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NFPA 329 Handling Underground Releases of Flammable and Combustible Liquids 1992 Edition

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National Fire Protection Association 1 Batterymarch Park, PO Box 9101, Quincy, MA 02269-9101

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Policy Adopted by NFPA Board of Directors on December 3, 1982

The Board of Directors reaffirms that the National Fire Protection Association recognizes that the toxicity of the products of combustion is an important factor in the loss of life from fire. NFPA has dealt with that subject in its technical committee documents for many years.

There is a concern that the growing use of synthetic materials may produce more or additional toxic products of combustion in a fire environment. The Board has, therefore, asked all NFPA technical committees to review the documents for which they are responsible to be sure that the documents respond to this current concern. To assist the committees in meeting this request, the Board has appointed an advisory committee to provide specific guidance to the technical committees on questions relating to assessing the hazards of the products of combustion.

Statement on NFPA Procedures

This material has been developed under the published procedures of the National Fire Protection Association, which are designed to assure the appointment of technically competent Committees having balanced representation. While these procedures assure the highest degree of care, neither the National Fire Protection Association, its members, nor those participating in its activities accepts any liability resulting from compliance or noncompliance with the provisions given herein, for any restrictions imposed on materials or processes, or for the completeness of the text.

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RP, G-AM-92

NFPA 329

Recommended Practice for

Handling Underground Releases of Flammable and Combustible Liquids

1992 Edition

This edition of NFPA 329, *Recommended Practice for Handling Underground Releases of Flammable and Combustible Liquids*, was prepared by the Technical Committee on Tank Leakage and Repair Safeguards, released by the Correlating Committee on Flammable Liquids, and acted on by the National Fire Protection Association, Inc. at its Annual Meeting held May 18-21, 1992, in New Orleans, LA. It was issued by the Standards Council on July 17, 1992, with an effective date of August 14, 1992, and supersedes all previous editions.

The 1992 edition of this document has been approved by the American National Standards Institute.

Changes other than editorial are indicated by a vertical rule in the margin of the pages on which they appear. These lines are included as an aid to the user in identifying changes from the previous edition.

Origin and Development of NFPA 329

This recommended practice began as a report (NFPA 30B), which was published until 1950. A manual on this subject was published in 1959. The manual was rewritten as a recommended practice in 1964, with subsequent revisions in 1965, 1972, 1977, 1983, 1987, and 1992.

Major changes incorporated in this 1992 edition include:

- A complete revision of Chapter 3, addressing techniques for identifying the source of a release.
- A completely new Chapter 4, "Release Detection for Underground Storage Tank Systems."
- A complete revision of Chapter 5, addressing techniques for tracing the underground flow of released liquids.
- A complete revision of Chapter 6 on the proper removal and disposal of contaminated liquid and groundwater.
- New Appendixes A and B, discussing the basic principles of volumetric and nonvolumetric tightness testing.
- New Appendix C, discussing the basic principles of the flow of liquids underground.

The text of this 1992 edition does not conflict with current U.S. Environmental Protection Agency guidelines for underground storage tank systems.

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Robert P. Benedetti, *Secretary*
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(Nonvoting)

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C. L. Kingsbaker, Atlanta, GA
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Eugene S. Schmitt, Dept. of State Police, MI
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Paul C. Lamb, Englewood, NJ
(Member Emeritus)

Technical Committee on Tank Leakage and Repair Safeguards

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Rep. Leak Detection Technology Assn.
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Rep. American Petroleum Inst.
Thomas Schruben, U.S. EPA, Washington, DC
Todd G. Schwendeman, Groundwater Technology Inc., NY
Bruce R. Sharp, Armor Shield Inc., OH
Robert P. Siegel, 3M Company, MN

Alternate

Tony Rieck, Armor Shield Inc., OH
(Alternate to B. R. Sharp)

Robert P. Benedetti, NFPA Staff Liaison

This list represents the membership at the time the Committee was balloted on the text of this edition. Since that time, changes in the membership may have occurred.

NOTE: Membership on a Committee shall not in and of itself constitute an endorsement of the Association or any document developed by the Committee on which the member serves.

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Recommended Practice for

Handling Underground Releases of Flammable and Combustible Liquids

1992 Edition

NOTICE: Information on referenced publications can be found in Chapter 7 and Appendix E.

Chapter 1 Introduction

1-1 Scope. This recommended practice provides appropriate methods for responding to fire and explosion hazards resulting from an underground release of a flammable or combustible liquid. Although this recommended practice is intended to address only these fire and explosion hazards, it should be recognized that other authorities should be consulted regarding the environmental impact of such releases.

1-2 Purpose. The purpose of this recommended practice is to provide for the safe and efficient handling of flammable or combustible liquids when, for whatever reason, they are found unwanted or unconfined. Options are given for detecting and investigating the source of a release, for mitigating the fire and explosion hazards resulting from the release, and for tracing the released liquid back to its source. These options are not intended to be, nor should they be considered to be, all-inclusive or mandatory in any given situation. If better or more appropriate alternative methods are available, they should be used.

1-3 Caveat. The National Fire Protection Association does not, by the publication of this recommended practice, recommend action that is not in compliance with applicable laws and regulations and should not be considered as doing so. Users of this recommended practice must consult all applicable federal, state, and local laws and regulations.

1-4 The Problem.

1-4.1 Flammable liquids [those having a flash point below 100°F (37.8°C)] and combustible liquids [those having a flash point at or above 100°F (37.8°C)] are used by the millions of gallons daily and, of necessity, are stored and handled in locations immediately adjacent to structures, facilities, and people. These liquids include chemicals, cleaning fluids, motor gasolines, diesel fuel, and heating oils. Motor gasolines are the most widely used of these liquids, and they are commonly stored underground at service stations.

1-4.2 In spite of constant effort to maintain and operate storage and transfer equipment properly, accidents do happen, equipment does fail, and people do make mistakes that sometimes permit the escape of these liquids. Leaks can develop from corrosion or be caused by mechanical damage, or some liquid can be spilled during transfer. Generally, the amount of liquid lost is small and is dissipated by evaporation or is otherwise assimilated before it creates a serious problem. However, it occasionally happens that some flammable or combustible liquid finds its way into an underground facility, such as a basement, utility conduit, sewer, or well. Whether or not it creates an immediate hazard will depend on many things, such as how much liquid or vapor is involved, where it is found, how it is confined, possible sources of ignition, etc. But, because a flammable or combustible liquid unconfined in the ground can move from place to place, any indication that such liquids have escaped into the ground must be considered as a potential, if not immediate, hazard.

1-5 Cooperation and Responsibility.

1-5.1 The responsibility for proper handling of a suspected escape of flammable or combustible liquids, or a potential hazard from such an escape, will fall on various individuals and organizations. The successful handling of these problems will depend on the best possible cooperation between them.

1-5.2 One of the prime purposes of this recommended practice is to provide a basis for this cooperation. Because of the almost infinite number of variables involved, it can't be a rule book in the strict sense of the word. It can, however, provide a definite course of cooperative action that will ensure the most effective use of skills and equipment and the fairest assessment of responsibility and will result in the best possible protection of life and property. A positive, cooperative attitude of anyone involved will benefit everyone, regardless of the final results. Lack of cooperation could result in inadequate protection of life and property.

1-5.3 Since leakage of flammable liquids, especially those liquids having low flash points, is a fire problem, necessary steps to be taken will normally be under the jurisdiction of the fire officials. It therefore becomes important for such officials to understand the many facets of the problem and to secure the cooperation of all involved parties as outlined above.

1-5.4 Recent developments, problems, and attitudes have now also involved health and environmental officials. Particularly when dealing with water pollution and the more persistent slow- or non-evaporating combustible liquids, the concern of these officials can be paramount.

1-5.5 The location of leaks, testing of tanks and piping, removal of leaky tanks, and removal of liquid in the ground will require equipment and facilities that might be more available to the industries involved than to the public authorities. In addition, much of the work is not the responsibility of the fire department or other agencies, but rather is the responsibility of the owner of the leaking equipment.

1-5.6 Regardless of the willingness of individuals or companies to cooperate with governmental agencies during an emergency, the agencies should recognize that they should officially request such cooperation.

1-5.7 When tanks are to be removed or other work, such as excavation, is to be done on private equipment or on private property, this work must be authorized by the owner. Such authorization generally is easy to secure if the work has been requested by officials. In some cases, these requests must of necessity be in the form of a written order. Regardless of conditions, leadership and a close spirit of cooperation should be established by the responsible agency.

1-5.8 In addition, those in industry having special qualifications in dealing with leakage should be called upon for help and guidance. Their knowledge and experience should merit careful consideration.

1-5.9 This recommended practice is intended for the information of all organizations and persons involved.

Chapter 2 Procedure When Life or Property Might Be in Danger

2-1 General. The need for cooperative effort by many individuals and organizations is stressed in the introduction preceding this chapter. Good judgment must be used in assembling the various groups. Always seek assistance in the interests of safety, but avoid creating unnecessary alarm or unwarranted interruption of normal activities. Owners, operators, or others becoming aware of a hazardous condition should notify the fire department, police, or other proper authority. However, make every reasonable effort to determine the degree of the problem. Excessive alarming, such as might be caused by unwarranted evacuation or publicity, can create more hazard than the original problem. Good judgment applied to the following step-by-step guide will materially improve the chances for successful results.

2-2 Conditions. The potential that unconfined flammable or combustible liquids exist underground will normally become known by discovery of one of the following conditions:

2-2.1 Combustible or flammable liquids or their vapors are reported in:

(a) Normally inhabited subsurface structures such as basements, subways, and tunnels;

(b) Other subsurface structures such as sewers, utility conduits, and observation wells near tanks;

(c) Groundwater such as that drawn from wells, on or in surface water, or emerging from cuts or slopes in the earth.

2-2.2 User reports loss of stock or presence of water in the storage facility. *Each condition requires different handling*:

2-3 Condition 2-2.1(a) — Normally Inhabited Subsurface Structures Such As Basements, Subways, and Tunnels.

2-3.1 General. This condition implies a strong potential hazard to life or property, and immediate steps should be taken to protect the public from the danger of explosion and fire.

2-3.2 Eliminating Sources of Ignition.

2-3.2.1 Smoking or other sources of ignition should not be permitted in the suspected area. Lights and other electrical switches should not be turned on or off, and extension cords should not be removed from outlets. Any such action can create a spark capable of igniting flammable vapors. Use only those switches located well away from the contaminated area to disconnect electrical power. This might require that the electric utility effect a remote cutoff.

2-3.2.2 After the presence of flammable vapors has been verified, the electric and gas services to the building, where possible and feasible, should be disconnected or shut outside the structure. The shutting off of the gas service outside of the building removes the fuel from pilot lights and gas burners, which could be sources of ignition.

2-3.2.3 No one should enter the contaminated area except as described in 2-3.3. Where liquids or vapor within or above the flammable range are found in a building, the building should not be entered, and evacuation of building occupants, at least in areas exposed, should be ordered. Construction and layout as well as occupancy are factors to be considered in ordering evacuation. Traffic should be stopped through tunnels and subways until qualified personnel determine there is no danger of explosion or fire.

2-3.3 Entering the Area.

2-3.3.1 The presence of flammable vapors in a building is generally reported because of an odor. For example, most persons can detect gasoline vapor in concentrations as low as 0.25 parts per million. However, smell cannot be relied on to determine the type of vapor or its concentration. The use of a combustible gas indicator is the only practical, positive method to determine the presence and extent of a flammable vapor concentration.

2-3.3.2 To enter an area in which there is an undetermined concentration of some unknown vapor is to risk the possibility of fire or explosion. Entry should not be made until the vapor concentration has been checked with a combustible gas indicator. Portable combustible gas indicators are reasonable in price and are recommended for use by all fire departments. If the fire department does not have such an indicator, arrangements should be made for securing one or more from utilities, oil companies, or others who might have them available. The combustible gas indicator should be well maintained and used by a trained operator.

2-3.3.3 Also, an additional life hazard might exist because of toxic vapors or insufficient oxygen. If these conditions are suspected, instruments to detect toxic vapors or insufficient oxygen should be used.

2-3.3.4 Use the combustible gas indicator continuously to determine the range of vapor concentrations in the affected area. If areas of vapor concentration above 50 percent of the lower flammable limit (LEL on indicators) are exposed to a source of ignition, leave the area and evacuate everyone within the danger zone. Ventilate the area to remove or reduce the flammable vapors and thus reduce the fire or explosion hazard. As soon as the flammable vapor has been reduced below 50 percent of the lower flammable limit, entry can be made to locate and eliminate the source of vapor. Wear self-contained breathing apparatus when entering.

2-3.4 Ventilating the Area. Natural ventilation provided by opening doors and windows might be adequate. Grounded mechanical exhaust ventilating equipment might be required to remove vapors from all areas, particularly from low, confined spaces. Use fans driven by motors approved for Class I, Group D locations, hand-driven fans, or air eductors to remove vapors. (*See Figure 2-3.4.*) Eliminate sources of ignition near the exhaust outlets. Provide openings for free entry of fresh air, but never force air into the area. A water hose with the nozzle set in a spray pattern can be used for ventilating the area when set in a window and discharging outwardly.

