NFPA® 329

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

2015 Edition

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NFPA® 329

Recommended Practice for

Handling Releases of Flammable and Combustible Liquids and Gases

2015 Edition

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. It was issued by the Standards Council on November 11, 2014, with an effective date of December 1, 2014, and supersedes all previous editions.

This edition of NFPA 329 was approved as an American National Standard on December 1, 2014.

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, 1992, and 1999.

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 NFPA 328 was withdrawn in May 1999.

The 2005 edition of NFPA 329 was the result of a major rewrite effort to comply with the *Manual of Style for NFPA Technical Committee Documents* and also incorporated amendments to several defined terms in order to use preferred NFPA definitions.

The 2010 edition of NFPA 329 was amended to ensure that all referenced documents were correctly listed as pertains to title and edition date. In addition, Figure 5.4.7.1 was revised to show a grounding connection for the air eductor; an Annex item was added to Section 9.1 to cross-reference requirements for control of ignition sources, as set forth in NFPA 326, *Standard for the Safeguarding of Tanks and Containers for Entry, Cleaning, or Repair*; and errors in the headings of Table A.4.1.11 were corrected.

In the 2015 edition of NFPA 329, referenced publications have been updated to current revision dates. In addition, definitions have been revised to better describe the terminology used in the standard and, where appropriate, to use the preferred definition found in other NFPA publications.

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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.

Contents

NFPA 329

Recommended Practice for

Handling Releases of Flammable and Combustible Liquids and Gases

2015 Edition

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

A reference in brackets [ ] following a section or paragraph indicates material that has been extracted from another NFPA document. As an aid to the user, the complete title and edition of the source documents for extracts in the recommendations sections of this document are given in Chapter 2 and those for extracts in the informational sections are given in Annex F. Extracted text may be edited for consistency and style and may include the revision of internal paragraph references and other references as appropriate. Requests for interpretations or revisions of extracted text should be sent to the technical committee responsible for the source document.

Information on referenced publications can be found in Chapter 2 and Annex F.

Chapter 1 Administration

1.1 Scope.

1.1.1 This recommended practice provides methods for responding to fire and explosion hazards resulting from the release of a flammable or combustible liquid, gas, or vapor that can migrate to a subsurface structure.

1.1.2 Although this recommended practice is intended to address only fire and explosion hazards, other authorities should be consulted regarding the environmental and health impacts and other hazardous conditions of such releases.

1.1.3 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 release back to its source.

1.1.4 The options outlined in this recommended practice 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.

1.1.5* The procedures outlined in this recommended practice can apply to hazardous substances other than flammable and combustible liquids that might have adverse human health effects. However, the physical characteristics of the specific hazardous substance released must be understood before any action is taken. *(See also 1.1.2.)*

1.2 Purpose.

1.2.1 The purpose of this recommended practice is to provide regulatory officials, fire authorities, contractors, and owners of subsurface structures guidance on problems involving flammable and combustible liquids and gases that might be found in subsurface structures and other areas.

1.2.2* The responsibility for correct handling of a suspected release of a flammable or combustible liquid or gas or the potential hazard from such a release will be shared by various individuals, organizations, and regulatory agencies.

1.2.2.1 The successful handling of these problems will depend on the best possible cooperation among those individuals, organizations, and regulatory agencies.

1.2.2.2 This recommended practice is intended for the information of all organizations and persons involved.

1.2.2.3 Owners, operators, or others who become aware of a hazardous condition should notify the fire department, police, or other applicable authority.

1.3 Application. (Reserved)

1.4 Retroactivity. The provisions of this recommended practice reflect a consensus of what is necessary to provide an acceptable degree of protection from the hazards addressed in this recommended practice at the time the recommended practice was issued.

1.4.1 Unless otherwise specified, the provisions of this recommended practice should not apply to facilities, equipment, structures, or installations that existed or were approved for construction or installation prior to the effective date of the recommended practice. Where specified, the provisions of this recommended practice should be retroactive.

1.4.2 In those cases where the authority having jurisdiction determines that the existing situation presents an unacceptable degree of risk, the authority having jurisdiction should be permitted to apply retroactively any portion of this recommended practice deemed appropriate.

1.4.3 The retroactive provisions of this recommended practice should be permitted to be modified if their application clearly would be impractical in the judgment of the authority having jurisdiction, and only where it is clearly evident that a reasonable degree of safety is provided.

1.5 Equivalency. Nothing in this recommended practice is intended to prevent the use of systems, methods, or devices of equivalent or superior quality, strength, fire resistance, effectiveness, durability, and safety over those prescribed by this recommended practice.

1.5.1 Technical documentation should be submitted to the authority having jurisdiction to demonstrate equivalency.

1.5.2 The system, method, or device should be approved for the intended purpose by the authority having jurisdiction.

1.6 Units and Formulas. (Reserved)

Chapter 2 Referenced Publications

2.1 General. The documents or portions thereof listed in this chapter are referenced within this recommended practice and should be considered part of the recommendations of this document.

2.2 NFPA Publications.
NFPA 30, *Flammable and Combustible Liquids Code,* 2015 edition.

2.3 Other Publications.

2.3.1 API Publications. American Petroleum Institute, 1220 L Street, N.W., Washington, DC 20005-4070.

API Publication 1628, *A Guide to the Assessment and Remediation of Underground Petroleum Releases*, 3rd edition, 1996.

API Publication 1629, *Guide for Assessing and Remediating Petroleum Hydrocarbons in Soil*, 1st edition, 1993.

2.3.2 ASTM Publications. ASTM International, 100 Barr Harbor Drive, P.O. Box C700, West Conshohocken, PA 19428-2959.

ASTM D 5/D5M, *Standard Test Method for Penetration of Bituminous Materials*, 2013.

ASTM D 323, *Standard Test Method for Vapor Pressure of Petroleum Products (Reid Method)*, 2008.

ASTM D 4359, *Standard Test Method for Determining Whether a Material is a Liquid or a Solid*, 2012.

2.3.3 U.S. Environmental Protection Agency Publications. U.S. Environmental Protection Agency, Washington, DC 20460.

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

2.3.4 Other U.S. Government Publications. U.S. Government Printing Office, Washington, DC 20402.

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

2.3.5 Other Publications.
Merriam-Webster's Collegiate Dictionary, 11th edition, Merriam-Webster, Inc., Springfield, MA, 2003.

2.4 References for Extracts in Recommendations Sections.
NFPA 30, *Flammable and Combustible Liquids Code,* 2015 edition.
NFPA 77, *Recommended Practice on Static Electricity,* 2014 edition.
NFPA 326, *Standard for the Safeguarding of Tanks and Containers for Entry, Cleaning, or Repair,* 2015 edition.
NFPA 921, *Guide for Fire and Explosion Investigations,* 2014 edition.
NFPA 1500, *Standard on Fire Department Occupational Safety and Health Program,* 2013 edition.

