

NFPA 329

Underground Leakage of Flammable and Combustible Liquids

1987 Edition



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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.

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NFPA 329

Recommended Practice for Handling Underground Leakage of Flammable and Combustible Liquids

1987 Edition

This edition of NFPA 329, *Recommended Practice for Handling Underground Leakage 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 Fall Meeting held November 17-20, 1986, Denver, Colorado. It was issued by the Standards Council on December 10, 1986, with an effective date of December 30, 1986, and supersedes all previous editions.

The 1987 edition of this standard 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, and 1983.

This 1987 edition replaces the 1983 edition and incorporates the following major changes:

- a new appendix covering leak detection through inventory control;
- revision of the procedure for hydrostatic test to 150 percent of the anticipated working pressure;
- revision of the criteria for the precision test of Chapter 4.

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NFPA 329

Recommended Practice for Handling

Underground Leakage of
Flammable and Combustible Liquids

1987 Edition

NOTICE: An asterisk (*) following the number or letter designating a paragraph indicates explanatory material on that paragraph in Appendix A.

Information on referenced publications can be found in Appendix C.

Foreword

NFPA does not, by the publication of this document, intend to urge action that is not in compliance with applicable laws and this document may not be construed as doing so. Users of this document should consult applicable federal, state, and local laws and regulations.

Chapter 1 Introduction

The purpose of this recommended practice is to provide a guide for the safe and efficient handling of flammable and combustible liquids when, for whatever reason, they are found unconfined and unwanted. For the proper installation of underground tanks, see NFPA 30, *Flammable and Combustible Liquids Code*.

1-1 The Problem.

1-1.1 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.

1-1.2 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 may develop from corrosion, or be caused by mechanical damage, or some liquid may be spilled during transfer. Generally, the amount of liquid lost is small and it 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 liquid vapor is involved, where it is found, how it is confined, possible sources of ignition, etc. But, because a flam-

mable 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.

1-2 Cooperation and Responsibility.

1-2.1 The responsibility for proper handling of a suspected escape of flammable or combustible liquids, or a potential hazard from such an escape, will fall upon various individuals and organizations. The successful handling of these problems will depend upon the best possible cooperation between them.

1-2.2 One of the prime purposes of this guide 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, the fairest assessment of responsibility, and will result in the best possible protection of life and property. A positive, cooperative attitude of anyone potentially involved will benefit everyone, regardless of the final results. Lack of cooperation could result in inadequate protection of life and property.

1-2.3 Since leakage of flammable liquids, especially such 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 interested groups as outlined above.

1-2.4 Recent developments, problems, and attitudes have now also involved health and environmental officials. When dealing particularly with water pollution and the more persistent slow- or non-evaporating combustible liquids, the concern of these officials may be paramount.

1-2.5 The location of leaks, testing of tanks and piping, removal of leaky tanks, and removal of liquid in the earth will require equipment and facilities that may 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.

1-2.6 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.

1-2.7 When tanks are to be removed, or other work done on private equipment, or on private property, such as holes being dug, 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 may 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.

1-2.8 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.

1-2.9 This guide is intended for the information of all organizations and persons involved.

Chapter 2 Procedure When Life or Property May 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 may 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 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 must 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. Such ac-

tion may create a spark capable of igniting flammable vapors. Use only those switches located well away from the contaminated area to cut off electrical power, which may require the electric utility to make 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 cut off outside the structure. The shutting off of the gas service outside of the building removes the fuel from pilot lights and gas burners, which may be sources of ignition.

2-3.2.3 No one should enter the contaminated area except as described in "Entering the Area" (2-3.3). Where liquids or vapor within or above their 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. Most persons can detect gasoline vapor in concentrations as low as 0.005 percent. However, smell cannot be relied upon 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 may have them available. A trained operator should use the combustible gas indicator, which must be well maintained.

2-3.3.3 Also, an additional life hazard may 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 limits (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 may 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 by

opening doors and windows may be adequate. Grounded mechanical exhaust ventilating equipment may 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 1.) 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 may be used for ventilating the area when set in a window and discharging outwardly.

2-3.5 Locating Seepage into Building. When the area has been made safe for entry, it may 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 off such places. Untrapped drains, dry traps, pipes, or other openings through floors or foundations are common sources of liquid or vapor entry into a building. Check any gas pipes in the area; the flammable vapor may be fuel gas. If this appears to be the source, call the gas company.

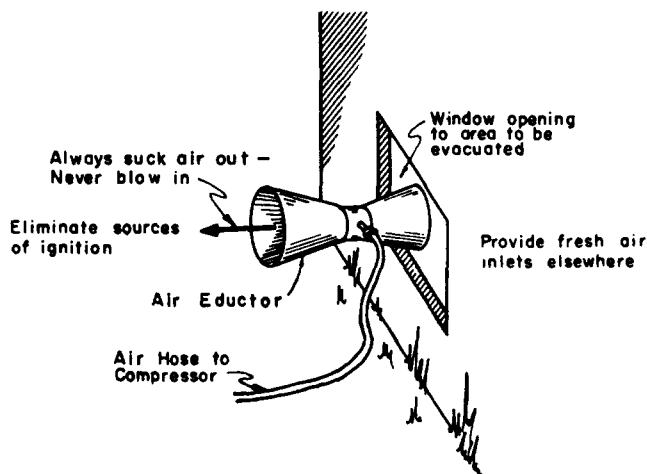


Figure 1 Exhaust Venting

2-3.6 Preventing Seepage into Buildings.

2-3.6.1 Entrance of vapors or liquids through drains, pipes, or other openings may be stopped by plugging such openings. Sewer pipes may be the source of entry. If only vapor is entering through a sewer pipe, it may 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 may be such that it cannot be effectively stopped from the inside of the structure. In this case an intercepting hole or trench, holes for pumps, or well points may 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; for conduit, the electrical, telephone and gas companies' engineering departments. Normally, the maintenance and engineering departments of such organizations will be well equipped to take charge of the situation; police, if needed, may be asked to keep the public clear of the danger areas. The fire department may be needed to assist in fire control and purging. Those involved with the storage and handling facilities of flammable and combustible liquids that may be the source of the problem should offer all possible assistance. (See NFPA 328, *Flammable Liquids and Gases in Manholes and Sewers*, and Chapter 5 of this guide for further details.)

2-4.2 Entering the Area. Basically the same as for Condition 2-2.1(a); however, the flammable vapors in a sewer or conduit may not originate from flammable liquids. They may be vapors from overheated insulation, sewer-generated gases, fuel gases, or industrial gases. Consequently, special instruments, equipment, and skills may 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 It may be that water flushing is the better means of purging the area of flammable vapors. For example, the generation of sewer gas may be stopped or significantly reduced by this method. In a similar fashion, flammable and combustible liquids may 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, location of the source of the leak should be determined 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 1628-1980, Underground Spill Cleanup Manual*, for additional information.)

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 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. Turn power off outside any well house or similar trap that may 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 may be resumed if desirable for purging. (See *Chapter 6* for details.)

2-5.3 Surface Water.

2-5.3.1 When flammable or combustible liquids are found on surface water or water emerging from hillsides or cuts, concentrations may develop in ditches or collection points that may create an explosion or fire hazard. Normally, the amount of flammable or combustible liquid found on the surface water will be in such a thin layer that it does not create a fire hazard. This is the case when the liquid is dispersed into small bubbles or pools, or when 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 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 may 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 Primary Search for the Source

3-1 General.

3-1.1 Once all necessary precautions have been taken to protect life and property, the next most important step is to determine the source of the flammable or combustible liquid and prevent any further escape.

3-1.2 Generally, the source of a flammable or combustible liquid will be relatively near the location of the discovery of unconfined liquids or vapors. However, liquids can travel blocks or even miles underground through porous soil or rock, trenches filled with porous soil, alongside pipes or conduits, or in sewer pipes. Consequently, the area from which an escaped liquid could have come may be remote and extensive, and include many facilities storing and handling flammable or combustible liquids. If a check of potential sources (see *3-2.2.1 for checklist*) immediately adjacent to, or within a few hundred feet of, the discovery does not reveal an obvious or possible source, organize a general search of the area.

3-1.3 Efforts should be made to secure information on groundwater flow from the local United States Geological Survey (USGS) office, public works departments, or equivalent agency and primary search efforts should be initiated upgradient of 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 in a notebook. Good data, well organized, will prove invaluable in subsequent efforts to solve the problem.

3-1.5 Organize teams of as many qualified persons as are needed and available to conduct the search. A very efficient method is to assign two-person teams (with one person representing the local public authority) to specific

areas on the map. Begin with the nearest and most obvious potential sources and work out from the point of discovery, concentrating on moving uphill, upstream of underground water flow, or upstream of sewer or conduit flow.

3-1.6 Quite often the source can be found by inquiry or simple inspection. Begin with the primary search described in Section 3-2. If this fails to discover an obvious or very likely source within the first few hours, it is advisable, while the primary search continues, to begin testing equipment for concealed leaks at the closest and most probable sources (*see Chapter 4*) and to take the first steps in tracing underground liquids (*see Chapter 5*).

3-2 Primary Search Procedure.

3-2.1 Flammable or combustible liquids will escape into the ground from one of two principal sources: (a) liquid has been spilled during transfer and has run into a sewer or soaked into porous soil; or (b) a leak has developed in storage, transporting, or handling equipment.

Use the list below to check for spills or other possible sources by asking questions and by a careful inspection of premises and equipment. Unless an obvious source is found, substantial enough to account for the seepage, do not stop the search at the first sign of a potential source. First impressions can be misleading.

3-2.2 Liquids may travel slowly underground or may not move at all until the water table rises. As a result, there can be a considerable time lapse between the occurrence of a leak or spill and the report of finding liquid or vapor. Record all history or evidence of potential sources regardless of how long ago they occurred; do not eliminate any potential sources on the basis of time until data is available and the analysis of that data justifies elimination.

3-2.2.1 Possible sources to check:

- (a) Gasoline service stations.
- (b) Automotive garages or agencies.
- (c) Fleet operators such as taxicab companies, dairies, bakeries, municipal garages, etc.
- (d) Contractors or equipment dealers who may store fuels on their premises.
- (e) Fuel distributors that supply service stations or commercial users.
- (f) Heating oil distributors.
- (g) Cleaning establishments.
- (h) Chemical companies.
- (i) Industrial plants that may use and store flammable or combustible liquids.
- (j) Airports and marinas.
- (k) Check public records, make inquiries about any high-pressure petroleum or gas lines in the area. They may be marked with signs at street and railroad crossings.
- (l) Any abandoned flammable or combustible liquid tanks.
- (m) Any other properties on which flammable or combustible liquids may be stored.