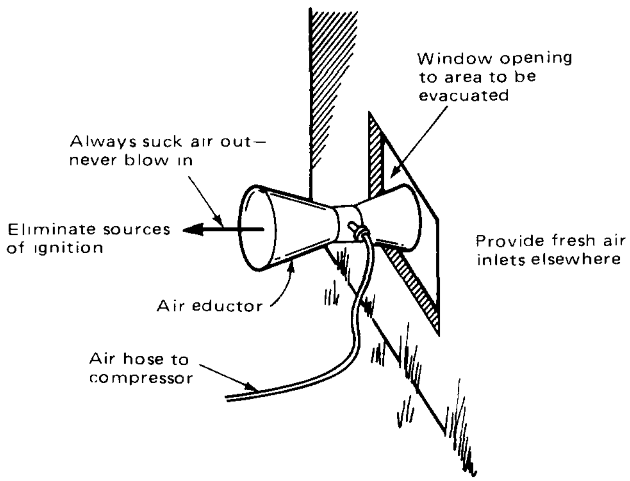


Figure 2-3.4 Exhaust venting.

2-3.5 Locating Seepage into Building. When the area has been made safe for entry, it can be examined to determine the source of the flammable vapors. If the place or places of entry of the liquid or vapors can be determined, appropriate steps should be taken to seal them off. Untrapped drains, dry traps, pipes, or other openings through floors or foundations are common sources of liquid or vapor entry. Check any gas pipes in the area; the flammable vapor might be fuel gas. If this appears to be the source, call the gas company.

2-3.6 Preventing Seepage into Buildings.

2-3.6.1 Entrance of vapors or liquids through drains, pipes, or other openings can be stopped by plugging such openings. Sewer pipes might be the source of entry. If only vapor is entering through a sewer pipe, it might be because the trap is dry. Filling the trap with water is an effective means of blocking further gas or vapor entry.

2-3.6.2 The nature of seepage might be such that it cannot be effectively stopped from inside the structure. In this case, an intercepting hole or trench, holes for pumps, or well points can be used outside the contaminated structure, between it and the suspected source. (*See Chapter 6 for details.*)

2-4 Condition 2-2.1(b) — Other Subsurface Structures Such As Sewers, Utility Conduits, and Observation Wells Near Tanks.

2-4.1 Liquids or vapors in such structures imply a potential for explosion or fire but, generally, a low potential of hazard to life and property other than to the structure involved. If the detection of flammable or combustible liquids or their vapors indicates an unusual condition wherein vapors are escaping from the sewer or conduit into an area similar to Condition 2-2.1(a), or if the proximity to other structures or facilities is such that an explosion or fire would be relatively as serious as Condition 2-2.1(a), then proceed with the guidelines of 2-2.1(a) in addition to the following procedures.

2-4.1.1 Contact those directly responsible for the facility involved: the municipal sanitary department or highway or street department for sewers; the electrical or telephone, or gas companies' engineering departments for conduit. Normally, the maintenance and engineering departments of such organizations will be well equipped to take charge of the situation; police, if needed, can be asked to keep the public clear of the danger areas. The fire department might be needed to assist in fire control and purging. Those involved with facilities that store and handle flammable and combustible liquids that might be the source of the problem should offer all possible assistance. (*See NFPA 328, Recommended Practice for the Control of Flammable and Combustible Liquids and Gases in Manholes, Sewers, and Similar Underground Structures, and Chapter 5 of this recommended practice for further details.*)

2-4.2 Entering the Area. Procedures are basically the same as for Condition 2-2.1(a); however, the flammable vapors in a sewer or conduit might not originate from flammable liquids. They might be vapors from overheated insulation, sewer-generated gases, fuel gases, or industrial gases. Consequently, special instruments, equipment, and skills might be needed. The guidance of the utility owning and operating the facility should be solicited and followed.

2-4.3 Ventilating the Area.

2-4.3.1 Some type of grounded mechanical ventilating will normally be required. Use explosionproof equipment if the vapors are drawn out. Remove all sources of ignition from the vicinity of vapor exit.

2-4.3.2 Water flushing might be the better means of purging the area of flammable vapors. For example, the generation of sewer gas can be stopped or significantly reduced by this method. In a similar fashion, flammable and combustible liquids can be removed from the area.

2-4.3.3 In any case, follow the guidance of the owner or operator of the facility, as that person will be most familiar with its characteristics and the consequences of any action taken.

2-4.4 Locating the Seepage. Assist the facility owner in any way practicable. See Chapter 5 for information on tracing liquids underground.

2-4.5 Preventing Continued Seepage.

2-4.5.1 When leakage is detected in a sewer, the source of the leak should be located by backtracking with combustible gas indicators. If points of entry to the sewer system are limited in number, interception of the leak can be achieved by use of trenches, well holes, or well points. (*See API Publication 1628, Guide to the Assessment and Remediation of Underground Petroleum Releases.*)

2-4.5.2 If entry of liquid or vapor into the conduit or sewer is to be stopped, and the inside of the facility is not accessible, probe or drill alongside the facility to determine the extent of its exposure to the saturated soil. Uncover the exposed area and caulk the facility from the outside.

2-5 Condition 2-2.1(c) — Groundwater Such As That Drawn from Wells, on or in Surface Water, or Emerging from Cuts or Slopes in the Earth.

2-5.1 General. These liquid seepages on water will often be more of a problem because of pollution than as an explosion or fire hazard. However, until the source of the flammable or combustible liquid is found and stopped and all liquid and vapor safely removed, there is a potential hazard of explosion or fire.

2-5.2 Wells.

2-5.2.1 When flammable or combustible liquids are found in well water, stop pumping and avoid any source of ignition around well houses and water storage tanks until vapor concentrations are checked. Disconnect electrical power outside any well house or similar trap that might collect vapors from the well or stored water.

2-5.2.2 If vapor concentrations are below 50 percent of the lower explosive limit, pumping can be resumed if desirable for purging. (*See Chapter 6 for details.*)

2-5.3 Surface Water.

2-5.3.1 Where flammable or combustible liquids are found on surface water or water emerging from hillsides or cuts, explosive vapor concentrations can develop in ditches or collection points. Normally, the amount of flammable or combustible liquid found on the surface water will be in such a thin layer that it will not create a fire hazard. This is the case where the liquid is dispersed into small bubbles or pools, or where only color patterns are visible on the surface of the water.

2-5.3.2 However, if the entire surface of the water is covered, or there are large pools in the order of 20 ft (6 m) or more across, a fire hazard does exist. If this occurs in an inhabited area or along a street or highway, and the police and fire department are not present, they should be called. Traffic should be stopped, and the public kept away from the area. If large amounts of vapor are being generated, check the wind and remove all sources of ignition within at least 100 ft (30 m) downwind of the source. It is unlikely that vapors will be in the flammable range farther than 100 ft (30 m) away. However, if large amounts are involved, and the air is relatively still, a combustible gas indicator should be used to determine the extent of the hazardous area. Its use is desirable in any event if flammable liquids are involved.

2-5.3.3 Normally, the only effective means to stop further accumulation will be to find the source of the release and stop it. (*See Chapters 5 and 6.*) It may be desirable to construct dikes or dams to prevent further spreading of the liquids or of contaminated water.

2-5.3.4 Floating booms can be used on flowing water to hold the contaminating liquid. (*See Chapter 6 for details.*)

2-5.3.5 Once the source of flammable or combustible liquids is stopped, evaporation or normal dispersal and dilution will often be the best means of removal. Collection with adsorbents or skimming devices or filtering devices might be necessary. (*See Chapter 6 for details.*)

2-6 Condition 2-2.2 — User Reports Loss of Product or Presence of Water in Storage Facility. An inventory loss, or water in tanks, does not directly imply a hazard of fire and explosion. Check the immediate vicinity for any signs of escaping liquid; if any exist, follow the procedures given for Conditions 2-2.1(a), 2-2.1(b), or 2-2.1(c), as appropriate. Otherwise, proceed in accordance with Chapter 4, "Testing for Underground Leaks."

Chapter 3 Searching for the Source

3-1 General.

3-1.1 After all necessary precautions have been taken to mitigate fire and explosion hazards, the next most important step is to locate the source of the flammable or combustible liquid and prevent any further release.

3-1.2 Generally, the source of the liquid will be relatively near the location where unconfined liquid or vapor has been discovered. However, liquids can travel hundreds of feet or even miles underground, through porous soil or rock, through trenches filled with porous material, alongside pipes or conduits, or in sewer pipes. Consequently, the location from which a released liquid might have originated can be remote and extensive and can include many facilities that handle and store flammable or combustible liquids. Also, the source of the release might be an abandoned underground storage tank. If a check of potential sources adjacent to or within several hundred feet of the discovery is not conclusive, then the investigation should be expanded to include other potential sources in the general area of the discovery. Some potential sources are:

(a) Automotive service stations, both retail and private;

(b) Automotive garages or dealerships;

(c) Fleet operations, such as taxicab companies, municipal garages, dairies, bakeries, etc.;

(d) Contractors or equipment dealers who store fuels on their premises;

(e) Motor fuel and heating fuel distributors;

(f) Cleaning establishments, including dry cleaners;

(g) Industrial and chemical process plants;

(h) Airports and marinas;

(i) Underground petroleum or gas transmission lines;

(j) Any abandoned tanks that stored flammable or combustible liquids in the past;

(k) Any other property on which flammable or combustible liquids are or may be stored.

3-1.3 Efforts should be made to secure information on groundwater flow patterns from the regional U.S. Geological Survey (USGS) office, local public works departments, or similar agencies, and search efforts should be initiated up-gradient from the leak.

3-1.4 Obtain or sketch a map of the area, mark each facility found on the map, and record all the information obtained. Well-organized, accurate data will prove invaluable in subsequent efforts to solve the problem.

3-1.5 Organize search teams of as many qualified persons as are necessary to conduct the search. One efficient method is to assign a two-person team to each specific zone on the map. One of the team members should represent the local public authority. Begin with the nearest and most obvious potential sources and work out from the point of discovery, moving uphill, up-gradient of groundwater flow, or upstream of sewer or conduit flows.

3-1.6 Often the source can be found by inquiry or simple inspection. Begin with the procedure outlined in Section 3-2. If an obvious or very likely source is not found within several hours, it is then advisable, while the primary search continues, to begin testing the closest and most probable sources, such as equipment, underground storage tanks, or underground piping, for concealed points of release.

3-2 Search Procedure.

3-2.1 Flammable and combustible liquids will most likely escape into the ground for the following reasons:

(a) Liquid has been spilled during transfer and has reached an underground conduit or soaked into porous soil;

(b) A leak has developed in a storage, transportation, or handling system.

Use the lists in this section as a guide in checking for spills or other possible sources of the release by asking questions and by careful inspection of the premises and equipment. Unless an obvious source that is large enough to account for the release is found, do not stop the search at the first sign of a potential source. First impressions can be misleading. It is useful to check available public records for any prior history of releases.

Also, because liquids can travel slowly through the ground or not move at all until the groundwater table rises, a considerable amount of time can pass between the actual release of liquid and its discovery. Therefore, record all history or evidence of potential leaks or spills, regardless of how long ago they occurred. Do not eliminate any potential source on the basis of time until all information is available and its analysis justifies elimination of that source.

3-2.2 The following questions should be asked of all facility operators in the area of the search:

(a) Has there been a spill during loading or unloading?

(b) Is any storage or handling equipment leaking or has there been a leak? Check for excavations or other evidence of repairs that might have damaged underground facilities.

(c) Has there been any maintenance on pipes, tanks, or other equipment that might have resulted in a release?

(d) Has there been any odor or other signs of liquids in areas where there should not be?

(e) Are inventory and use records kept? Do they show any indication of a release?

(f) Has water been found in any underground storage system?

(g) Is there any knowledge of an accident that might have released liquids from a tank vehicle, container, or storage tank? A check with local law enforcement agencies is useful here.

(h) Ask about the age of underground facilities. If subsequent tests are made, the older equipment might be suspect.

(i) Have any problems been encountered during pumping and liquid transfer?

3-2.3 If inquiry fails to disclose any potential source, ask each premises owner or operator for cooperation in checking equipment. If an operator refuses because he or she is not the owner, then obtain permission from the owner. If necessary, enlist the assistance of local governmental officials to secure such cooperation.

3-2.4 The following guidance will be helpful in checking equipment:

(a) Inspect on-site leak detection equipment for proper operation and for indications of a leak.

(b) Check the areas around fill pipes where liquid is transferred from tank vehicles to storage tanks for signs of spillage. Saturated or darkened soil, stained concrete, or disintegrated asphalt indicates that repeated spills might have occurred and accumulated underground.

(c) Check the areas around aboveground tanks for similar signs of leakage.

(d) Check all exposed piping for signs of leaks.

(e) Check dispensing equipment for leaks. It is advisable to use a combustible gas indicator when checking dispensers of the type used at automotive service stations. Open the cover of the dispenser just enough to insert the indicator probe into the area beneath the dispenser. Opening the cover wide might provide enough ventilation to dilute any vapors present and give a reading low enough to indicate no leak. IF THE VAPOR CONCENTRATION INDICATES A POTENTIAL RELEASE, REMOVE THE DISPENSER COVER AND INSPECT PIPING, VALVES, AND FITTINGS FOR SIGNS OF LEAKS. Check the dispensing nozzle and hose also.

(f) If a remote pumping unit is used, check its housing or pit with a combustible gas indicator before opening. Then open the unit for inspection.

(g) Check automotive repair areas for signs of waste liquids being dumped into inappropriate floor drains or sumps.

The use of any equipment found to be leaking should be stopped until repairs are effected. Any storage tank or piping that is found to be leaking should be emptied if liquid is still escaping.

3-2.5 If all the equipment appears to be in order and there is no obvious sign of spilling or dumping into sumps or sewers, check the grounds and areas around the premises. The following guidance will be helpful in checking the area:

(a) Look for signs of waste liquids having been dumped onto the ground.

(b) Check nearby streams and bodies of water for signs of flammable or combustible liquids. Look for a sheen or slick on the surface of the water and along the banks.

(c) Check vegetation for indication of damage by spilling, dumping, or contaminated groundwater.

