NFPA 329

Recommended Practice for Handling Releases of Flammable and Combustible Liquids and Gases

1999 Edition

National Fire Protection Association, 1 Batterymarch Park, PO Box 9101, Quincy, MA 02269-9101
An International Codes and Standards Organization

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Recommended Practice for

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This edition of NFPA 329, *Recommended Practice for Handling Releases of Flammable and Combustible Liquids and Gases*, was prepared by the Technical Committee on Tank Leakage and Repair Safeguards and acted on by the National Fire Protection Association, Inc., at its May Meeting held May 17–20, 1999, in Baltimore, MD. It was issued by the Standards Council on July 22, 1999, with an effective date of August 13, 1999, and supersedes all previous editions.

This edition of NFPA 329 was approved as an American National Standard on August 13, 1999.

Origin and Development of NFPA 329

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

The 1999 edition of this recommended practice is a combination of the relevant and updated material contained in earlier editions of NFPA 328, *Recommended Practice for the Control of Flammable and Combustible Liquids and Gases in Manholes, Sewers, and Similar Underground Structures*, and NFPA 329, *Recommended Practice for Handling Releases of Flammable and Combustible Liquids and Gases*. NFPA 328 was withdrawn in May 1999.

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This list represents the membership at the time the Committee was balloted on the text of this edition. Since that time, changes in the membership may have occurred. A key to classifications is found at the back of this document.

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

Committee Scope: This Committee shall have primary responsibility for documents on safeguarding against fire, explosion, and health hazards associated with entry, cleaning, and repair of tank systems and methods for detecting, controlling, and investigating releases that could cause these hazards.

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Recommended Practice for

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

Information on referenced publications can be found in Chapter 8 and Appendix F.

Foreword

Releases of flammable and combustible liquids and gases can result from leaks in tanks or lines, surface spills, or human error. Generally, the amount of liquid or gas that is lost is small and can be dissipated by evaporation or otherwise assimilated. However, because of the physical and chemical characteristics of many flammable and combustible liquids or gases, it is possible that a release can find its way into a subsurface structure, such as a basement, utility conduit, sewer, or well. Whether or not an immediate hazard exists depends on a number of factors, such as the amount of liquid or gas released, where it is found, how it is confined, and possible sources of ignition.

Because a flammable or combustible liquid that is unconfined in the subsurface can move from place to place, any indication that such liquids have escaped into the subsurface must be considered as a potential, if not immediate, hazard. The probability of an explosion or fire within a subsurface space depends on the following two factors:

The atmosphere must contain a mixture of flammable vapor and air within the flammable range.

There must be a coincident source of ignition.

The severity of an individual explosion or fire and its consequences depends on various factors. The possibility that any one explosion could result in a major catastrophe is always present.

This recommended practice will provide regulatory officials, fire authorities, contractors, and owners of subsurface structures guidance on problems involving flammable and combustible liquids and gases that could be found in subsurface structures and other areas.

Chapter 1 General Provisions

1-1 Scope.

1-1.1 This recommended practice provides appropriate methods for responding to fire and explosion hazards resulting from the release of a flammable or combustible liquid, gas, or vapor that could migrate to a subsurface structure. Although this recommended practice is intended to address only these fire and explosion hazards, other authorities should be consulted regarding the environmental and health impact and other hazardous conditions of such releases.

1-1.2 This recommended practice outlines options for detecting and investigating the source of a release, for mitigating the fire and explosion hazards resulting from the release, and for tracing the released liquid back to its source. These options are not intended to be, nor should they be considered to be, all-inclusive or mandatory in any given situation. If better or more appropriate alternative methods are available, they should be used.

1-1.3 The procedures outlined in this recommended practice can apply to hazardous substances other than flammable and combustible liquids that could have adverse human health effects. However, the physical characteristics of the hazardous substance released must be understood before taking any action. It should be recognized that other authorities, such as federal or state hazardous materials personnel, should be consulted regarding the environmental and health impact and other hazardous conditions of these substances. Guidance regarding maximum acceptable levels of these substances can be found in the *Material Safety Data Sheet (MSDS);* OSHA 29 *CFR* 1910.1000, Subpart Z; other OSHA substance-specific standards; ACGIH *Threshold Limit Values (TLV) for Chemical Substances and, Physical Agents;* and the NIOSH *Pocket Guide to Chemical Hazards.*

1-1.4* The condition created by the releases of liquids and vapors in subsurface structures can be grouped into the following two classes:

(1) Flammable
(2) Injurious to life

The latter condition results from the toxic or suffocating properties of the gases or vapors. Some of these liquids and gases fall into both classes. While this publication deals primarily with the flammable limits associated with liquids and gases, some of which are listed in Table A-1-1.4, additional precautions could be required to protect against health hazards. An example is benzene; its dangerous breathing concentration is only a small fraction of the lower flammable limit (LFL).

1-1.5 The responsibility for proper handling of a suspected release of flammable and combustible liquids and gases, or a potential hazard from such a release, will be shared by various individuals, organizations, and regulatory agencies. The successful handling of these problems will depend on the best possible cooperation between them. This recommended practice is intended for the information of all organizations and persons involved. Owners, operators, or others becoming aware of a hazardous condition should notify the fire department, police, or other proper authority.

1-1.6 The National Fire Protection Association does not, by the publication of this recommended practice, recommend action that is not in compliance with applicable laws and regulations and should not be considered as doing so. Users of this recommended practice should consult all applicable federal, state, and local laws and regulations, especially with respect to any applicable reporting requirements.

1-2 Definitions. For the purpose of this recommended practice, the following terms should have the meanings given below.

Authority Having Jurisdiction.* The organization, office, or individual responsible for approving equipment, materials, an installation, or a procedure.

Bonding. The permanent joining of metallic parts to form an electrically conductive path that will ensure electrical continuity and the capacity to conduct safely any current likely to be imposed.

Combustible Gas Indicator. An instrument that samples air and indicates whether there are combustible vapors present. Some units may indicate the percentage of the lower explosive limit of the air–gas mixture.

Combustible Liquid. A liquid that has a closed-cup flash point at or above 37.8°C (100°F).

Container. A device that is intended to contain an accumulation of hazardous substances that is too small for human entry or has a capacity that can be effectively and safely cleaned without human entry.

Flammable Liquid. A liquid that has a closed-cup flash point that is below 37.8°C (100°F) and a maximum vapor pressure of 2068 mm Hg (40 psia) at 37.8°C (100°F).

Hazardous Substance. A substance that is capable of creating harm to people, the environment, or property. The dangers may arise from, but are not limited to, toxicity, reactivity, ignitibility, or corrosivity. A hazardous substance includes combustible and flammable liquids and flammable gases.

Hot Tapping. The technique of welding and drilling on in-service tanks or containers that contain flammable, combustible, or other hazardous substances.

Hot Work. Any work that is a source of ignition, including open flames, cutting and welding, sparking of electrical equipment, grinding, buffing, drilling, chipping, sawing, or other similar operations that create hot metal sparks or surfaces from friction or impact.

Inert Gas. Any gas that is nonflammable, nonreactive, and noncontaminating.

Inerting. A technique by which the atmosphere of a tank or container is rendered nonignitible or nonreactive by the addition of an inert gas.

Liquid. Any material that has a fluidity greater than that of 300 penetration asphalt when tested in accordance with ASTM D 5, *Standard Test Method for Penetration of Bituminous Materials*. Unless otherwise specified, the term *liquid* includes both flammable and combustible liquids.

Lower Flammable Limit (LFL). That concentration of a combustible material in air below which ignition will not occur. Also known as the lower explosive limit (LEL). Mixtures below this limit are said to be "too lean."

Oxygen Monitor. A device capable of detecting and measuring concentrations of oxygen in the atmosphere.

Purging. The process of displacing vapors or gases from an enclosure or confined space.

Qualified Person. A person, who by possession of a recognized degree, certificate, professional standing, or skill, and who by knowledge, training, and experience, has demonstrated the ability to deal with problems associated to the subject matter, the work, or the project.

Self-Contained Breathing Apparatus. A portable respiratory device designed to protect the wearer from an oxygen-deficient or other hazardous atmosphere. It supplies a respirable atmosphere that is either carried on, in, or generated by the apparatus and is independent of the ambient environment. It is equipped with a full-face mask and is approved by the U.S. Mine Safety and Health Administration and the National Institute for Occupational Safety and Health.

Standby Person. A person who is assigned to remain on the outside of the confined space and to be in communication with those working inside.

Static Electricity. The electrification of materials through physical contact and separation, and the various effects that result from the positive and negative charges so formed, particularly where they constitute a fire or explosion hazard.

Subsurface Structure. Subsurface structures include manholes, sewers, utility conduits, observation wells, storm drains, vaults, water lines, fuel gas distribution systems, electric light and power conduits, telephone and telegraph communication lines, street-lighting conduits, police and fire signal systems, traffic signal lines, refrigeration service lines, steam lines, petroleum pipelines, subways, tunnels, and the substructural areas of buildings such as basements and parking garages.

Tank. A stationary or portable device that is intended to contain an accumulation of hazardous substances that is large enough to allow human entry.

Toxic Materials, Gases, or Vapors. Any material whose properties contain the inherent capacity to produce injury to a biological system. This is dependent on concentration, rate, method, and site of absorption.

Toxicity. The quality or degree a substance is harmful to humans.

Unstable or Reactive Materials. A liquid that, in the pure state or as commercially produced or transported, will vigorously polymerize or decompose or will become self-reactive under conditions of shock, pressure, or temperature.

Vapor. The evaporated phase of a substance that is normally a liquid at room temperature and pressure.

Volatile Liquid. A liquid that evaporates readily at normal temperature and pressure.

Work. Activities performed on tanks and containers in accordance with this document; including, but not limited to, safeguarding, repair, hot work, cleaning, change of service, maintenance, inspection, and transportation.

Chapter 2 Sources of Flammable and Combustible Liquids and Gases

2-1 General.

2-1.1 Flammable and combustible liquids and gases are commonly stored and handled in locations that are immediately adjacent to structures, facilities, and people. Flammable and combustible liquids include chemicals, cleaning fluids, motor gasoline, diesel fuel, and heating oil. Motor gasoline is the most widely used of these liquids, and is commonly stored underground at service stations and other vehicle fueling operations. Flammable and combustible gases include natural gas, propane, sewage gases, and refrigerant gases.