3-2.2.2 Questions to ask:

- (a) Has there been a spill during loading or unloading?
- (b) Any storage or handling equipment leaking, or has there been a leak? Check for excavations that may have damaged underground facilities or give evidence of repairs.
- (c) Has any maintenance work involved release of liquids from tanks, pipes, or equipment?
- (d) Has there been any odor or sign of liquids where they should not be?
- (e) Are inventory and use records kept? (*See Appendix B.*)
- (f) Has water been found in the storage facility?
- (g) Is there any knowledge of an accident in the area that may have released liquid from tank trucks, barrels, or large fuel tanks? (A check with local police may be in order.)
- (h) Ask about the age of underground facilities. If subsequent equipment checks are made, the older equipment is suspect as a leaking source because of corrosion.
- (i) Have any pumping problems been experienced?

If inquiry fails to disclose any potential source, ask the owner or operator for cooperation in checking the equipment and the area around the premises. If the operator refuses because he/she does not own the equipment, contact the owner for his/her cooperation. If necessary, governmental authority, such as exercised by fire officials, may be used to obtain such cooperation.

3-2.2.3 Checking equipment:

- (a) Check the area around fill pipes where liquid is transferred from trucks to tanks for signs of frequent spills. Saturated and darkened soil, stained concrete, or disintegrated asphalt indicates repeated spills that may accumulate underground.
- (b) Check the area around aboveground tanks for similar signs that may indicate a leak or overfilling.
- (c) Check any exposed piping for signs of leaks.
- (d) Check pumping equipment for leaks. It is advisable to use a combustible gas indicator when checking pumps/dispensers of the type used in service stations. Open the cover of the unit just far enough to insert the indicator probe into the bottom area. Opening the cover wide may provide sufficient ventilation to give such a low reading as to indicate no leak. Also, check the hose and nozzle.
- (e) If a remote pumping unit is used, check its housing or pit with a gas indicator before opening and then open for visual check for signs of leaks.
- (f) Check automotive repair areas for signs of waste liquids being dumped into floor drains or sumps.

3-2.2.4 Checking the area:

3-2.2.4.1 If all equipment seems to be in order and there is no obvious sign of spilling or dumping into sumps or sewers, check around the grounds and adjoining areas.

- (a) Look for signs of dumping waste liquids on the ground.
- (b) Check nearby streams and bodies of water for signs of flammable or combustible liquids.

(c) Check vegetation in the area for any indication of damage by spillage, dumping, or contaminated groundwater.

(d) Using a combustible gas indicator, check sewers and other underground cavities such as telephone and utility conduit manholes for presence of vapors and make visual inspection for signs of foreign liquids on water surfaces.

(e) Check nearby excavations and steep cuts or natural slopes below the potential source for signs of liquid coming through the soil.

3-2.2.4.2 When leaks in equipment are discovered, ask the user and owner to stop use of the equipment until the leak is repaired. Pump out liquid in storage if it is still escaping through the leak.

3-2.2.4.3 If large spills have been reported or there are indications that there has been repeated dumping or spilling of flammable or combustible liquids into sewers or on the ground, ask those involved to modify their operations to prevent recurrence.

3-2.2.4.4 Be reasonable and fair; recognize that small spills may inadvertently occur and that a very small amount of petroleum liquid (just one cup of gasoline, for example) on a wet pavement will spread over a large area, appearing to be a more severe spill than it actually is. Spills on the surface that spread out will dissipate rapidly and are not likely sources of underground contamination. The significant spills are large spills that can flow to points of access to underground structures or areas of porous soil, or repeated smaller spills that immediately flow into structures or soak into soils and reach the water table.

3-2.2.4.5 If an obvious source, or one or more likely sources, has been found and further escape of liquids eliminated, further search may be temporarily suspended to determine whether, in fact, the located source(s) is the cause of the problem. While removal and protective measures are taken, monitor and record the flow of liquid, the amount of liquid, and the vapor concentration at those locations where the problem exists. If there is a distinct and continuous decrease it may be assumed that the source(s) has been found and further contamination eliminated. The decrease may not show up immediately; it may, in fact, require days or weeks to remove liquid that has accumulated underground or for it to dissipate. Refer to Chapter 5, "Tracing Liquids Underground," to determine how much time may be required before a decrease at the monitoring point may be expected.

3-2.2.4.6 If, after a reasonable length of time as determined with the reference above, the supply of liquid to the threatened area does not stop or show definite decrease, further investigation should be conducted simultaneously along two paths. These two paths also should be followed if no source is found.

3-2.2.4.7 One path is to test flammable or combustible liquid storage and handling equipment in the vicinity of the contaminated area; the other is to trace the liquid underground from its point of discovery. Tracing is conducted to determine the extent of the contamination, the

direction of flow, and any potential more-remote source(s). Tests on underground equipment are performed to determine definitely whether or not they are a source. (See Chapter 4, "Testing for Underground Leaks," and Chapter 5, "Tracing Liquids Underground.")

Chapter 4 Testing for Underground Leaks

4-1 General.

4-1.1 Tests to determine the tightness of underground liquid-handling equipment will have to be conducted when:

(a) The search procedures of Chapter 3 or the tracing procedures of Chapter 5 indicate a probable or likely leakage source, 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 a report of the accumulation of water in a tank.

4-1.2 Review all data previously gathered to determine the most efficient method or methods of testing. There are several quick and simple tests described in this chapter that may reveal a leak under certain circumstances. If one of these preliminary tests 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 Precision Test is undertaken. (See 4-3.11.)

4-1.3 One or more of these preliminary tests would be particularly desirable if Precision Test equipment is not immediately available. If such equipment is available, time and labor costs may be reduced by immediately making a Precision Test.

4-1.4 Regardless of the testing procedure involved, keep in mind that liquid-handling equipment should be tested in a condition as close as possible to operating conditions. Excessive pressures or tests by nonrepresentative liquids may indicate leaks where none exists or conceal leaks where one, in fact, exists.

4-2 Action Preliminary to Testing.

4-2.1 Before actual equipment testing is undertaken, review the results of the primary search in Chapter 3. This review may reveal information that will eliminate the need for further testing or this information will be useful in making further tests.

4-2.2 Ensure that spills or deliberate disposal are not the leakage source, keeping in mind the possible transit of liquids by trenches and underground water. (See Chapter 5.)

4-2.3 Recheck stock records for indications of loss; but do not jump to conclusions. Meters may be off calibration, causing only a paper loss, not a physical loss.

4-2.4 Temperature change may falsely indicate a loss. The volume of petroleum products is highly sensitive to temperature change. A drop of one degree Fahrenheit will shrink 1000 gal (3785 L) of gasoline by "0.7" gal (2.2 L). This may at first seem small but consider a typical example. In the spring, the ground will still be relatively cool from the preceding cold weather, while liquids stored and transported aboveground may be relatively warm.

4-2.5 A typical underground gasoline storage tank may handle 20,000 gal (75 700 L) in one month. If, on the average, this liquid cooled 5°F (2.8°C) after delivery, stock records will show a loss of $5 \times 0.7 \times 20 = 70$ gal (265 L). Ten degrees cooling would appear as a 140-gal (530-L) loss for 20,000 gal (75 700 L) handled, and a 280-gal (1060-L) loss for 40,000 gal (151 400 L) handled. Obviously, a temperature increase would have the opposite effect and could actually conceal a physical loss.

4-2.6 Finally, theft may be the cause of reported stock loss.

4-2.7 Consequently, further checking must be performed before a facility is implicated on book stock losses alone. Check meters for calibration. Check relative temperature of delivered and stored product during the period in question. Check for the possibility of theft.

4-3 Checking Inventory Records.

4-3.1 A careful check of inventory records will be very helpful in determining the course of further investigation. (See *Appendix B* for a description of inventory control procedures.)

4-3.1.1 If the reason for the check is a report of loss of inventory but no liquid or vapor has been reported in unexpected locations:

(a) Loss due to meters out of correct calibration, loss by contraction due to lower temperatures, or theft would indicate that a hazard need not be expected. Further testing is not necessary;

(b) If not solved as in (a), evidence of an inventory loss requires further testing to determine the cause. It also indicates that a potential hazard may develop from the escaped liquids and a check of the surrounding area should be made for signs of contamination. (See 3-2.2.4 through 3-2.2.4.7.)

4-3.1.2 If the reason for the check is discovery of escaped liquids or vapors found underground:

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

(b) Loss 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.

4-3.1.3 In-tank monitoring systems that incorporate automatic gauging equipment may be used to accomplish inventory control and to indicate possible leakage.

4-3.2 Pressure Testing with Air or Other Gases. Pressure testing, with air or other gases, of tanks or piping containing flammable or combustible liquids is not recommended, should not be required by regulations or ordinances, and should be discouraged in practice. Such tests are not likely to detect a leak that is below the liquid level in the tank, and there is severe danger of causing a tank rupture, or expulsion of contained liquid through normal openings.

NOTE: There are systems that use unique gases that are not dependent on pressure for detection of leaks.

4-3.3 Testing Underground Facilities.

4-3.3.1 Using the information gained from the primary search procedure (see *Section 3-2*), use the following tests in a logical process of elimination. For example, if water is reported as entering a tank, or if the tanks are old and corrosion is known to exist in the area, make the preliminary checks on the tanks first. On the other hand, if pumping troubles are reported, the piping is suspected and preliminary tests should be performed on underground piping first.

4-3.3.2 The tests described on the following pages are listed in approximate order of ease of performance, the easiest being first. The sequence should be varied to fit the circumstances, as noted in the preceding paragraph.

4-3.4 Checking Underground Pipe.

4-3.4.1 Check for:

(a) Recent digging, driveway repair, or other work in the area which may have damaged underground lines.

(b) Any recent repairs that may have been made indicating a previous leak or perhaps creating a leak due to faulty work.

(c) Any evidence of shifting ground, such as frost heave, which may have damaged lines.

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

4-3.4.2 If information on the location of liquid underground has been compiled by methods described in Chapter 5, "Tracing Liquids Underground," review this information for possible patterns that may indicate a specific pipe is likely to be the source. It may be advisable to drive or drill additional holes to define more definitely where the liquids are and how they are flowing. (Review in particular the information in connection with Figure 10 in Chapter 5.)

4-3.4.3 The test to be used on piping will depend on the method used to move or pump the stored liquid.