(d) Using a combustible gas indicator, check sewers and other underground conduits and cavities, such as utility manholes, for the presence of vapors and make visual inspection for signs of foreign liquids on the surface of any standing water in these areas.

(e) Check the barrels of any fire hydrants in the area.

(f) Check nearby excavations and steep cuts or natural slopes down-gradient from the potential source for signs of liquid.

3-2.6 Keep in mind that dumping or spilling flammable or combustible liquids into sewers or on the ground might be a violation of state or federal law and should be reported to the proper authorities immediately.

3-2.7 Keep in mind that small spills do occur inadvertently and might indicate a release that is much larger than it really is. For example, a small amount of liquid (one cup of fuel, for example) spilled onto a wet pavement will spread over a relatively large area. Small spills that spread out over a large area will dissipate rapidly and are not likely sources of underground contamination. The significant releases are large spills and repeated small spills that can flow to points of access into underground structures or porous soils and then reach the groundwater table.

3-3 Procedures to Verify the Source.

3-3.1 Once an obvious source or one or more likely sources has been found and further release of liquid has been stopped, further search efforts can be temporarily suspended. It now must be determined if each identified source is, in fact, the actual source of the release. While removal and protective measures are taken, monitor and record the flow of the liquid, the amount of liquid, and the vapor concentrations at those locations where the problem exists. If a distinct and continuous decrease occurs, then it can be assumed that the source of the release has been identified. The decrease might not occur immediately; it might, in fact, take days or weeks for liquid that has accumulated underground to be removed or to dissipate. Refer to Chapter 5 for further information on estimating the time required for a decrease to occur at the monitored point.

3-3.2 If after a reasonable length of time, as determined in accordance with Chapter 5, the flow of liquid to the affected area does not stop or show a definite decrease, further investigation should be conducted simultaneously using the two procedures described below. These two paths should also be followed in cases where an obvious or likely source is not found.

(a) Conduct release detection tests on any liquid storage or handling system in the vicinity of the affected area. These tests will identify those systems that are, in fact, releasing liquid. Refer to Chapter 4, "Release Detection for Underground Storage Tank Systems."

(b) Trace the path of the liquid underground from its point of discovery to the source. Tracing will determine the actual extent of the release, its direction of flow, and any potential, more remote sources. Refer to Chapter 5, "Tracing Liquids Underground."

Chapter 4 Release Detection for Underground Storage Tank Systems

4-1 General.

4-1.1 Before actual equipment testing is undertaken, review the results of applicable search procedures conducted in accordance with Chapter 3. This review might reveal information that will eliminate the need for further testing or be useful in making further tests.

4-1.2 Ensure that spills or deliberate disposal are not the leakage source, keeping in mind the possible movement of liquids by trenches and underground water. (*See Chapter 5.*)

4-1.3 Check stock records for indications of loss.

4-1.4 Review all data previously gathered to determine the most efficient method or methods of testing. There are several quick and simple methods described in this chapter that can reveal a leak under certain circumstances. If one of these preliminary techniques does not reveal the source of a suspected leak, it cannot be concluded that the liquid-handling system is tight. But the possibility of quickly solving the problem will often warrant the limited effort involved before a tightness test or other release detection method is undertaken.

4-1.5 Regardless of the procedure involved, keep in mind that liquid-handling equipment should be evaluated in a manner that is as close as possible to normal operating conditions. Excessive pressures or tests by nonrepresentative liquids might indicate a leak where none exist or might conceal leaks that do, in fact, exist. For example, perforation of a tank shell might not be detected due to impermeable backfill, the water table, sludge, or rust plugs, all of which can inhibit release of product from the tank.

4-1.6 Tests conducted to determine the tightness of underground liquid-handling equipment or to evaluate whether there has been a release to the subsurface environment will have to be conducted where:

(a) The search and tracing procedures of Chapter 3 indicate a probable or likely source of the release, but the actual cause is not determined from surface observation;

(b) There is a suspicion of a leak because of reported stock losses;

(c) There is an unexplained accumulation of water in a tank.

4-2 Action Preliminary to Release Detection/Tightness Testing.

4-2.1 Checking Underground Tanks.

4-2.1.1 Review the information obtained from the search procedures described in Chapter 3. Ask about, observe, and note in particular:

(a) Method of filling tanks. Damaged fill pipes, poorly maintained tight-fill connections or hose couplings, driver carelessness, or even overemphasis on full deliveries might cause some of the product to be spilled around the pipe when a delivery is made. Particularly check fill pipes installed under covers.

(b) Any evidence of ground settlement around tanks and any sign of work that might have damaged the tank or its fittings.

(c) History of past or recent work on the tanks or attached piping.

(d) The presence of excessive amounts of water in the tank and any history of past water removal. (Use water-finding paste on the gauge stick.) If possible, determine whether the water increases during periods of heavy rainfall and remains constant or diminishes during dry spells. Also, if possible, determine the depth of the water table (i.e., the static level of the groundwater) by using an easily drilled, probed, or excavated area close to the tank(s) or some existing undrained opening.

(e) The age of the facility.

(f) The location and flow of liquid found underground by gas sensors or visual inspection.

All of this information will be useful in guiding subsequent inspection and testing.

4-2.1.2 When Water Is Reported to Be Entering a Tank.

(a) Check the fill pipe to ensure that water is not entering through a loose fill cap.

(b) Check the surface area around vent lines for evidence that water might be entering by this route. Standing water over vent lines could be the source. Note this possibility for future use.

(c) If no explanation other than a possible leak is found for water in the tank, carefully record the depth of water using water-finding paste or other appropriate means on the gauge stick and tightly close and lock the fill cap. After 8 to 12 hours, remove the cap and again check for water. If the rise in 12 hours exceeds 1/2 in. (12.7 mm), close and lock the cap and check after another 8 to 12 hours. If the rise in the second period closely matches that of the first, a leak is probable. A rise of less than 1/4 in. (6.4 mm) in 8 hours is inconclusive due to the inability to measure increments to within 1/4 in. (6.4 mm). Longer test periods will have to be used to determine if a leak does, in fact, exist. Best results will be obtained if the water depth is less than 3 in. (75 mm) at the beginning of the test.

(d) The above test is not conclusive if the water table is above the top of the tank, as water could be entering around pipe connections into the tank top or through unused, plugged, or capped openings in the top of the tank that are not watertight. Also, if water is entering the tank at these top openings, it is not significant from the standpoint of tank leakage. Likewise, these tests are not conclusive if the tank is full, or substantially full, of product.

(e) In fact, water might not enter the tank if the level of product is at or above the level of the water table outside the tank. This test is relatively effective if the tank is practically empty and the water table is high but still below the tank top. A tank that is partially below the water table can have water enter or can lose product through the same leak, depending on the relative levels of the groundwater and the product in the tank.

4-2.2 Checking Underground Piping.

4-2.2.1 Check for:

(a) Recent digging, driveway repair, or other work in the area that might have damaged underground piping.

(b) Any recent repairs that might have created the leak due to faulty workmanship or that might indicate a previous leak.

(c) Any evidence of shifting ground, such as a frost heave, that might have damaged piping.

(d) Soft spots in asphalt paving indicating solvent action of liquids or vapor.

(e) Evidence of abandoned, capped, or disconnected piping, such as unused dispensing islands or other unused ancillary facilities.

(f) Evidence of improper operation of in-line leak detection devices.

4-2.2.2 If information on the location of liquid underground has been compiled by methods described in Chapter 5. Review this information for possible patterns that indicate a specific pipe to be the source. It might be advisable to drive or drill additional holes to determine exactly where the liquids are and how they are flowing. (*In particular, see Section 5-2.*)

4-2.2.3 Preliminary Testing of Piping Systems. The test to be used on piping will depend on whether the stored liquid is moved by suction or pressure.

4-2.2.4 Testing of Suction Piping.

(a) If the pump used in moving the liquid is above ground and the supply pipe operates under vacuum or suction, certain pumping characteristics will indicate either a leaking check valve or a leaking pipe. Air will enter the pipe through a leaking check valve or through a pipe leak as liquid drains back into the tank. The presence of this air will be indicated by the action of the pump in the first few seconds of operation after an idle period. If the pump is equipped with a meter and cost/quantity display device such as is found in a gasoline service station, pumping of air might be indicated by "skipping" of the volume display, a rattling sound in the pump, or erratic liquid flow due to mixing of air and liquid. Another indication is overspeed of the pump when first turned on, followed by slowing of the pump as it begins to move liquid. A third indication is "churning" of the pump, i.e., running, but not moving liquid at all.

(b) If any of the preceding conditions indicate a leak in the suction line, the check valve should be inspected first. Some check valves are located close to the pump inlet, others are mounted in the underground pipe just above the tank, and some are installed on the end of the suction stub inside the tank. Some of these valves located in the pipe above the tank can be inspected and repaired from the surface of the ground through a special extractor mechanism installed with the valve. If the valve is inside the tank, it might be necessary to dig down to the tank to check the valve or disconnect and seal off the pipe for a hydrostatic pressure test.

(c) Generally, digging down to the check valve or tank should be delayed until other, more easily performed surface tests have failed to reveal the leak. If there is any doubt that the check valve seats tightly, repair it, replace it, or seal it off. Then repeat the pumping test and, if air is still entering the suction line, it can be assumed that the pipe is leaking underground and it should be exposed for inspection. Dig carefully to avoid any damage to the pipe that might make it impossible to verify whether a leak actually existed prior to excavation.

(d) If the pump does not exhibit symptoms of a leak, as described above, but there is still reason to suspect a pipe leak, or if a complete system check has been performed and it is now necessary to isolate and check the piping system, individual pipe runs can be isolated and hydrostatic pressure tested.

4-2.2.5 Testing of Pressurized Piping.

(a) Quite often, pumps are located remote from the dispensing devices, either in the tank or, on rare occasions, just above the tank. In such cases, the pipe to the dispensing equipment operates under pressure. A leak in this line will cause rapid loss of pressure after the pump is turned off. This can be checked using the following procedure. The method described is specific to pressurized piping at vehicle refueling operations. At other types of facilities, a comparable method might have to be used.

(i) At the dispenser end of the pipe, close the emergency shutoff valve at the base of each dispenser served or close all valves upstream of any hose to hold pressure at the dispenser end. The pump end can be sealed off by setting the check and relief valves in the head of the pump. The check valve is readily accessible in the manhole over the pump and most are equipped with a screw or bolt for the specific purpose of positively seating these valves for line checking.

(ii) Install a pressure gauge in the line. A minimum 3-in. (76-mm) dial with maximum 60 psi (3100 mm Hg) range should be used to clearly show graduations of 1 psi (51.72 mm Hg). Generally, the best location for the gauge is at the emergency shutoff valve under the dispenser where $^1/_4$-in. or other small-size plugs are installed for this purpose.

(iii) Start the pump, note the maximum pressure, seat the check valve, then turn off the pump and observe any pressure drop. The test should be maintained for at least 10 minutes. If the pressure drops, it indicates the possibility of a leak in the piping. However, it should be noted that a loss of liquid pressure can be attributed to the following: a line leak, a decrease in liquid temperature in the line, piping distortion due to the liquid pressure, or vapor trapped in the piping.

(b) If the preceding test does not reveal a leak, the procedures described in Section 4-3 should be followed.

4-2.3 Checking Inventory Records.

4-2.3.1 A careful check of inventory records will be very helpful in determining the course of further investigation. (*See Appendix D for a description of inventory control procedures.*)

4-2.3.2 If the reason for the check is a report of loss of inventory but no liquid or vapor has been reported in unexpected locations, check the following:

(a) Loss due to meters that are not correctly calibrated.

(b) Loss by contraction due to lower temperatures.

(c) Theft.

(d) Use of a conversion chart that does not conform to actual tank geometry.

(e) Malfunctioning automatic tank gauging probe.

In any of these cases, further testing is not necessary.

4-2.3.3 If a loss of inventory cannot be attributed to any of the causes noted in 4-2.3.2, or if a statistical inventory reconciliation procedure discloses a loss of product, further testing is necessary. It also indicates that a potential hazard might develop from the escaped liquid, and a check of the surrounding area should be made for signs of contamination. (*See Chapter 3.*)

4-2.3.4 If the reason for the check is the discovery of escaped liquid or vapor underground:

(a) Evidence of inventory loss strongly implies the source has been found but subsequent checks to determine how the loss has occurred should be made before definite conclusions can be drawn.

(b) Any loss that is partially or totally explained by off-calibration meters, temperature shrinkage, or theft cannot be considered as conclusive evidence that the site in question is not a source. Records are often incorrect or inadequate. Unless another source is found and considered to be a satisfactory solution to the problem, other tests must be performed to draw definite conclusions.

4-2.3.5 Temperature change may falsely indicate a loss. The volume of petroleum products is highly sensitive to temperature change. A drop of 1°F will shrink 1000 gal (3785 L) of gasoline by 0.7 gal (2.2 L). Obviously, a temperature increase would have the opposite effect and could actually conceal a physical loss.

4-2.3.6 In summary, there are other factors to consider. Further checking should be performed before a facility is implicated on inventory losses alone. Theft or meter inaccuracies might be the actual cause.

4-3 Release Detection Methods.

4-3.1 With the information gained from the search procedures of Chapter 3 as a basis, use the techniques described in 4-3.2 through 4-3.7 in a logical process of elimination.

(a) Means and methods of release detection conducted or installed in accordance with federal or state regulations should be operated in accordance with manufacturers' recommended procedures. Personnel utilizing these methods should be properly trained in their use and operation. Proper documentation of procedures and results should be provided. Additional information regarding recommended procedures is provided in EPA/530/UST-89 1012, *Detecting Leaks: Successful Methods Step-by-Step.*

(b) Methods of release detection must comply with applicable local, state, and federal environmental regulations.