Chapter 3 Definitions

3.1 General. The definitions contained in this chapter apply to the terms used in this recommended practice. Where terms are not defined in this chapter or within another chapter, they should be defined using their ordinarily accepted meanings within the context in which they are used. *Merriam-Webster's Collegiate Dictionary*, 11th edition, is the source for the ordinarily accepted meaning.

3.2 NFPA Official Definitions.

3.2.1* Authority Having Jurisdiction (AHJ). An organization, office, or individual responsible for enforcing the requirements of a code or standard, or for approving equipment, materials, an installation, or a procedure.

3.2.2 Recommended Practice. A document that is similar in content and structure to a code or standard but that contains only nonmandatory provisions using the word "should" to indicate recommendations in the body of the text.

3.2.3 Should. Indicates a recommendation or that which is advised but not required.

3.2.4 Standard. An NFPA Standard, the main text of which contains only mandatory provisions using the word "shall" to indicate requirements and that is in a form generally suitable for mandatory reference by another standard or code or for adoption into law. Nonmandatory provisions are not to be considered a part of the requirements of a standard and shall be located in an appendix, annex, footnote, informational note, or other means as permitted in the NFPA Manuals of Style. When used in a generic sense, such as in the phrase "standards development process" or "standards development activities," the term "standards" includes all NFPA Standards, including Codes, Standards, Recommended Practices, and Guides.

3.3 General Definitions.

3.3.1 Bonding. For the purpose of controlling static electric hazards, the process of connecting two or more conductive objects together by means of a conductor so that they are at the same electrical potential, but not necessarily at the same potential as the earth. [**77,** 2014]

3.3.2 Combustible Gas Indicator. An instrument that samples air to indicate whether there are combustible vapors or gases present and can also indicate the percentage of the lower explosive limit of the vapor or gas mixture.

3.3.3* Combustible Liquid. Any liquid that has a closed-cup flash point at or above 37.8°C (100°F), as determined by the test procedures and apparatus set forth in Section 4.4 of NFPA 30.

3.3.4 Container. For the purpose of handling releases of flammable and combustible liquids and gases, 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.

3.3.5* Flammable Liquid. Any liquid that has a closed-cup flash point below 37.8°C (100°F), as determined by the test procedures and apparatus set forth in Section 4.4 of NFPA 30 and a Reid Vapor pressure that does not exceed an absolute pressure of 276 kPa (40 psi) at 37.8°C (100°F), as determined by ASTM D 323, *Standard Test Method for Vapor Pressure of Petroleum Products (Reid Method).*

3.3.6 Hazardous Substance. A substance, including combustible and flammable liquids and flammable gases, that is capable of creating harm to people, the environment, or property due to the dangers that can arise from, but are not limited to, toxicity, reactivity, ignitability, or corrosivity. [**326,** 2015]

3.3.7 Hot Tapping. The technique of welding and drilling on in-service tanks or containers that contain flammable, combustible, or other hazardous substances. [**326**, 2015]

3.3.8 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 operations that create hot metal sparks or surfaces from friction or impact. [**326,** 2015]

3.3.9 Inert Gas. For the purpose of handling releases of flammable and combustible liquids and gases, a gas that is nonflammable, chemically inactive, noncontaminating for the use intended, and oxygen-deficient to the extent required.

3.3.10 Inerting. A technique by which the atmosphere in a tank or container is rendered nonignitible or nonreactive by the addition of an inert gas. [**326,** 2015]

3.3.11 Liquid. Any material that (1) has a fluidity greater than that of 300 penetration asphalt when tested in accordance with ASTM D 5/D5M, *Standard Test Method for Penetration of Bituminous Materials*, or (2) is a viscous substance for which a specific melting point cannot be determined, but that is determined to be a liquid in accordance with ASTM D 4359, *Standard Test Method for Determining Whether a Material is a Liquid or a Solid.* [**30**, 2015]

3.3.12* Lower Flammable Limit (LFL). That concentration of a flammable vapor in air below which ignition will not occur. Also known as the lower explosive limit (LEL). [**30,** 2015]

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

3.3.14 Purging. For the purpose of handling releases of flammable and combustible liquids and gases, the process of displacing vapors or gases from an enclosure or confined space.

3.3.15 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 related to the subject matter, the work, or the project. [**1500**, 2013]

3.3.16 Self-Contained Breathing Apparatus. For the purpose of handling releases of flammable and combustible liquids and gases, a portable respiratory device that (1) is designed to protect the wearer from an oxygen-deficient or other hazardous atmosphere, (2) supplies a respirable atmosphere that is either carried on, in, or generated by the apparatus, and (3) is independent of the ambient environment.

3.3.17 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.

3.3.18 Static Electric Discharge. A release of static electricity in the form of a spark, corona discharge, brush discharge, or propagating brush discharge that might be capable of causing ignition under appropriate circumstances. [**77**, 2014]

3.3.19 Static Electricity. For the purpose of handling releases of flammable and combustible liquids and gases, the electrification of materials through physical contact and separation and the various effects that result from the positive and negative charges so formed.

3.3.20 Subsurface Structure. A structure located belowground, such as a manhole, sewer, utility conduit, observation well, storm drain, vault, water line, fuel gas distribution system, electric light and power conduit, telephone and telegraph communication line, street-lighting conduit, police and fire signal system, traffic signal line, refrigeration service line, steam line, petroleum pipeline, subway, tunnel, or the substructural areas of a building, such as a basement or parking garage.

3.3.21 Tank. A stationary or portable device that is intended to contain an accumulation of hazardous substances.

3.3.22* Toxic Materials, Gases, or Vapors. Any substance whose properties contain the inherent capacity to produce injury to a biological system.

3.3.23 Toxicity. The degree to which a substance is harmful to humans.

3.3.24 Unstable or Reactive Materials. A liquid that, in the pure state or as commercially produced or transported, will vigorously polymerize, decompose, undergo condensation reaction, or become self-reactive under conditions of shock, pressure, or temperature. [**30**, 2015]

3.3.25 Vapor. The gas phase of a substance, particularly of those that are normally liquids or solids at ordinary temperatures. [**921**, 2014]

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

3.3.27 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 4 Flammable and Combustible Liquids and Gases

4.1 General.

4.1.1 Releases of flammable and combustible liquids and gases can result from leaks in tanks, containers, or pipelines, from surface spills, or from human error.

4.1.2 In most cases, the amount of liquid or gas that is lost is small and can be dissipated by evaporation or otherwise assimilated into the environment.

4.1.3 Because of the physical and chemical characteristics of many flammable and combustible liquids and gases, it is possible that a release can find its way into a subsurface structure, such as a basement, utility conduit, sewer, or well.