4-3.5 Hydrostatic Test of 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 lb per sq in. (34.48 kPa) gauge at the highest point of the system. The test should be maintained for at least 10 minutes. If the pressure drops, it indicates the

possibility of a leak in the piping and it is recommended that a volumetric 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 entrapped vapor in the piping. Accumulated liquid loss during a volumetric test of more than 0.05 gallons (0.19 liters) per hour during timed restoration may indicate a leak in the piping.

4-3.6 Suction Line Testing.

4-3.6.1 If the pump used in moving the liquid is above ground, the supply pipe operates under vacuum or suction and certain pumping characteristics indicate either a leaking check valve or a leaking pipe. If there is a leak, air will enter the pipe as liquid drains back into the tank through the check valve or through a pipe leak into the ground. The presence of 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 is indicated by the display wheels skipping or jumping. Other indications of air in the suction line are:

- (a) The pump is running but not pumping liquid.
- (b) The pump seems to overspeed when first turned on and then slow down as it begins to pump liquid.
- (c) A rattling sound in the pump and erratic liquid flow indicates air and liquid are mixed.

4-3.6.2 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 may be on the end of the suction stub inside the tank. Some of those 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 not, or if the valve is inside the tank, it may be necessary to dig down to the tank to check the valve or disconnect and seal off the pipe for a hydrostatic pressure test.

4-3.6.3 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 may be assumed the pipe is leaking underground and it should be exposed for inspection. Dig carefully to avoid damage to the pipe which might make it impossible to verify whether a leak actually existed prior to uncovering.

4-3.6.4 If the pumps do not exhibit the 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 may be isolated and hydrostatic pressure tested.

4-3.6.5 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 con-

nection 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) in order to prevent damage to the pump.

4-3.7 Discharge Pipe Line Testing (Pipe under Pressure from Remote Pump).

4-3.7.1 Quite often pumps are located in the tank, or, on some rare occasions, just above the tank but remote from the dispensing devices. 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 procedure described in 4-3.5 or, if not practical, in the following manner.

4-3.7.2 At the dispenser end of the pipe, close the emergency shutoff valve at the base of the dispensers or close any valve 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 supplied for the specific purpose of positively seating these valves for line checking. Install a pressure gage 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 gage is in the emergency shutoff valve under the dispenser where ¼-in. or other small-size plugs are installed for this purpose. Start the pump, note the maximum pressure, seat the check valve, 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 and it is recommended that a volumetric 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 entrapped vapor in the piping. Accumulated liquid losses during a volumetric test of more than 0.05 gallons (0.19 liters) per hour during timed restoration may indicate a leak in the piping.

4-3.8 If the preceding tests do not reveal a leak, they should not be considered as conclusive and underground piping must be included in the Precision Test described in 4-3.11.

4-3.9 Checking Underground Tanks.

4-3.9.1 Review the information obtained from the primary search 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 may cause some of the product to be spilled around the pipe when a delivery is made. Particularly, check fill pipes installed under manhole covers. On night deliveries in which the tank is filled into the fill pipe a warmer underground product temperature can cause considerable overflow due to expansion before dispensing begins the following day;

(b) Any evidence of ground settlement around tanks and any sign of work that may 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 gage stick.) Ascertain, if possible, if the water increases during periods of heavy rainfall and remains constant or diminishes during dry spells. Also, if possible, ascertain 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 tank; in particular, as it relates to the history of corrosion in the vicinity;

(f) The location and flow of liquid found underground by gas sensors or visual inspection. It may be advantageous to drive or drill additional holes to develop more detailed information.

4-3.9.2 Use this information to guide subsequent inspection and testing.

4-3.10 When Water is Reported to Be Entering a Tank.

4-3.10.1 Check the fill pipe to ensure that water is not entering through a loose fill cap.

4-3.10.2 Check the surface area around vent lines for evidence that water may be entering by this route. Standing water over vent lines may be the source. Note this possibility for future use.

4-3.10.3 If no explanation, except a possible leak, is found for water in the tank, carefully record the depth of water by water-finding paste, 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 $\frac{1}{2}$ in. (12.7 mm), close and lock the cap and check for another 8 to 12 hours. If the rise in the second period closely matches that of the first period, a leak is probable. A rise of less than $\frac{1}{4}$ in. (6.4 mm) in 8 hours is inconclusive due to the inability to measure the water level closer than to within $\frac{1}{4}$ in. (6.4 mm). Longer test periods will have to be used to determine definitely 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.

4-3.10.4 The above tests are 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.

4-3.10.5 In fact, water may not enter the tank if the level of product is at or above the level of the water table outside the tank. These tests are relatively effective if the tank is practically empty and the water table is high but still below the tank top. A tank partially below the water table can have water enter, or lose product, through the

same leak depending on the relative levels of the groundwater and the product in the tank.

4-3.10.6 If a leak is indicated by the above test, take appropriate action.

4-3.11* Precision Test.

4-3.11.1 *Precision Test*, as used throughout this pamphlet, means any test that takes into consideration the temperature coefficient of expansion of the product being tested as related to any temperature change during the test, and is capable of detecting a loss of 0.05 gal (190 ml) per hour.

4-3.11.2 A test chosen from currently available technology to reasonably determine whether an underground liquid storage and handling system is leaking should be used. Any testing device used for the Precision Test must be capable of detecting leaks as small as 0.05 gal (190 ml) in one hour, adjusted for variables, a limiting criterion widely accepted by most authorities. Precision Tests should be performed by qualified technical personnel experienced in the use of the test method and in the interpretation of data produced.

4-3.11.3 The test procedure should measure the amount of liquid lost based upon fundamentally sound principles. It should detect a leak anywhere in the complete underground storage and handling equipment. If the net change exceeds 0.05 gal (190 ml) per hour or equivalent criterion established for the technology employed, a leak is likely to exist, and appropriate corrective action is necessary.

4-3.11.4 The Precision Test should account for all the variables that will affect the determination of the leak rate. An understanding of what these variables are and how they are handled is essential to effective performance of the test. Following is a discussion of some of those variables and how they affect the measurement.

4-3.12 The Effect of Temperature.

4-3.12.1 Liquids expand with an increase in temperature and contract with a decrease in temperature. Figure 2 lists the thermal coefficient of expansion for some of the more common flammable and combustible liquids.

4-3.12.2 For example, note that a temperature decrease of only 0.02°F (0.011°C) in one hour in a 6000 gal (22 710 L) tank containing gasoline would cause a volumetric decrease of $0.02^{\circ}\text{F} (0.011^{\circ}\text{C}) \times 0.0007 \times 6000 \text{ gal} (22\,710 \text{ L}) = 0.084 \text{ gal} (318 \text{ ml})$ which exceeds the 0.05 gal (190 ml) considered to indicate a leak. If this temperature change was 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.

4-3.12.3 It is sometimes proposed that this problem can be overcome by filling the tank 10 or 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

Thermal Expansion of Liquids

	Volumetric Coefficient of Expansion per Degree
Acetone.....	0.00085
Amyl acetate.....	0.00068
Benzol (benzene).....	0.00071
Carbon disulfide.....	0.00070
Ethyl ether.....	0.00098
Ethyl acetate.....	0.00079
Ethyl alcohol.....	0.00062
*Fuel Oil #1 - Kerosene.....	0.0005
*Fuel Oil #2 - Diesel.....	0.00045
*Gasoline.....	0.0007
Methyl alcohol.....	0.00072
Toluol (toluene).....	0.00063
Water — at 68°F.....	0.000115

*These are typical coefficients of expansion, but may vary depending on components of the mixture and on the temperature. See ASTM D 1250-80, Petroleum Measurement Tables, for further information.

Figure 2

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 (0.11°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 assure compliance with 4-3.11.

4-3.12.4 Another temperature effect that must be recognized and accounted for is temperature stratification or "layering." Layering occurs when product of a different temperature is added to product already in a tank (i.e., product is added to warmer 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.

4-3.13 The Effect of Tank End Deflection.

4-3.13.1 Some techniques require filling the tank to a point above grade. This increase in height of liquid increases the pressure inside the underground tank over the normal operating pressure. This is illustrated in Figure 3.

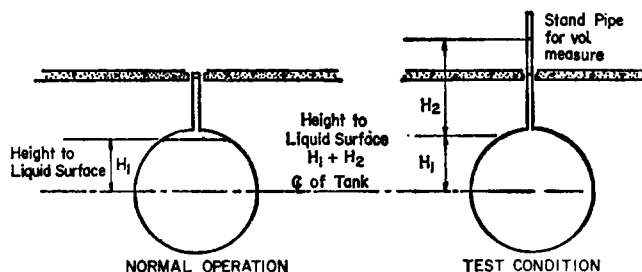


Figure 3

4-3.13.2 In a 6-ft (1.8-m) diameter tank the average pressure on the end or "head" of a tank full of typical

gasoline is 0.98 psi (50 mm Hg). If the tank is buried 3 ft (1 m) under the driveway (typical for most gasoline tanks), the average pressure on the head will increase to approximately 2.95 psi (153 mm Hg) when the fill pipe and standpipe are filled to 3 ft (1 m) above grade. The increase of approximately 1.95 psi (100 mm Hg) in the average pressure exerts an additional force on the end or "head" of the tank of about 8000 pounds, or 4 tons.

4-3.13.3 Most tank ends¹ of the type normally used underground are made of ¼-in. (6.4-mm) thick steel plate and will deflect outward as pressure inside the tank increases. (See Figure 4.)

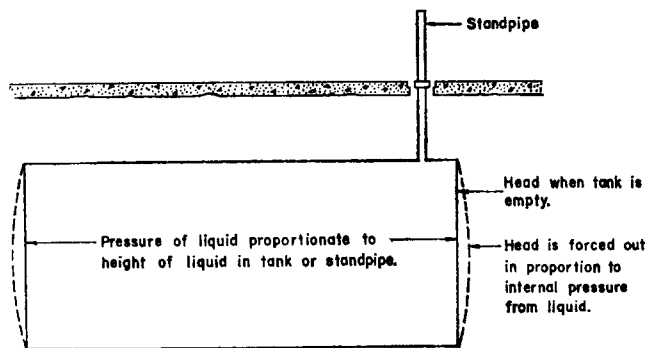


Figure 4 Tank End Deflection

4-3.13.4 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 support from the surrounding soil, and it is not possible to predict how much movement will take place. Very solid soil may 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.

4-3.13.5 Extensive study and testing have revealed that in almost all cases tank movement significant to the test for leaks will occur. It will not occur 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. The table in Figure 5 shows the volume increase as a result of various degrees of movement in the tank ends. The figures 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.²

The Precision Test method employed should be able to clearly indicate the possible effects of tank end deflection and either provide a means of compensation or elimination of the effects.