(c) Means and methods of release detection should be documented relative to their detection capabilities in accordance with local, state, and federal regulatory requirements. Third party validation is recommended.

(d) If a release is indicated by any of the described methods, further investigation is required by either confirming testing (*see Section 4-4*) or the tracing techniques described in Chapter 5, whichever is most appropriate.

(e) If no release is indicated by the described methods, the investigation should be expanded to other off-site potential sources.

4-3.2 Manual Tank Gauging. For tanks of 1,000 gallons (3785 L) capacity or less, a manual tank gauge can be used, if the liquid level measurements are taken at the beginning and end of a period that is at least 36 hours long and during which no liquid is added or removed from the tank. See Appendix D.

4-3.3 Automatic Tank Gauging. If the tank is equipped with an automatic tank gauging system that has a "leak test" mode, a "leak test" should be conducted in accordance with the manufacturer's operating instructions. Automatic tank gauging equipment must be capable of detecting a leak rate at least as low as 0.2 gallon per hour (0.8 L per hour) from any portion of the tank that routinely contains product, with a probability of detection of 0.95 and a probability of false alarm of 0.05.

4-3.4 Tank Systems Equipped with Secondary Containment.

4-3.4.1 If the tank system is of double wall construction or is installed with a secondary containment system, the interstitial space monitor point or the well(s) located within the secondary containment area, whichever is applicable, should be checked for the indication of a release. When groundwater is present, the monitoring method utilized must be capable of detecting the presence of at least $^1/_8$ in. (3.2 mm) of free product.

4-3.4.2 Interstitial monitors might indicate either the presence of leaked liquid or gaseous products or monitors can check for a change in condition indicating a breach (for example, by loss of vacuum or change in a liquid level established between the walls of a tank). Monitoring can be continuous or intermittent. Even a dipstick can be used at the lowest point of containment to check for leaks.

WARNING: The interstitial space of a double wall tank should not be tested with pressure beyond the manufacturer's recommendations, particularly since materials and construction techniques vary.

4-3.5 Vapor or Groundwater Monitoring Wells. If vapor or groundwater monitoring wells have been installed in the tank system excavation area, they should be checked for indication of a release. When groundwater is present, the monitoring method utilized must be capable of detecting the presence of at least $^1/_8$ in. (3.2 mm) of free product.

4-3.6 Underground Piping Line Leak Detectors. If line leak detector(s) are installed on pressurized product piping systems, operational testing should be conducted.

4-3.7 If inventory records have been analyzed by quantitative statistical methods, the analysis should be examined for indications of a probable release, assuming that the data can be analyzed conclusively.

4-3.8 Other methods might be approved by the local regulatory agency.

4-4 Testing.

4-4.1 If the release detection methods described in Section 4-3 are not available or do not yield conclusive identification of the potential source of a release, testing of the piping, tank, or both, might be necessary. The test procedures should detect a leak anywhere in the complete underground storage and handling system unless other information has eliminated some portion of the system from the search. Certain test methods might allow additional product to be released from the system or might cause structural damage to the tank or piping during the test. Where it is reasonable to assume that a leak exists, the effects on safety and the environment should be considered when determining which test method to use.

4-4.2 Tightness testing of the tank and piping must be capable of detecting a leak of as little as 0.10 gallon (380 ml) per hour, with a probability of detection of 0.95 and a probability of false alarm of 0.05. This is a performance standard to determine the detection capabilities of the testing device and procedure. The detection threshold for declaring a leak will vary based on individual manufacturer's specifications. Additional information on volumetric and nonvolumetric tightness test methods is provided in Appendix A and B, respectively.

4-4.3 If the results of a tightness test indicate that a leak might exist, either appropriate corrective action or additional testing to confirm the leak should be performed.

4-4.4 Pressure Testing.

4-4.4.1 Pressure Testing with Air or Other Noninert Gases.

WARNING: Pressure testing with air or other noninert gases of tanks or piping that contain flammable or combustible liquid is not recommended, should not be required by regulations or ordinances, and should be discouraged in practice.

4-4.4.2 Testing with Inert Gases. Inert or unique gases can be used for the purpose of detecting a leak for both tank and piping systems. The pressure exerted by both the product and the inert gas must not exceed the limits recommended by the tank manufacturer. The use of pressure-limiting devices is required in this application.

4-4.4.3 Atmospheric underground storage tanks are normally fabricated according to standards established by a trade association or a testing laboratory and recognized by the authority having jurisdiction. Tanks are tested in accordance with these recognized standards. To prevent structural damage, tests used to determine tank tightness, whether positive or negative pressure, should not exceed the limits recommended by the tank manufacturer. Consideration for hydrostatic and geotechnical influences should also be provided in the test procedure.

4-4.5 Hydrostatic Testing of Piping. Hydrostatic testing of piping is a relatively simple test that can quickly indicate a leak. If the pressure drops, it indicates the possibility of a leak in the piping, and it is recommended that a volumetric tightness test be performed. It should be noted that a loss of liquid pressure can be attributed to the following: a line leak, a decrease in liquid temperature in the line, piping distortion due to the liquid pressure, or vapor trapped in the piping.

4-4.5.1 Pressurized Piping. Isolate the piping and conduct a hydrostatic pressure test at 150 percent of the maximum anticipated pressure of the system, but not less than 5 psi (34.48 kPa) gauge at the highest point of the system. The test should be maintained for at least 10 minutes.

4-4.5.2 Suction Piping. A liquid volumetric pressure test can be performed on a suction line by connecting to the exit port of the air eliminator or other appropriate fitting. This connection will permit pressure to be applied to the suction piping from the pump to the check valve. In this test, the hydrostatic pressure should not exceed 15 psi (103.4 kPa) to prevent damage to the pump.

Chapter 5 Tracing Liquids Underground

5-1 General. Although the following guidelines are given in an approximate order of importance, they are not necessarily in the preferred order for all cases. The actual sequence of procedures and the actual choice of test methods will depend on the circumstances of the problem, information gained from the primary search, and any previous test results.

5-2 Procedure for Determining Underground Flow.

5-2.1 On a sketch of the local area (preferably on a scale of 1 in. = 100 ft), note any undergound facility as illustrated in Figure C-10. Also note any pertinent geological data that is available and the locations of manholes, tanks, fill pipes, vent risers, and pumps. Include any abandoned ditches or stream beds that have been filled and covered. Some sources for this information are:

(a) Municipal and state public works agencies, water departments, and sewer departments.

(b) Local, state, and federal geological departments.

(c) Utility companies.

(d) Facility owners and local residents. (Pay special attention to elderly and long-time residents. They will often provide valuable information about the area prior to its development.)

5-2.2 If necessary, use metal detectors to locate and trace buried steel pipe.

5-2.3 Information gathered and plotted on the sketch up to this point might indicate that a specific nearby facility is a very likely source. If so, proceed with tests to verify this, as described in Chapter 4.

5-2.4 Check potential liquid flow paths as follows:

(a) Visually check manholes, inlet boxes, wells, open trenches, exposed slopes and cuts, etc. Samples of water should be taken to test for the presence of flammable or combustible liquids.

(b) A combustible gas indicator should be used to determine the presence of vapors.

(c) If checking underground structures does not give a clear indication of the direction of movement of the underground flow, a more detailed search can be conducted in porous backfill or pervious strata by testing for vapors in the soil. This testing can be conducted in a number of ways. The simplest method is to drive a ³/₄-in. to 1-in. (19 to 25 mm) diameter bar into the ground with a sledge hammer, then test the atmosphere in the hole with a portable detection instrument. Alternatively, a hand-operated soil augur can be used to drill the hole, thereby reducing the risk of damage to any underground utility line or structure. Another method is to drive a hollow soil probe into the ground and pump vapors out of the probe to a portable detection instrument. The soil probe method is more sensitive than the driven bar or soil augur methods because there is less opportunity for surface air to mix with and dilute the atmosphere in the hole, thus making detection of flammable or combustible vapors more accurate. Care should be taken to avoid damage to underground utilities. If there is any question about the presence or absence of such, then investigation in that area should be suspended until specific locations can be identified.

5-2.5 If the potential for natural gas or sewer gas exists, make particular note of the readings of a combustible gas indicator relative to the location of sewer and gas lines.

5-2.6 When this testing has determined the probable direction from which the contamination is coming, extend the search upgradient using these same methods to determine the next most likely source. Check on both sides of the direction of flow to determine its width.

5-2.7 As the area of the search expands beyond the original sketch, obtain a smaller scale map or sketch and plot all additional data. As the area becomes larger, the data become more important to the search and subsequent handling of the contamination.

5-2.8 If the initial efforts (about one day's checking) fail to establish a clearly defined problem, additional expert assistance should be obtained. Local industries might be able to provide some of this assistance. Whenever possible, obtain the help of a local geologist who is familiar with the local geology.

5-2.9 It is beyond the scope of this recommended practice to cover the problem in all its potential complexities; that is the purpose for seeking expert assistance. Other methodologies such as soil gas analysis and test wells can be beneficial.

5-2.10 If the investigation fails to locate an active source of release, it is possible that the problem could be a result of an accumulation from a previous equipment failure, spill, or improper disposal of the liquid. Experience has indicated that many such residual deposits have existed and remained undetected for long periods of time before becoming large enough to make their presence known.

5-2.11 As the problem becomes more complex, other methods of testing and tracing might be useful. However, the advantages and disadvantages of each test procedure must be recognized if valid conclusions are to be reached.

5-3 Dye Tracing. The use of a dye tracer is often suggested as a means of tracing the flow of liquid. The method involves adding a strong dye to the storage system suspected as the source of the release, then seeing if the dyed liquid appears at the point of discovery.

5-4 Chromatographic and Spectrographic Analysis. The chromatograph and the spectrograph are instruments capable of detecting traces of the elements of almost any compound. For example, they can detect a trace quantity of an element that is unique to a particular method of manufacture, thus identifying the source. They can also detect the amount of the element present. These are relatively inexpensive tests and only involve a small sample taken at the point of discovery. These tests should be used in cases that involve complex mixtures, such as petroleum liquids. However, these tests might not be conclusive because some identifying component can be lost in the ground or a component not originally present can be picked up from the ground or from contact with buried materials.

5-5 Other Chemical Analysis. Other methods of chemical analysis are available. They are essentially the same as the tests described in Section 5-4, and the same comments apply. One significant factor that can sometimes be determined by chemical analysis is the age of the contaminant.

Chapter 6 Removal and Disposal of Contaminated Liquid

6-1 General.

6-1.1 The presence of unconfined flammable or combustible liquid will continue to present a hazard until the contamination has been reduced to a safe level. While methods by which this can be accomplished will depend on the physical circumstances of the contaminated areas, the most effective results are obtained when the efforts of all interested parties and authorities are coordinated by the local or state fire official, usually the fire marshal. It is their inherent authority to enforce compliance with all rules pertaining to the cleanup operation, and it is their recognized responsibility to the public to exercise this responsibility from the time of discovery until safety is assured.

6-1.2 Removal and disposal methods will depend on the liquid involved and on the contaminated area.

6-1.3 The characteristics of liquids that are significant to the methods of removal and disposal are:

(a) Liquids that rapidly evaporate at ambient temperature will leave little or no residue. Typical liquids are volatile solvents and gasolines.

(b) Liquids that do not readily evaporate will tend to remain in place for long periods of time and will leave residues. Typical liquids are heating oils, food processing oils, and other nonvolatile liquids.

6-1.4 In general, purging a structure or enclosure of vapors of volatile liquids is primarily a matter of ventilation, while nonvolatile liquids must be physically collected and removed.

6-1.5 The principal categories of receptors involved are:

(a) Normally inhabited subsurface structures, such as basements, subways, tunnels, and mines.

(b) Normally uninhabited subsurface structures, such as crawlspaces, sewers, and utility tunnels.

(c) Bodies of water and groundwater.

(d) Soil.

6-2 Basements.

6-2.1 With very few exceptions, the quantity of liquid that will be found in a basement will be relatively small, because the liquid will normally be detected before significant quantities can accumulate and additional flow can be intercepted or stopped. Where volatile liquids and their vapors are involved, the primary removal and disposal action is ventilation, as described in Chapter 2. Small amounts of liquid that remain can be removed with commercial absorbents.

6-2.2 Contaminated absorbents should be placed in covered metal containers to prevent the further spread of vapors. Once all liquids have been removed, final cleanup can be accomplished by flushing out basement sumps and floor drains with water and washing down all contaminated surfaces with a biodegradable surfactant. Ventilation and checking with a combustible gas indicator should be continued throughout the cleanup procedure.

6-2.3 In the rare cases involving relatively large volumes of volatile liquids, ventilation might not sufficiently reduce the vapor concentration to a safe level due to the continued evaporation of the liquid. In these cases, bail or pump the liquid into barrels, drums, or other suitable containers or into portable tanks or tank vehicles. It might be necessary to dig an interceptor trench between the source of the release and the affected structure.

6-2.4 When nonvolatile liquids, such as fuel oils, are involved, ventilation is ineffective because the liquid evaporates at such a low rate. Absorbents should be used for thin films of liquid on water surfaces or on solid surfaces. Whenever possible, remove liquids with pumps or by bailing. Contaminated water should be put into barrels or other containers to allow separation by settling. The water can then be siphoned off and the remaining liquid brought to a disposal facility. (*See Figure 6-2.*) If final cleanup requires flushing sumps and drains and washing surfaces, check with local sanitation and environmental authorities before flushing such liquids to sanitary sewers.

6-3 Subways, Tunnels, Mines, Etc.