2-1.2 Flammable vapors in subsurface structures can result from a release of a flammable or combustible liquid. Examples of these releases include cleaning solvents and compounds washed down drains by industrial and domestic users and a surface release that can enter a sewer or drain. A release can also result from damage to tanks, containers, and lines from corrosion, structural failure, excavation in the area, or fire.

2-1.3 If a flammable or combustible liquid or gas is present in the soil, as could be produced by decaying organic matter, there is some likelihood that it will penetrate an adjacent subsurface structure. Particular attention should be paid to landfill sites developed by the depositing of garbage and trash. Gas from this source, primarily methane, might not have an odor.

2-1.4 Flammable gases or vapors can enter conduits, sewers, drains, or basements because subsurface structures constructed of cement, concrete, brick, or vitreous tile generally are not built to be impervious to gases or vapors. Gases or vapors can enter the subsurface sections of buildings through cracks or around any underground conduits that penetrate the substructure walls or floors.

2-2 Sources of Ignition.

2-2.1 The possibility of ignition of flammable gases or vapors that could collect in subsurface structures is limited by certain fundamental conditions. The vapor must be mixed with sufficient air to make a flammable mixture or it must be escaping into air at a point where a flammable mixture can be created. Heat of sufficient intensity to ignite the particular air–vapor mixture involved must be present at the place where a flammable mixture exists. Such heat could be caused by an open flame, an electric arc or spark, or other hot surface.

2-2.2 The flammable limits of some gases and vapors that have been found in subsurface structures are listed in Appendix B. Flammable mixtures are formed when the concentration of these gases and vapors in air is between the lower and upper limits shown.

2-2.3 Potential sources of ignition can be encountered in everyday operations. Little control can be exerted over these sources of ignition when flammable vapors are escaping from or into subsurface structures. Such sources of ignition include open flames, furnace pilot lights, automotive and other internal combustion engines, tar pots, and smoking.

2-2.4 Static electricity can be a source of ignition and its accumulation is generally greatest in an atmosphere of low humidity. The hazard appears when static accumulates to the extent where a spark discharge occurs. Static electricity can be generated when a liquid under pressure escapes from a pipe at high velocity. Particles of dust, scale, or rust, or liquid droplets inside the pipe can become heavily charged with static when blown out by gas or vapor; and, if they impinge on an electrically isolated body, the body will accumulate the charge and a spark discharge can occur.

Chapter 3 Initial Response

3-1 Indicators of a Release. A release of flammable or combustible liquids or gases can be indicated by physical discovery or by indications of a potential release.

3-1.1 A release of flammable or combustible liquids or gases can be indicated by physical discovery in the following:

(1) Normally inhabited subsurface structures such as basements, subways, and tunnels
(2) Other subsurface structures such as manholes, sewers, utility conduits, observation wells, and similar subsurface structures near tanks
(3) Groundwater
(4) Drinking water supplies
(5) Surface water
(6) Seepage from the earth

3-1.2 Indications of a potential release of flammable or combustible liquids, gases, or vapors can be detected by the following:

(1) Evidence of a spill
(2) Failure of a tightness test
(3) Monitoring equipment
(4) Loss of inventory
(5) Presence of water in a tank
(6) Odors

3-2 Initial Response to Physical Discovery.

3-2.1 Depending on the circumstances of physical discovery, conditions can exist where there could be a potential hazard to life or property, and immediate steps should be taken to protect the public from the danger of explosion and fire.

3-2.2 For uninhabited structures, those directly responsible for the facility involved should be contacted, such as the municipal sanitary department or highway or street department for sewers, and the electrical or telephone or gas companies' engineering departments for conduit. Normally, the maintenance and engineering departments of such organizations will be well equipped to take care of the situation. Police, if needed, can be asked to keep the public clear of the danger areas. The fire department could be needed to assist in fire control and purging. Those involved with facilities that store and handle flammable and combustible liquids that could be the source of the problem should offer all possible assistance.

3-2.3 The presence of flammable gases or vapors in a building or subsurface structure is generally reported because of an odor. However, smell cannot be relied on to determine the type of gas or vapor or its concentration. The use of an appropriate instrument, such as a combustible gas indicator or photoionization detector, is required to determine the presence and extent of a flammable gas or vapor concentration.

3-2.4 No one should enter areas where flammable or combustible liquids, gases, or vapors have been discovered, except as described in Section 3-3.

3-2.4.1 If liquids, gases, or vapors within or above the flammable range are found in a building, the building should not be entered. Evacuation of building occupants, at least in areas that were exposed, should be ordered. Construction and layout as well as occupancy are factors to be considered in ordering evacuation.

3-2.4.2 If liquids, gases, or vapors are found in tunnels or subways, traffic should be stopped until qualified personnel determine that there is no danger of explosion, fire, or health hazards.

3-2.5 Eliminating Sources of Ignition.

3-2.5.1 Smoking or other sources of ignition should not be permitted in areas where flammable or combustible liquids, gases, or vapors have been discovered. Lights and other electrical switches should not be turned on or off, and power cords should not be removed from outlets. Any such action can create a spark that is capable of igniting flammable gases or vapors. Use only those switches located well away from the area to disconnect electrical power. This situation could require that the electric utility effects a remote cutoff.

3-2.5.2 After the presence of flammable or combustible liquids, gases, or vapors has been verified in a building or subsurface structure, the electrical and gas services to the building or structure, where possible and feasible, should be disconnected or shut off outside the structure. Shutting off the gas service outside of the building removes the fuel from pilot lights and gas burners, which could be sources of ignition.

3-2.6 Entering the Area.

3-2.6.1 To enter an area in which there is an undetermined concentration of some unknown gas or vapor is to risk the possibility of fire or explosion. Flammable gases or vapors in a sewer or conduit might not originate from flammable liquids. They could be vapors from overheated insulation, sewer-generated gases, fuel gases, or industrial gases. Consequently, special instruments, equipment, skills, and procedures (confined space entry) could be necessary. The guidance of the utility owning and operating the facility should be solicited and followed. Entry should not be made until the gas or vapor concentration has been checked with an appropriate instrument as indicated in 3-2.3.

3-2.6.2 An additional life hazard could exist because of toxic gases or vapors or insufficient oxygen. If these conditions are suspected, instruments to detect toxic gases or vapors or insufficient oxygen should be used.

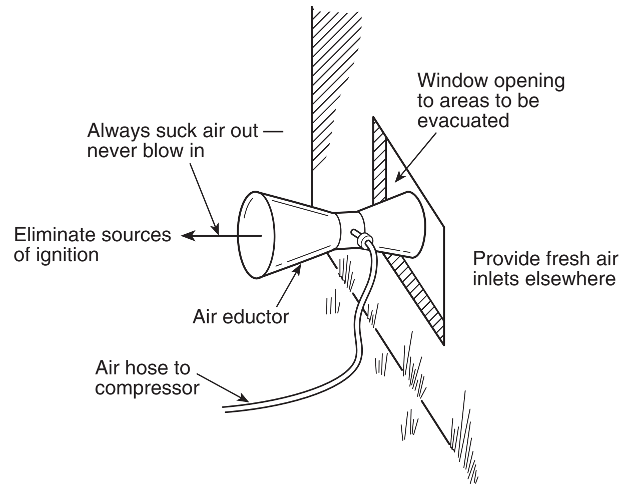
3-2.6.3 The appropriate instrument should be used frequently to determine the gas or vapor concentrations in the affected area. Where gas or vapor concentrations are above 50 percent of the lower flammable limit, everyone within the affected area must be evacuated. The area should be ventilated to remove or reduce the flammable gas or vapors and thus reduce the fire or explosion hazard. As soon as the flammable gas or vapor has been reduced below 50 percent of the lower flammable limit, entry can be made to locate and eliminate the source of gas or vapor. Self-contained breathing apparatus should be worn when entering the affected area.

3-2.6.4 Natural ventilation provided by opening doors and windows and removing manhole covers or other accesses could be adequate to remove vapors from the affected area. Grounded mechanical exhaust ventilating equipment could be required to remove vapors from all areas, particularly from low, confined spaces. Fans driven by motors that are approved for Class I, Group D locations, hand-driven fans, or air eductors can be used to remove vapors *(see Figure 3-2.6.4)*. Sources of ignition near the exhaust outlets should be eliminated. Openings for free entry of fresh air should be provided, but air should never be forced into the area. A water hose with the nozzle set in a spray pattern can be used for ventilating the area if it is set in a window and discharges outwardly.

3-2.7 The generation of sewer gas can be stopped or significantly reduced by flushing the sewer or conduit with water.

3-2.8 When the area has been made safe for entry, it can be examined to determine the source of the flammable or combustible liquids, gases, or vapors. If the place or places of entry of the liquid, gas, or vapor can be determined, appropriate steps should be taken to seal them off. Untrapped drains, dry traps, pipes, or other openings through floors or foundations are common sources of liquid, gas, or vapor entry. Any gas pipes in the area should be checked; the flammable gas or vapor could be fuel gas. If this appears to be the source, the gas company should be called.

Figure 3-2.6.4 Exhaust venting.



3-2.8.1 If vapor is entering through a drain or collection pipe, it could be because the trap is dry. Filling the trap with water is an effective means of blocking further gas or vapor entry.

3-2.8.2 The nature of seepage could be such that it cannot be effectively stopped from inside the structure. In this case, an intercepting hole or trench, holes for pumps, or well points can be used outside the contaminated structure, between it and the suspected source.

3-2.8.3* When seepage is detected in a sewer, the source should be located by backtracking with appropriate instruments. 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.

3-2.8.4 If entry of liquid, gas, or vapor into the conduit or sewer is to be stopped, and the inside of the facility is not accessible, the area alongside the facility should be probed or drilled to determine the extent of its exposure to the saturated soil. The exposed area should be uncovered and the facility should be sealed from the outside.

3-2.9 Liquid seepages of water will often be more of a pollution problem than an explosion or fire hazard. However, until the source of the flammable or combustible liquid is found and stopped and all liquid and vapor are safely removed, there is a potential hazard of explosion or fire.

3-2.10 When flammable or combustible liquids are found in well water, pumping should be stopped and any source of ignition around well houses and water storage tanks should be avoided until vapor concentrations are checked. Electrical power outside any well house or similar trap that could collect vapors from the well or stored water should be disconnected.