¹Although most fiberglass tanks have oval or spherical ends, the same phenomenon of expansion will occur due to flexure between the ribs on the sides of the tank.

²Compatible figures are not yet available for fiberglass tanks. The latest data indicate that expansion due to side flexure may exceed that for flexure of steel tanks.

**Apparent Loss of Liquid Volume in Gallons
Due to Increased Pressure in a Tank**

Outward Deflection at Center of Head in Inches

	$\frac{1}{16}$	$\frac{1}{8}$	$\frac{3}{16}$	$\frac{1}{4}$	$\frac{5}{16}$	$\frac{3}{8}$	$\frac{7}{16}$	$\frac{1}{2}$	$\frac{9}{16}$	$\frac{5}{8}$	$\frac{3}{4}$	1
Tank Dia. Inches												
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.

Figure 5

4-3.14 The Effects of Water Table. As stated in subsection 4-3.10, there are many instances where water may enter a tank system. The Precision Test method employed should be able to indicate clearly the possible effects of water in the backfill area around the tank system and provide a means of either compensation or elimination of the effects.

4-3.15 Effects of Entrapped Vapor. High-vapor-pressure materials combined with air in the form of a vapor-air pocket will be affected by both temperature and pressure changes; volume expansion or contraction will occur. Precision Test methods employed should be able to indicate the presence of entrapped vapor that may 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.

4-3.16 Effects of Evaporation. Some liquids, especially highly volatile liquids, have high rates of evaporative losses if their surfaces are exposed. The Precision Test method employed should be able to indicate clearly the possible effects of evaporative losses and compensate for them.

4-3.17 Water Testing.

4-3.17.1 Tests involving the addition of water to a tank may be useful when tanks are empty. 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.

4-3.18 In summary, the following major factors must be accounted for in the Precision Test to determine the presence or absence of a leak in an underground liquid storage facility:

- The temperature change of the liquid in that period of time.
- The movement of tank ends as pressure is increased.
- Water table.
- Entrapped vapor.
- Evaporation.

Chapter 5 Tracing Liquids Underground

5-1 General. The *underground*, as referred to in this recommended practice, consists of an almost infinite variety of rocks and soils, tunneled, pierced, and trenched by man-made structures and pipes. All these provide paths

for movement of liquid underground. Flow of liquid in tunnels, sewer pipes, and open trenches is obvious and relatively easy to trace by observation and vapor testing. Flow in soil and rocks is a complicated matter. A few basic principles will provide an understanding that will often prove sufficient to solve many problems of tracing the source of unconfined liquids. Even though such basic understanding may prove inadequate for a particular problem, it is essential to select and coordinate the particular expert skills necessary to solve the more complex problems.

5-2 Background.

5-2.1 The principal characteristic that permits liquids to enter, and accumulate or flow through soil or rock is porosity or, simply, the space or "voids" between the particles that make up the soil or rock. The size of the voids in soil will vary from large in gravel, through small in sand and topsoil, to essentially zero in fine, dense clay. Rock almost never has large voids but sandstones and limestones have voids similar to a fine sand.

5-2.2 Rate of flow through soils and rocks depends largely on the size of the voids; with large voids (gravel) the flow can be several feet per minute; medium voids (sand) will provide several feet per hour; and fine voids (shale or sandstone) may be as slow as one foot per day.

5-2.3 The term used to express this rate of flow is *pervious*. A very pervious soil will permit fast liquid flow; a relatively *impervious* soil will permit only very slow flow. When the word *impervious* is used alone, it implies no flow; thus glass is impervious to the flow of water.

5-2.4 Porosity does not ensure a pervious condition. If the pores of a rock are not interconnected, the rock will be impervious.

5-2.5 Crystalline rocks, such as granite and marble, are essentially impervious in their solid state but these rocks often have fractures or cracks that do permit flow. Rate of flow through rock fractures will vary from large continuous cracks which will act like a pipe, to very small irregular cracks which may result in flows similar to those found in fine sand.

5-2.6 Almost all flammable and combustible liquids are lighter than water and consequently they will float on water unless they are water soluble. When these liquids escape into the ground they will normally flow down to the water in the ground and there move with that water. An understanding of groundwater flow is essential to trace flammable and combustible liquids underground.

5-2.7 Water is almost universally found underground at some level in soil or rock. It may be in very limited quantities and only "dampen" the soil. But when it fills all the voids and "saturates" the soil or rock up to a certain level, it becomes similar to water in a pail and establishes a definite top, referred to as the water table.

5-2.8 Figure 6 illustrates that this groundwater may occur in several layers underground. A porous layer between two nonporous layers may be completely filled or it may be only partially filled and have its own water table.

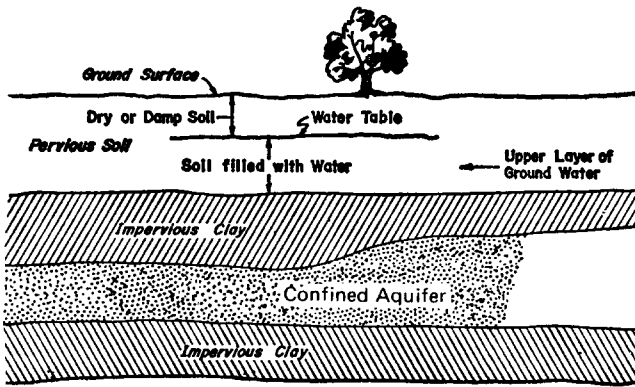


Figure 6

The primary concern with unconfined flammable and combustible liquids is with the uppermost layer and its water table. However, other layers must be recognized because even though they may be very deep at one location, they may be near the surface and hence the top layer at other locations. (See Figure 7.)

5-2.9 All groundwater, with the exception of narrow bands along the seacoasts, comes from rain or snow fall-

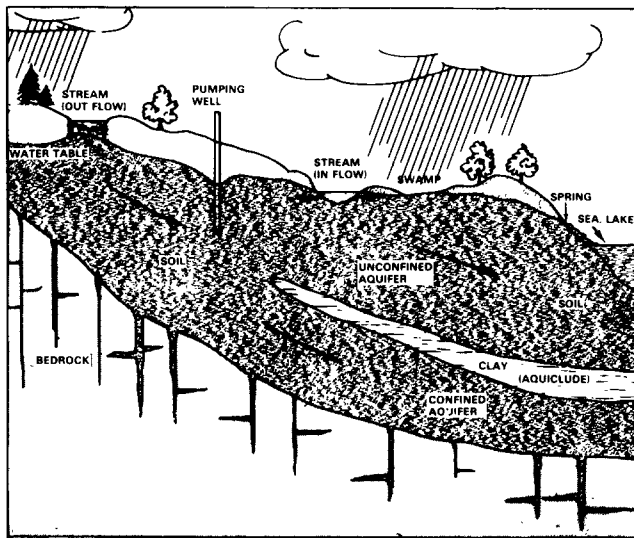


Figure 7 Hypothetical Groundwater System

ing on the surface and flowing down into the soil. Figure 7 shows that, at any given location, the water may have come from rain or snow on the surface immediately above; or it may have flowed underground for long distances through pervious soil or rock from a point where the pervious layer "outcrops" or comes to the surface. Water from rain and snow may also flow to lakes and rivers and then into underground layers.

5-2.10 Water tends to seek its own level underground just as it does on the surface as it flows through the soil. However water flowing underground will not flow as fast as water on the surface because of the interference or resistance of the particles in the soil. This has the effect of steepening the slope of the water table because the water does not move through the soil to lower levels as fast as it

fills the soil at the higher elevation. The same effect is shown where the lake is supplying water to the pervious soil. Expressed in another way, pressure is required to overcome the resistance to flow, and the increase in elevation of the water table provides the necessary pressure.

5-2.11 The height or elevation of the water table will depend not only on how fast the water flows out of the strata, 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 will drop as water flows out at springs and is taken out by wells, or "wicks," through dry soil to eventually evaporate into the air. When water is being added faster than it flows out, the water table will rise. This rise and fall can be several feet in a few days as the weather changes from wet to dry, or from dry to wet.

5-2.12 In summary, the principal factors important to tracing unconfined liquids underground are:

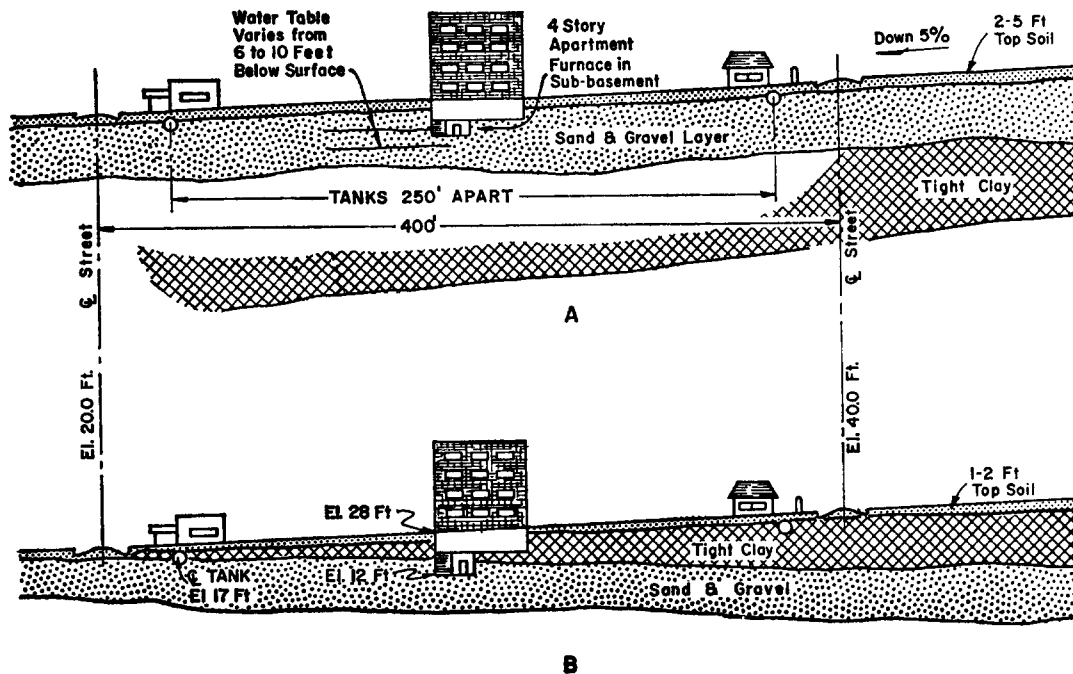
- (a) Most flammable and combustible liquids float on water.
- (b) When unconfined in the ground, these liquids will float on the top or water table of the groundwater and move with that water.
- (c) Groundwater will flow through pervious soil or rock toward lower elevations. Flow rate will vary from several feet per minute to only one or two feet per day.
- (d) Groundwater may be trapped underground and be stationary as if in a lake.
- (e) The top or water table will be level with no flow but slope down in the direction of flow when flow occurs.
- (f) The water table will rise and fall (in some cases several feet in a few days) depending on supply by rain or melting snow.