6-3.1 If only small amounts of volatile liquids are involved, ventilation alone might be adequate to permit safe entry and possibly continued use of the facility. In such cases, the same removal and disposal methods as described previously for basements can be used. However, added precautions must be employed due to the greater potential exposure to the public and, normally, due to the greater exposure to potential ignition sources. The authority responsible for the facility, the fire department, and other public safety officials should effect a cooperative effort for maximum public safety.

6-3.2 Subways, tunnels, and mines will normally be more prone to underground seepage than other subterranean structures, such as basements. Consequently, even though entry of a flammable liquid is thought to have been stopped, monitoring with a combustible gas indicator should be continued for an extended period of time after remediation to check for recurrence.

Maintain a constant check for at least 24 hours after remediation has been completed. If results are negative, extend the check periods to an 8-, 12-, or 24-hour cycle,

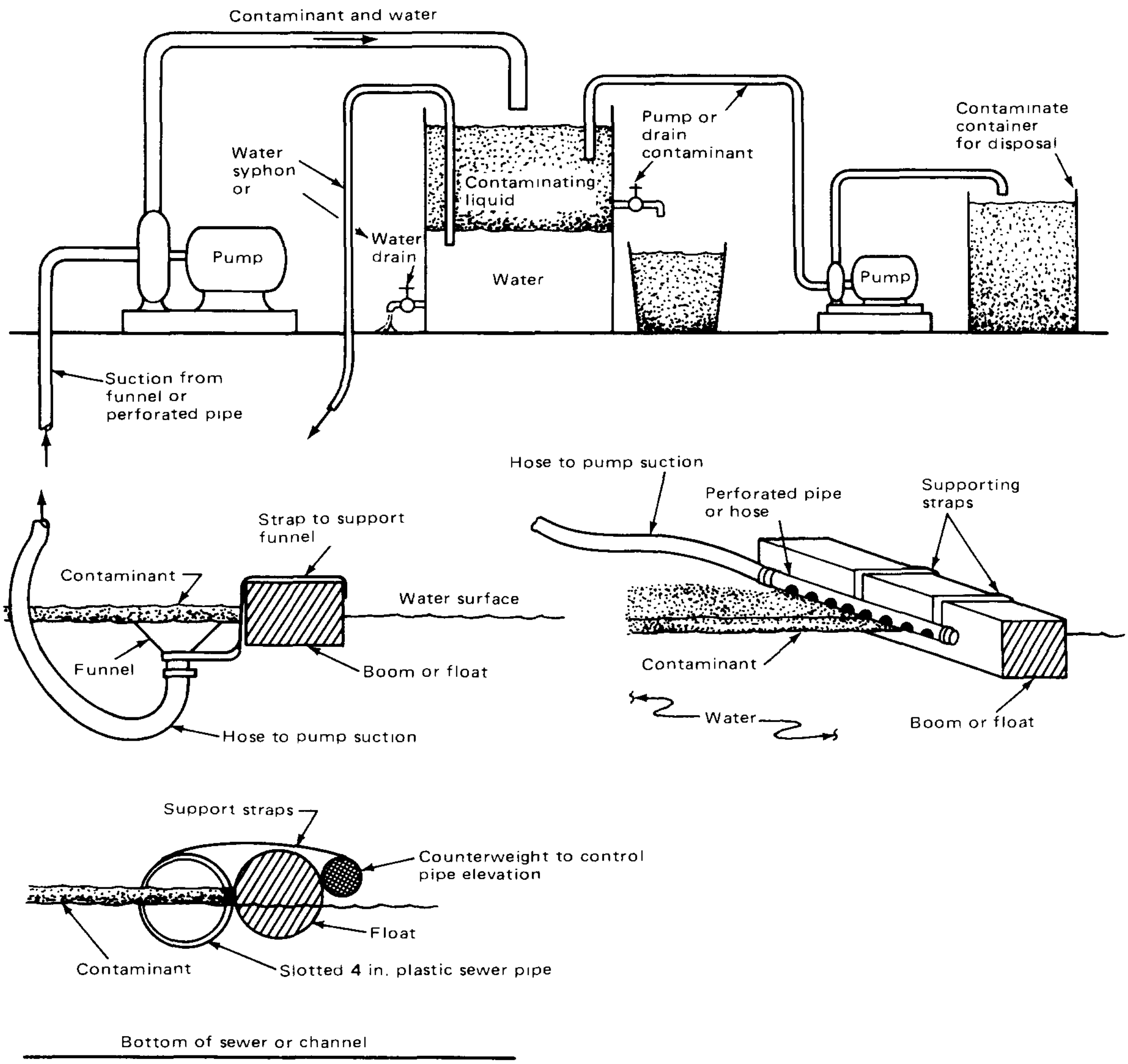


Figure 6-2 Typical skimming and gravity settling installation.

depending on the use of the facility. Subsequent checks should be continued to include periods of extreme changes in groundwater levels. Significant rainfall and rising groundwater can carry with it more liquid.

6-3.3 If a relatively large amount of liquid is involved or if leakage continues, it might be necessary to close the facility to the public and suspend normal operations. It might also be necessary to deactivate any high voltage electric lines or electric transit tracks in the vicinity of the seepage. Maintain ventilation and provide a collection point for intercepting seepage and pumping it out. Use only a nonsparking or air-operated pump motor.

Use a drum or small tank for liquid settling and separation; transfer the separated volatile liquid to drums or tanks for transport to a disposal facility. Consult with the facility operator to determine the degree to which cleanup and remediation are necessary. Normally, once further entry of volatile liquids has been stopped, such facilities can be adequately purged of vapors with reasonable periods of ventilation.

6-3.4 If nonvolatile liquids are involved, the potential for ignition is greatly reduced. However, make sure that continued use or operation does not present a potential ignition source. It might still be necessary to disconnect any electric services near the seepage, as explained in 6-3.3.

Absorb, bail, or pump the liquid, whichever is more appropriate, using drums or tanks for separation by settling, and remove the liquid for transport to a disposal facility. Consult with the facility operator to determine the acceptability of using detergents, dispersants, or coagulants for final flushing and cleaning. As with volatile liquids, periodic monitoring must be performed to detect any possible recurrence. Use the same time periods and groundwater changes as described in 6-3.3.

6-4 Utility Conduits.

6-4.1 Removal and disposal methods for utility conduits differ from those described for other subterranean structures previously covered for the following reasons:

(a) Concentrations of contaminating liquids will normally be higher because early discovery and preventive measures are unlikely.

(b) Access to entry points and contaminated areas is usually from manholes, but such access might not be available.

(c) Exposure and danger to the public are greatly reduced.

The utility operator should be consulted on all details of the remediation effort and the proposed purging procedures. The operator's special knowledge will be essential to selecting the exact procedures and techniques to be used.

6-4.2 Where water is mixed with the contaminating liquid, it is preferable to separate the two by settling in drums or tanks to avoid downstream drainage facilities.

6-5 Sewers.

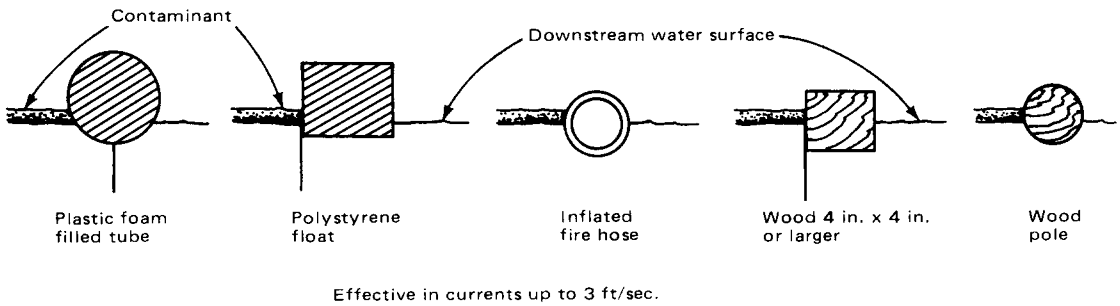
6-5.1 On occasion, sewers can collect flammable or combustible liquids from a surrounding contaminated area. It is seldom practical to seal off all entry points into the sewer. Consequently, removal of contaminating liquids will normally be a continuing effort until the entire area is purged. When relatively large amounts of liquid are involved, every reasonable effort should be taken to divert the affected sewer flow to a separator.

If this is not practical, it might be possible to set up a skimming facility at some point on the stream flow. One method is to float a boom or inflated tube (such as a fire hose) across the stream. If the contaminant is mostly on the surface of the stream flow, and flow is not turbulent, significant amounts of the contaminating liquid can be trapped behind the boom and can be removed with skimmer pumps or absorbents. [*See Figures 6-2 and 6-5(a).*] Weirs can also be used in the same way by installing them in such a manner that water can flow underneath, trapping the liquid behind the upper part of the weir. Weirs should be used whenever possible because of their greater efficiency, particularly where the stream flow exceeds 3 ft per second (1m/sec). [*See Figure 6-5(b).*]

6-5.2 Where relatively small amounts of liquid are involved or where the contaminating liquid is mixed with the water, settling tanks or basins must be used for separating the contaminant from the water. Sewage treatment plants might have such facilities. Note that this is only applicable to liquids that are immiscible with water.

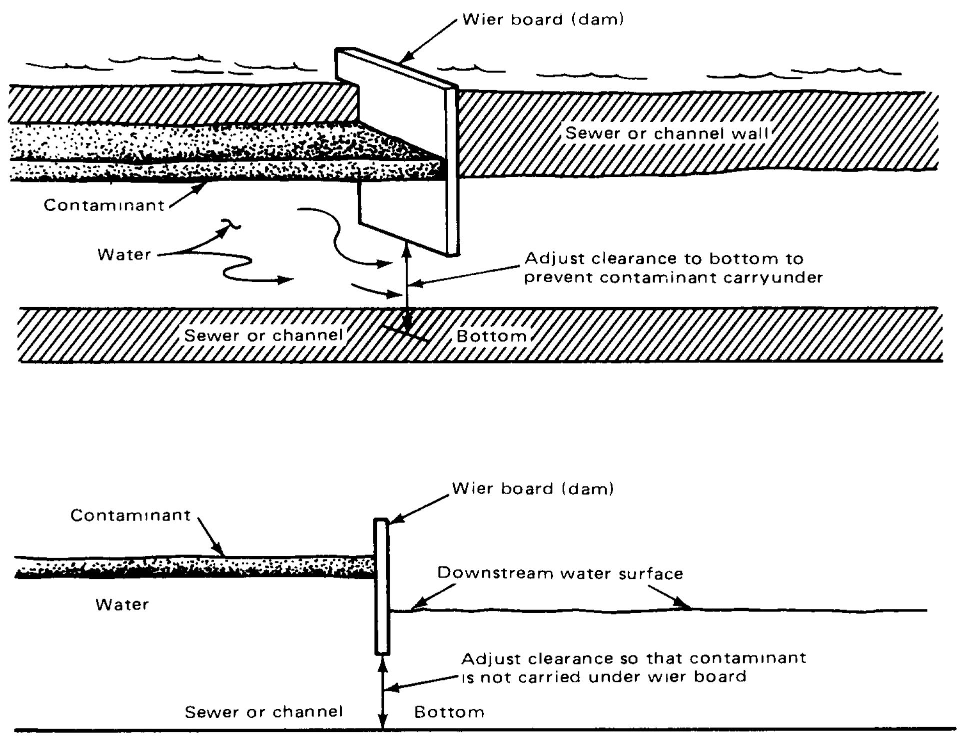
6-5.3 Where contamination exists on the surface of a body of water that is directly exposed to the open atmosphere, the problem should be referred to the appropriate environmental authority.

6-6 Underground Contamination. A knowledge of the local geology is basic to effective removal of flammable or combustible liquid contamination from subsurface soils. A geologist who is familiar with the area should be consulted before field activities are begun. Subsurface assessment will most likely be required to further determine the movement of contamination, to define the extent of the contamination, and to properly design the remediation efforts. Additional information can be found in API Publication 1628, *Guide to the Assessment and Remediation of Underground Petroleum Releases.*



For SI Units: 1 ft = 0.305 m; 1 in. = 25.4 mm.

Figure 6-5(a) Typical floats and booms for trapping contaminants floating on water.



When current flow exceeds 3 ft/sec, contaminants can be trapped by creating a difference in upstream and downstream surface with a baffle or wier board.

Figure 6-5(b) Typical installation of a wier in a flowing stream.

Chapter 7 Referenced Publications

7-1 The following documents or portions thereof are referenced within this recommended practice and should be considered part of the recommendations of this document. The edition indicated for each reference is the current edition as of the date of the NFPA issuance of this document.

7-1.1 NFPA Publication. National Fire Protection Association, 1 Batterymarch Park, P.O. Box 9101, Quincy, MA 02269-9101.

NFPA 328, *Recommended Practice for the Control of Flammable and Combustible Liquids and Gases in Manholes, Sewers, and Similar Underground Structures*, 1992 edition.

7-1.2 API Publication. American Petroleum Institute, 1220 L St., NW, Washington, DC 20005.

API Publication 1628, *Guide to the Assessment and Remediation of Underground Petroleum Releases*, Second Edition, 1989.

7-1.3 U.S. Government Publication. Office of Underground Storage Tanks, U.S. Environmental Protection Agency, Washington, DC 20460.

EPA 530/UST-89 1012, *Detecting Leaks: Successful Methods Step-by-Step*, November 1989.

Appendix A Volumetric Tightness Testing

This Appendix is not part of the recommendations of this NFPA document, but is included for informational purposes only.

A-1 Definition.

