material is found in high concentrations in peat and other highly organic soils. The presence of humic material can cause analytical interferences, yielding a false positive indication of the presence of TPH or BTEX. Organic material in soil also enhances the adsorption of certain organic compounds, making desorption more difficult.

Metals Concentration

In the past, various lead compounds (e.g., tetraethyl lead) were commonly used as fuel additives to boost the octane rating in gasoline. Although the use of lead has been discontinued, sites of older spills may have relatively high lead concentrations in the soil. The presence of metals in soil can have two implications: (1) limitations on disposal of the solid wastes generated by desorption, and (2) attention to air pollution control regulations that limit the amount of metals that may be released in stack emissions. At normal LTTD operating temperatures, heavy metals are not likely to be significantly separated from soils.

Bulk Density

Bulk density is required to estimate the mass of contaminated soil from the volume of soil excavated. The typical *in situ* (bank) bulk density range is 80-120 lb/ft³. *Ex situ* (excavated) soil bulk density ranges from 75 to 90 percent of the *in situ* bulk density.

Constituent Characteristics

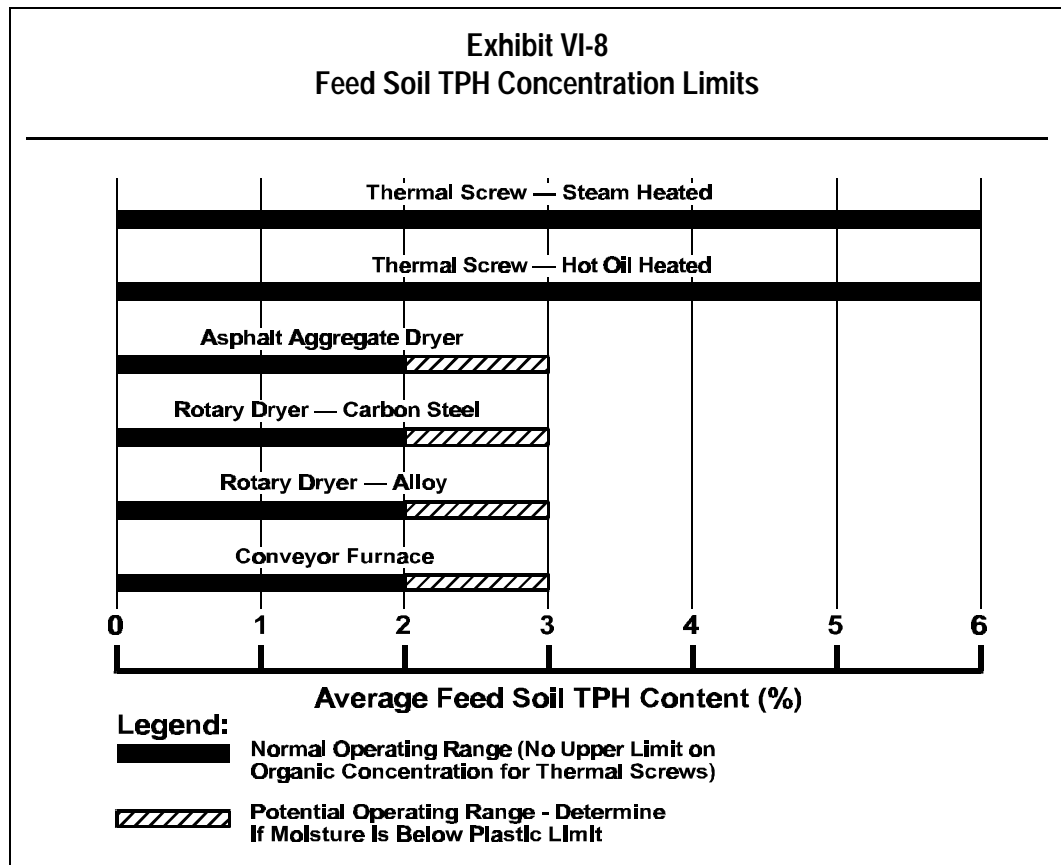
The concentrations and characteristics of constituents are the key parameters to be evaluated during screening studies to evaluate the potential use of thermal desorption processes. The thermal treatment contractor will want to know the concentration of total petroleum hydrocarbons (TPH) in the soil. A number of state and local regulatory agencies require testing of the soils for other specific hazardous characteristics. The following analyses may be required to be conducted during screening studies:

- Benzene, toluene, ethylbenzene, xylenes (BTEX)
- Total organic halides (TOX)
- Toxicity Characteristic Leaching Procedure (TCLP) for volatiles, semivolatiles, and metals
- Total metals
- Polychlorinated biphenyls (PCBs)
- Ignitability
- Corrosivity
- Reactivity

Constituent Concentrations

Constituent concentrations have several impacts on the thermal desorption process. The selection of the appropriate LTTD process configuration is dependent to some extent on constituent concentrations because they influence the soil treatment temperature and residence time required to meet soil cleanup criteria. Each petroleum product possesses a heating value that is a measure of the amount of thermal energy that will be released when the product is burned. High concentrations of petroleum products in soil can result in high soil heating values. Heat released from soils can result in overheating and damage to the desorber. Soils with heating values > 2,000 Btu/lb require blending with cleaner soils to dilute the high concentration of hydrocarbons. High hydrocarbon concentrations in the offgas may exceed the thermal capacity of the afterburner and potentially result in the release of untreated vapors into the atmosphere.

Excessive constituent levels in soil could also potentially result in the generation of vapors in the desorber at concentrations exceeding the lower explosive limit (LEL). The LEL for most organics is generally 1-5 percent by volume. For safety reasons, the concentration of organic compounds in the exhaust gas of a thermal desorption device operating in an oxygen-rich environment should be limited to < 25 percent of the lower explosive limit. For directly heated rotary dryers, the maximum concentration of TPH in feed material that can be treated without exceeding the lower explosive limits is generally in the range of 1-3 percent. If the organic content exceeds 3 percent, the soil must be blended with soil that has a lower organics content to avoid exceeding the LEL. Systems that operate in an inert atmosphere (e.g., thermal screws) do not have limitations on the concentration of organics that can be processed. In an inert atmosphere, the concentration of oxygen is too low (< 2 percent by volume) to support combustion. Exhibit VI-8 shows feed soil TPH concentration limits for various LTTD system configurations.



Boiling Point Range

Petroleum products are often classified by their boiling point ranges. Because the boiling point of a compound is a measure of its volatility, the applicability of LTTD at a site can be estimated from the boiling point range of the petroleum product present. In general, most petroleum-related organics are capable of removal by LTTD, but higher molecular weight (and higher boiling point) constituents require longer residence time in the desorber and higher desorber operating temperatures. Heavier products tend to break down before volatilizing, or they may form non-toxic wax-like compounds that do not volatilize. The boiling point ranges for common petroleum products are shown in Exhibit VI-9.

Exhibit VI-9 Petroleum Product Boiling Ranges		
Product	Boiling Range (°C)	Boiling Range (°F)
Gasoline	40 to 225	104 to 437
Kerosene	180 to 300	356 to 572
Diesel fuel	200 to 338	392 to 640
Heating oil	> 275	> 527
Lubricating oils	Nonvolatile	Nonvolatile

Most desorbers operate at temperatures between 300°F-1,000°F. Desorbers constructed of special alloys can operate at temperatures up to 1,200°F. More volatile products (e.g., gasoline) can be desorbed at the lower operating range, while semivolatile products (e.g., kerosene, diesel fuel) generally require temperatures in excess of 700°F, and relatively nonvolatile products (e.g., heating oil, lubricating oils) require even higher temperatures.

Vapor Pressure

Vapor pressure is the force per unit area exerted by a vapor in an equilibrium state with its pure solid, liquid, or solution at a given temperature. Along with boiling point, vapor pressure is used to measure a compound's volatility. Vapor pressure influences the rate of thermal desorption and increases exponentially with an increase in temperature. Therefore, modest increases in desorption temperature result in large increases in the rate of desorption.

Octanol/Water Partition Coefficient (K_{ow})

The octanol/water partition coefficient (K_{ow}) represents the ratio of the solubility of a compound in octanol (a non-polar solvent) to its solubility in water (a polar solvent). The higher the K_{ow} , the more non-polar the compound. Log K_{ow} is generally used as a relative indicator of the tendency of an organic compound to adsorb to soil. Log K_{ow} values are generally inversely related to aqueous solubility and directly proportional to molecular weight. Compounds with high Log K_{ow} values tend to remain sorbed to soil for a long period of time and are more difficult to desorb than compounds with low values.

Aqueous Solubility

Aqueous solubility is a measure of the extent to which a compound will dissolve in water. Solubility is generally inversely related to molecular weight: the higher the molecular weight, the lower the solubility. Compounds with higher molecular weight are also generally more difficult to desorb from soil than are compounds with lower molecular weight.