4.1.4 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.

4.1.5 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.

4.1.6 Flammable vapors in subsurface structures can result from a release of a flammable or combustible liquid.

4.1.6.1 Examples of these releases include cleaning solvents and compounds washed down drains by industrial and domestic users or a surface release that enters a sewer or drain.

4.1.6.2 A release can also result from damage to tanks, containers, and pipelines from corrosion, structural failure, excavation in the area, or fire.

4.1.7 If a flammable or combustible liquid or gas is present in the soil, as might be produced by decaying organic matter, there is a likelihood that it will penetrate an adjacent subsurface structure.

4.1.8 Particular attention should be paid to landfill sites. Gas from decomposing material in landfills, primarily methane, might not have an odor.

4.1.9 Flammable gases or vapors can enter conduits, sewers, drains, or basements because subsurface structures constructed of cement, concrete, brick, or vitreous tile typically are not built to be impervious to gases or vapors.

4.1.10 Gases or vapors can enter the subsurface sections of buildings through cracks or around any underground conduits that penetrate the subsurface walls or floors.

4.1.11* 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

4.1.11.1 The condition of "injurious to life" specified in 4.1.11(2) 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.4.1.11, additional precautions might 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).

4.1.12 Flammable and combustible liquids and gases are commonly stored and handled in locations that are immediately adjacent to structures, facilities, and people.

4.1.13 Flammable and combustible liquids include but are not limited to, chemicals, cleaning fluids, gasoline, alternative fuels, diesel fuel, and heating oil.

4.1.14 Gasoline is the most widely used of these liquids and is commonly stored aboveground and underground at motor fuel dispensing facilities and service stations.

4.1.15 Flammable and combustible gases include natural gas, propane, sewage gases, and refrigerant gases.

4.2 Fires and Explosions.

4.2.1 The probability of an explosion or fire within a subsurface space depends on the following two factors:

(1) The atmosphere must contain a mixture of flammable vapor and air within the flammable range.
(2) There must be a coincident source of ignition.

4.2.2 The severity of an individual explosion or fire and its consequences depend on various other factors and the possibility that any one explosion might result in a major catastrophe is always present.

4.3 Sources of Ignition.

4.3.1 The possibility of ignition of flammable gases or vapors that collect in subsurface structures is limited by the following conditions:

(1) The vapor must be mixed with sufficient air to make a flammable mixture or it must escape into the air at a point where a flammable mixture can be created.
(2) Heat of sufficient intensity to ignite the particular air–vapor mixture involved must be present at the place where the flammable mixture exists.

4.3.2 Flammable mixtures are formed when the concentration of these gases and vapors in air is between the lower and upper flammability limits.

4.3.3 Flammable limits of some gases and vapors that have been found in subsurface structures are listed in Table A.4.1.11.

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

4.3.5 Static electricity can be a source of ignition when it accumulates to the extent that an ignition-capable spark discharge occurs.

4.3.5.1 The accumulation of a static electric charge is easiest and greatest in an atmosphere of low humidity.

4.3.5.2 Static electricity can be generated when a liquid under pressure escapes at high velocity from a pipe. Particles of dust, scale, or rust or liquid droplets inside the pipe can become heavily charged when blown out by gas or vapor and, if they impinge on an electrically isolated body, that body will accumulate the charge and a spark discharge can occur.

Chapter 5 Initial Response

5.1 Indicators of a Release. The release of a flammable or combustible liquid or gas can be indicated by physical discovery of an actual release or by indication of a potential release.

5.1.1 Physical discovery of an actual release of a flammable or combustible liquid or gas can be indicated by the presence of the liquid or gas in any of the following:

(1) Normally inhabited subsurface structures, such as basements, subways, or tunnels
(2) Subsurface structures not normally inhabited, such as manholes, sewers, utility conduits, utility vaults, or observation wells
(3) Groundwater
(4) Drinking water supplies
(5) Surface water
(6) Seepage from the soil

5.1.2 Potential release of a flammable or combustible liquid, gas, or vapor 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) Odor

5.2 Initial Response to Physical Discovery.

5.2.1 Depending on the circumstances of physical discovery, conditions might exist where a potential hazard to life or property exists, in which case immediate steps should be taken to protect the public from the danger of an explosion or fire.

5.2.2* For uninhabited structures, those directly responsible for the facility should be contacted, such as a municipal sanitary, highway, or street department for sewers or the electrical, telephone, or gas company's engineering department for utility conduit.

5.2.3 Police should be asked to keep the public clear of any danger areas.

5.2.4 If necessary, the fire department should assist in fire control and purging.

5.2.5 Those involved with facilities that store and handle flammable and combustible liquids that might be the source of the problem should offer all possible assistance.

5.2.6 Although the presence of flammable gases or vapors in a building or subsurface structure is typically reported because of an odor, smell cannot be relied on to determine the type of gas or vapor or its concentration. A properly calibrated and adjusted instrument such as a combustible gas indicator or photoionization detector should be used to determine the presence and extent of a flammable gas or vapor concentration.

5.2.7 No one should enter areas where flammable or combustible liquids, gases, or vapors have been discovered, except as described in Section 5.4.

5.2.7.1 If liquids, gases, or vapors within or above the flammable range are found in a building, the building should not be entered.

5.2.7.2 Evacuation of building occupants, at least in areas that are exposed, should be ordered.

5.2.7.3 Building construction, building layout, and building occupancy are factors that should be considered in ordering evacuation.

5.2.8 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.

5.3 Eliminating Sources of Ignition.

5.3.1 Smoking or other sources of ignition should not be permitted in areas where flammable or combustible liquids, gases, or vapors have been discovered.

5.3.2* Lights and other electrical switches should not be turned on or off. Power cords should not be removed from outlets. Only those switches located well away from the area should be used to disconnect electrical power.

5.3.3* 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 should be disconnected or shut off outside the structure.

5.4 Entering the Area.

5.4.1 Due to the risk of toxic exposure, fire, or explosion, personnel should use caution when entering an area where there is an undetermined concentration of an unknown gas or vapor.

5.4.2 Flammable gases or vapors in a sewer or conduit might not originate from flammable liquids but might be vapors from overheated insulation, sewer-generated gases, fuel gases, or industrial gases. In these cases, special instruments, equipment, skills, and procedures (confined space entry) should be used, as necessary.

5.4.3 The guidance of the owner or operator of the facility should be solicited and should be followed. Entry should not be made until the gas or vapor concentration has been checked by instrument. *(See 5.2.6.)*

5.4.4 An additional hazard might exist because of the presence of toxic gases or vapors or because of insufficient oxygen. If these conditions are suspected, a properly calibrated and adjusted instrument appropriate to the suspected hazard should be used to determine the nature and extent of the hazard.