The term *volumetric tightness test*, as used in this recommended practice, refers to any test that fulfills the detection capabilities set forth in Section 4-4 and quantifies a leak rate. There are a number of variables that affect the ability of any particular tightness testing technology to perform within these detection capabilities. The following information addresses some, but not all, of the variables that might be encountered. An understanding of these variables and how they are handled is essential to effective performance of the test. Each manufacturer of a volumetric tightness testing technology should identify in writing a procedure or means of dealing with the variables described in this Appendix, as applicable.

A-2 Variables Affecting Volumetric Tightness Testing. The variables that are addressed here are as follows:

— Temperature
— Tank deflection
— Water table
— Entrapped air/vapor
— Evaporation
— Tank volume
— Vibration
— Wind
— Operator error
— Product characteristics
— Tank configuration
— Preexisting soil or groundwater contamination
— Testing with water

A-2.1 Temperature. Liquids expand or contract with a change in temperature. Table A-2 lists the thermal coefficient of expansion for some of the more common flammable and combustible liquids. For example, note that a temperature decrease of only 0.04°F (0.022°C) in one hour in a 6,000 gal (22,710 L) tank containing gasoline would cause a volumetric decrease of 0.04°F (0.022°C) × 0.0007 × 6,000 gal (22,710 L) = 0.168 gal (636 ml), which exceeds the 0.10 gal (380 ml) leak detection capability. If this temperature change were not detected and accounted for in a test, a leak would be assumed where none existed. And, in a like manner, if the temperature increased, a leak could be concealed by volumetric expansion if the temperature change was not detected.

Table A-2 Coefficients of Thermal Expansion for Some Common Liquids

	Volumetric Coefficient of Thermal Expansion per °F
Acetone	0.00085
Amyl Acetate	0.00068
Benzene	0.00071
Carbon Disulfide	0.00070
Ethyl Ether	0.00098
Ethyl Acetate	0.00079
Ethyl Alcohol	0.00062
Fuel Oil No. 1 & Kerosene*	0.00050
Fuel Oil No. 2 & Diesel Fuel*	0.00045
Gasoline*	0.00070
Methyl Alcohol	0.00072
Toluene	0.00063
Water (at 68°F)	0.000115

*The coefficient of thermal expansion given for each of these liquids is typical for that liquid, but may vary depending on the components of the liquid and on temperature. See ASTM D1250-80, *Petroleum Measurement Tables*, for further information.

It is sometimes proposed that this problem can be overcome by filling the tank 10 to 12 hours before a test run, on the assumption that the product temperature will stabilize. Extensive tests have shown that this is seldom, if ever, true. When liquid is added to fill a tank for testing, it will often require several days for the liquid to stabilize to ground temperature, which in itself is constantly changing. The rate of temperature change in the first day or two will generally be in the range of 0.02°F (0.011°C) per hour to 0.25°F (0.7°C) per hour. In addition, the rate of temperature change will vary depending on the temperature and volume of the product in the tank, as well as the product added. Obviously, the test must be capable of detecting temperature changes to the accuracy necessary to ensure compliance with Chapter 4.

Another temperature effect that must be recognized and accounted for is temperature stratification or "layering." Layering occurs when a product of a different temperature is added to a product already in a tank (i.e., the product added is colder than the product already in the tank). In addition, layering occurs as a result of ground temperature variations with depth. Temperature measurement must include a method for averaging any differences in temperature throughout the tank.

A-2.2 Tank Deflection. Some techniques require filling the tank to a point above grade. This increase in the height of the liquid increases the pressure inside the underground tank above its normal operating pressure and will deflect the tank ends outward. This is illustrated in Figure A-2.2(a).

In a 6 ft (1.8 m) diameter tank, the average pressure on the end or "head" of a tank that is filled with gasoline is 0.98 psi (50 mm Hg). If the tank is buried 3 ft (1 m) below grade (typical for most gasoline tanks), the average pressure on the tank head will increase to approximately 2.95 psi (153 mm Hg) when the fill pipe and standpipe are filled to a level 3 ft (1 m) above grade. This increase in pressure of approximately 1.95 psi (100 mm Hg) exerts an additional force on the end or "head" of the tank of about 8,000 pounds, or 4 tons. The ends of most tanks typical of underground use are made of 1/4-in. (6.4-mm) thick steel plate and will deflect outward as pressure inside the tank increases, as shown in Figure A-2.2(b). Although most fiberglass tanks have dished or hemispherical ends, the same phenomenon of expansion will occur due to flexure between the ribs on the side of the tank.

If the tank is located above ground and the heads are not supported in any way, it is possible to predict the amount of movement that will result from any given change in pressure and, when the amount of movement is known, the resulting increase in volume of the tank can be calculated. However, when tanks are located underground they are subject to an infinite variation in the mechanical support from the surrounding soil, and it is not possible to predict how much movement will take place. Very solid soil can sometimes provide close to full support. But normally soils will consolidate to some degree, particularly if they are wet, thereby allowing tank expansion and end deflection.

Extensive study and testing have revealed that, in almost all cases, tank movement that is significant enough to affect tightness tests occur. It will happen suddenly because of the time required to consolidate the soil. Under a constant increased pressure, it will normally take several hours for the tank to stabilize. Table A-2.2(c) shows the volume increase as a function of tank end deflection. The numbers underlined are the maximum normally encountered with underground steel tanks; the last figure in each horizontal row is the maximum possible for the tank size in that row. Similar information is not yet available for fiberglass tanks. The latest data indicate that expansion due to side flexure might exceed that for flexure of steel tanks.

The test method employed should be capable of clearly indicating the possible effects of tank end deflection and should provide a means of compensation or elimination of the effects.

A-2.3 Water Table. As stated in 4-2.1.2, there are many instances where water might enter a tank system. The relationship of the water table to the depth of burial of the tank system has a direct bearing on volumetric tightness testing procedures and results. The test method employed should be able to indicate clearly the possible effects of water in the back fill area around the tank system and provide a means of compensation or elimination of the effects.

A-2.4 Entrapped Air/Vapor. Stored materials combined with air in the form of a pocket of air/vapor mixture will be affected by both temperature and pressure changes. Volume expansion or contraction will occur. Volumetric tightness test methods employed should be able to indicate the presence of entrapped vapor or air that might affect the results of the test. The test method must require the removal of the entrapped vapor or compensate for the effects of the entrapped vapor.

A-2.5 Evaporation. Some liquids, especially highly volatile liquids, have high rates of evaporative losses if exposed to the ambient atmosphere. The volumetric tightness test method employed should be able to clearly indicate the possible effects of evaporative losses and compensate for them.

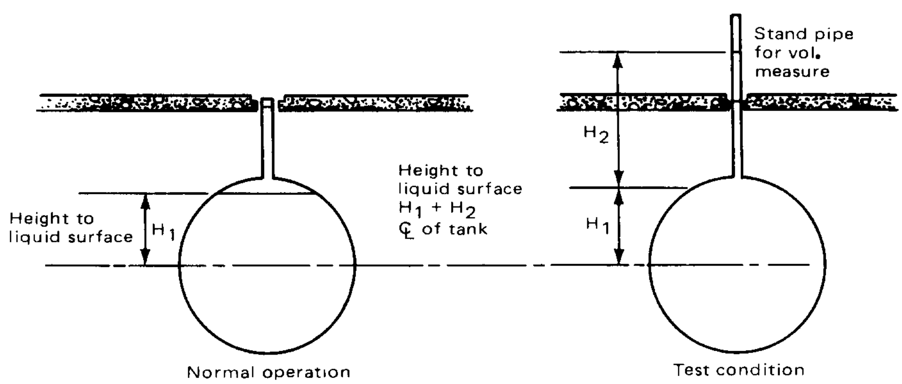


Figure A-2.2(a) Static pressure on tank shell — normal operation vs. test condition.

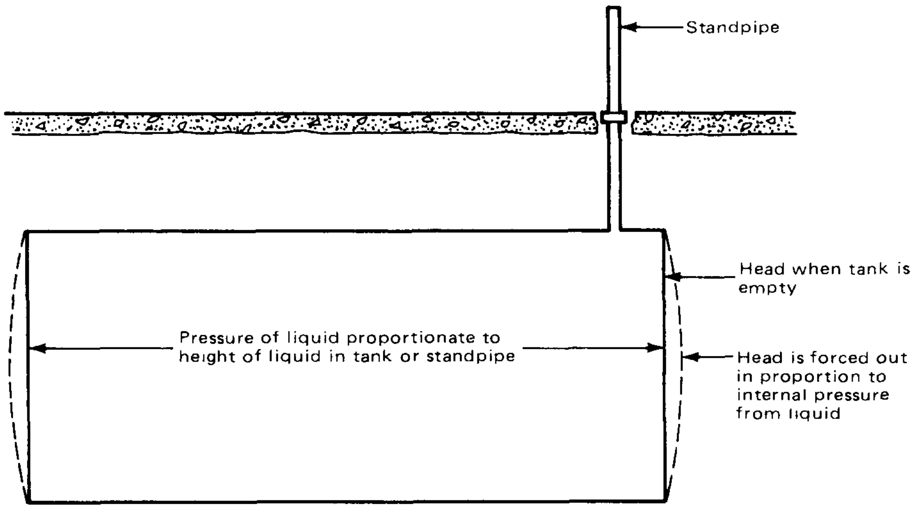


Figure A-2.2(b) Tank end deflection.

Table A-2.2(c) Increase in Volume, in Gallons, of Tank Due to Tank End Deflection Apparent Loss of Liquid Volume in Gallons Due to Increased Pressure in a Tank

Outward Deflection at Center of Head in Inches

Tank Dia. Inches	1/16	1/8	3/16	1/4	5/16	3/8	7/16	1/2	5/8	3/4	7/8	1
48	.49	.98	1.47	1.95	2.44	2.93	3.42					
64	.87	1.74	2.61	3.48	4.35	5.22	6.10	6.97				
72	1.10	2.20	3.31	4.41	5.51	6.62	7.72	8.82	11.0			
84	1.50	3.00	4.50	6.00	7.50	9.00	10.50	12.00	15.0	18.0	21.0	
96	1.96	3.91	5.87	7.82	9.77	11.75	13.70	15.65	19.6	23.5	27.4	31.3
102	2.21	4.42	6.65	8.25	11.06	13.30	15.50	17.70	22.6	26.6	31.0	35.4
120	3.06	6.12	9.18	12.25	15.30	18.4	21.4	24.5	30.6	36.7	42.8	49.0

For SI Units: 1 in. = 25.4 mm.

A-2.6 Tank Volume. Differences in the nominal volume and the actual true volume of an underground storage tank can affect the accuracy of the measurement technology employed during a volumetric tightness test. The best sources of information regarding the true volume of an underground tank are the "strapping" charts supplied with the tank being tested or by checking with the tank manufacturer. If these charts are not available, then volume charts based on design specification and not true volume must be used. Under no circumstance should testing personnel "best guess" the true volume of the tank.

If there is no other reasonable means of determining the true volume, a metered delivery of product could be made and the tank size calculated.

A-2.7 Vibration. Vibration in the test area can affect the capabilities of test and measurement equipment. Tightness testing equipment having a computer-driven metering pump associated with the volume measurement systems or a manual tightness tester with an auto-leveler on the volume measurement system are two means often used to eliminate or minimize this variable.

A-2.8 Wind. Wind can affect the accuracy of some volume measurement devices. Shielding the measurement equipment from the effects of the wind should compensate for this. If the testing system is operated by a microprocessor-based computer, it might be possible to calculate out the effects. Where a volumetric tightness test is being performed "in the tank" (below the tank top), winds across the vent can also interfere in the accuracy of the test.

A-2.9 Operator Error. The more complicated the testing procedure, the greater the potential for operator error. Typically, this is minimized or reduced by using trained and experienced operators to conduct the testing. All testing personnel should have documentation as to training and qualifications for the testing equipment being used.

Having been trained on the technical aspects of the testing equipment is not sufficient. A good general working knowledge of the mechanical components of the tank system is also necessary to avoid testing problems and a potential release of product as a result of operator error.

A-2.10 Product Characteristics. Most tightness testing technologies have been developed for use with motor fuels or other petroleum-based liquids and water. Petroleum products that have a greater viscosity than motor or aviation fuels may not be easily tested by most testing technologies. For example, No. 6 fuel oil at a stored temperature less than 120°F is normally not free flowing. Although a release detection technology might be able to measure observed volume changes in the tank despite the viscosity of the product, a leak might not be detected.

Testing non-petroleum-based solvents can also be a problem due to incompatibility of the stored material with the test equipment.

A-2.11 Tank Configuration. Most tightness testing technologies are designed to be used on tank systems of a specific configuration. Usually tanks are horizontal cylinders with flat or hemispherical ends and a number of vertical access ports or a manway. Where a computerized tester is involved, the data base is often designed to measure temperature and volume change in a tank of this configuration. If the same tightness testing system is used to test a vertical cylinder or a square concrete fuel bunker, modification of the mechanical components of the data base might be necessary.

The mechanical components of a tightness testing system often require direct access to the tank through a vertical fill pipe. If the tank system has only a remote fill pipe (i.e., pipe where there is no direct access to the tank), mechanical modification of the tank components might be necessary.

When a product level-sensitive detection method is used to determine leaks in an underground storage tank, tank inclination can affect detection accuracy. In an inclined tank, the volume change per unit of level change is different than in a level tank. This is due to the difference between cross-sectional areas. This effect can be corrected by measurement of the level changes due to a known product volume change.

Some tightness testing technologies detect an ingress of water. Where a tank is installed on an incline, water sensing equipment might not be capable of detecting an ingress.

A-2.12 Preexisting Soil or Groundwater Contamination. Tightness testing technologies that detect an ingress of water might fail to sound an alarm or might indicate a tight tank where there is a substantial concentration of free product in the soil around the tank prior to the test.