Thermal Stability

Petroleum hydrocarbons are not expected to significantly decompose/combust in LTTD units, provided that the offgas temperature is below the temperature at which a compound will spontaneously combust (the autoignition temperature). Autoignition temperature is, therefore, an indicator of the thermal stability of petroleum hydrocarbons, and the degree of thermal decomposition is related to the maximum temperature exposure.

Dioxin Formation

Dioxins can be formed from the thermal destruction of PCBs and other chlorinated compounds. The petroleum hydrocarbons typically present at UST sites do not contain PCBs; therefore, formation of dioxins is usually not of concern. Waste oils that contain chlorinated hydrocarbons may, however, be potential precursors of dioxins. Soils from waste oil spills should be analyzed for PCBs and other chlorinated hydrocarbons.

Process Operating Conditions

Process operating conditions are dependent upon the type of thermal desorption system and vary over a wide range. Each system configuration has its own advantages and disadvantages, and each is

applicable for treatment of specific ranges of constituents (Exhibit VI-10). LTTD systems vary in the manner in which the soils are transported through the desorber, the method used to heat the soils; the temperature at which the desorber operates; the time required to treat the soils; and the offgas treatment method used to control emissions.

Types Of Low-Temperature Thermal Desorption Systems

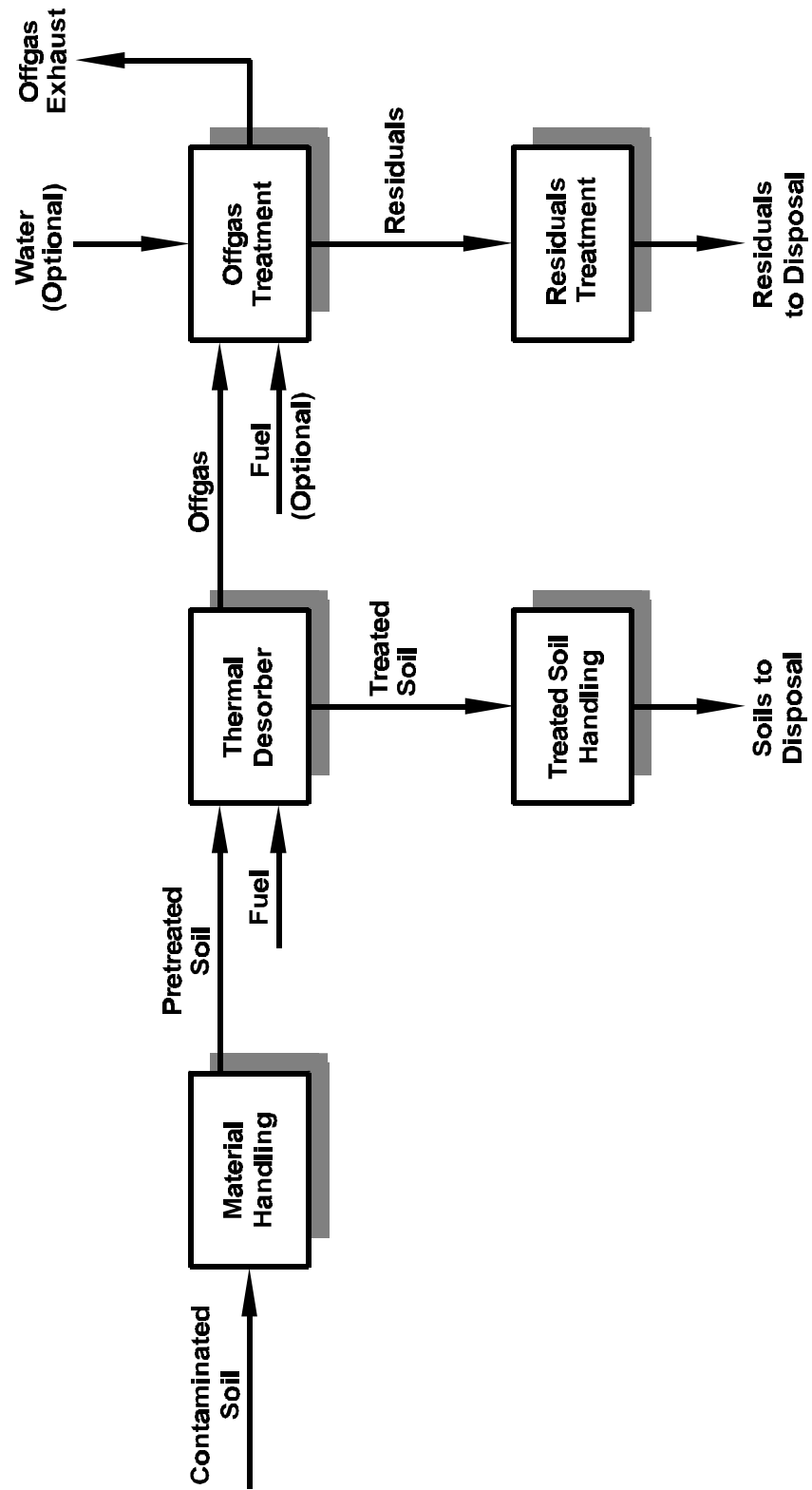
The term thermal desorber describes the primary treatment operation that heats petroleum-contaminated materials and desorbs organic materials into a purge gas. Mechanical design features and process operating conditions vary considerably among the various types of LTTD systems. Desorption units are available in the following configurations: rotary dryer, asphalt plant aggregate dryer, thermal screw, and conveyor furnace. Systems may either be stationary facilities or mobile units. Contaminated soils are excavated and transported to stationary facilities, while mobile units can be operated directly on the site of the contaminated soil.