5-2.13 The following examples illustrate how these principles are applied to tracing flammable and combustible liquids.

5-2.13.1 Figure 8 shows the effect of the slope of underground strata on the direction of flow of liquids. Parts A and B show identical surface conditions. A four-story apartment building is approximately midway in the block, between two streets 400 ft (122 m) apart. The surface of the ground slopes up from left to right at a 5 percent grade, placing the elevation of the upper street (on the right) 20 ft (6 m) higher than the lower street.

5-2.13.2 In Figure 8(a), the underground strata follows the general slope of the surface and groundwater in the sand and gravel layer flows from right to left. Under these circumstances, if gasoline in liquid or vapor form was discovered in the subbasement of the apartment building, the source of that gasoline would most likely be from the service station on the right at the higher elevation, or from other tanks farther up the hill.

5-2.13.3 However, Figure 8(b) shows an underground strata condition in which the station downhill is the most probable source. In this case, the water-bearing strata of sand and gravel slopes down from left to right, opposite that of the surface of the ground. Groundwater flow



For SI Units: 1 ft = 0.305 m.

Figure 8

would also be from left to right and would carry gasoline escaping from the lower station to the basement of the apartment building.

5-2.13.4 One other condition illustrated in Figure 8(a) is the effect of a rising and falling water table. During the dry season, when the water table is below the sub-basement floor of the apartment building, gasoline on the water table would not be discovered. But when the water table rises the gasoline will be lifted above the sub-basement floor. There have been many cases where this was the cause of alternating discovery and disappearance of escaped gasoline due to a significant rise in the water table with each significant rain.

5-2.13.5 Figure 9 illustrates another example of how underground water flow can be contrary to the surface slope of the ground. In this case, flammable liquids are stored in an underground tank a few hundred feet from, and 30 or 40 ft (9 or 12 m) above, a small lake. From the surface, it would appear that an escape of liquids from this tank would show up in the lake. But, because the tank is in a pervious water-bearing layer that slopes away from the lake, wells at houses high above the service station are contaminated by the gasoline that has escaped.

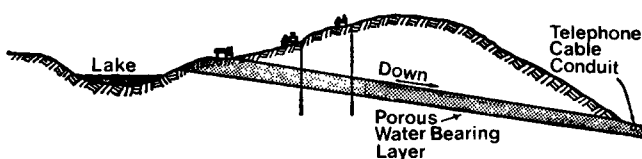


Figure 9

Note also that if an underground leak existed unknown for a long period of time and there were no wells in the

strata to discover contamination, the first discovery of escaped flammable or combustible liquids could occur in the telephone cable conduit on the other side of the hill from the service station, possibly several miles distant.

5-2.13.6 Figure 10 illustrates other important effects of a rising and falling water table and the ability of trenches dug in relatively impervious soil but filled with sand or other porous material to act like interconnected piping. Figure 10(a) is a phantom view of a tank containing gasoline installed in a hole dug in clay and backfilled with sand. The suction and vent lines are likewise in trenches dug in clay and backfilled with sand.

5-2.13.7 Figure 10(b) is a plan showing the layout of a tank installed next to a building with a basement. A water line to the building on the left is also a trench backfilled with sand as is the city water main and sewer. And, finally, a low area between the buildings was filled

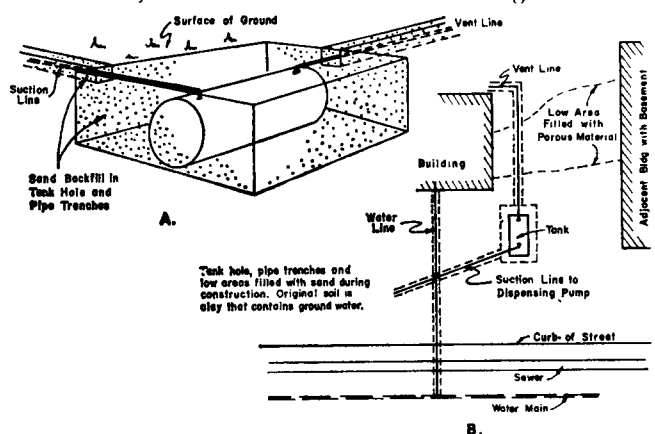


Figure 10

with sand and gravel during construction.

5-2.13.8 The "parent" or original soil is clay. A water table exists in the clay but has very little horizontal movement because of the resistance of the clay to flow. As a consequence, the water table rises and falls in direct response to supply of water from rain. During wet periods the water table will be within a foot of the surface and during dry periods will drop to or below the bottom of the tank hole.

5-2.13.9 It is easy to see how a leak in this tank could cause a collection of gasoline on a low water table in this hole much as if it were in an open square tank. Then, if rainfall raised the water table above the bottom of the pipe trenches, water with gasoline on top could flow along the sand-filled trenches much as it would through a pipe. At points where the trenches intersected other trenches or the sand and gravel fill between the buildings, the flow could find its way to the building or to the sewer or water main in the street.

5-2.13.10 Note that it will not necessarily enter the sewer pipe in the street. The water and gasoline may flow along the outside of the sewer or water pipe in the porous backfill of those pipe trenches and not appear until it comes to some point where it could leak into a manhole or sewer inlet.

5-2.13.11 Another condition illustrated by Figure 10 is the potential for a flammable or combustible liquid to move without the aid of groundwater. If a severe leak occurred in the suction line, pure gasoline could flow along the trenches.

5-2.13.12 The principles and concepts discussed in the preceding pages point up the importance of knowledge about underground soil conditions and underground facilities when tracing the source of escaped liquids. It will not always be possible to obtain all the data desired but the effort should be made.

5-3 Test to Determine Underground Flow.

5-3.1 The sequence of what to inspect and what test to use will depend to considerable degree on the circumstances of the problem, information gained from the primary search, and previous tests. Consequently, the following methods are not necessarily in the proper sequence for all conditions. They are, however, in an approximate descending order of importance. Tools are noted as they are needed.

5-3.1.1 On a sketch of the local area (scale: 1 in. = 100 ft) note underground facilities as illustrated in Figure 10(b) and any geological data available. Be sure to include abandoned ditches and streambeds that have been filled and covered. Sources of information are:

(a) Surface observation of manholes, fill pipes, pumps, vent risers, etc.

(b) City engineer; sewer, water and street departments; highway engineer; city, state, and federal geological departments.

(c) Utility companies.

(d) Owners of the facilities and local residents. Do not

overlook the old-timer who may have valuable knowledge of the area before it was built up.

(e) Metal detectors can be used to locate steel pipe if conditions warrant.

5-3.1.2 Information gathered to this point and plotted on the sketch may indicate that a certain nearby facility is a very likely source. If so, proceed with a test for leaks as described in Chapter 4. If not:

5-3.1.3 Check potential paths for liquid flow by:

(a) Visual check in manholes, inlet boxes, wells, open trenches, exposed slopes or cuts, etc. Put samples of water in a glass bottle for close inspection to determine the possible presence of flammable liquids.

(b) Use a combustible gas indicator to determine presence of vapors. To check underground porous backfill or pervious strata use a bar ($\frac{3}{4}$ in. to 1 in.) (19 to 25.9 mm) and a sledge hammer to drive a hole to the level to be checked. A small hand-operated earth auger is very useful for this purpose. A larger auger, as used for power posthole digging, is also good and has the added advantage of providing a visual check and the opportunity to obtain both liquid and soil samples. This equipment is usually available from a state highway department. Maintain an accurate log of soil samples, and, in particular, note the top and bottom depths at which any soil samples have an odor indicating contamination. Retain representative samples of soil in vaportight containers.

(c) Use a rod or stick with water-finding paste and a paste sensitive to the contaminating liquid to determine the water table elevation. Note these elevations on the sketch and determine the probable direction of flow.

5-3.1.4 If the potential of natural or sewer gas still exists at this point in the search, make particular note of indications by the combustible gas indicator relative to the location of sewer and gas lines.

5-3.1.5 When this testing has determined the probable direction from which the contamination is coming, extend the search upstream using these same methods to determine the next most likely source. Check on both sides of the direction of flow to determine its width.

5-3.1.6 There is new technology to determine groundwater flow direction without the need for drilling numerous test wells.

5-3.1.7 As the area of search extends beyond the original sketch, obtain a smaller scale map or sketch, and plot and record all data. As the area becomes larger, the data become more important to the search and subsequent disposal of contamination.

5-3.1.8 If the initial efforts, approximately one day's checking, fail to establish a clearly defined problem, additional expert help should be engaged. Ask industry for the assistance of experts who have had experience with these problems; and, whenever possible, obtain help from a local geologist familiar with local geology.

5-3.1.9 It is beyond the scope of this recommended practice to cover the problem in all its potential complex-

ities; that is the purpose of seeking the assistance of experts. However, it will probably be advisable for those originally in charge to maintain control while the experts act as consultants and advisors. The following information will be helpful in understanding, appraising, and coordinating the expanded effort.

5-3.1.10 When the investigation fails to locate an active source of seepage, it is possible that the product could be a residual accumulation from some previous equipment failure, spill, or improper disposal of petroleum product. Experience has indicated that many such residual deposits have existed and remained undetected over a long period of time before they became sufficiently large to make their presence known.

5-3.1.11 As the problem becomes more complex, other methods of testing and tracing may be helpful or suggested. However, both the advantages and disadvantages of these tests must be recognized if valid conclusions are to be reached.

5-4 Other Tracing Test Methods.

5-4.1 Dye.

5-4.1.1 The use of dye is often suggested as a means of tracing. The method is to add a strong dye to the stored liquid suspected of being the source and see if it shows up at the point of discovery. This is seldom successful for several reasons.

(a) Dye may cause pollution of underground water supplies.

(b) If only vapor is found at the discovery point, dye will be useless.

(c) The dye may be leached out or bleached by chemicals in the soil before it reaches the point of discovery.

(d) If underground flow is very slow, too much time will be consumed in the tests.