5.4.5 The gas or vapor concentrations in the affected area should be checked continuously or at intervals determined by a qualified person.

5.4.5.1 Where gas or vapor concentrations are above 50 percent of the LFL, everyone in the affected area should be evacuated.

5.4.5.2 The affected area should be ventilated to remove or reduce the flammable gas or vapor concentration and thus reduce the fire or explosion hazard.

5.4.5.3 As soon as the flammable gas or vapor has been reduced below 50 percent of the LFL, entry can be made to locate and eliminate the source.

5.4.5.4 Personnel should wear self-contained breathing apparatus when entering the affected area.

5.4.6 Natural ventilation provided by opening doors and windows and removing manhole covers or other access closures might be sufficient to remove vapors from the affected area and should be used.

5.4.7 Where natural ventilation is not capable of removing vapors from all areas, particularly from low, confined spaces, grounded and bonded mechanical exhaust ventilating equipment should be used.

5.4.7.1 Fans driven by electric motors that are approved for Class I, Group D locations, Division 1 or Zone 0 or Zone 1 hand-driven fans, or air eductors should be used to remove vapors, as shown in Figure 5.4.7.1.

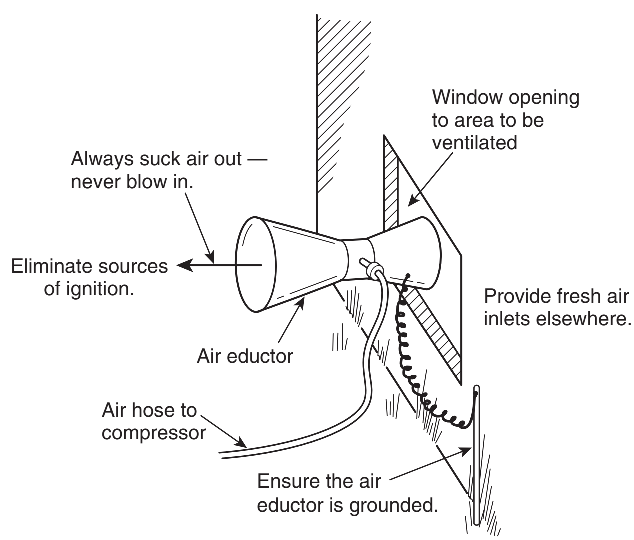

FIGURE 5.4.7.1 Exhaust Ventilation.

5.4.7.2 Sources of ignition close to the exhaust outlets should be eliminated.

5.4.7.3 Openings for free entry of fresh air should be provided, but air should never be forced into the area.

5.4.8 The generation of sewer gas might be stopped or significantly reduced by slowly flushing the sewer or conduit with water.

5.4.9 When the area has been tested and determined to be safe for entry, entry can be made to remove or control the source of the flammable or combustible liquids, gases, or vapors.

5.4.10 If the place or places of entry of the liquid, gas, or vapor can be determined, steps should be taken to seal them off.

5.4.11 Untrapped drains, dry traps, pipes, or other openings through floors or foundations through which liquid, gas, or vapor might gain entry should be checked. If vapor is entering through a trapped drain or collection pipe and the trap is dry, the trap should be filled with water to block further entry of gas or vapor.

5.4.12 Any gas pipes in the area should be checked to determine if fuel gas is the source of the flammable gas or vapor. If fuel gas appears to be the source, the gas company should be called.

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

5.4.14* When seepage is detected in a sewer, the source should be located by backtracking using 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.

5.4.15 If entry of liquid, gas, or vapor into a 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.

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

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

5.4.18 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.

5.4.18.1 In most cases, 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.

5.4.18.2 If the entire surface of the water is covered or there are large pools on the order of 6 m (20 ft) or more across, a fire hazard does exist.

5.4.18.3* 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.

5.4.18.4 In most cases, the only effective means to stop further accumulation is to find the source of the release and stop it.

5.4.18.5 If practical, dikes or dams should be constructed or floating booms should be used to prevent further spreading of the liquids or of contaminated water.

5.4.18.6 Once the source of flammable or combustible liquids is stopped, removal can be accomplished by evaporation, dispersal, dilution, collection with adsorbents, skimming devices, or filtering devices. *(See Chapter 9 for details.)*

5.5 Initial Response to Indications of a Potential Release.

5.5.1 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.

5.5.2 If signs of escaping liquid are found, the procedures given for initial response to physical discovery in Section 5.2 should be followed. Otherwise, the procedures in Chapters 7, 8, and 9 should be followed.

5.5.3 The actions recommended in Chapter 9 should be followed if there is evidence of a spill.

Chapter 6 Searching for the Source

6.1 General.

6.1.1 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.

6.1.2 In most cases, the source of the liquid will be relatively close to the location where unconfined liquid or vapor has been discovered.

6.1.2.1 Liquids can travel hundreds of feet or even miles underground through porous soil or rock, through trenches filled with porous material, alongside pipes or conduits, or in sewer pipes. Consequently, the location from which a released liquid might have originated can be remote and extensive and can include facilities that handle and store flammable or combustible liquids.

6.1.2.2 The source of the release might be an abandoned underground storage tank.

6.1.3 If a check of potential sources adjacent to or within 100 m (330 ft) of the discovery is not conclusive, then the investigation should be expanded to include other potential sources in the general area of the discovery.

6.1.4 The following are potential sources and should be checked:

(1) Motor fuel dispensing facilities (automotive and marine 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

6.1.5 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 other governmental agencies.

6.1.6* 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. *(See Annex C.)*

6.1.7 Search efforts should be initiated up-gradient from the leak.

6.1.7.1* Teams should be organized as necessary to conduct the search.

6.1.7.2 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.

6.1.8 If an obvious or probable source is not found within 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. The procedure outlined in Section 6.2 should be followed.

6.2 Search Procedure.

6.2.1 Flammable and combustible liquids will 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.

6.2.2 The recommendations in Section 6.2 should be used to check for spills or other possible sources of the release. Also, inquiries should be made of the facility operator, and the premises and equipment should be inspected.

6.2.3* 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.

6.2.4 A potential source should not be eliminated on the basis of time until all information is available and its analysis justifies elimination of that source.

6.2.5 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 might have damaged underground facilities? *(See Annex D.)*
(4) Has there been any maintenance on pipes, tanks, or other equipment that might have resulted in a release?
(5) Has there been any odor or other signs of liquids in areas where there should not be?
(6) Do inventory and use records 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 might have released liquids from a tank vehicle, container, or storage tank?
(9) Have any problems been encountered during pumping and liquid transfer?

6.2.6 If inquiry fails to disclose any potential source, each premises' owner or operator should be asked for cooperation in checking equipment.