A-2.13 Testing with Water. Tests that involve adding water to a tank can be useful when tanks are empty. However, water is difficult to use in cold weather. It will not detect leaks of less viscous liquids, and contamination of the storage and dispensing system can be a major problem (and result in frozen pipes in cold weather). If a tank previously contained a petroleum product and a test using water is considered, it might be more difficult to dispose of the product-contaminated water than to fill the tank with product for the test. Water is often used for an initial test of a new tank system that has not yet contained any product. Also, water has a greater surface tension than some petroleum products. If a test is performed using water, it is recommended that a surfactant be used to lower the surface tension of the water to near that of the product stored for a more accurate test. Contact the manufacturer of the tightness testing method regarding the use of a surfactant and check with local authorities regarding the disposal of the water after the test.

Appendix B Nonvolumetric Tightness Testing

This Appendix is not part of the recommendations of this NFPA document, but is included for information purposes only.

B-1 Definition. The term *non-volumetric tightness test*, as used in this recommended practice, refers to any test that fulfills the detection capabilities set forth in Section 4-4 and that does not quantify a leak rate. There are a number of variables that affect the ability of any particular tightness testing technology to perform within these detection capabilities. The following information addresses some, but not all, of the variables that might be encountered. An understanding of these variables and how they are handled is essential to effective performance of the test. Each manufacturer of a non-volumetric tightness testing technology should identify in writing a procedure or means of dealing with the variables described in this Appendix, as applicable.

B-2 Variables Affecting Nonvolumetric Tightness Testing. The variables that are addressed here are as follows:

— Extraneous noise
— Water table/impermeable soils
— Operator error
— Product characteristics
— Tank characteristics
— Preexisting soil or groundwater contamination

B-2.1 Extraneous Noise. Extraneous noise can be a factor where the chosen non-volumetric tightness testing technology relies on sound-sensitive signals to detect a release. Elimination of the source of the extraneous noise might be necessary for completion of a valid test.

B-2.2 Water Table/Impermeable Soils. Some non-volumetric tightness testing technologies employ the use of tracer materials to detect a leak. The movement of these tracer materials can sometimes be inhibited by impermeable soils or groundwater, thereby reducing the detection capability of the testing technology or causing an extension of the test time.

B-2.3 Operator Error. The more complicated the testing procedure, the greater the potential for operator error. Typically, this is minimized or reduced by using trained and experienced operators to conduct the testing. All testing personnel should have documentation as to training and qualifications for the testing equipment being used.

Having been trained on the technical aspects of the testing equipment is not sufficient. A good general working knowledge of the mechanical components of the tank system is also necessary to avoid testing problems and a potential release of product as a result of operator error.

B-2.4 Product Characteristics. Most tightness testing technologies have been developed for use with motor fuels or other petroleum-based liquids and water. Petroleum products that have a greater viscosity than motor or aviation fuels may not be easily tested by most testing technologies. For example, No. 6 fuel oil at a stored temperature less than 120°F is normally not free flowing. Although a release detection technology might be able to measure observed volume changes in the tank despite the viscosity of the product, a leak might not be detected.

Testing non-petroleum-based solvents can also be a problem due to incompatibility of the stored material with the test equipment.

B-2.5 Tank Configuration. The mechanical components of a tightness testing system often require direct access to the tank through a vertical fill pipe. If the tank system has only a remote fill pipe (i.e., pipe where there is no direct access to the tank), mechanical modification of the tank components might be necessary.

Some tightness testing technologies detect an ingress of water. Where a tank is installed on an incline, water sensing equipment may not be capable of detecting an ingress.

B-2.6 Preexisting Soil or Groundwater Contamination. Tightness testing technologies that detect an ingress of water might fail to sound an alarm or indicate a tight tank where there is a substantial concentration of free product in the soil around the tank prior to the test.

B-3 Internal Inspection. If warranted, an internal inspection of the tank should be conducted to evaluate the condition of the tank interior. Proper procedures for safe entry should be followed.

Appendix C Basic Principles and Concepts of Underground Flow

This Appendix is not part of the recommendations of this NFPA document, but is included for information purposes only.

C-1 The principal characteristic that permits liquids to enter, accumulate, and flow through soil or rock is porosity: the space or voids that exist between the particles that make up the soil or rock. The size of the voids will vary from large, as in gravel, through small, as in sand and topsoil, to essentially zero, as in fine, dense clay. Rock almost never has large voids, but sandstones and limestones have voids similar to a fine sand.

Crystalline rocks, such as granite and marble, are essentially impervious, but these rocks often have fractures and cracks that will permit flow. The rate of flow through rock fractures will vary from large continuous cracks that will act like a pipe, to very small irregular cracks that result in flows similar to what would be found in fine sand.

The rate of flow through soils and rocks depends largely on the size of the voids, with flows ranging from 6 ft per year in fine clays to 6 ft per day in gravels. The term used to describe soils that allow flow is *pervious.* A very pervious soil will allow rapid flow of liquid, while an impervious soil will allow only very slow flow. When the word *impervious* is used alone, it implies absolutely no flow; for example, glass is impervious to the flow of water. It should be understood that porosity does not always mean a pervious condition. In order for the soil or rock to be pervious, the pores must be interconnected. A porous rock whose pores are isolated from each other will be impervious.

C-2 Almost all flammable and combustible liquids are lighter than water and will float on the water, unless the liquid is water soluble. When these liquids escape into the ground, they will normally flow downward until they encounter a layer of groundwater. Then they will flow along with the groundwater. Understanding the flow of groundwater is essential to tracing the flow of a flammable or combustible liquid underground.

C-3 Water is almost universally found underground at some level in soil or rock. It might be in very limited quantities and only able to dampen the soil. But when it fills all the pores and voids in the soil and saturates the soil or rock up to a certain level, it becomes somewhat like water in a bucket and establishes a definite top surface, called a water table. Figure C-3(a) shows that groundwater can occur in several layers underground. A porous layer between two impervious layers might be completely filled or might be only partially filled and have its own water table. However, other layers must be considered, since, even though these might be very deep at one location, they can be close to the surface at others. See Figure C-3(b).

C-4 All groundwater, with the exception of narrow bands along the seacoast, originates as rain or snowfall that seeps into the soil. As shown in Figure C-3(b), at any given location, the water might have come from precipitation on the surface immediately above or it might have flowed underground for long distances through pervious soil or rock from a point where the pervious layer "outcrops" or intercepts the surface. Of course, water from precipitation can also flow to lakes and rivers and then into underground layers.

C-5 Water tends to seek its own level underground, just as it does on the surface. However, water flowing underground will not flow as fast as on the surface because of the resistance of the soil particles. This has the effect of steepening the slope of the water table. The water does not flow to lower levels as fast as it fills the soils at shallower depths. The same effect is shown where a lake or other body of water supplies water to the pervious soil. Expressed another way, pressure is required to overcome the resistance to flow and the increase in elevation provides the necessary pressure.

C-6 The height or elevation of the water table will depend not only on how fast the water flows out of the strata (layers), but also on how fast it is fed into the strata by rain or melting snow. When no water is being added, the water table drops, as water flows out at springs and wells and as it "wicks" through dry soil to evaporate at the surface.

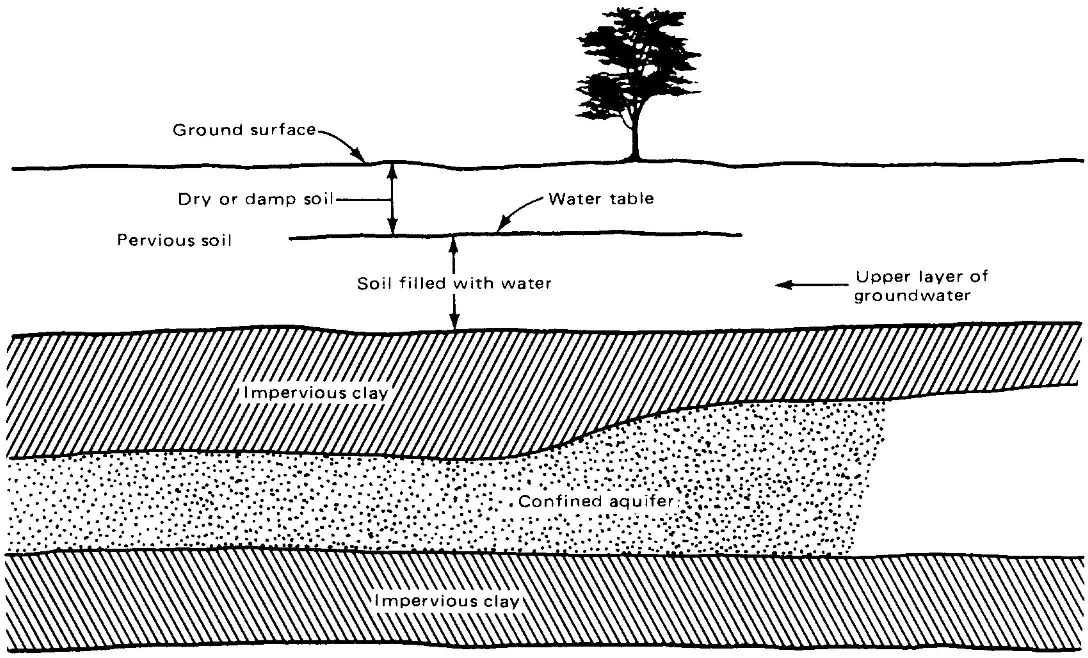


Figure C-3(a) "Layering" of groundwater between and above impervious strata.

When water is added faster than it can flow out, the water table rises. This rise and fall can be several feet in a few days, as the weather changes from dry to wet and vice versa.

C-7 In summary, the principal factors that are important to tracing unconfined liquids underground are:

(a) Most flammable and combustible liquids will float on water.

(b) When unconfined in the ground, flammable and combustible liquids will float on the top of the water table and will flow along with it.

(c) Groundwater will flow through pervious soil or rock toward lower elevations at a flow rate that will vary from several feet per day to several feet per year.

(d) The top of the water (the water table) will slope downward in the direction of flow.

(e) The water table will rise and fall (in some cases, several feet in a few days), depending on the supply of rain or melting snow.

C-8 Figures C-8(a) and (b) show the effect of the slope of the underground strata on the direction of liquid flow. The figures show identical surface conditions, but differing subsurface conditions. A 4-story building lies approximately midway between two streets that are 400 ft apart. A 5 percent grade from left to right places the street on the right about 20 ft higher than the street on the left.

In Figure C-8(a), the underground strata follows the general slope of the surface and groundwater in the sand and gravel layers flows from right to left. Under these conditions, if gasoline liquid or vapors were found in the subbasement of the building, the source of that gasoline would most likely be from the service station to the right, at the higher elevation, or from other tanks farther up the hill.

In Figure C-8(b), the situation is such that the service station downhill is the most likely source. The water-bearing strata of sand and gravel slopes down from left to right, opposite to that of the surface of the ground. Groundwater flow would also be from left to right and would carry any gasoline escaping from the service station on the left to the subbasement of the building.

One other condition shown in Figure C-8(a) is the effect of a rising and falling water table. During a dry season, when the water table is below the subbasement floor of the building, gasoline floating on the water table would not be able to enter the subbasement. But, as the water table rises, the gasoline will be lifted along with it, eventually reaching the subbasement level. There have been many cases where this has been the reason for the alternating appearance and disappearance of contaminating liquid.

C-9 Figure C-9 illustrates another example of how underground flow can be contrary to the slope of the ground above. In this case, flammable liquids are stored in a tank that is some distance above a small body of water. From the surface, it would appear that escaping liquid would flow into the pond. But, because the tank is over a pervious strata that slopes away from the pond, the liquid flows in that direction, contaminating wells that serve buildings at a much higher elevation than the tank. Note also that if the wells were not present, discovery would be delayed, probably until the release reached the ground on the other side of the hill. This could be several miles away.