Although all LTTD systems use heat to separate (desorb) organic contaminants from the soil matrix, each system has a different configuration with its own set of advantages and disadvantages. The decision to use one system over another depends on the nature of the contaminants as well as machine availability, system performance, and economic considerations. System performance may be evaluated on the basis of pilot tests (e.g., test burns) or examination of historical machine performance records. Pilot tests to develop treatment conditions are generally not necessary for petroleum-contaminated soils.

Mechanical design features and process operating conditions vary among the different types of LTTD systems. The four systems mentioned above are briefly described below, and the advantages and disadvantages of each are listed.

Rotary Dryers. Rotary dryer systems use a cylindrical metal reactor (drum) that is inclined slightly from the horizontal. A burner located at one end provides heat to raise the temperature of the soil sufficiently to desorb organic contaminants. The flow of soil may be either cocurrent with or countercurrent to the direction of the purge gas flow. As the drum rotates, soil is conveyed through the drum. Lifters raise the soil, carrying it to near the top of the drum before allowing it to fall through the heated purge gas. Mixing in a rotary dryer enhances heat transfer by convection and allow soils to be rapidly heated. Rotary desorber units are manufactured for a wide range of treatment capacities; these units may be either stationary or mobile.

Exhibit VI-10
Thermal Desorption System Schematic Design



The maximum soil temperature that can be obtained in a rotary dryer depends on the composition of the dryer shell. The soil discharge temperature of carbon steel drums is typically 300°-600° F. Alloy drums are available that can increase the soil discharge temperature to 1,200° F. Most rotary dryers that are used to treat petroleum contaminated soil are made of carbon steel. After the treated soil exits the rotary dryer, it enters a cooling conveyor where water is sprayed on the soil for cooling and dust control. Water addition may be conducted in either a screw conveyor or a pugmill.

Besides the direction of purge gas flow relative to soil feed direction, there is one major difference in configuration between countercurrent and cocurrent rotary dryers. The purge gas from a countercurrent rotary dryer is typically only 350°F-500°F and does not require cooling before entering the baghouse where fine particles are trapped. A disadvantage is that these particles may not have been decontaminated and are typically recycled to the dryer. Countercurrent dryers have several advantages over cocurrent systems. They are more efficient in transferring heat from purge gas to contaminated soil, and the volume and temperature of exit gas are lower, allowing the gas to go directly to a baghouse without needing to be cooled. The cooler exit gas temperature and smaller volume eliminates the need for a cooling unit, which allows downstream processing equipment to be smaller. Countercurrent systems are effective on petroleum products with molecular weights lower than No.2 fuel oil.

In cocurrent systems, the purge gas is 50°-100°F hotter than the soil discharge temperature. The result is that the purge gas exit temperature may range from 400°-1,000°F and cannot go directly to the baghouse. Purge gas first enters an afterburner to decontaminate the fine particles, then goes into a cooling unit prior to introduction into the baghouse. Because of the higher temperature and volume of the purge gas, the baghouse and all other downstream processing equipment must be larger than in a countercurrent system. Cocurrent systems do have several advantages over countercurrent systems. The afterburner is located upstream of the baghouse ensuring that fine particles are decontaminated. In addition, because the heated purge gas is introduced at the same end of the drum as the feed soil, the soil is heated faster, resulting in a longer residence time. Higher temperatures and longer residence time mean that cocurrent systems can be used to treat soils contaminated with heavier petroleum products. Cocurrent systems are effective for light and heavy petroleum products including No. 6 fuel oil, crude oil, motor oil, and lubricating oil.