6.2.6.1 If an operator refuses because he or she is not the owner, then permission should be obtained from the owner.

6.2.6.2 If necessary, local government officials should be contacted to secure such cooperation.

6.2.7 The following guidance should be helpful in checking equipment.

(1) On-site leak detection equipment should be inspected for correct operation and for indications of a leak.
(2)*The areas around fill pipes where liquid is transferred from tank vehicles to storage tanks should be checked for signs of spillage.
(3) The areas around aboveground tanks should be checked for signs of leakage.
(4) All exposed piping should be checked for signs of leaks.
(5) Dispensing equipment should be checked for leaks. *(See 6.2.8.)*
(6) Dispensing nozzles and hoses should also be checked.
(7) If a remote pumping unit is used, its housing or pit should be checked with a combustible gas indicator before being opened. The unit can then be opened for inspection.
(8) Automotive repair areas should be checked for signs of waste liquids being dumped into floor drains or sumps not intended for the purpose.
(9) Equipment found to be leaking should not be used until repairs are made.
(10) A storage tank or piping that is found to be leaking should be emptied if liquid is still escaping.

6.2.8 A properly calibrated and adjusted combustible gas indicator should be used to check dispensers of the type used at motor fuel dispensing facilities and should be used in the following manner:

(1) 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 can provide enough ventilation to dilute any vapors present and give a reading low enough to indicate that there is no leak.
(2) 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.

6.2.9 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 according to the following:

(1) Signs of waste liquids that have been dumped or spilled onto the ground should be identified.
(2) Any areas of contamination that might have been covered up, such as fresh gravel, sod, or soil, should arouse suspicion and should be checked.
(3) 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.
(4) Vegetation should be checked for an indication of damage from spilling, dumping, or contaminated groundwater.

(5) A photoionization detector or other 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.
(6) The barrels of any fire hydrants in the area should be checked.
(7) Nearby excavations and steep cuts or natural slopes downgradient from the potential source should be checked for signs of liquid.

6.2.10 Dumping or spilling flammable or combustible liquids into sewers or on the ground might be a violation of state or federal law or regulation and should immediately be reported to the proper authorities.

6.2.11* Care should be taken not to confuse small inadvertent spills with significant releases.

6.2.12 Releases that should be considered significant 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.

6.3 Procedures to Verify the Source.

6.3.1 Once an obvious source or sources have been found and the further release of liquid has been stopped, it should be determined if each identified source is, in fact, the actual source of the release. Further search efforts can be temporarily suspended.

6.3.2 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.

6.3.3* If a distinct and continuous decrease occurs, it can be assumed that the source of the release has been identified. *(See Chapter 8.)*

6.3.4 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:

(1) Release detection tests should be conducted on any liquid-storage or -handling system in the vicinity of the affected area. *(See Chapter 7.)*
(2)*The path of the liquid underground should be traced from its point of discovery to the source. *(See Chapter 8.)*

Chapter 7 Detecting Releases from Tanks and Piping

7.1 General.

7.1.1* All data previously gathered should be reviewed to determine the most efficient method or methods of testing.

7.1.2 For additional details on the latest testing and release detection methods, industry publications and regulatory officials should be consulted.

7.1.3* 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 might indicate a leak where none exists, or might conceal leaks that do exist.

7.2 Action Preliminary to Release Detection or Tightness Testing.

7.2.1 Underground Tanks. The information obtained from the search procedures described in Chapter 6 should be reviewed. In particular, the following should be identified:

(1)*The method of filling tanks
(2) Damaged fill pipes, in particular, those installed under covers
(3) Any evidence of ground settlement around tanks
(4) Any sign of work that might have damaged the tank or its fittings
(5) History of past or recent work on the tanks or attached piping
(6)*Presence of excessive amounts of water in the underground tank and any history of past water removal
(7) The age of the facility
(8)*The location and flow of liquid found underground by gas sensors or visual inspection
(9) Inventory control records
(10) Type of tank gauge system and whether the gauge system was in operation at the time the release was first detected *(See 7.2.4.)*
(11)*Whether the tank is of secondary containment–type design
(12)*Condition of the submersible turbine pump sump, if present

7.2.2* Aboveground Tanks. The information obtained from the search procedures described in Chapter 6 should be reviewed. In particular, the following should be identified:

(1)*The method of filling tanks
(2) Any evidence of settlement of the foundation or tank supports
(3) Past or recent work on tanks or attached piping and any sign of work that might have damaged the tank or its fittings
(4) The age of the facility
(5) The location and flow of liquid found underground by gas sensors or visual inspection. *[See A.7.2.1(8).]*
(6) The Spill Prevention Control and Countermeasures (SPCC) Plan as required by 40 CFR 112, "Protection of Environment," particularly records of previous spills and specific recommendations on how spills are contained
(7) Inventory control records
(8)*Type of tank gauge system and whether the gauge system was in operation at the time the release was first detected *(See 7.2.4.)*
(9) Whether the tank is of secondary containment–type design *[See A.7.2.1(11).]*

7.2.3 Piping.

7.2.3.1 For piping systems, the following should be checked:

(1) Recent excavation, digging, pavement repair, or other work in the area that might have damaged underground piping
(2) Any recent repairs that might have created a leak due to faulty workmanship or that might indicate a previous leak
(3) Any evidence of shifting ground, such as a frost heave or settlement, that might 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) Correct operation of in-line leak detection devices and evidences of release from them
(7) Type of underground piping
(8) Type of corrosion control system, if present
(9) Pipe integrity test records

7.2.3.2* If the supply piping operates under vacuum or suction, evidence of a leaking check valve or a leak in the piping should be checked, as detailed in A.7.2.3.2.

7.2.3.3 If there is doubt that the check valve seats tightly, as might be indicated by the procedures in A.7.2.3.2, the following procedure should be performed:

(1) The check valve should be repaired, replaced, or sealed off.
(2)*The pumping test should be repeated. 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.

7.2.3.4 If the procedures in 7.2.3.2 and 7.2.3.3 fail to indicate the source of the leak but there is still reason to suspect a leak, the piping should be tested in accordance with Section 7.5.

7.2.4 Inventory Records. *(See also Annex E.)*

7.2.4.1 A check of inventory records should be made to ensure that a loss of inventory is not due to one of the following:

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

7.2.4.2* Although evidence of inventory loss strongly implies that the source has been found, subsequent checks should be made to determine how the loss has occurred before definite conclusions are drawn.

7.3 Release Detection.

7.3.1 General. With the information from the search procedures in Chapter 6 as a basis, the means and methods of release detection described in Section 7.3 should be used in a logical process of elimination.

7.3.1.1 Means of release detection should be installed, maintained, and operated in accordance with the manufacturer's recommended procedures.