3-2.11 Where flammable or combustible liquids are found on surface water or emerging from the earth, flammable vapor concentrations can develop in ditches or collection points. Normally, the amount of flammable or combustible liquid found on the surface water will be in such a thin layer that it will not create a fire hazard. This is the case where the liquid is dispersed into small bubbles or pools or where a sheen is visible on the surface of the water.

3-2.11.1 If the entire surface of the water is covered or there are large pools in the order of 6 m (20 ft) or more across, a fire hazard does exist. If large amounts of vapor are being generated, the wind direction should be checked and all sources of ignition within at least 30 m (100 ft) downwind of the source should be removed. It is unlikely that vapors will be in the flammable range farther than 30 m (100 ft) away. However, if large amounts are involved, and the air is relatively still, an appropriate instrument should be used to determine the extent of the hazardous area. Its use is desirable in any event if flammable liquids are involved.

3-2.11.2 Normally, the only effective means to stop further accumulation is to find the source of the release and stop it. Dikes or dams could need to be constructed to prevent further spreading of the liquids or of contaminated water. Floating booms can be used on flowing water to hold the contaminating liquid. *(See Chapters 6 and 7.)*

3-2.11.3 Once the source of flammable or combustible liquids is stopped, removal can be accomplished by evaporation, normal dispersal, dilution, collection with adsorbents, skimming devices, or filtering devices. *(See Chapter 7 for details.)*

3-3 Initial Response to Indications of a Potential Release.

3-3.1 An inventory loss, water in tanks, failure of a tightness test, or other monitoring equipment indications do not directly indicate a hazard of fire and explosion. The immediate vicinity should be checked for any signs of escaping liquid. If any exist, the procedures given for initial response to physical discovery should be followed as appropriate. *(See Section 3-2.)* Otherwise, the procedures of Chapters 5, 6, and 7 should be followed.

3-3.2 The actions recommended in Chapter 7 should be followed if there is evidence of a spill.

Chapter 4 Searching for the Source

4-1 General.

4-1.1 After all the necessary precautions have been taken to mitigate fire and explosion hazards, the next most important step is to locate the source of the flammable or combustible liquid and prevent any further release.

4-1.2 Generally, the source of the liquid will be relatively near the location where unconfined liquid or vapor has been discovered. However, liquids can travel hundreds of feet or even miles underground through porous soil or rock, through trenches filled with porous material, alongside pipes or conduits, or in sewer pipes. Consequently, the location from which a released liquid could have originated can be remote and extensive and can include many facilities that handle and store flammable or combustible liquids. Also, the source of the release could be an abandoned underground storage tank. If a check of potential sources adjacent to or within several hundred feet of the discovery is not conclusive, then the investigation should be expanded to include other potential sources in the general area of the discovery. Some potential sources include the following:

(1) Automotive service stations, both retail and private
(2) Automotive garages or dealerships
(3) Fleet operations such as taxicab companies, municipal garages, dairies, and bakeries
(4) Contractors or equipment dealers who store fuels on their premises
(5) Motor fuel and heating fuel distributors
(6) Cleaning establishments, including dry cleaners
(7) Industrial and chemical process plants
(8) Airports and marinas
(9) Underground petroleum or gas transmission lines
(10) Any abandoned tanks that stored flammable or combustible liquids in the past
(11) Any other property on which flammable or combustible liquids are or can be stored

4-1.3 Efforts should be made to secure information on groundwater flow patterns from the regional U.S. Geological Survey (USGS) office, local public works departments, or similar agencies. Search efforts should be initiated up-gradient from the leak.

4-1.4 A map of the area should be obtained or sketched, each facility should be marked on the map, and all the information that is obtained should be recorded. Well-organized, accurate data will prove invaluable in subsequent efforts to solve the problem *(see Appendix C)*.

4-1.5 Teams should be organized as necessary to conduct the search. One efficient method is to assign a two-person team to each specific zone on the map. One of the team members should represent the local public authority. The search should begin with the nearest and most obvious potential sources and work out from the point of discovery, moving uphill, up-gradient of groundwater flow, or upstream of sewer or conduit flows.

4-1.6 Often the source can be found by inquiry or simple inspection. The procedure outlined in Section 4-2 should be followed. If an obvious or very likely source is not found within several hours, it is then advisable, while the primary search continues, to begin testing the closest and most probable sources, such as equipment, underground storage tanks, or underground piping, for concealed points of release.

4-2 Search Procedure.

4-2.1 Flammable and combustible liquids will most likely escape into the ground for the following reasons:

(1) Liquid has been spilled during transfer and has reached an underground conduit or soaked into porous soil.
(2) A leak has developed in a storage, transportation, or handling system.

The lists in this section can be used as a guide in checking for spills or other possible sources of the release. Also, questions should be asked, and the premises and equipment should be carefully inspected. Unless an obvious source that is large enough to account for the release is found, the search should not stop at the first sign of a potential source. First impressions can be misleading. It is useful to check available public records for any prior history of releases. Also, because liquids can travel slowly through the ground or not move at all until the groundwater table rises, a considerable amount of time can pass between the actual release of a liquid and its discovery. Therefore, all history or evidence of potential leaks or spills should be recorded, regardless of how long ago they occurred. Any potential source should not be eliminated on the basis of time until all information is available and its analysis justifies elimination of that source.

4-2.2 The following questions should be asked of all facility operators in the area of the search:

(1) Has there been a spill during loading or unloading?
(2) Is any storage or handling equipment leaking, or has there been a leak?
(3) Is there evidence of excavations or repairs that could have damaged underground facilities? *(See Appendix D.)*
(4) Has there been any maintenance on pipes, tanks, or other equipment that could have resulted in a release?
(5) Has there been any odor or other signs of liquids in areas where there should not be?
(6) Are inventory and use records kept? Do they show any indication of a release?
(7) Has water been found in any underground storage system?
(8) Is there any knowledge of an accident that could have released liquids from a tank vehicle, container, or storage tank? A check with local law enforcement agencies is useful here. The age of underground facilities should be considered. If subsequent tests are made, older equipment could be suspect.
(9) Have any problems been encountered during pumping and liquid transfer?

4-2.3 If inquiry fails to disclose any potential source, each premise's owner or operator should be asked for cooperation in checking equipment. If an operator refuses because he or she is not the owner, then permission should be obtained from the owner. If necessary, local governmental officials can help to secure such cooperation.

4-2.4 The following guidance should be helpful in checking equipment.

(a) On-site leak detection equipment should be inspected for proper operation and for indications of a leak.

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

(c) The areas around aboveground tanks should be checked for similar signs of leakage.

(d) All exposed piping should be checked for signs of leaks.

(e) Dispensing equipment should be checked for leaks. A combustible gas indicator should be used when checking dispensers of the type used at automotive service stations. The cover of the dispenser should be opened just enough to insert the indicator probe into the area beneath the dispenser. Opening the cover wide could provide enough ventilation to dilute any vapors present and give a reading low enough to indicate that there is no leak. If the vapor concentration indicates a potential release, the dispenser cover should be removed and the piping, valves, and fittings should be inspected for signs of leaks. The dispensing nozzle and hose should also be checked.

(f) If a remote pumping unit is used, its housing or pit should be checked with a combustible gas indicator before opening. The unit can then be opened for inspection.

(g) Automotive repair areas should be checked for signs of waste liquids being dumped into inappropriate floor drains or sumps.

Any equipment found to be leaking should not be used until repairs are effective. Any storage tank or piping that is found to be leaking should be emptied if liquid is still escaping.

4-2.5 If all the equipment appears to be in order and there is no obvious sign of spilling or dumping into sumps or sewers, the grounds and areas around the premises should be checked. The following guidance will be helpful in checking the area.

(a) Signs of waste liquids that have been dumped or spilled onto the ground should be identified. Any areas of contamination that could have been covered up, such as fresh gravel, sod, or soil, should arouse suspicion.

(b) Nearby streams and bodies of water should be checked for signs of flammable or combustible liquids, such as a sheen or slick on the surface of the water and along the banks.

(c) Vegetation should be checked for an indication of damage from spilling, dumping, or contaminated groundwater.

(d) A photoionization detector or other appropriate instrument should be used to check sewers and other underground conduits and cavities, such as utility manholes, for the presence of vapors and a visual inspection should be made for signs of foreign liquids on the surface of any standing water in these areas.

(e) The barrels of any fire hydrants in the area should be checked.

(f) Nearby excavations and steep cuts or natural slopes down-gradient from the potential source should be checked for signs of liquid.

4-2.6 Dumping or spilling flammable or combustible liquids into sewers or on the ground could be a violation of state or federal law and should immediately be reported to the proper authorities.

4-2.7 Small spills do occur inadvertently and could appear to be larger than they really are. A small amount of liquid (e.g., 1 cup of fuel) spilled onto wet pavement will spread over a relatively large area. Small spills that spread out over a large area will dissipate rapidly and are not likely sources of underground contamination. The significant releases are large spills and repeated small spills that can flow to points of access into subsurface structures or porous soils and then reach the groundwater table.

4-3 Procedures to Verify the Source.

4-3.1 Once an obvious source or sources have been found and the further release of liquid has been stopped, further search efforts can be temporarily suspended. It now should be determined if each identified source is, in fact, the actual source of the release. While removal and protective measures are taken, the flow of the liquid, the amount of liquid, and the vapor concentrations at those locations where the problem exists should be monitored and recorded. If a distinct and continuous decrease occurs, then it can be assumed that the source of the release has been identified. The decrease might not occur immediately; it could, in fact, take days or weeks for liquid that has accumulated underground to be removed or to dissipate. *(See Chapter 6.)*

4-3.2 If after a reasonable length of time the flow of liquid to the affected area does not stop or show a definite decrease, further investigation should be conducted simultaneously using the following two procedures.

(a) Release detection tests should be conducted on any liquid storage or handling system in the vicinity of the affected area. *(See Chapter 5.)*

(b) The path of the liquid underground should be traced from its point of discovery to the source. Tracing will determine the actual extent of the release, its direction of flow, and any other potential. *(See Chapter 6.)*

Chapter 5 Release Detection of Tanks and Piping

5-1 General.