Asphalt Plant Aggregate Dryers. Hot-mix asphalt plants use aggregate that has been processed in a dryer before it is mixed with liquid asphalt. The use of petroleum contaminated soils for aggregate material is widespread. Aggregate dryers may either be stationary or mobile. Soil treatment capacities range from 25-150 tons per hour. The soil may be incorporated into the asphalt as a recycling process or the treated soil may be used for other purposes.

Asphalt rotary dryers are normally constructed of carbon steel and have a soil discharge temperature of 300°-600°F. Typically, asphalt plant aggregate dryers are identical to countercurrent rotary desorbers described above and are effective on the same types of contaminants. The primary difference is that an afterburner is not required for incorporation of clean aggregate into the asphalt mix. In some areas, asphalt plants that use petroleum contaminated soil for aggregate may be required to be equipped with an afterburner.

Thermal Screws. A thermal screw desorber typically consists of a series of 1-4 augers. The auger system conveys, mixes, and heats contaminated soils to volatilize moisture and organic contaminants into a purge gas stream. Augers can be arranged in series to increase the soil residence time, or they can be configured in parallel to increase throughput capacity. Most thermal screw systems circulate a hot heat-transfer oil through the hollow flights of the auger and return the hot oil through the shaft to the heat transfer fluid heating system. The heated oil is also circulated through the jacketed trough in which each auger rotates. Thermal screws can also be steam-heated. Systems heated with oil can achieve soil temperatures of up to 500°F, and steam-heated systems can heat soil to approximately 350°F.

Most of the gas generated during heating of the heat-transfer oil does not come into contact the waste material and can be discharged directly to the atmosphere without emission controls. The remainder of the flue gas maintains the thermal screw purge gas exit temperature above 300°F. This ensures that volatilized organics and moisture do not condense. In addition, the recycled flue gas has a low oxygen content (< 2 percent by volume) which minimizes oxidation of the organics and reduces the explosion hazard. If pretreatment analytical data indicates a high organic content (> 4 percent), use of a thermal screw is recommended. After the treated soil exits the thermal screw, water is sprayed on the soil for cooling and dust control. Thermal screws are available with soil treatment capacities ranging from 3-15 tons per hour.

Since thermal screws are indirectly heated, the volume of purge gas from the primary thermal treatment unit is less than one half of the volume from a directly-heated system with an equivalent soil processing capacity. Therefore, offgas treatment systems consist of relatively small unit operations that are well suited to mobile applications. Indirect heating also allows thermal screws to process materials with high organic contents since the recycled flue gas is inert, thereby reducing the explosion hazard.

Conveyor Furnace. A conveyor furnace uses a flexible metal belt to convey soil through the primary heating chamber. A one-inch-deep layer of soil is spread evenly over the belt. As the belt moves through the system, soil agitators lift the belt and turn the soil to enhance heat transfer and volatilization of organics. The conveyor furnace can heat soils to temperatures from 300°-800°F. At the higher temperature range, the conveyor furnace is more effective in treating some heavier petroleum hydrocarbons than are oil or steam-heated thermal screws, asphalt plant aggregate dryers, and carbon steel rotary dryers. After the treated soil exits the conveyor furnace, it is sprayed with water for cooling and dust control. As of February, 1993, only one conveyor furnace system was currently in use for the remediation of petroleum contaminated soil. This system is mobile and can treat 5-10 tons of soil per hour.

OffGas Treatment

Treatment systems for LTDD system offgas are designed to address three types of air pollutants: particulates, organic vapors, and carbon monoxide. Particulates are controlled with both wet (e.g., venturi scrubbers) and dry (e.g., cyclones, baghouses) unit operations. Rotary dryers and asphalt aggregate dryers most commonly use dry gas cleaning unit operations. Cyclones are used to capture large particulates and reduce the particulate load to the baghouse. Baghouses are used as the final particulate control device. Thermal screw systems typically use a venturi scrubber as the primary particulate control.

The control of organic vapors is achieved by either destruction or collection. Afterburners are used downstream of rotary dryers and conveyor furnaces to destroy organic contaminants and oxidize carbon monoxide. Conventional afterburners are designed so that exit gas temperatures reach 1,400°-1,600°F. Organic destruction efficiency typically ranges from 95 to > 99 percent.