7.3.1.2 Personnel utilizing release detection means and methods should be trained in their use and operation.

7.3.1.3 Documentation of procedures and results should be provided.

7.3.1.4 Means and methods of release detection should comply with applicable local, state, and federal environmental regulations and should be documented with respect to accuracy.

7.3.1.5 If a release is indicated by any of the described methods, further investigation might be required by testing *(see Sections 7.4, 7.5, and 7.6)* or by the tracing techniques described in Chapter 8, whichever is most applicable.

7.3.2 Underground Tanks. For underground storage tanks, additional information regarding recommended procedures is provided in EPA 530/UST-89 1012, *Detecting Leaks: Successful Methods Step-by-Step*.

7.3.2.1 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.

7.3.2.2 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.

7.3.2.3 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 Annex E.)*

7.3.2.4 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 indication of a release.

7.3.2.5 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 indication of a release. Other methods might be approved by the local regulatory agency.

7.3.3 Aboveground Storage Tanks.

7.3.3.1 Visual Inspection. An external visual inspection of the tank system should be performed.

7.3.3.2 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 indication of a release, and leak detection ports, if present, should be checked.

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

7.4 Testing of Underground Tanks.

7.4.1 If the release detection methods described in Section 7.3 are not available or do not yield conclusive identification of the source of a release, testing of the piping or tank or both might be necessary. 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*.

7.4.2 The test procedures used should be capable of detecting a leak anywhere in the complete underground storage and handling system unless other information has eliminated one or more portions of the system from the search.

7.4.3* Where it is reasonable to assume that a leak exists, the effects on personnel safety and the environment should be a factor in determining which test method to use.

7.4.4 Means and methods of testing should be performed in accordance with the manufacturer's recommended procedures.

7.4.5 Personnel should be trained to perform the tests used.

7.4.6 Documentation of test procedures and results should be provided.

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

7.4.8* 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.

7.4.9 A nonvolumetric tightness test is capable of leak detection; however, it does not quantify a leak rate.

7.4.10 If the results of a tightness test indicate the probability of a leak, either corrective action or additional testing to confirm the leak should be performed.

7.4.11 Pressure Testing.

7.4.11.1 Pressure Testing with Air or Other Noninert Gases. 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.

7.4.11.2 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.

7.4.12 If warranted, an internal inspection of the tank should be conducted to evaluate the condition of the tank interior. Applicable procedures for safe entry should be followed.

7.5 Testing of Underground Piping.

7.5.1 Hydrostatic Testing of Piping. A hydrostatic test of piping is a relatively simple test that can quickly indicate a leak.

7.5.1.1 The piping should be isolated from other portions of the system.

7.5.1.2 The test should be conducted at 150 percent of the maximum anticipated pressure of the system, but not less than a gauge pressure of 34.5 kPa (5 psi), measured at the highest point of the system.

7.5.1.3 The test should be maintained for at least 10 minutes.

7.5.1.4 If a drop in pressure indicates the possibility of a leak in the piping, a volumetric tightness test should be performed.

7.5.1.5 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

7.5.2 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 fitting.

7.5.2.1 Pressure should be applied to the suction piping from the pump back to the check valve.

7.5.2.2 In this test, the hydrostatic pressure should not exceed a gauge pressure of 103 kPa (15 psi), to prevent damage to the pump.

7.5.3* Tracer or Dye Testing. If tracer or dye testing is used, it should be approved for the product handled by the piping.

7.6 Testing of Aboveground Storage Tanks.

7.6.1 Acoustic Emission. Acoustic emission leak detection technology uses acoustic detectors to listen for characteristic noises created by a leak from the bottom of a tank and to locate its source.

7.6.2 Volumetric Leak Detection.

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

7.6.2.2 Mass-Measurement Method. The mass-measurement method of volumetric leak detection measures the pressure acting close to 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.

7.6.3 Tracer Gas Testing. This method of volumetric leak detection involves adding a tracer gas to the storage system and then testing for its presence outside the storage system.

7.6.4 Pressure Testing with Inert Gases. Inert gases can be used for the purpose of detecting a leak for both tank and piping systems.

7.6.4.1 The pressure exerted by both the product and the inert gas should not exceed the limits recommended by the tank manufacturer.

7.6.4.2 Pressure-limiting devices should be used in this application.

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

Chapter 8 Tracing Liquids Underground

8.1 General.

8.1.1 The guidelines presented in this chapter are not necessarily given in a preferred order of importance.

8.1.2 The actual sequence of procedures and the choice of test method will depend on the circumstances of the problem, information gained from the primary search, and any previous test results.

8.1.3 It is beyond the scope of this recommended practice to cover the problem in all its potential complexities.

8.1.4 If initial efforts fail to identify the source, additional expert assistance might be necessary.

8.2 Procedure for Determining Underground Flow.

8.2.1* The following should be identified on a sketch of the local area:

(1) Any potential sources and pathways
(2) Any pertinent geological data that are available
(3) The locations of sewers, streets, conduits, streams, manholes, tanks, fill pipes, vent risers, and pumps
(4) Any abandoned ditches or stream beds that have been filled or covered

8.2.2 Sources for this information include, but are not limited to, the following:

(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

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

8.2.4 Information gathered and plotted on the sketch up to this point might indicate that a specific nearby facility is a probable source. If so, tests to verify this, as described in Chapter 7, should be conducted.

8.2.5 Potential liquid flow paths should be checked as follows:

(1) Manholes, sewers, inlet boxes, wells, open trenches, exposed slopes and cuts, and other features should be visually checked.
(2) Samples of water should be taken to test for the presence of flammable or combustible liquids.
(3) A photoionization detector or other instrument should be used to determine the presence of vapors.
(4) Other sources of vapor readings, such as natural gas lines, landfills, and sewer gas, should be investigated.
(5) If checking underground structures does not give a clear indication of the direction of movement of the underground flow, a more detailed search should be conducted in porous backfill or pervious strata by testing for vapors in the soil.

8.2.6 When testing has determined the probable direction from which the contamination is coming, the search should be extended up-gradient using the methods described in Section 8.2 to determine the next most probable source. Both sides of the direction of flow should be checked to determine its width.

8.2.7 As the problem is shown to be more complex, other methods of testing and tracing might be useful, such as those outlined in Sections 8.3 through 8.5 or other methods not described here.

8.2.8 The advantages and disadvantages of each test procedure should be recognized if valid conclusions are to be reached.

8.3 Dye Tracing. 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 might take minutes, hours, or days.

8.4* Chromatographic and Spectrographic Analyses. The chromatograph and the spectrograph are instruments capable of detecting traces of the elements of almost any compound and should be used in cases that involve complex mixtures, such as petroleum liquids.