(e) It may very likely make the liquid tested unusable.

(f) If it is used but does not appear at the point of discovery, it is not conclusive because of item (c). It would be of benefit only if it did appear.

5-4.1.2 Dye is not a recommended method of tracing but may be used as one possible source of information in special cases.

5-5 Chromatographic and Spectrographic Identification of Components. The chromatograph and spectrograph are instruments capable of detecting traces of elements in almost any compound. They can, for example, detect a trace of some element unique to a particular method of manufacture and therefore identify where the liquid originated. They can also detect the amount of an element involved. They are relatively inexpensive tests and only involve a sample of the product found at the point of discovery. These tests should be used in cases of complex mixtures as a possible source of additional information. However, they may not be conclusive because some identifying element may be lost in the ground, or an element not in the original liquid may be picked up from the ground or from contact with buried materials.

5-6 Other Chemical Analysis. Any other chemical analysis is essentially the same as the chromatographic test and the same comments apply to both. One significant factor that may be determined by chemical analysis is the age of the contaminant.

Chapter 6 Removal and Disposal

6-1 The presence of unconfined flammable and combustible liquids will continue to be a potential hazard until the contamination has been reduced to a safe level. While methods by which this can be accomplished depend upon the physical circumstances of the polluted areas, the most effective results are obtained when the efforts of all interested parties are coordinated under the direction of the fire marshal's office or other enforcing authority. It is their inherent authority to recommend compliance in all phases of the cleanup operation, and it is their recognized responsibility to the public to exercise this jurisdiction from the moment that migration of flammable liquid or vapors in sizable volume is reported until safety is assured.

6-2 Removal and disposal methods will depend on the liquid involved and the area contaminated.

6-3 The characteristics of liquids significant to methods of removal and disposal are:

(a) Liquids that rapidly vaporize at ambient temperatures and leave little or no residue. Typical examples are solvents and gasolines. These are referred to as volatile liquids.

(b) Liquids that do not readily vaporize. Typical examples are heating oils and food processing oils. These are referred to as nonvolatile liquids.

6-4 In general, purging a facility of volatile liquids is primarily a matter of ventilation, while nonvolatile liquids must be collected and picked up.

6-5 The principal categories of area relating to methods of removal are:

6-5.1 Normally inhabited subsurface structures.

- (a) Basements and similarly confined areas.
- (b) Subways, tunnels, and mines.

6-5.2 Normally uninhabited substructures (*see NFPA 328, Control of Flammable and Combustible Liquids and Gases in Manholes, Sewers, and Similar Underground Structures*).

- (a) Utility conduits.
- (b) Sewers.

6-5.3 Water surfaces.

6-5.4 The soil.

- (a) Surface.
- (b) Subsurface.

6-6 Basements.

6-6.1 With very few exceptions, the quantity of liquids found in basements will be relatively small, as detection will normally occur before significant quantities can accumulate and further flow will be quickly stopped. When volatile liquids and their vapors are involved, the primary removal and disposal action is ventilation as described in 2-3.4. Small amounts of liquid not evaporated can be picked up with rags or commercial absorbents.

6-6.2 Be sure to put contaminated rags or absorbents in covered metal containers to prevent further spread of vapors. Final cleanup is accomplished by flushing out basement sumps and floor drains with water and washing down contaminated surfaces. Only water is necessary for flushing volatile liquids from drains; biodegradable detergents may be used on surfaces. *Maintain ventilation and checks for vapor throughout the cleaning period.*

6-6.3 In those rare cases involving relatively large volumes of volatile liquids, ventilation may not be able to sufficiently reduce the vapor concentration to a safe level due to continuing evaporation from the liquid. In such cases, bail or pump the liquid into barrels, drums, or tank trucks, and dig holes outside the structure to prevent further contamination (*see Section 6-11*).

6-6.4 When nonvolatile liquids (fuel oils, etc.) are involved, ventilation will not be an effective method of removal. Use absorbents for thin films or solid surfaces. Whenever possible, pick up liquids with pumps or by bailing. Put water mixtures into barrels or drums for separation by settling. Siphon off the water and carry the contaminating liquid to a disposal facility (*see Figure 11*). If final cleanup requires flushing sumps and drains and washing surfaces, check with local sanitation and pollution authorities before flushing such liquids into sewers.

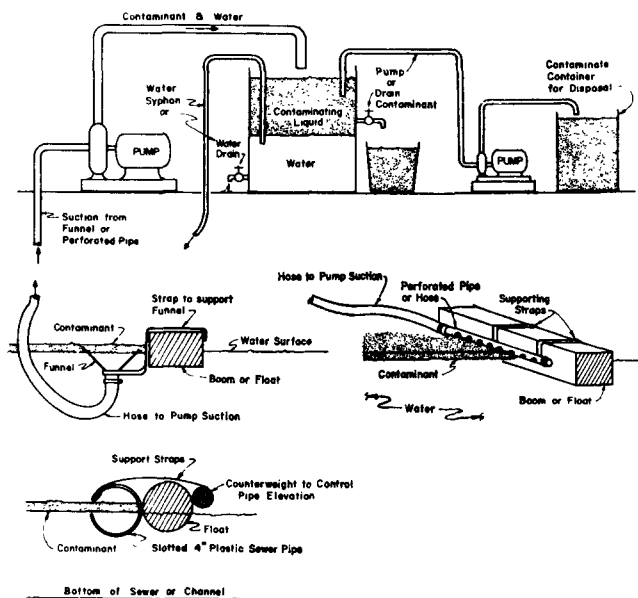


Figure 11

6-7 Subways, Tunnels, and Mines.

6-7.1 If only small amounts of volatile liquid are involved, ventilation may be adequate to permit entry and possibly even continued use of the facility. In such cases, the same removal and disposal methods as described previously for basements may be used. However, additional precautions must be employed because of greater exposure to the public and, normally, more exposure to sources of ignition. The authority responsible for the facility, the fire department, and police must effect a cooperative effort for maximum safety.

Subways, tunnels, and mines will normally have much greater exposure to underground seepage than do other substructures such as basements. Consequently, even though entry of a flammable liquid is thought to have been stopped, monitoring with a combustible gas indicator must be continued for an extended subsequent period to ensure against recurrence. Maintain a constant check for at least 24 hours after cleanup.

6-7.2 If results are negative, extend check periods to 8, 12, or 24 hours depending on use of the facility. Subsequent checks should be continued to include extreme conditions of groundwater changes. Significant rainfall and rising groundwater may carry additional liquids from the soil.

6-7.3 If relatively large amounts of volatile liquids are involved or leakage continues, it may be necessary to close the facility to the public and suspend normal operations. Maintain ventilation, and provide a pumping point, and pump liquids out with explosionproof equipment. Use a drum or tank for separating water by settling; transfer the volatile liquids to drums or tanks for transport to disposal facilities (*see Figure 11*). Consult with the authority operating the facility to determine the degree to which flushing and cleanup are necessary. Normally, once further entry of volatile liquids has been stopped, such facilities can be adequately purged of volatile liquids with reasonable periods of ventilation.

6-7.4 When nonvolatile liquids are involved, the potential for fire or explosion is greatly reduced. However, make sure that continued use or operation does not present a potential ignition source; for example, it may be necessary to deactivate high-power electric lines and tracks if they are anywhere near the contaminating liquid.

6-7.5 Absorb, bail, or pump the liquid as appropriate, using drums or tanks for separation by settling, and remove the nonvolatile liquid for transport to disposal facilities. Consult with the authority operating the facility 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 above for volatile liquids.

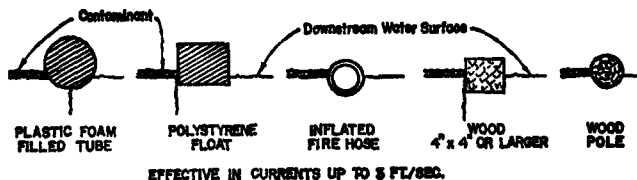
6-8 Utility Conduits.

6-8.1 Removal and disposal methods for these facilities are different from the other substructures previously covered for three principal reasons:

(a) Normally, concentrations of contaminating liquids will be much higher because early discovery and preventive measures are unlikely.

(b) Access to entry points and contaminated areas is usually from manholes but in some cases such access is not available.

(c) Exposure and danger to the public are greatly reduced. The utility operator must be consulted on all details of the proposed purging procedures; his/her special knowledge is essential in such work and normally he/she will select the exact procedures and techniques used.



EFFECTIVE IN CURRENTS UP TO 3 FT/SEC.

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

Figure 12

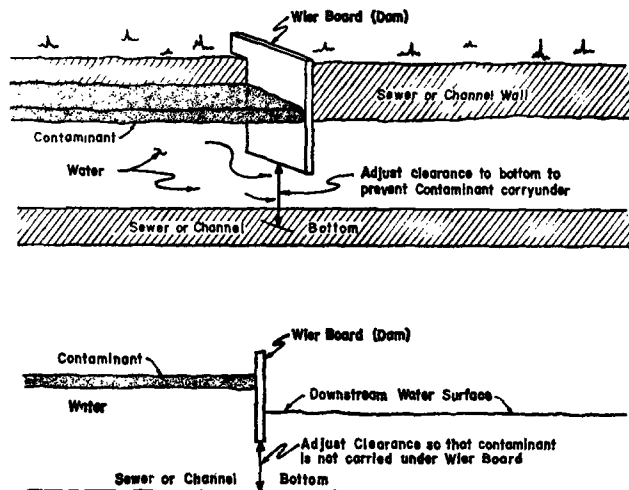
6-8.2 Where water is mixed with the contaminating liquid, it is preferable to separate the two by settling in drums or tanks to avoid contamination of downstream drainage facilities.

6-9 Sewers.

6-9.1 Sewers, on occasion, may collect flammable or combustible liquids from a surrounding contaminated area, and it is seldom practical to effectively seal off all entry points. Consequently, removal of contaminating liquids will normally be a continuing effort until the entire area is purged. When relatively large amounts of the contaminating liquid are involved, every reasonable effort should be made to divert the affected sewer flow to a separator where water and contaminant can be separated by gravity. If this is not practical, it may be possible to set up a skimming facility somewhere on the stream flow. One method is to throw a floating boom of polyurethane foam or an inflated tube such as a fire hose across the stream flow. If the contaminant is mostly on top of the water and surface flow is not turbulent, significant amounts of the contaminated liquid can be trapped behind the boom and removed with skimmer pumps and/or absorbent materials (see Figures 11 and 12). Weir boards can be used in the same way by raising them to permit water flow underneath and should be used whenever possible because of their greater efficiency, particularly when flow rates exceed 3 ft (1 m) per second (see Figure 13).