Condensers and activated carbon may also be used to treat the offgas from thermal screw systems. Condensers may be either water-cooled or electrically-cooled systems to decrease offgas temperatures to 100° - 140°F. The efficiency of condensers for removing organic compounds ranges from 50 to > 95 percent. Noncondensable gases exiting the condenser are normally treated by a vapor-phase activated carbon treatment system. The efficiency of activated carbon adsorption systems for removing organic contaminants ranges from 50-99 percent. Condensate from the condenser is processed through a phase separator where the non-aqueous phase organic component is separated and disposed of or recycled. The remaining water is then processed through activated carbon and used to rehumidify treated soil.

Treatment Temperature

Treatment temperature is a key parameter affecting the degree of treatment of organic components. The required treatment temperature depends upon the specific types of petroleum contamination in the soil. Exhibit VI-4 illustrates the recommended treatment temperatures for various petroleum products and the operating temperature ranges for various LTTD systems. The actual temperature achieved by an LTTD system is a function of the moisture content and heat capacity of the soil, soil particle size, and the heat transfer and mixing characteristics of the thermal desorber.

Residence Time

Residence time is a key parameter affecting the degree to which decontamination is achievable. Residence time depends upon the design and operation of the system, characteristics of the contaminants and the soil, and the degree of treatment required.

Pilot Testing

The requirement for pilot testing of petroleum-contaminated soils, in which a quantity of soil from the site is processed through the LTTD system (a "test burn"), is specified by state and local regulations. The results of preliminary testing of soil samples should identify the relevant constituent properties, and examination of the machine's performance records should indicate how effective the system will be in treating the soil. However, it should be noted that the proven effectiveness of a particular system for a specific site or waste does not ensure that it will be effective at all sites or that the treatment efficiencies achieved will be acceptable at other sites. If a test burn is conducted, it is important to

ensure that the soil tested is representative of average conditions and that enough samples are analyzed before and after treatment to confidently determine whether LTTD will be effective.

Determination Of The Practicality Of Using LTTD

This section identifies the factors that determine whether LTTD is a practical remedial alternative. While many of these factors are dependent upon site-specific characteristics (e.g., the location and volume of contaminated soils, site layout), practicality is also determined by regulatory, logistical, and economic considerations. The economics of LTTD as a remedial option are highly site-specific. Economic factors include site usage (because excavation and onsite soil treatment at a retail site (e.g., gasoline station, convenience store) will most likely prevent the business from operating for an extended period of time), the cost of LTTD per unit volume of soil relative to other remedial options, and the location of the nearest applicable LTTD system (because transportation costs are a function of distance). Further discussion of the economics of LTTD use is beyond the scope of this manual.

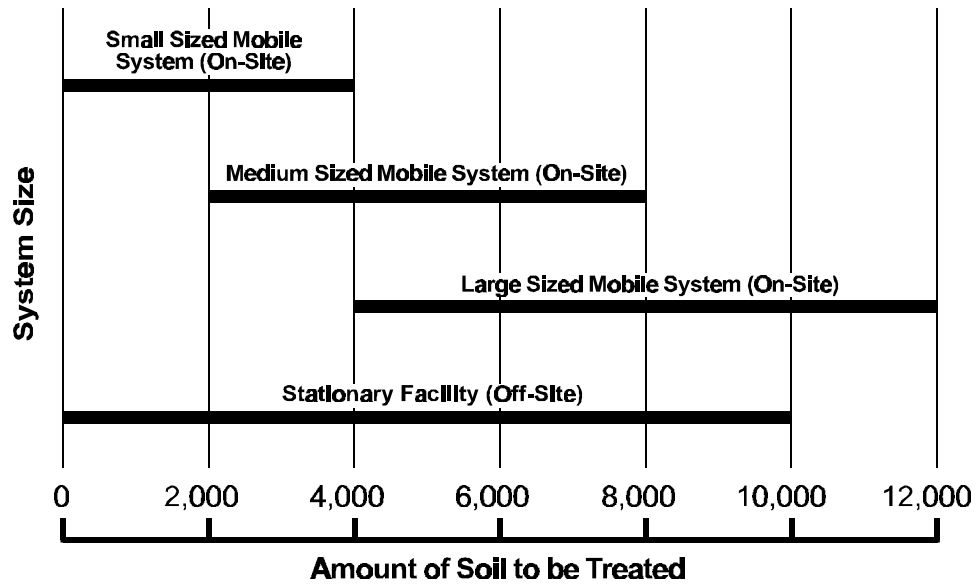
Vertical And Horizontal Extent Of Contamination

Because soils to be treated in an LTTD unit must be excavated, their location must be suitable for removal by excavation techniques. Soils that are located more than 25 feet below the land surface cannot be removed by conventional equipment. In addition, soils that are located beneath a building or near building foundations cannot be excavated without removal of the building itself. In addition, as mentioned previously, soils located beneath the groundwater table can be excavated but generally cannot be treated in the LTTD unit unless dried, dewatered, or blended with other soils to reduce moisture content.