8.5* Other Chemical Analyses. Other methods of chemical analysis are available that are capable of identifying additives or the age of the contaminant.

8.6 Other Sources. If the investigation fails to locate an active source of release, it is possible that the problem is a result of an accumulation from a previous equipment failure, spill, or improper disposal of the liquid. Experience has shown that such residual deposits can exist and remain undetected for long periods of time before becoming large enough to make their presence known.

Chapter 9 Removal and Disposal of Flammable and Combustible Liquids

9.1* General.

9.1.1 The removal and disposal methods will depend on the amount of flammable or combustible liquid released to the environment (i.e., to soil, groundwater, or surface water) or present in a structure or on the surface, its chemical and physical characteristics, and the area affected.

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

9.1.2.1 Flammable liquids such as solvents, gasoline, and other volatile liquids rapidly evaporate at ambient temperature.

9.1.2.2 Combustible liquids such as heating oils, edible cooking oils, and other nonvolatile liquids do not readily evaporate and tend to remain in place for longer periods of time.

9.1.3 In general, purging a structure or enclosure of vapors of volatile liquids is primarily a matter of ventilation while the liquids themselves are physically collected and removed.

9.1.4 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 and vaults
(3) Surface water
(4) Groundwater
(5) Soil

9.1.5 The procedures in Section 5.2 should be followed.

9.1.6 Spilled petroleum product should not be washed from street surfaces into drains or sewers; doing so is potentially dangerous and often unlawful. Other disposal means, such as soaking up the substance with sand, clay, rags, or mops, should be used.

9.1.7 If, in an emergency, no alternative is available, disposal by washing into a drain or sewer should be done only on the decision of a qualified person and only after public authorities have been notified.

9.2 Basements.

9.2.1 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, in most cases, be detected before significant quantities can accumulate and additional flow can be intercepted or stopped.

9.2.2 Where volatile liquids and their vapors are involved, the primary means of removal and disposal should be ventilation, as described in 5.4.6 and 5.4.7.

9.2.3 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.

9.2.4 Once all flammable or combustible liquids have been removed, final cleanup should be accomplished by flushing out basement sumps and floor drains with water and washing down all affected surfaces with a biodegradable surfactant.

9.2.5 Ventilation and checking with a combustible gas indicator should be continued throughout the cleanup procedure.

9.2.6 In the rare cases that involve 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.

9.2.6.1 In these cases, the liquid should be bailed or pumped into barrels, drums, or other containers or into portable tanks or tank vehicles.

9.2.6.2 It might be necessary to dig an interceptor trench between the source of the release and the affected structure.

9.2.7 When nonvolatile liquids, such as fuel oils, are involved, ventilation is ineffective because the liquid evaporates at such a low rate.

9.2.7.1 Absorbents should be used for thin films of flammable or combustible liquid on water surfaces or on solid surfaces.

9.2.7.2 Wherever possible, flammable or combustible liquids should be removed with pumps or by bailing.

9.2.7.3 If final cleanup requires flushing sumps and drains and washing surfaces, local sanitation and environmental authorities should be consulted before such flammable or combustible liquids are flushed into sanitary sewers.

9.2.8 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.

9.3 Subways, Tunnels, and Mines.

9.3.1 If only small amounts of volatile liquids are involved, ventilation alone should be capable of removing vapors to a level that will allow safe entry, and, possibly, continued use of the facility. In such cases, the same removal and disposal methods as described in Section 9.2 for basements can be used.

9.3.1.1 Added precautions should be employed due to the greater potential exposure to the public and due to the greater exposure to potential ignition sources.

9.3.1.2 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.

9.3.2* 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.

9.3.2.1 A constant check should be maintained for at least 24 hours after remediation has been completed.

9.3.2.2 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.

9.3.2.3* Subsequent checks should be continued to include periods of extreme changes in groundwater levels.

9.3.3 If a relatively large amount of flammable or combustible liquid is involved or if leakage continues, closing the facility to the public and suspending normal operations should be considered.

9.3.3.1 It might be necessary to deactivate any electric lines or transit tracks in the vicinity of the seepage.

9.3.3.2 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.

9.3.3.3 Collected materials should be removed for disposal.

9.3.4* The facility operator should be consulted to determine the degree to which cleanup and remediation are necessary.

9.3.5 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 5.4.7. Elimination of the vapors might not be possible until remediation of the affected environmental media has been completed.

9.4 Normally Uninhabited Structures — Utility Conduits.

9.4.1 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, in most cases, be higher because early discovery and preventive measures do not typically happen.
(2) Access to entry points and affected areas is typically from manholes, but such access might not be available.

9.4.2* The utility operator should be consulted on all details of the remediation effort and the proposed purging procedures.

9.4.3 Where vapors in the utility conduit are the result of a release of flammable or combustible liquid to the environmental media, the utility conduit should be ventilated.

9.4.4 Elimination of the vapors might not be possible until remediation of the affected environmental media has been completed.

9.5 Normally Uninhabited Structures — Sewers.

9.5.1 On occasion, sewers can collect flammable or combustible liquids from a surrounding area affected by the liquids.

9.5.2 It is seldom practical to seal off all entry points into the sewer. Consequently, removal of the flammable or combustible liquids will, in most cases, be a continuing effort until the entire area is purged.

9.5.3 When relatively large amounts of flammable or combustible liquid are involved, efforts should be taken to divert the affected water flow to a separator. If diversion is impractical, it might be possible to set up a skimming facility or float a boom or inflated tube across the stream flow.

9.5.4 If the flammable or combustible liquid is 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, as shown in Figure 9.5.4(a) and Figure 9.5.4(b).

9.5.4.1 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.

9.5.4.2 Weirs should be used whenever possible because of their greater efficiency, particularly where the stream flow exceeds 0.9 m/sec (3 ft/sec), as shown in Figure 9.5.4.2.

9.5.5 Where vapors in sewers are the result of a release of flammable or combustible liquids to the environmental media, the primary removal and disposal method should be ventilation, as described in 5.4.6 and 5.4.7. Elimination of the vapors might not be possible until remediation of the affected environmental media has been completed.

9.6 Underground Release.

9.6.1 A knowledge of the local geology is basic to effective removal of flammable or combustible liquids or their components from subsurface soils and groundwater.