5-1.1 All data previously gathered should be reviewed to determine the most efficient method or methods of testing. There are several methods described in this chapter that can reveal a leak prior to conducting a tightness test. If one of these preliminary techniques does not reveal the source of a suspected leak, it cannot be concluded that the liquid-handling system is tight. But the possibility of quickly solving the problem will often warrant the limited effort involved before a tightness test or other release detection method is undertaken. For additional details on the latest testing and release detection methods, industry publications and officials should be consulted.

5-1.2* Regardless of the procedures involved, liquid-handling equipment should be evaluated in a manner that is as close as possible to normal operating conditions. Excessive pressures or tests by nonrepresentative liquids could indicate a leak where none exist or could conceal leaks that do exist.

5-2 Action Preliminary to Release Detection or Tightness Testing.

5-2.1 Checking Underground Tanks. The information obtained from the search procedures described in Chapter 4 should be reviewed. In particular, the following should be noted.

(a) The method of filling tanks. Damaged fill pipes, poorly maintained tight-fill connections or hose couplings, driver carelessness, or even overfilling the tank can cause some of the product to be spilled around the pipe when a delivery is made. In particular, fill pipes that are installed under covers should be checked.

(b) Any evidence of ground settlement around tanks and any sign of work that could 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 underground tank and any history of past water removal, which can be determined by water-finding paste on the gauge stick. If possible, it should be determined whether the water increases during periods of heavy rainfall and remains constant or diminishes during dry spells. Also, if possible, the depth of the water table should be determined by checking a monitoring well in the immediate tank area. Any accessible openings should be checked to determine whether water is entering through a loose cap. The surface area around vent lines should be checked for evidence that water could be entering by this route (standing water over vent lines could be the source). Vent openings should be checked to ensure that there is protection against rainwater intrusion.

(e) The age of the facility.

(f) The location and flow of liquid found underground by gas sensors or visual inspection. A release detected at a monitoring well usually indicates that a significant release has occurred.

(g) Inventory control records, the type of tank gauge system, and whether the gauge was in operation should be checked. *(See 5-2.4.)*

(h) It should be determined that the tank includes secondary containment. Containment areas normally include a port for monitoring releases and should serve as one of the first areas checked to see if a release has occurred. If submersible turbine pumps are used to pump the liquid, they are located in a sump above the tank. A visual check of the sump area is also an important checkpoint.

5-2.2 Checking Aboveground Tanks. The information obtained from the search procedures described in Chapter 4 should be reviewed. In particular, the following should be noted.

(a) The method of filling tanks. Aboveground tanks are normally filled by pressurized pumps. In addition to the items noted for underground tanks, spills from overfills can also be observed near normal and emergency vent openings and around the tank itself.

(b) It is not unusual for water to be present at the bottom of bulk storage tanks due to condensation and deliveries. Since groundwater is normally below the bottom of an aboveground tank, the presence of water is not necessarily reflective of a leak in the bottom of the tank.

(c) Any evidence of foundation or support settlement around tank systems. Past or recent work on the tanks or attached piping and any sign of work that could have damaged the tank or its fittings.

(d) The age of the facility.

(e) The location and flow of liquid found underground by gas sensors or visual inspection. A release detected at a monitoring well usually indicates that a significant release has occurred.

(f) Aboveground tanks often require a spill prevention control and countermeasure plan (SPCCP) as required by 40 *CFR* 112, "Protection of Environment." The plan should be checked for spill records and for specific recommendations on how such facilities are instructed to contain spills.

(g) Inventory control records, the type of tank gauge system, and whether the gauge is in operation. With large aboveground tanks, the volume of the tank makes a reliable assessment of tank integrity, through inventory records or gauge readings, more difficult. *(See 5-2.4.)*

(h) Whether there is secondary containment around and under the tank. Containment areas normally include a port for monitoring releases and should be one of the first areas checked to see if a release has occurred.

5-2.3 Checking Piping.

5-2.3.1 For piping systems, the following should be checked:

(1) Recent excavation, digging, pavement repair, or other work in the area that could have damaged underground piping
(2) Any recent repairs that could have created a leak due to faulty workmanship or that could indicate a previous leak
(3) Any evidence of shifting ground, such as a frost heave or settlement, that could have damaged piping or pipe supports
(4) Deteriorated asphalt paving or distressed vegetation that indicates a spill or solvent action of liquids or vapor
(5) Evidence of abandoned, capped, or disconnected piping, such as unused dispensing islands or other unused ancillary facilities
(6) In-line leak detection devices for proper operation and evidences of a release
(7) Type of underground piping and corrosion control system
(8) Pipe integrity test records

5-2.3.2 For suction piping, the following should be checked:

(a) If the pump used in moving the liquid is above ground and the supply pipe operates under vacuum or suction, certain pumping characteristics will indicate either a leaking check valve or a leaking pipe. Air enters the pipe through a leaking check valve or through a pipe leak as liquid drains back into the tank. The presence of this air is 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 could be indicated by skipping of the volume display, a rattling sound in the pump, or erratic liquid flow due to mixing of air and liquid. Another indication is overspeed of the pump when first turned on, followed by slowing of the pump as it begins to move liquid. A third indication is churning of the pump (i.e., running but not moving liquid at all).

(b) If any of the conditions listed in 5-2.3.2(a) indicate a leak in the suction line, the check valve should be inspected first. Some check valves are located close to the pump inlet, others are mounted in the underground pipe just above the tank, and some are installed on the end of the suction stub inside the tank. Some of these valves located in the pipe above the tank can be inspected and repaired from the surface of the ground through a special extractor mechanism installed with the valve. If the valve is inside the tank, it could be necessary to dig down to the tank to check the valve or disconnect and seal off the pipe for a hydrostatic pressure test.

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

(d) If the procedures in 5-2.3.2(c) fail to indicate the source of the leak but there is still reason to suspect a leak, the piping should be tested according to 5-4.2.

5-2.4 Checking Inventory Records.

5-2.4.1 A careful check of inventory records will be very helpful in determining the course of further investigation. *(See Appendix E.)*

5-2.4.2 A check should be made to be sure that a loss of inventory is not due to one of the following:

(1) Meters that are not correctly calibrated
(2) Contraction due to lower temperatures
(3) Theft
(4) Use of a conversion chart that does not conform to actual tank geometry
(5) Malfunctioning automatic tank gauging probe

5-2.4.3 Evidence of inventory loss strongly implies that the source has been found but subsequent checks to determine how the loss has occurred should be made before definite conclusions can be drawn. Any loss that is partially or totally explained by the causes listed in 5-2.4.2 cannot be considered as conclusive evidence that the site in question is not the only source. Records are often incorrect or inadequate. Unless another source is found and considered to be a satisfactory solution to the problem, other tests should be performed to draw definite conclusions.

5-3 Release Detection Methods.

5-3.1 Installation, Maintenance, and Operation. With the information from the search procedures of Chapter 4 as a basis, the techniques described in Section 5-3 can be used in a logical process of elimination. The following should be considered when applying release detection methods.

(a) Means and methods of release detection should be installed, maintained, and operated in accordance with the manufacturer's recommended procedures. Personnel utilizing these methods should be properly trained in their use and operation. Proper documentation of procedures and results should be provided.

(b) As applicable, methods of release detection should comply with applicable local, state, and federal environmental regulations and be documented with respect to accuracy.

(c) If a release is indicated by any of the described methods, further investigation could be required by either confirmatory testing *(see Section 5-4)* or the tracing techniques described in Chapter 6, whichever is most appropriate.

5-3.2 Underground Storage Tanks. Additional information regarding recommended procedures is provided in EPA 530/UST-89 1012, *Detecting Leaks: Successful Methods Step-by-Step.*

5-3.2.1 Automatic Tank Gauging. If the tank is equipped with an automatic tank gauging system that has a leak test mode, a leak test should be conducted in accordance with the manufacturer's operating instructions. Automatic tank gauging equipment should be capable of detecting a leak rate at least as low as 800 ml/hr (0.2 gal/hr) from any portion of the tank that routinely contains product, with a probability of detection of 0.95 and a probability of false alarm of 0.05.

5-3.2.2 Inventory Reconciliation Analysis. If inventory records have been analyzed by quantitative statistical methods, the analysis should be examined for indications of a probable release, assuming that the data can be analyzed conclusively.

5-3.2.3 Manual Tank Gauging. For tanks of 3785-L (1000-gal) capacity or less, manual tank gauging can be used, if the liquid level measurements are taken at the beginning and end of a period that is at least 36 hours long and during which no liquid is added or removed from the tank. *(See Appendix E.)*

5-3.2.4 Tanks Equipped with Secondary Containment. If the tank is of double wall construction or is installed with a secondary containment system, the monitoring point should be checked for the indication of a release.

5-3.2.5 Vapor or Groundwater Monitoring Wells. If vapor or groundwater monitoring wells have been installed in the tank system excavation area, they should be checked for the indication of a release. Other methods could be approved by the local regulatory agency.

5-3.3 Aboveground Storage Tanks.

5-3.3.1 Visual Inspection. An external visual inspection of the tank system should be performed.

5-3.3.2 Tanks Equipped with Secondary Containment. If the tank is of double wall construction or is installed with a secondary containment system, the monitoring point should be checked for the indication of a release. The leak detection ports, if present, should be checked.

5-3.3.3 Vapor or Groundwater Monitoring Wells. If vapor or groundwater monitoring wells have been installed in the tank system area, they should be checked for the indication of a release.

5-4 Testing.

5-4.1 Underground Tanks.

5-4.1.1 If the release detection methods described in Section 5-3 are not available or do not yield conclusive identification of the source of a release, testing of the piping or tank, or both, could be necessary. The test procedures should detect a leak anywhere in the complete underground storage and handling system unless other information has eliminated some portion of the system from the search. Certain test methods could allow additional product to be released from the system or could cause structural damage to the tank or piping during the test. Where it is reasonable to assume that a leak exists, the effects on safety and environment should be considered when determining which test method to use.

5-4.1.2 The following should be considered when applying testing methods.

(a) Means and methods of testing should be performed in accordance with the manufacturer's recommended procedures. Personnel utilizing these methods should be properly trained. Proper documentation of procedures and results should be provided.

(b) Methods of testing should comply with applicable local, state, and federal environmental regulations and be documented with respect to accuracy.