You should identify the location of the proposed excavation and verify that soils to be excavated are less than 25 feet below land surface, above the water table, and not beneath or near buildings or other structures.

The vertical and horizontal extent of contamination determines the volume of soil that must be treated. The cost of remediation and time required for processing is directly proportional to the volume of contaminated soil to be treated. Volume also determines whether onsite treatment is viable. A small mobile LTTD system with a throughput capacity of 5 to 15 tons per hour may be able to stockpile materials and operate in an area as small as $\frac{1}{4}$ acre. Exhibit VI-11 shows the relationship between thermal desorber size and the amount of soil to be treated.

**Exhibit VI-11
Thermal Desorption Size Versus Amount Of Soil To Be Treated**



	System Type			
	Small Mobile	Medium Mobile	Large Mobile	Stationary Facility
	1 - 2	3 - 6	7 - 10	NA
	5 - 15	15 - 30	30 - 50	30 - 120
	5 - 15 ^a	15 - 30 ^a	30 - 50	30 - 100 ^b
	5 - 15	15 - 30	25 - 100	30 - 300

^a Systems with Condensers do not include Afterburners.

^b Some Fixed Base Asphalt Aggregate Dryers do not include Afterburners.

Site Layout

Site layout factors influence whether excavation of soils is possible at all. If excavation is possible, consideration can be given to whether onsite thermal treatment is a viable option. Site layout factors that must be considered in evaluating onsite thermal desorption treatment include:

- Amount of space available for stockpiling treated and untreated materials and operating process equipment,
- Space required for continuation of daily business, and
- Minimum distances required by fire and safety codes for operating thermal desorption equipment in the vicinity of petroleum storage facilities.

The amount of area available to stockpile soils and operate processing equipment may dictate the maximum size of the treatment system that can be operated at the site. In general, onsite treatment operations will require a minimum of ½ acre. This has further economic implications because the costs associated with LTTD are strongly affected by the physical size and soil processing capacity of the thermal treatment system.

Adjacent Land Use

When land adjacent to an UST site is being used for schools, parks, health care facilities, high-value commercial development, or dense residential development, problems may develop in obtaining permits for the use of onsite thermal desorption. Air discharge restrictions may require the use of expensive control measures that could make onsite treatment economically infeasible. Thermal desorption units are most economical when they are operated on a 24-hour-per-day schedule. However, noise considerations may limit hours of operation in some locations.

Other Considerations

Treatment goals are also important when considering the use of LTTD. For soils contaminated with lighter petroleum hydrocarbons, residual TPH levels can be reduced to 10 ppm or less. Some newer rotary units can consistently achieve TPH levels of < 1 ppm and BTEX levels < 100 ppb. System effectiveness can be evaluated based on the treatment records for a specific machine.

Treated soils are typically disposed of in a landfill, used as cover in landfills, incorporated into asphalt, or returned to the site to backfill the excavation. Final disposition of the soil depends upon the residual levels of contaminants in the treated soil and economic factors such as transportation and disposal costs, as well as costs for clean material to backfill the excavation. It should be noted that treatment processes may alter the physical properties of the material. A thorough geotechnical evaluation of the treated material may be necessary to determine its suitability for use in an engineering application (e.g., road bed, building foundation support, grading and filling).

Evaluation Of The Effectiveness Of LTTD

For sites with petroleum contaminated soils, the primary concern is to reduce the residual concentration of the organic constituents to or below regulatory levels. This criterion applies to both the soil surrounding the excavation and the soil that was excavated and thermally treated. An appropriate number of soil samples should be collected from around the walls and bottom of the excavation. These samples should then be analyzed for the requisite parameters to ensure that all of the soil that must be thermally treated has been excavated.