C-10 Figures C-10(a) and (b) illustrate some other aspects of a rising and falling water table and the ability of trenches to behave like interconnected piping, especially when dug in relatively impervious soil, then backfilled with a more porous material. Figure C-10(a) shows a tank installed in an excavation dug in clay and backfilled with sand. Product supply and vent lines are likewise in trenches dug in

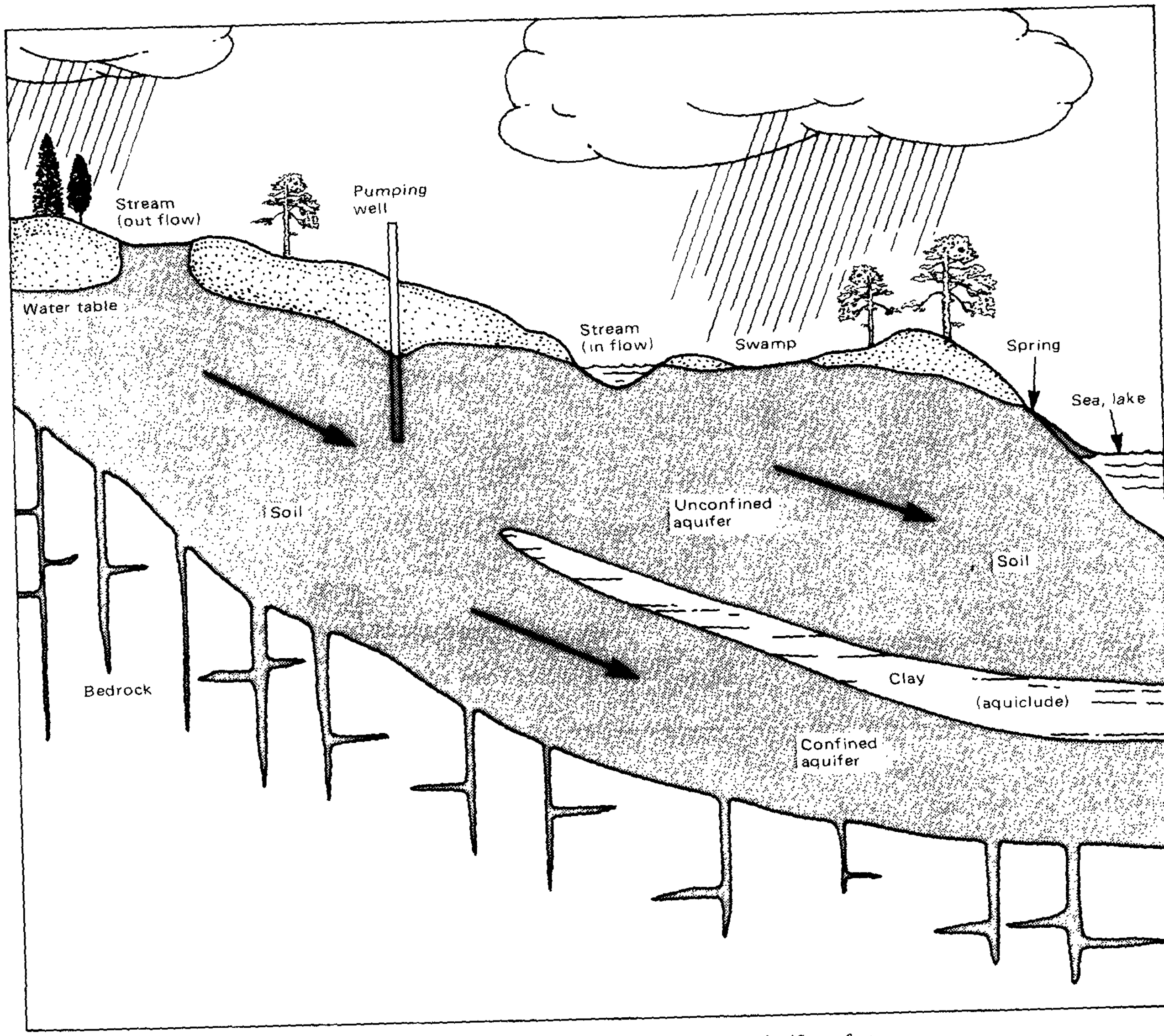


Figure C-3(b) Hypothetical groundwater systems showing significant features.

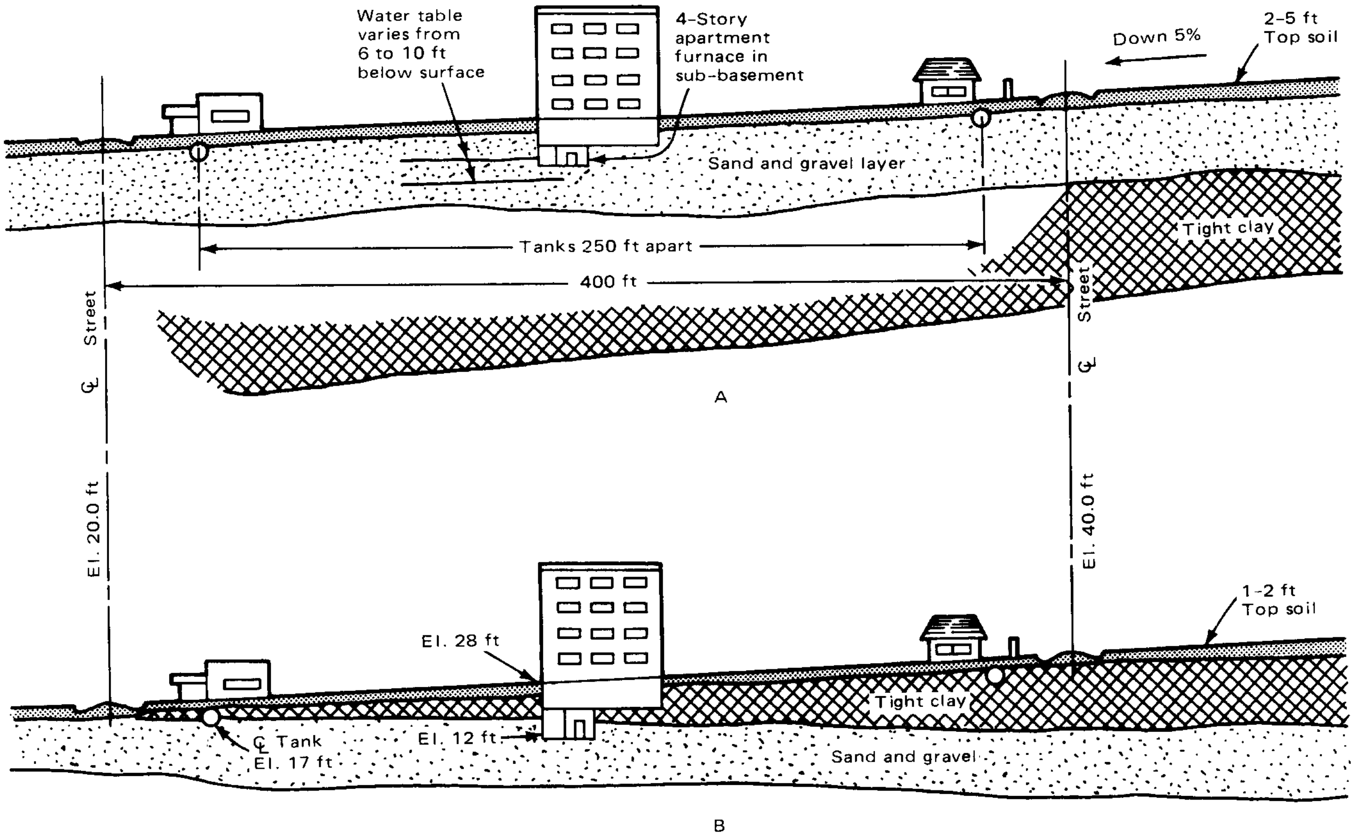
clay and backfilled with the same material as the tank. Figure C-10(b) shows the layout of a tank installed next to a building with a basement. The water supply line to the building is also in a trench backfilled with sand, as is the city water main and sewer line. Finally, a low area between the buildings is filled with sand and gravel.

The parent or original soil is clay. A water table that exists in this clay will have little horizontal flow, due to the resistance of the clay. Consequently, the water table rises and falls with changes in the weather. For this example, assume that the water table is within 1 ft of the surface during wet periods, but falls to a level below the bottom of the tank excavation during dry periods.

It is easy to see that a leak in the tank will result in contaminating liquid collecting on the bottom of the excavation, as if it were in an open square tank. If rainfall raises the water table to a level above the bottom of the pipe trenches, then the contaminated groundwater can flow along the pipe trenches, much as it would flow through a pipe. By means of intersections with other trenches or with zones of more pervious fill, this contaminated water can spread to the adjacent buildings or to the sewer and water main trenches. Note that it will not necessarily enter the sewer pipe in the street. It might flow along the trench, outside of the pipes themselves and not appear until it comes to a point where it can seep into a manhole or catch basin.

Another condition illustrated here is the potential for the contaminating liquid to move without the presence of groundwater. If a serious leak were to occur in the suction piping, pure liquid could flow along the trenches.

C-11 Summary. The principles and concepts discussed in this Appendix point out the importance of a knowledge of the underground soil conditions and subterranean features when tracing the movement of escaped liquids from the point of discovery back to the source. It will not always be possible to obtain all the data desired, but the effort must be made for remediation to be successful.



For SI Units: 1 ft = 0.305 m.

Figure C-8 Effect of slope of underground strata on groundwater flow.

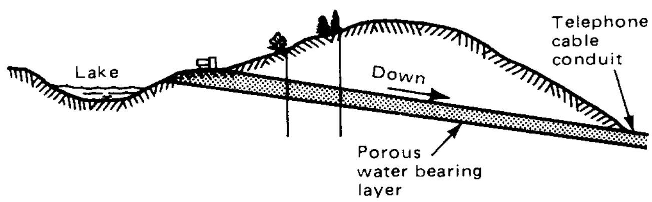


Figure C-9

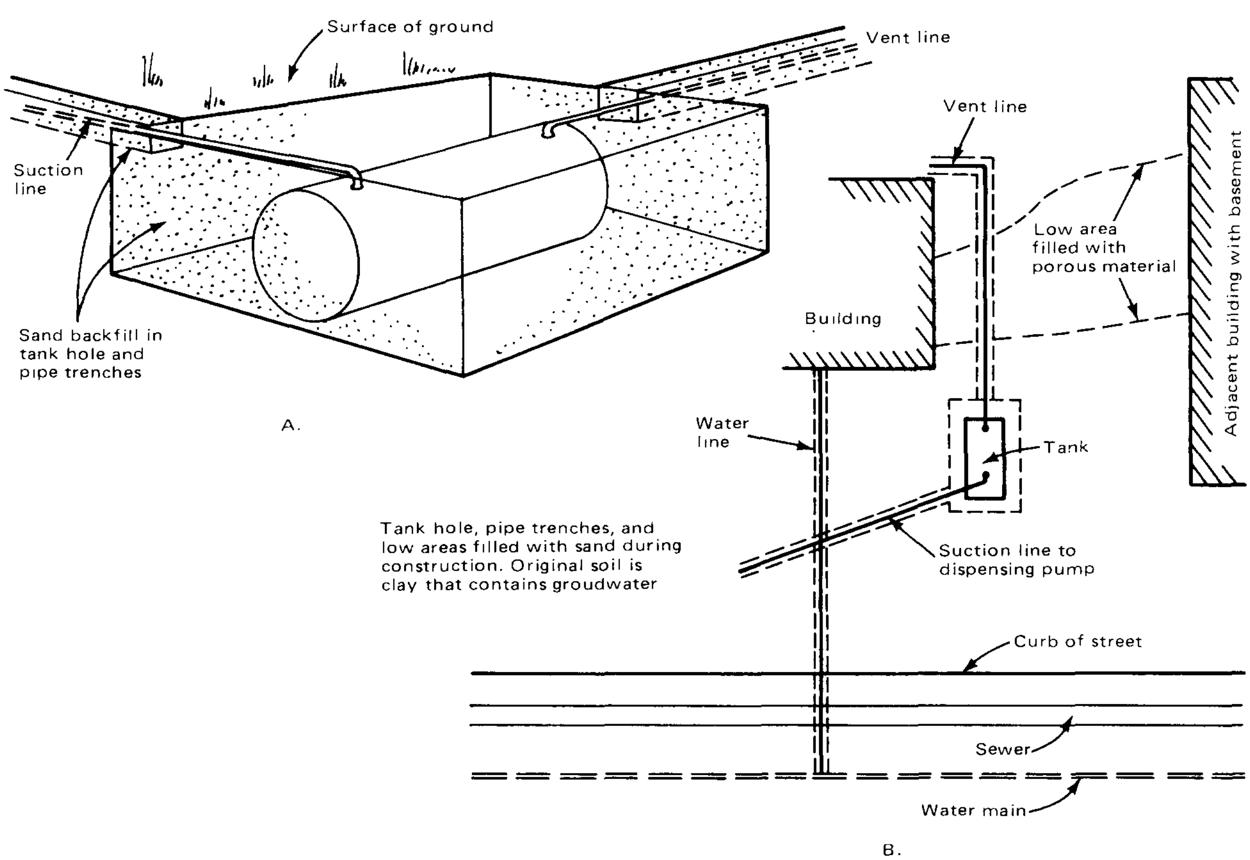


Figure C-10

Appendix D Inventory Control Procedures

This Appendix is not part of the recommendations of this NFPA document, but is included for information purposes only.

D-1 Tanks with Metered Dispensing. For this method to be effective, all meters that measure liquid dispensed from the underground system should be properly calibrated to local standards for meter calibration or an accuracy of 6 in.^{3}/gal for every 5 gal (approximately 5 ml per Liter) of products withdrawn. A meter that reads significantly higher than actual volume pumped can hide a leak. Conversely, a meter that indicates less than the true volume might suggest a leak where one does not exist.

D-1.1 Daily Procedures. At the beginning of each business day (or each shift, if preferred), the tank volume should be manually measured using a gauge stick, or other means, and a calibration chart to convert the tank level into gallons. Level measurements should be based on the average of two consecutive stick readings. This gauging operation should be carried out with great care to ensure maximum accuracy. Opening meter totalizer readings should also be recorded for each dispenser.

When liquid is added to the underground tank, the tank volume should be gauged both before and after the delivery. The operator should also check the tank for presence of water to the nearest $1/8$ in. using, for example, water-finding paste or other appropriate means. This procedure, however, is not applicable to water-miscible liquids. Water that is detected should be accounted for in the inventory procedures and any significant accumulation [i.e., greater than $1/2$ in. (12.7 mm)] should be promptly removed.

At the close of the business day (or the end of the shift), tank volume should again be gauged and meter totalizer readings recorded. The difference between the opening and closing totalizer readings is the sales for the inventory period. All readings that are recorded as part of this procedure should be kept in a safe location and retained for a minimum of one year. Detailed instructions covering tank gauging, water gauging, meter calibration checks, and record keeping are contained in American Petroleum Institute Publication 1621, *Recommended Practice for Bulk Liquid Stock Control at Retail Outlets.*

D-1.2 Daily Reconciliation. Inventory reconciliation consists of comparing the measured closing inventory to the book inventory, which is obtained by adding deliveries and subtracting sales and on-site usage from the measured