6-9.2 When relatively small amounts of liquid are involved, or the contaminating liquid is mixed with the water, settling tanks or basins must be used for separation by gravity (sewage treatment plants may have such facilities).

6-9.3 Water surfaces, as referred to in this chapter, are those on top of the ground exposed to the open air. When



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

Figure 13

such contamination exists, the problem should be referred to the proper water pollution authority. Water surfaces underground, such as in sewers, are covered in Section 6-9.

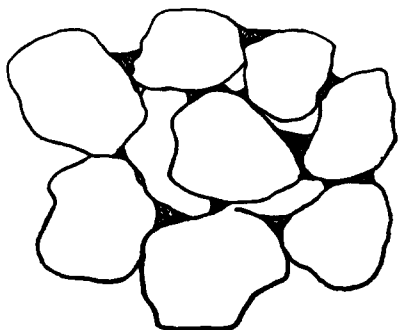
6-10 Underground Soil Contamination.

6-10.1 A knowledge of the local geology is basic to effective removal of flammable and combustible liquids from subsurface areas. Consequently, a geologist, familiar with the area, should be consulted whenever possible.

6-10.2 The removal of flammable or combustible liquids from underground will involve gathering of the liquid in some pooling point, generally from the top of groundwater, or mixed in with that groundwater. However, the liquid will often be present above the water table as well as on it, and removal and disposal is not complete until this liquid is also purged. Some concept of how this occurs is essential to an understanding of methods of removal. Reference to the discussion on geology in Chapter 5 will be helpful. When a liquid is released into a porous soil or rock, gravity will pull it downward through the pores or cracks. As it moves, some will be left behind on the surface of each particle that it contacts and some will be suspended by surface tension between two surfaces that are nearly in contact (see Figure 14).

6-10.3 The liquid will continue to move downward until the supply is exhausted by the coating action and by retention in the corners of the voids or until it reaches a barrier such as an impervious layer of soil or rock or the water table. If the supply of liquid continues after the barrier has been reached, the lower portion of the porous layer will begin to fill (see Figure 15).

6-10.4 If the barrier is the water table and the groundwater is moving, the contaminating liquid will tend to



After a liquid has passed through a porous soil each particle will be coated with a thin film of that liquid and surface tension will hold small amounts of that liquid in corners of the voids as shown here in the dark areas.

Figure 14

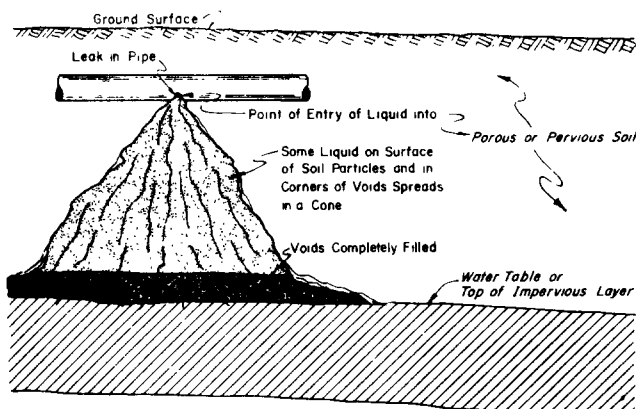


Figure 15

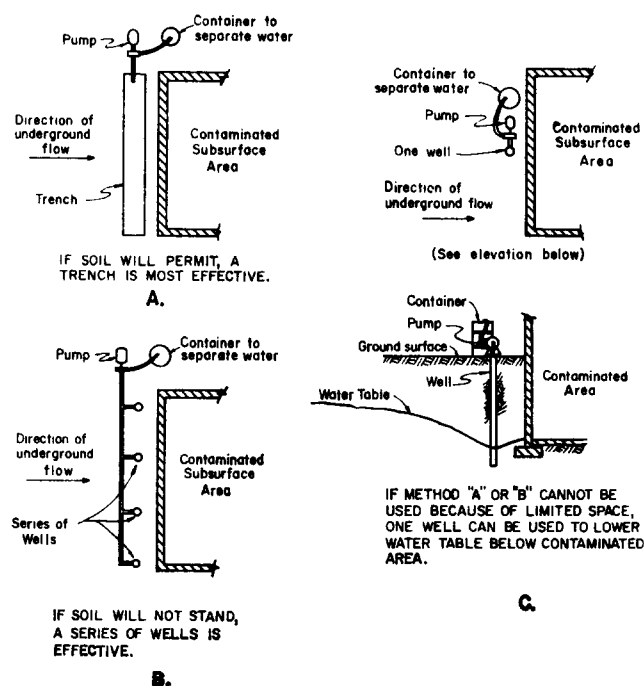


Figure 16

move with it. However, most of the contaminating liquid that has remained up in the porous soil above the water table will stay there until it is washed down by subsequent rainfall or other water flowing down through the contaminated soil.

6-11 Removal of Liquids.

6-11.1 Trenches.

6-11.1.1 Sometimes the same method used for removing liquids from underground will serve to limit further spread. An intercepting hole or holes or trench illustrated in Figure 16 and Figure 17 are such methods. It will greatly improve the ability of the trench to prevent escape of the contaminating liquid if the downstream side of the trench at the water surface is lined with an impervious barrier. Figure 16 further illustrates various methods of using wells or trenches as interceptors upstream of contaminated buildings.

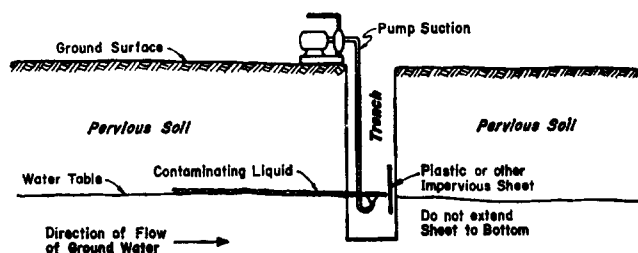


Figure 17

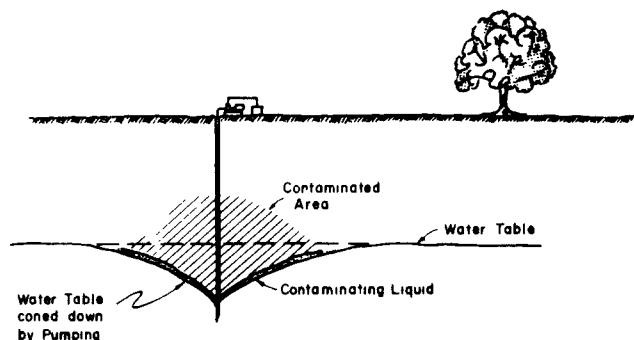


Figure 18

6-11.2 Wells.

6-11.2.1 Recovery wells can be used instead of intercepting trenches. These wells are practical in cases when the contaminated strata is both shallow and deep. A cone of depression is created by lowering the water level in the well below the surrounding natural water table. Flammable liquids will then migrate along the top of the water table into the well (see Figures 19 and 20). This procedure will establish an underground funnel radiating outward in all directions.

6-11.2.2 Care must be exercised in drilling and casing monitoring wells to ensure that the proper depth is not exceeded and that the well does not create conduits through impermeable layers.