5-4.1.3 Both volumetric and nonvolumetric tightness testing methods can be used. Additional information on volumetric and nonvolumetric tightness test methods is provided in EPA 530/UST-89 1012, *Detecting Leaks: Successful Methods Step-by-Step.*

5-4.1.4 When volumetric tightness testing is performed, the method should be capable of detecting a leak of as little as 380 ml/hr (0.10 gal/hr), with a probability of detection of 0.95 and a probability of false alarm of 0.05. This detection capability is a performance standard to determine the detection capabilities of the testing device and procedure. The detection threshold for declaring a leak will vary based on the individual manufacturer's specifications.

5-4.1.5 A nonvolumetric tightness test is an acceptable test for leak detection; however, it does not quantify a leak rate.

5-4.1.6 If the results of a tightness test indicate that a leak could exist, either appropriate corrective action or additional testing to confirm the leak should be performed.

5-4.1.7 Pressure Testing.

5-4.1.7.1 Pressure Testing with Air or Other Noninert Gases.

WARNING

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

5-4.1.7.2 Testing with Inert Gases. Inert gases can be used for the purpose of detecting a leak for both tank and piping systems. The pressure exerted by both the product and the inert gas should not exceed the limits recommended by the tank manufacturer. The use of pressure-limiting devices is required in this application.

5-4.1.8 If warranted, an internal inspection of the tank should be conducted to evaluate the condition of the tank interior.

CAUTION

Proper procedures for safe entry should be followed.

5-4.2 Underground Piping.

5-4.2.1 Hydrostatic Testing of Piping. A hydrostatic test of piping is a relatively simple test that can quickly indicate a leak. In a hydrostatic test, the piping is isolated and a hydrostatic pressure test is conducted at 150 percent of the maximum anticipated pressure of the system, but not less than a gauge pressure of 34.48 kPa (5 psi) at the highest point of the system. The test should be maintained for at least 10 minutes. A drop in pressure indicates the possibility of a leak in the piping, and a volumetric tightness test should be performed. It should be noted that a loss of liquid pressure can be attributed to the following:

(1) A line leak
(2) A decrease in liquid temperature in the line
(3) Piping distortion due to the liquid pressure
(4) Vapor trapped in the piping

5-4.2.2 Suction Piping for Vehicle Fueling. A liquid volumetric pressure test can be performed on a suction line by connecting to the exit port of the air eliminator or other appropriate fitting. This connection permits pressure to be applied to the suction piping from the pump back to the check valve. In this test, the hydrostatic pressure should not exceed a gauge pressure of 103.4 kPa (15 psi) to prevent damage to the pump.

5-4.2.3 Tracer or Dye Testing. Where tracer or dye testing has been approved for the product, it has the advantage of leaving the pipe system in service while the test is performed.

5-4.3 Aboveground Storage Tanks.

5-4.3.1 Acoustic Emission. Acoustic emission leak detection technology is the listening for characteristic noises created by a leak from the bottom of a tank. The system operates essentially by detection and location of noise signals consistent with the types of signals emitted from tank bottom leaks.

5-4.3.2 Volumetric Leak Detection. There are two basic forms of volumetric leak detection, the temperature-level method and the mass-measurement method.

5-4.3.2.1 Temperature-Level Method. The temperature-level method measures the liquid level accurately and compensates for thermal expansion or contraction using a vertical array of temperature sensors to compensate for vertical thermal gradients. A leak is indicated by a drop in the temperature-compensated level.

5-4.3.2.2 Mass-Measurement Method. The mass-measurement method measures the pressure acting near the bottom of the tank. The pressure corresponds to the mass above the measuring point and should be independent of liquid level changes caused by thermal expansion.

5-4.3.3 Tracer Gas Testing. This method involves adding a tracer gas to the storage system and then testing for its presence outside the storage system.

5-4.3.4 Pressure Testing with Inert Gases. Inert gases can be used for the purpose of detecting a leak for both tank and piping systems. The pressure exerted by both the product and the inert gas should not exceed the limits recommended by the tank manufacturer. The use of pressure-limiting devices is required in this application.

5-4.3.5 Internal Inspection. If warranted, an internal inspection of the tank should be conducted to evaluate the condition of the tank interior.

CAUTION

Proper procedures for safe entry shall be followed.

Chapter 6 Tracing Liquids Underground

6-1 General. Although the following guidelines are given in an approximate order of importance, they are not necessarily in the preferred order for all cases. The actual sequence of procedures and the choice of test methods will depend on the circumstances of the problem, information gained from the primary search, and any previous test results. It is beyond the scope of this recommended practice to cover the problem in all its potential complexities. If initial efforts fail to identify the source, additional expert assistance could be necessary.

6-2 Procedure for Determining Underground Flow.

6-2.1 Any potential sources and pathways should be noted on a sketch of the local area. Also, any pertinent geological data that is available and the locations of sewers, streets, conduits, streams, manholes, tanks, fill pipes, vent risers, and pumps should be noted. Any abandoned ditches or stream beds that have been filled and covered should be included. A USGS map or aerial photograph can serve as a useful base. Some sources for this information are as follows:

(1) Municipal and state public works agencies, water departments, and sewer departments
(2) Local, state, and federal geological departments
(3) Utility companies
(4) Facility owners and local residents (Special attention should be given to elderly and long-time residents. They will often provide valuable information about the area prior to its development.)

6-2.2 If necessary, metal detectors should be used to locate and trace buried steel pipe.

6-2.3 Information gathered and plotted on the sketch up to this point could indicate that a specific nearby facility is a very likely source. If so, tests to verify this, as described in Chapter 5, can be conducted.

6-2.4 Potential liquid flow paths should be checked as follows.

(a) Manholes, sewers, inlet boxes, wells, open trenches, exposed slopes and cuts, and the like, should be visually checked. Samples of water should be taken to test for the presence of flammable or combustible liquids.

(b) A photoionization detector or other instrument should be used to determine the presence of vapors. Other sources of vapor readings, such as natural gas lines, landfills, and sewer gas, should be considered.

(c) If checking underground structures does not give a clear indication of the direction of movement of the underground flow, a more detailed search can be conducted in porous backfill or pervious strata by testing for vapors in the soil.

6-2.5 When this testing has determined the probable direction from which the contamination is coming, extend the search up-gradient using these same methods to determine the next most likely source. Both sides of the direction of flow should be checked to determine its width.

6-2.6 As the problem becomes more complex, other methods of testing and tracing could be useful as outlined in Sections 6-3 through 6-5, or other methods not described here. However, the advantages and disadvantages of each test procedure should be recognized if valid conclusions are to be reached.

6-3 Dye Tracing. The use of a dye tracer is often suggested as a means of tracing the flow of liquid. This method involves adding a compatible dye to the storage system that is suspected as the source of the release, then seeing if the dyed liquid appears at the point of discovery. (This procedure could take minutes, hours, or days.)

6-4 Chromatographic and Spectrographic Analysis. The chromatograph and the spectrograph are instruments capable of detecting traces of the elements of almost any compound. For example, they can detect a trace quantity of an element that is unique to a particular method of manufacture, thus identifying the source. They can also detect the amount of the element present. This procedure only involves a small sample taken at the point of discovery. These tests should be used in cases that involve complex mixtures, such as petroleum liquids. However, these tests could be inconclusive because some identifying component can be lost in the ground or a component not originally present can be picked up from the ground or from contact with buried materials.

6-5 Other Chemical Analysis. Other methods of chemical analysis are available, and many of the same comments in Section 6-4 could apply. Examples of significant factors that can sometimes be determined by chemical analysis are additives and the age of the contaminant.

6-6 Other Sources. If the investigation fails to locate an active source of release, it is possible that the problem could be a result of an accumulation from a previous equipment failure, spill, or improper disposal of the liquid. Experience has indicated that many such residual deposits have existed and remained undetected for long periods of time before becoming large enough to make their presence known.

Chapter 7 Removal and Disposal of Flammable and Combustible Liquids

7-1 General.

7-1.1 In general, removal and disposal methods will depend on the amount of flammable or combustible liquid released to environmental media (i.e., soil, groundwater, or surface water) or present in a structure or on the surface, its chemical and physical characteristics, and the area impacted.

7-1.2 The most significant chemical characteristic of a flammable or combustible liquid that is significant to methods of removal and disposal is the volatility or ability of the liquid to evaporate at ambient temperatures.

7-1.2.1 Flammable liquids such as solvents, gasoline, and other volatile liquids will rapidly evaporate at ambient temperature.

7-1.2.2 Combustible liquids such as heating oils, food processing oils, and other nonvolatile liquids do not readily evaporate and will tend to remain in place for longer periods of time.

7-1.3 In general, purging a structure or enclosure of vapors of volatile liquids is primarily a matter of ventilation, while liquids are physically collected and removed.

7-1.4 The principal categories of structures or environmental media involved are the following:

(1) Normally inhabited subsurface structures, such as basements, subways, tunnels, and mines
(2) Normally uninhabited subsurface structures, such as crawl spaces, sewers, and utility tunnels
(3) Surface water
(4) Groundwater
(5) Soil

7-1.5 Refer to safety procedures in Section 3-2.

7-1.6 Before washing spilled petroleum products from street surfaces into drains or sewers — a potentially dangerous action and often an unlawful practice — other disposal means, such as soaking up the substance with sand, rags, or mops, should be considered. If, in an emergency, no alternative is available, disposal in a drain or sewer should be done only on the decision of a qualified person after appropriate public authorities have been notified.

7-2 Normally Inhabited Subsurface Structures.

7-2.1 Basements.

7-2.1.1 With very few exceptions, the quantity of flammable or combustible liquid that will be found in a basement will be relatively small, because a liquid will normally be detected before significant quantities can accumulate and additional flow can be intercepted or stopped. Where volatile liquids and their vapors are involved, the primary removal and disposal action is ventilation, as described in Chapter 3. Small amounts of liquid that remain can be removed with commercial absorbents. Used absorbents should be placed in covered containers to prevent the further spread of vapors. Once all flammable or combustible liquids have been removed, final cleanup can be accomplished by flushing out basement sumps and floor drains with water and washing down all impacted surfaces with a biodegradable surfactant. Ventilation and checking with a combustible gas indicator should be continued throughout the cleanup procedure.