The effectiveness of an LTTD treatment system may be evaluated by either (1) determining whether residual contaminant levels are at or below regulatory limits or (2) calculating the percent reduction in soil constituent concentrations by comparing pre- and post-treatment levels. Monitoring plans should specify an adequate number of samples of treated soil to be analyzed. A typical sample density is one sample per 100 cubic yards of treated soil. Exhibit VI-12 lists typical monitoring locations and frequency for petroleum contaminated soils treated by LTTD.

Exhibit VI-12 Monitoring Recommendations			
Phase	Frequency	Where To Monitor	What To Monitor
Excavation	At proposed limit of excavation	<input type="radio"/> Excavation walls <input type="radio"/> Excavation floor	<input type="radio"/> TPH, constituents of concern
LTTD treatment	Every 100 cu.yd. of feed soil and treated soil	<input type="radio"/> Feed soil <input type="radio"/> Treated soil	<input type="radio"/> TPH, constituents of concern

Operation of LTTD units requires various permits and demonstration of compliance with permit requirements. Monitoring requirements for LTTD systems are by their nature different from monitoring required at an UST site. Monitoring of LTTD system waste streams (e.g., concentrations of particulates, volatiles, and carbon monoxide in stack gas) are required by the agency(ies) issuing the permits for operation of the facility. Compliance with limits specified by the permits is the responsibility of the LTTD facility owner/operator. Other LTTD system operating parameters (e.g., desorber temperature, soil feed rate, afterburner temperature) are also the responsibility of the LTTD facility owner/operator.

References

U.S. Environmental Protection Agency (EPA). *Low-temperature Thermal Treatment Technology: Applications Analysis Report*. Cincinnati, OH: U.S. EPA, Office of Research and Development. EPA/540/AR-92/019, 1992.

Troxler, W.L., J.J. Cudahy, R.P. Zink, and S.I. Rosenthal. *Thermal Desorption Applications Manual for Treating Nonhazardous Petroleum Contaminated Soils*. Cincinnati, OH: U.S. EPA, Office of Research and Development, 1994.

Anderson, W.C., ed. *Innovative Site Remediation Technology: Thermal Desorption, Volume 6*. Washington, D.C.: U.S. EPA, Office of Solid Waste and Emergency Response. EPA 542-B-93-011, 1993.

Checklist: Can LTTD Be Used At This Site?

This checklist can help you to evaluate the completeness of the CAP and to identify areas that require closer evaluation. As you go through the CAP, answer the following questions.

1. Evaluation Of LTTD Effectiveness

Yes **No**

- Do soils have high plasticity?
- Do soils contain large rocks or debris?
- Is moisture content > 35%?
- Is the TPH concentration > 2% by weight?
- Are hydrocarbons highly volatile?

If the answer to any of the above questions is yes, then the soils require pretreatment.

- Do the soils have a high concentration of humic material?
- Do the soils have a high concentration of heavy metals?
- Are contaminant K_{ow} s relatively high?
- Are dioxin precursors present in the soils?

If the answer to any of the above questions is yes, then a pilot test or "test burn" should be conducted to demonstrate that LTTD is an applicable remedial technology.

- Do the results of the pilot test indicate that LTTD is applicable?

2. Evaluation Of The Practicality Of Using LTTD

Yes No

- Is the depth of contaminated soil 25 feet or less below land surface?
- Is contaminated soil contained within site boundaries?
- Is there no contamination beneath buildings or near building foundations?

If the answer to any of the above questions is no, then excavation of the soil is not practical; therefore, LTTD is not practical. Consider an *in situ* remedial technology instead.

- Is sufficient land area available for operation of equipment and temporary storage (staging) of contaminated soil and treated soil?
- Is the distance to an off-site facility prohibitively far?
- Will surrounding land use permit operation of an onsite system in the neighborhood?

If the answer to any of the above questions is no, then excavated soils must be transported to an off-site facility for treatment.

3. Evaluation Of The Effectiveness Of Using LTTD

Yes No

- Will an adequate number of *in situ* soil samples be collected and analyzed?
- Will an adequate number of treated soil samples be collected and analyzed?

3. Evaluation Of The Effectiveness Of Using LTTD (continued)

Yes No

- | | | |
|--------------------------|--------------------------|---|
| <input type="checkbox"/> | <input type="checkbox"/> | Has the proposed desorption unit successfully treated similar soils with similar contaminant concentration levels? |
| <input type="checkbox"/> | <input type="checkbox"/> | Is the proposed ultimate disposal of the soil (e.g., return to excavation, transport to landfill for cover) acceptable? |

If the answer to any of the above questions is no, then additional information is necessary to evaluate whether LTTD is likely to be an effective remedial technology.