6-11.2.3 When the area is extensive, a line of recovery

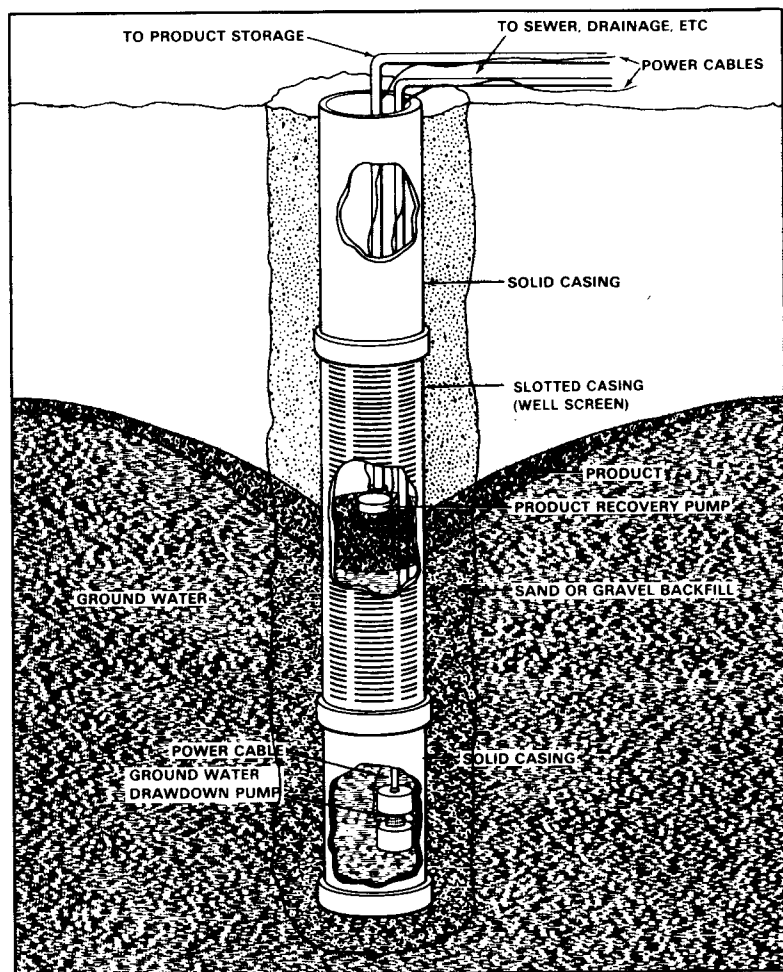


Figure 19 Double Pump Recovery Well

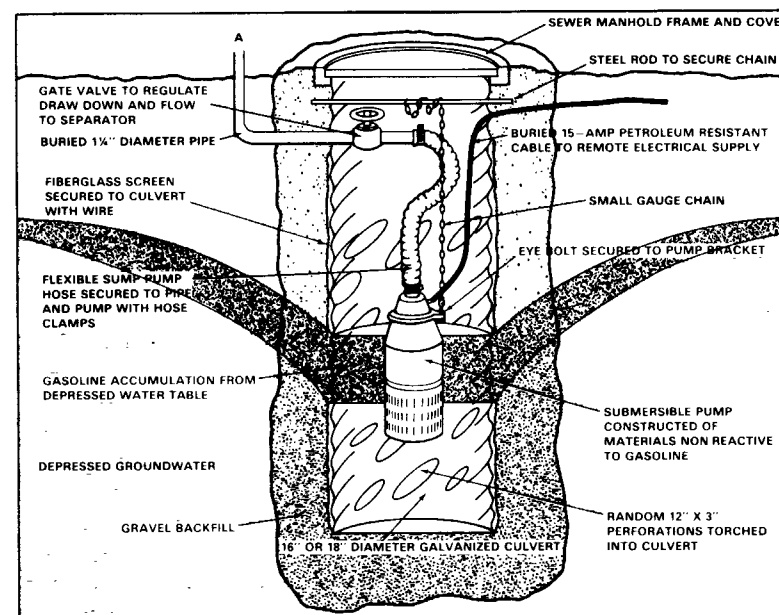


Figure 20 Recovery Well

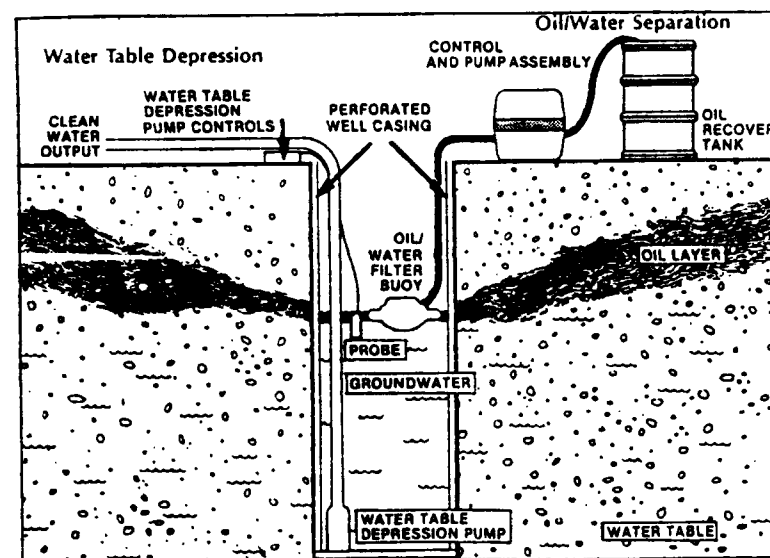


Figure 21 Recovery from Groundwater Using Filter and Water Table Depression Probe Pump

wells with overlapping cones of depression can be used to create an effective underground barrier preventing the further migration of contaminant, while at the same time collecting it for removal.

6-11.2.4 If significant lowering of the water table near buildings is possible, check with local engineering authorities to ensure against damage to substructures. (See API 1628, *Underground Spill Cleanup Manual*, for additional information.)

6-11.3 Pumping the Contaminant Out.

6-11.3.1 Refer to Figure 11 for the method of separating the oil and water mixture once it is raised to the surface. If large quantities of water are involved, bolted steel tanks can be obtained in sizes of several thousand gallons.

6-11.3.2 If the water table is reasonably shallow, two methods are available for removing the volatile liquid. One is a recovery well using a cone of depression to cause the contaminant to flow into the well. Floating filter buoys, skimmer, and pumps (see Figure 21) are available to collect and remove the contaminant. The second method is a trench, which may be dug if soil conditions permit (see Figure 17), and the same floating filter buoys and skimmers may be used.

It should be noted that the cone of depression will greatly speed the recovery process since it is drawing the spilled liquid to the recovery point.

6-11.3.3 If the water table is reasonably shallow [20 ft (6 m) or less] and the soil permits the digging of a trench, a "skimmer" suction at the top of the water table can be used. Figure 19 illustrates one method of skimming by using a funnel on the end of the suction hose mounted on the end of a pole for control.

6-11.3.4 Another method of skimming at shallow depths is illustrated in Figure 20. The depth at which this can be done will depend on the pump used. There are several available for use in decorative fountains; most will have a lift of 8 ft to 10 ft (2.5 m to 3 m), but some special units are available for lifts up to 20 ft (6 m). The pump is lowered by a rope or wire into the hole upside down to a level where its suction is just covered by the liquid surface. It is run intermittently or continuously depending on how fast the contaminating liquid is being generated.

6-11.4 Disposal.

6-11.4.1 In disposing of mixtures of contaminated material, local regulatory officials should be consulted to ensure that the disposal method has their approval.

Appendix A

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

**Physical Properties
Common Flammable and Combustible Liquids**

	Flash Point °F (°C)	Flammable Limits Lower % by Vol.	Upper	Specific Gravity Water = 1.0
Acetone	-4 (-20)	2.16	13	0.8
Amyl acetate	60 (16)	1.1	7.5	0.9
Amyl alcohol	91 (33)	1.2	10	0.8
Benzene (Benzol)	12 (-11)	1.3	7.1	0.9
Butyl acetate	72 (22.2)	1.7	7.6	0.9
Butyl alcohol	84 (28.9)	1.4	11.2	0.8
Carbon disulfide	-22 (-30)	1.3	50.0	1.3
Ethyl acetate	24 (-4.4)	2.0	11.5	0.9
Ethyl alcohol	55 (12.8)	3.3	19	0.8
Ethyl benzene	59 (15)	1.0	6.7	0.9
Fuel oil (diesel)	100-130			
furnace & kerosene)	(37.8-54.4)	0.7	5	<1.0
Gasoline	-45 (-43)	1.4	7.6	0.8
Heptane	25 (-3.9)	1.05	6.7	0.7
Hexane	-7 (-21.1)	1.1	7.5	0.7
Isopropanol	53 (11.7)	2.0	12.7	0.8
Methyl alcohol	52 (11.1)	6.0	36	0.8
Methyl cyclohexane	25 (-3.9)	1.2	6.7	0.8
Naphtha (high flash)	85 (29.4)	1.0	6.0	<1.0
Naphtha (regular)	28 (-2.2)	0.9	6.0	<1.0
Stoddard solvent	100-130			
	(37.8-54.4)	0.7	5	<1.0
Toluene	40 (4.44)	1.2	7.1	0.9
Xylene-o	90 (32.2)	1.0	6.0	0.9

A-4-3.11 It is important to emphasize that NFPA 329 is a recommended practice, and that the Precision Test is one method of determining whether or not a tank system might be leaking. It was never intended to preclude other technological approaches that might achieve the same end result.

The 0.05 gph (0.19 L/hr) criterion is not intended to imply that there is an acceptable level of leakage. Rather, that criterion was demonstrated to be a measurable rate given all of the variables associated with volumetric testing that render accurate testing difficult.

The 0.05 gph figure was arrived at when typical tank sizes ranged from 6000 gallons to 10,000 gallons. The testing is admittedly more difficult on increasingly larger tanks. For that reason, the following table is suggested as an alternative to the 0.05 gph when tank sizes exceed 12,500 gallons.

Table A-4-3.11 Precision Test Accuracy Criterion

Tanks Greater Than (gals)	and	Up to and Including (gals)	Criterion (gph)
0		12,500	0.05
12,500		17,500	0.063
17,500		22,500	0.075
22,500		27,500	0.088
27,500		32,500	0.100
32,500		37,500	0.113
37,500		42,500	0.125
42,500		47,500	0.138
47,500		52,500	0.150

Tanks larger than 52,500 gals require special consideration on a site-specific basis.

For SI Units: 1 gal = 3.785L; 1 gal/hr = 3.8 L/hr.

Appendix B Inventory Control Procedures

B-1 Inventory Control Procedures.

B-1-1 Tanks with Metered Dispensing. For this method to be effective, all meters that measure liquid dispensed from the underground system should be properly calibrated. A meter that reads significantly higher than actual volume pumped may be hiding a leak. Conversely, a meter that indicates less than the true volume may suggest a leak where one does not exist.

B-1-1.1 Daily Procedures. At the beginning of each business day (or shift), tank volume should be manually measured using a gage stick or other means and a calibration chart to convert the tank level into gallons. This gaging 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 gaged both before and after the delivery. The operator should also check his tank for the presence of water using a water finding paste on the end of the gage stick. This should be done on a daily basis as part of the opening routine as well as immediately after any delivery into the tank. Water that is detected should be accounted for in the inventory procedures and any significant accumulation [i.e. greater than ½ 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 gaged 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 gaging, water gaging, meter calibration checks, and recordkeeping are contained in the American Petroleum Institute Publication 1621.

B-1-1.2 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 opening inventory. Due to variables inherent in the process, this reconciliation will rarely balance exactly to the gallon and small daily "over" or "short" figures are to be expected. The calculated variance should be carried forward each day with the new over or short figure added (algebraically) to that of the previous day. Using this technique, the operator is able to identify trends over time; daily fluctuations tend to cancel out over the long term.

B-1-1.3 Inventory Reviews. The operator of an underground tank system storing flammable or combustible liquids should review the daily inventory records once a week. The operator should be concerned with small but growing daily losses or sudden unexplained changes from the established pattern. Either of these symptoms could indicate a potential leak.

For a facility that stores more than one variety of similar liquid (such as a retail service station), the operator should compare inventory records for the various tank systems. This will mitigate the effect of temperature-induced errors on the inventory accounting. Since the impact of temperature should be roughly the same, a significant difference in the inventory variance from one product to the next may indicate a leak. The first step in investigating this would be to check the meter calibrations on the support system.

At the end of each month, the operator should again review the daily inventory accounting. A cumulative shortage greater than 0.5 percent of the system throughput for the month may suggest a leak. The operator should look closely to see if the negative variance is a one-time fluctuation or if there is a consistent negative trend throughout the inventory period.

B-1-2 Tanks Without Metered Dispensing. For these systems, the inventory review is complicated by the fact that all withdrawals can only be measured by gaging the tank. Tank levels should be accurately gaged and recorded before and after any input or withdrawal. To determine if the storage system is losing liquid, the operator should compare the volume before an input or withdrawal with the measured volume after the previous input or withdrawal. This loss or gain figure for each period of tank inactivity should be carried forward and a cumulative variance maintained by adding the gain or subtracting the loss from the previous number. Since tank gaging errors are completely random, they should tend to cancel out from one measurement to the next. A consistent and increasing negative or positive trend indicates a potential leak that should be investigated.

For additional information on the subject, see the following.

(a) American Petroleum Institute Publication 1621: *Recommended Practice for Bulk Liquid Stock Control at Retail Outlets*, Third Edition, 1977.

(b) Environmental Protection Agency: *More About Leaking Underground Storage Tanks: A Background Booklet for the Chemical Advisory*, October 1984.

(c) Radian Corporation: *Analysis of Factors Affecting*