7-2.1.2 In the rare cases involving relatively large volumes of volatile liquids, ventilation might not sufficiently reduce the vapor concentration to a safe level due to the continued evaporation of the flammable or combustible liquid. In these cases, bail or pump the flammable or combustible liquid into barrels, drums, or other suitable containers or into portable tanks or tank vehicles. It could be necessary to dig an interceptor trench between the source of the release and the affected structure.

7-2.1.3 When nonvolatile liquids, such as fuel oils, are involved, ventilation is ineffective because the liquid evaporates at such a low rate. Absorbents should be used for thin films of flammable or combustible liquid on water surfaces or on solid surfaces. Whenever possible, flammable or combustible liquids should be removed with pumps or by bailing. If final cleanup requires flushing sumps and drains and washing surfaces, local sanitation and environmental authorities should be consulted before flushing such flammable or combustible liquids into sanitary sewers.

7-2.1.4 Where vapors in a basement are the result of a release of a flammable or combustible liquid to the environmental media, the primary removal and disposal action in the basement is ventilation. Elimination of the vapors might not be possible until remediation of the affected environmental media has been completed.

7-2.2 Subways, Tunnels, and Mines.

7-2.2.1 If only small amounts of volatile liquids are involved, ventilation alone could be adequate to permit safe entry and possibly continued use of the facility. In such cases, the same removal and disposal methods as described in 7-2.1.1 for basements can be used. However, added precautions should be employed due to the greater potential exposure to the public and, normally, due to the greater exposure to potential ignition sources. The authority having jurisdiction responsible for the facility, the fire department, and other public safety officials should effect a cooperative effort for maximum public safety.

7-2.2.2 Subways, tunnels, and mines will normally be more prone to underground seepage than other subterranean structures such as basements. Consequently, even though entry of a flammable or combustible liquid is thought to have been stopped, monitoring with a combustible gas indicator should be continued for an extended period of time after remediation to check for recurrence.

A constant check should be maintained for at least 24 hours after remediation has been completed. If results are negative, the check periods should be extended to an 8-, 12-, or 24-hour cycle, depending on the use of the facility. Subsequent checks should be continued to include periods of extreme changes in groundwater levels. Significant rainfall and rising groundwater can carry with it more liquid.

7-2.2.3 If a relatively large amount of flammable or combustible liquid is involved or if leakage continues, it could be necessary to close the facility to the public and suspend normal operations. It could also be necessary to deactivate any electric lines or transit tracks in the vicinity of the seepage. Ventilation should be maintained and a collection point should be provided for intercepting seepage and pumping it out. Only a nonsparking or air-operated pump motor should be used. The materials for proper disposal should be removed.

The facility operator should be consulted to determine the degree to which cleanup and remediation are necessary. Normally, once further entry of volatile liquids has been stopped, such facilities can be adequately purged of vapors with reasonable periods of ventilation.

7-2.2.4 Where vapors in subsurface structures are the result of a release of flammable or combustible liquid to the environmental media, the primary removal and disposal action in the subsurface structure is ventilation, as described in Chapter 3. Elimination of the vapors might not be possible until remediation of the affected environmental media has been completed.

7-3 Normally Uninhabited Structures.

7-3.1 Utility Conduits.

7-3.1.1 Removal and disposal methods for utility conduits differ from those described for other subterranean structures previously covered for the following reasons:

(1) The amounts of flammable or combustible liquids will normally be higher because early discovery and preventive measures are unlikely.
(2) Access to entry points and impacted areas is usually from manholes, but such access might not be available.

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

7-3.1.2 Where vapors in the utility conduit are the result of a release of flammable or combustible liquid to the environmental media, ventilation of the utility conduit could be appropriate. Elimination of the vapors might not be possible until remediation of the affected environmental media has been completed.

7-3.2 Sewers.

7-3.2.1 On occasion, sewers can collect flammable or combustible liquids from a surrounding area impacted by the liquids. It is seldom practical to seal off all entry points into the sewer. Consequently, removal of the flammable or combustible liquids will normally be a continuing effort until the entire area is purged. When relatively large amounts of flammable or combustible liquid are involved, every reasonable effort should be taken to divert the affected water flow to a separator.

If this is impractical, it could be possible to set up a skimming facility or float a boom or inflated tube across some point of the stream flow. If the flammable or combustible liquid is mostly on the surface of the stream flow, and flow is not turbulent, significant amounts of the liquid can be trapped behind the boom and can be removed with skimmer pumps or absorbents. *[See Figures 7-3.2.1(a) and 7-3.2.1(b).]* Weirs can also be used in the same way by installing them in such a manner that water can flow underneath, trapping the flammable or combustible liquid behind the upper part of the weir. Weirs should be used whenever possible because of their greater efficiency, particularly where the stream flow exceeds 0.9 m/sec (3 ft/sec). *[See Figure 7-3.2.1(c).]*

Figure 7-3.2.1(a) Typical skimming installation.

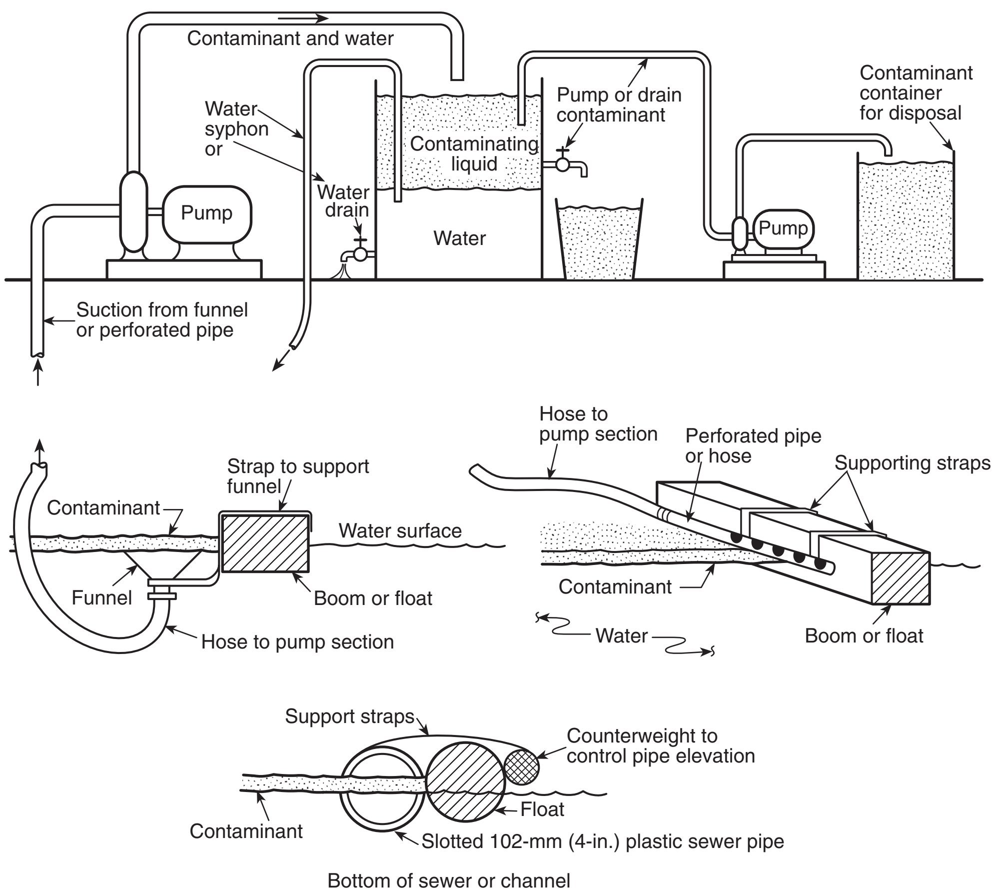


Figure 7-3.2.1(b) Typical floats and booms for trapping contaminants floating on water.

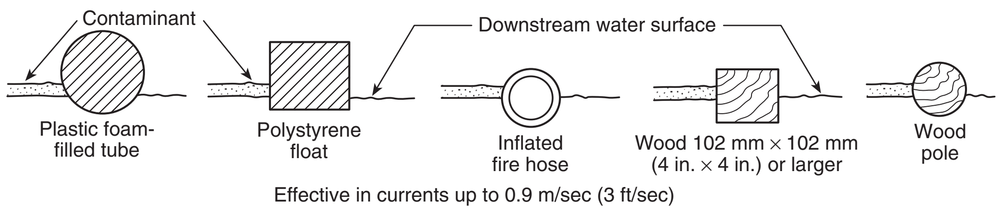
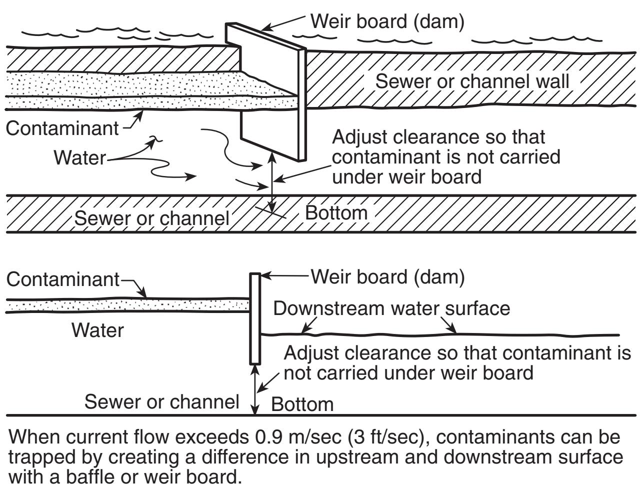


Figure 7-3.2.1(c) Typical installation of a weir in a flowing stream.



7-3.2.2 Where vapors in sewers are the result of a release of flammable or combustible liquids to the environmental media, the primary removal and disposal action in the sewer is ventilation, as described in Chapter 3. Elimination of the vapors might not be possible until remediation of the affected environmental media has been completed.

7-4 Underground Release. A knowledge of the local geology is basic to effective removal of flammable or combustible liquids or their components from subsurface soils and groundwater. A geologist who is familiar with the area should be consulted before field activities begin. Subsurface assessment will most likely be required to further define the extent of contamination and properly design the remediation efforts. Additional information can be found in API 1628, *A Guide to the Assessment and Remediation of Underground Petroleum Releases,* and API 1629, *Guide to the Assessment and Remediation of Petroleum Releases to Soil.*

Chapter 8 Referenced Publications

8-1 The following documents or portions thereof are referenced within this recommended practice and should be considered as part of its recommendations. The edition indicated for each referenced document is the current edition as of the date of the NFPA issuance of this recommended practice. Some of these documents might also be referenced in this recommended practice for specific informational purposes and, therefore, are also listed in Appendix F.

8-1.1 ACGIH Publication. American Conference of Governmental Industrial Hygienists, 1330 Kemper Meadow Drive, Cincinnati, OH 45240-1634.

Threshold Limit Values (TLV) for Chemical Substances and Physical Agents, 1998.

8-1.2 API Publications. American Petroleum Institute, 1220 L Street, NW, Washington, DC 20005.

API 1628, *A Guide to the Assessment and Remediation of Underground Petroleum Releases*, third edition, 1996.

API 1629, *Guide to the Assessment and Remediation of Petroleum Releases to Soil*, 1993.

8-1.3 ASTM Publication. American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959.

ASTM D 5, *Standard Test Method for Penetration of Bituminous Materials*, 1986.

8-1.4 U.S. Environmental Protection Agency Publication. U.S. Environmental Protection Agency, Washington, DC 20460.

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

8-1.5 U.S. Government Publications. U.S. Government Printing Office, Washington, DC 20402.

NIOSH *Pocket Guide to Chemical Hazards.*

OSHA, Title 29, *Code of Federal Regulations*, Part 1910.1000, Subpart Z.

OSHA, Title 40, *Code of Federal Regulations*, Part 112, "Protection of Environment."

OSHA, *Material Safety Data Sheet (MSDS).*

Appendix A Explanatory Material

Appendix A is not a part of the recommendations of this NFPA document but is included for informational purposes only. This appendix contains explanatory material, numbered to correspond with the applicable text paragraphs.

A-1-1.4 See Table A-1-1.4.

A-1-2 Authority Having Jurisdiction. The phrase "authority having jurisdiction" is used in NFPA documents in a broad manner, since jurisdictions and approval agencies vary, as do their responsibilities. Where public safety is primary, the authority having jurisdiction may be a federal, state, local, or other regional department or individual such as a fire chief; fire marshal; chief of a fire prevention bureau, labor department, or health department; building official; electrical inspector; or others having statutory authority. For insurance purposes, an insurance inspection department, rating bureau, or other insurance company representative may be the authority having jurisdiction. In many circumstances, the property owner or his or her designated agent assumes the role of the authority having jurisdiction; at government installations, the commanding officer or departmental official may be the authority having jurisdiction.

A-3-2.8.3 For information on underground petroleum releases, see API 1628, *A Guide to the Assessment and Remediation of Underground Petroleum Releases*.

A-5-1.2 For example, perforation of a tank shell might not be detected due to impermeable backfill, the water table, sludge, or rust plugs, all of which can inhibit release of the product from the tank.

Table A-1-1.4 Properties of Some Flammable and Combustible Liquids and Gases That Have Been Found in Underground Structures [1]

Substance	Flash Point (°F)	Flammable Limits in Air % by Volume (Water = 1)		Specific Gravity (Air = 1)	Vapor Density
		Lower	Upper		
Acetone	4	2.15	13.0	0.8	2.0
Acetylene	Gas	2.50	100.0	—	0.9
Ammonia	Gas	16.00	25.0	—	0.6
Benzene	12	1.30	7.1	0.9	2.8
Butadiene	Gas	2.00	12.0	—	1.9
Butane	Gas	1.60	8.5	—	2.0
Carbon disulfide	22	1.30	50.0	1.30	2.6
Carbon monoxide	Gas	12.50	74.0	—	1.0
Ethane	Gas	3.00	12.5	—	1.0
Ethyl chloride	58	3.80	15.4	0.9	2.2
Gas oil[2]	150	0.50	5.0	<1.0	—
Gasoline (values vary for different grades of gasoline)	45	1.40	7.6	0.8	3.0–4.0
Hydrogen	Gas	4.00	75.0	—	0.1
Hydrogen sulfide	Gas	4.00	44.0	—	1.2
Kerosene	100–162	0.70	5.0	<1.0	—
Methane	Gas	5.00	—	15.0	–0.6
Methyl bromide (practically nonflammable)	Gas	10.00	15.0	–3.3	—
Methyl chloride	Gas	8.10	17.4	–1.8	—
Natural gas[2]	Gas	3.80	13.0	—	—
Petroleum (petroleum ether)	<0	1.10	5.9	0.6	2.5
Propane	Gas	2.10	9.5	—	1.6
Toluene	40	1.20	7.1	0.9	3.1

[1]Properties of other flammable materials can be found in NFPA 325, *Guide to Fire Hazard Properties of Flammable Liquids, Gases, and Volatile Solids*, which is published in the *Fire Protection Guide to Hazardous Materials*.
[2]These liquids and gases are mixtures, and their properties can vary depending on the composition.

Appendix B Examples of Sources of Flammable and Combustible Liquids and Vapors

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

B-1 Natural Gas. Natural gas originates from naturally occurring gas- or oil-bearing strata. In oil-producing and natural gas–producing areas, cracks and faults in the underlying strata or abandoned wells can permit gas to permeate the soil and enter underground conduits and vaults. Within the boundaries of some cities, there are actively producing oil and gas fields and many of these underlie developed residential and industrial areas, where subsurface structures are not installed.

B-2 Fuel Gas. Fuel gases include natural gas, liquefied petroleum gas, coke-oven gas, coal gas, oil gas, carbureted water gas, water gas, producer gas, and blast furnace gas. These gases, except liquefied petroleum gas, have specific gravities lower than that of air, so that when they are released in a subsurface structure, they will tend to rise and diffuse rather rapidly above the point of leakage. These gases, when mixed with air within certain limits, produce flammable mixtures. Since the oxygen content of each of these gases, when not mixed with air, is usually below 1.0 percent, they can be classed as suffocating gases. With the exceptions of natural gas and liquefied petroleum gas, they are also highly toxic because of the high carbon monoxide content.

Natural gas and other fuel gases, as distributed by utility companies in underground pipes, are also a source of flammable gas. These pipes are subject to damage caused by corrosion, electrolysis, structural failures, and adjacent excavating.

B-3 Refrigerant Gases. A number of common refrigerants, such as ammonia, methyl chloride, ethyl chloride, methyl bromide, and ethyl bromide, have varying degrees of flammability. With the exception of ammonia, all of these refrigerants are heavier than air when in the vapor phase. Therefore, if they are released in large quantities in closed spaces, they will flow downward into the lowest areas. Of these, only ammonia has a sufficiently strong odor, in dilute concentrations, to indicate its presence. Exposure to ammonia vapors can cause severe burns even at concentrations below the flammable limits. Liquid ammonia is often distributed through underground street pipes for refrigeration service in the business districts of many large cities. This system of pipes is subject to the same exposure to physical damage as fuel gas pipes and petroleum pipelines.

B-4 Electric Cable and Other Insulating Material Gases. This source of flammable gas is practically limited to severely overloaded electric underground circuits. A breakdown of cable insulation will produce an electric arc. If the protective fuses do not operate promptly, this electric arc will continue. The heat of the arc can, by destructive distillation of cable insulation (e.g., varnished cambric, rubber, or paper), produce flammable gases that contain hydrogen, carbon monoxide, and hydrocarbons.

B-5 Chemicals. Accidental spillage in chemical processing plants and disposal of waste chemical products through sewers by industrial plants are potential sources or contributing causes for explosive conditions. Examples of such products are carbon disulfide and ammonia. Calcium carbide will react with water to produce the flammable gas acetylene.

B-6 Sewage Gases. Sewage gas results from the fermentation or decomposition of organic matter. These gases can be produced when organic matter has settled as a solid in sewer lines as a result of flat grades, crevices, sumps, or obstructions where consistent flow of sewage is lacking, or as a result of bacterial action on wood or other organic material immersed in water. These flammable gases are principally methane, hydrogen sulfide, and hydrogen, and, on the basis of present evidence, they seldom reach explosive concentrations in sewers and drains. However, when they are mixed with other flammable liquids and gases present in sewers, explosive conditions could exist.

B-7 Petroleum Pipeline Liquids. Liquid petroleum and liquefied petroleum gases are conveyed by pipelines installed beneath public streets and rights-of-way. These pipelines are exposed to the same sources of physical damage as fuel gas pipes. If any of these pipelines should fail, the escaping liquids and gases can penetrate substructure walls or rise to the street surface. Liquids can be washed into drains or enter the ventilating openings in the manhole covers of subsurface structures. Escaping liquid petroleum products can evaporate in the ground, penetrate the surrounding ground, or enter a confined space to produce a flammable mixture.

B-8 Electric Circuit Oil Switches and Oil-Insulated Transformers. This equipment is frequently installed in a street vault, and electrical failures will occasionally result in an explosion. This action of protective devices in shutting off current is usually very fast, approximately 2 seconds or less. This action has the effect of limiting the damage to the vault in which the failure occurs. However, when the vault is adjacent to or within a large structure, such an explosion can result in heavy damage.

Appendix C Basic Principles and Concepts of Underground Flow

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

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

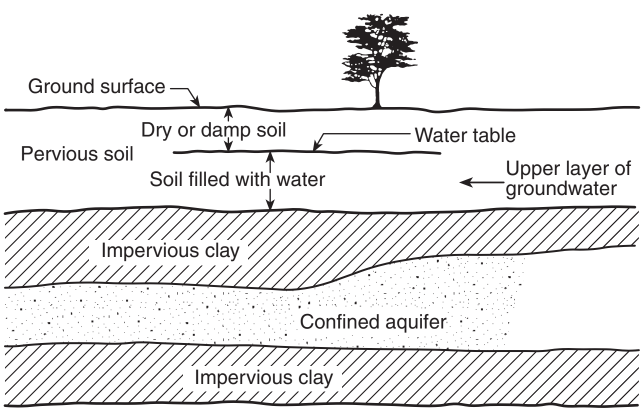
Crystalline rocks, such as granite and marble, are essentially impervious, but these rocks often have fractures and cracks that will permit flow. The rate of flow through rock fractures will vary from large continuous cracks that will act like a pipe to very small irregular cracks that result in flows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

The rate of flow through soils and rocks depends largely on the size of the voids, with flows ranging from 1.8 m (6 ft) per year in fine clays to 1.8 m (6 ft) per day in gravels. The term used to describe soils that allow flow is *pervious.* A very pervious soil will allow rapid flow of liquid, while an impervious soil will allow only very slow flow. When the word *impervious* is used alone, it implies absolutely no flow; for example, glass is impervious to the flow of the water. It should be understood that porosity does not always mean a pervious condition. In order for the soil or rock to be pervious, the pores must be interconnected. A porous rock whose pores are isolated from each other will be impervious.

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

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

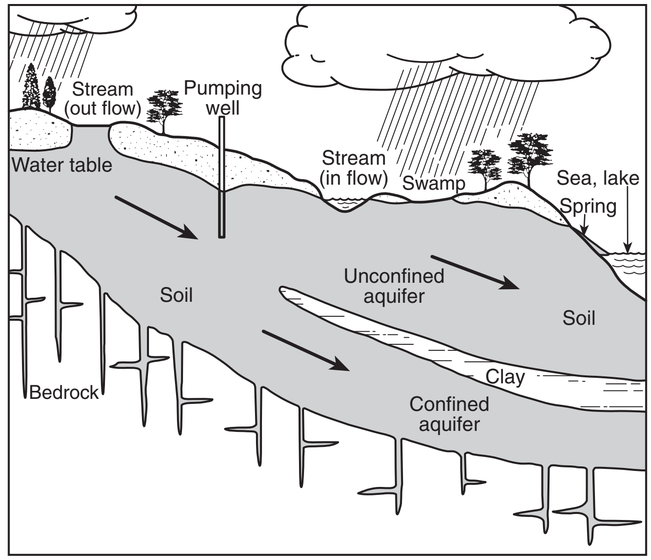
Figure C-3 Layering of groundwater between and above impervious strata.



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

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

Figure C-4 Hypothetical groundwater system showing significant features.



C-6 Water Table. The height or elevation of the water table will depend not only on how fast the water flows out of the strata (layers), but also on how fast it is fed into the strata by rain or melting snow. When no water is being added, the water table drops as water flows out at springs and wells and as it "wicks" through dry soil to evaporate at the surface. When water is added faster than it can flow out, the water table rises. This rise and fall can be several feet in a few days, as the weather changes from dry to wet and vice versa.

C-7 Summary. The following principal factors are important to tracing unconfined liquids underground:

(1) Most flammable and combustible liquids will float on water.
(2) When unconfined in the ground, flammable and combustible liquids will float on the top of the water table and will flow along with it.
(3) Groundwater will flow through pervious soil or rock toward lower elevations at a flow rate that varies from several feet per day to several feet per year.
(4) The top of the water (i.e., the water table) will slope downward in the direction of flow.
(5) The water table will rise and fall (in some cases, several feet in a few days), depending on the supply of rain or melting snow.

C-8 Slope. Figures C-8(a) and (b) show the effect of the slope of the underground strata on the direction of liquid flow. The figures show identical surface conditions, but differing subsurface conditions. In Figures C-8(a) and (b) a 4-story building lies approximately midway between 2 streets that are 122 m (400 ft) apart. A 5 percent grade from left to right places the street on the right about 6.1 m (20 ft) higher than the street on the left.

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

Figure C-8(a) Effects of slope of underground strata on groundwater flow I.

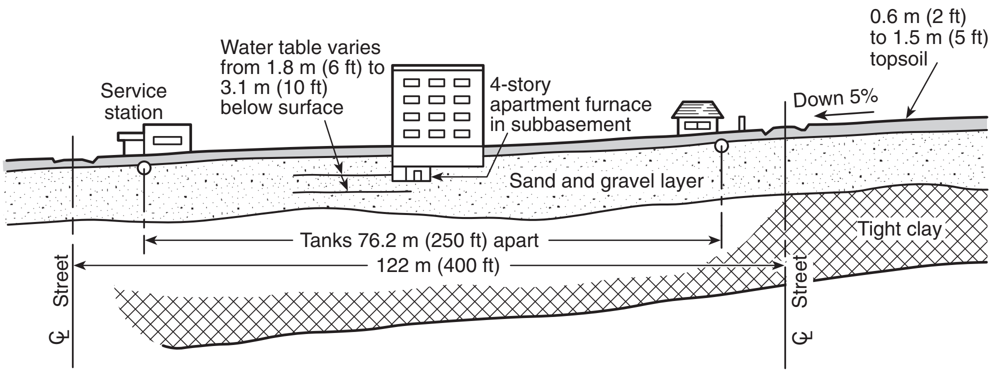
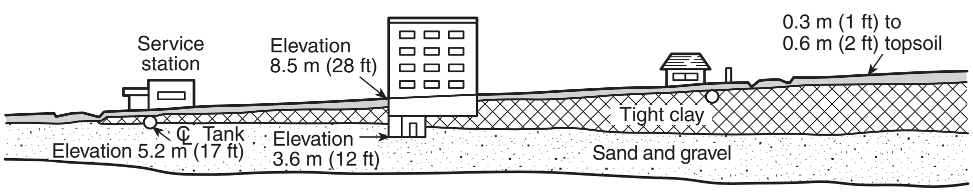


Figure C-8(b) Effects of slope of underground strata on groundwater flow II.

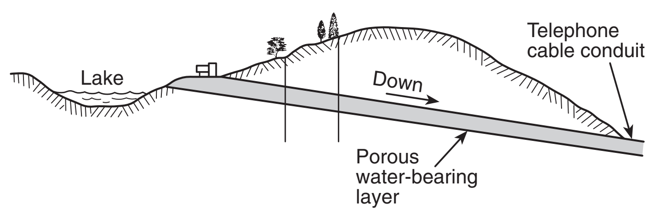


In Figure C-8(b), the situation is such that the service station downhill is the most likely source. The water-bearing strata of sand and gravel slopes down from left to right, opposite to that of the surface of the ground. Groundwater flow would also be from left to right and would carry any gasoline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

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

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

Figure C-9 Effects of slope of underground strata on groundwater flow III.



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

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

The parent or original soil is clay. A water table that exists in this clay will have little horizontal flow, due to the resistance of the clay. Consequently, the water table rises and falls with changes in the weather. For this example, assume that the water table is within 0.305 m (1 ft) of the surface during wet periods, but falls to a level below the bottom of the tank evacuation during dry periods.

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

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

Figure C-10(a) Excavation in clay and backfilled with sand.

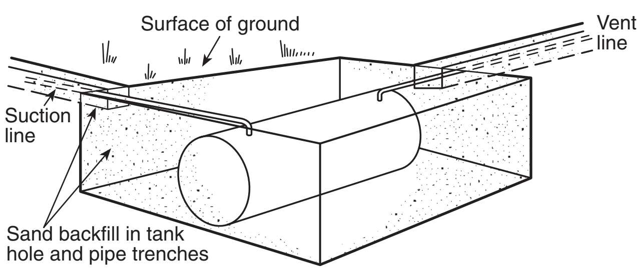
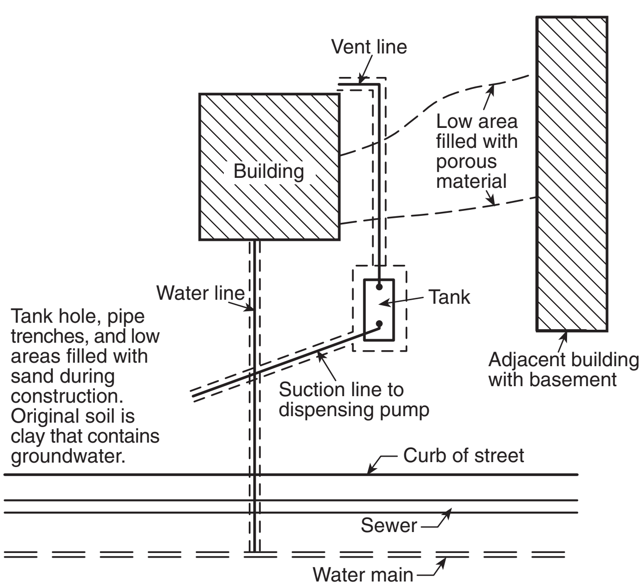


Figure C-10(b) Tank installed next to a building with a basement.



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

Appendix D Sources of Damage to Storage Containers and Lines

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

D-1 Corrosion. One type of corrosion affecting gas lines and petroleum pipelines occurs when the soil composition and resistance are such that electric current from the development of local action cells can flow readily from anodic areas on the pipe surface through the soil to the cathodic areas on the same pipe. Such conditions can be due to the soil's acid or alkali content, organic matter, variations of water or oxygen content, soil type, or the presence of certain bacteria in the soil. Corrosion can also occur as a result of chemical reaction between the pipe and surrounding soil. Corrosion of this type can be controlled with cathodic protection.

D-2 Stray Currents. Another cause of corrosion in underground lines is stray electric currents originating from such sources as direct-current electric railways and trolley lines using rails to carry return currents; industrial plant direct-current machinery using the ground as a return conductor; stray currents from cross-connections with other structures carrying current; and leakage from foreign system cathodic protection rectifiers. These currents might not be destructive where they enter the piping system, but drainage of these stray currents to ground can cause corrosion at these points of discharge.

D-3 Structural Failures. The allocation of insufficient space for the installation of subsurface structures can result, in some situations, in the encasement of gas and flammable and combustible liquid pipes in the walls of ducts and subsequently constructed masonry vaults. Such pipes from vaults could be fractured under certain conditions. Flood washouts, earthquakes, and landslides can cause the dislocation and movement of ground and are often responsible for pipe fractures. Rupture of water mains due to corrosion, electrolysis, or structural failure can, in turn, cause washout of soil that supports gas and flammable liquid pipes. Lacking support, these pipes can fracture.

D-4 Excavating. Contractors doing excavation work often encounter gas mains and flammable and combustible liquid pipes. Even though workers are aware of their presence, they could unintentionally damage a pipe, resulting either immediately or ultimately in a leak. Damage such as this is not always reported and often inadequate repairs are attempted by the party responsible for the physical damage.

D-5 Fire Damage. Fires in subsurface structures can result in spalling of concrete, destruction of protective linings, and deterioration of other interior surfaces. Such damage, if extensive, can weaken the structure.