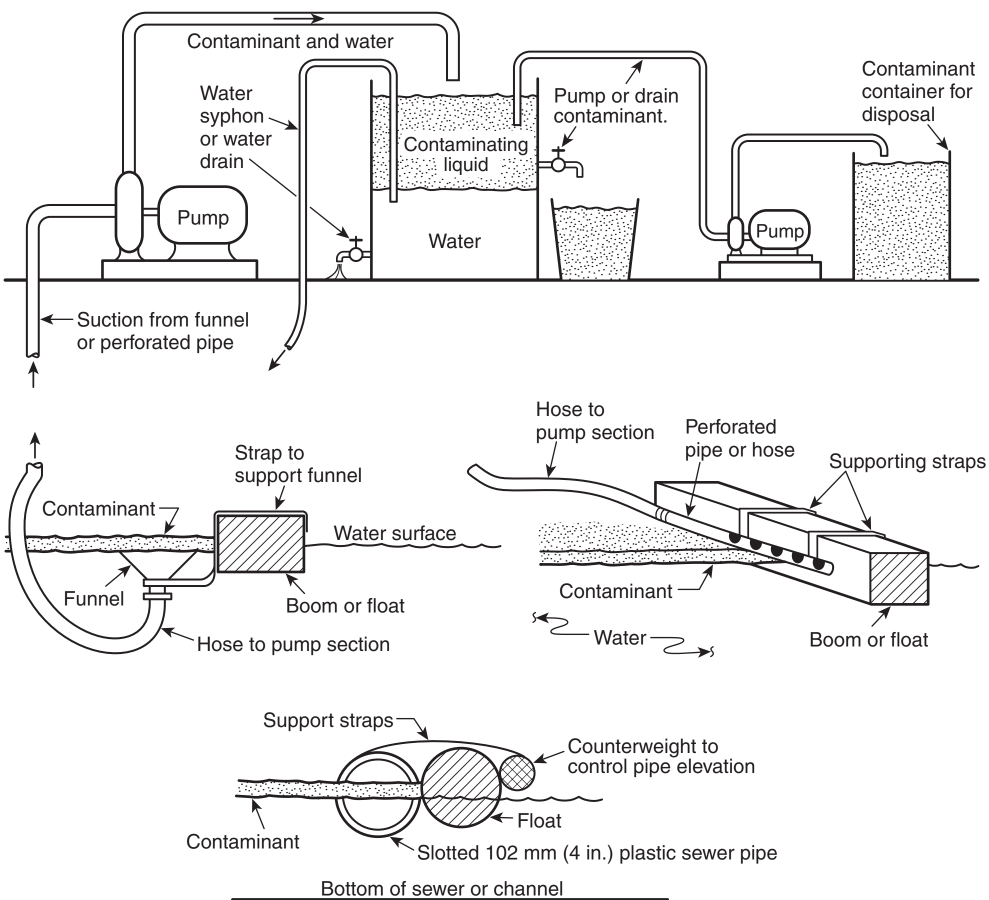

FIGURE 9.5.4(a) Typical Skimming Installation.

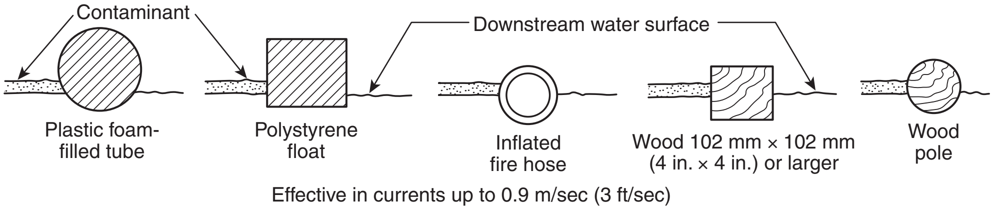

FIGURE 9.5.4(b) Typical Floats and Booms for Trapping Contaminants Floating on Water.

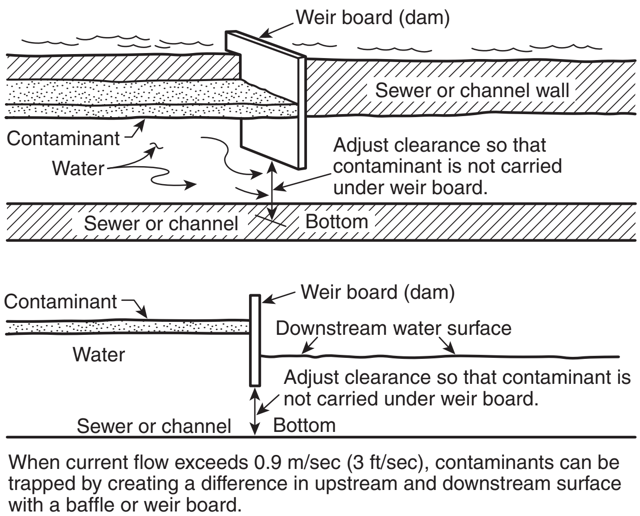

FIGURE 9.5.4.2 Typical Installation of a Weir in a Flowing Stream.

9.6.2 A geologist who is familiar with the area should be consulted before field activities begin.

9.6.3 Subsurface assessment will most likely be required to further define the extent of contamination and properly design the remediation efforts.

9.6.4 Additional information can be found in API 1628, *A Guide to the Assessment and Remediation of Underground Petroleum Releases*, and API 1629, *Guide for Assessing and Remediating Petroleum Hydrocarbons in Soil*.

Annex A Explanatory Material

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

A.1.1.5 Guidance regarding maximum acceptable levels of these substances can be found in the *Safety Data Sheet* (SDS); OSHA 29 CFR 1910.1000, Subpart Z; other OSHA substance-specific standards; ACGIH *Threshold Limit Values (TLV) for Chemical Substances and Physical Agents and Biological Exposure Indices*; and the NIOSH *Pocket Guide to Chemical Hazards*. Information about Safety Data Sheets can be found in 29 CFR 1910.1200(g).

A.1.2.2 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. Users of this recommended practice should consult all applicable federal, state, and local laws and regulations, especially with respect to any applicable reporting requirements.

A.3.2.1 Authority Having Jurisdiction (AHJ). The phrase "authority having jurisdiction," or its acronym AHJ, 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.3.3.3 Combustible Liquid. Combustible liquids are classified according to Section 4.3 of NFPA 30.

A.3.3.5 Flammable Liquid. Flammable liquids are classified according to Section 4.3 of NFPA 30.

A.3.3.12 Lower Flammable Limit (LFL). Mixtures below this limit are said to be "too lean."

A.3.3.22 Toxic Materials, Gases, or Vapors. The ability to produce injury to a biological system depends on concentration, rate, method, and site of absorption.

A.4.1.11 See Table A.4.1.11.

A.5.2.2 In most cases, the maintenance and engineering departments of such organizations are well equipped to take care of the situation.

A.5.3.2 Any such action can create an arc or spark capable of igniting flammable gases or vapors. This situation might require that the electric utility effect a remote cutoff.

A.5.3.3 Shutting off the gas service outside the building removes the fuel from pilot lights and gas burners, preventing them from serving as sources of ignition.

A.5.4.14 For information on underground petroleum releases, see API 1628, *A Guide to the Assessment and Remediation of Underground Petroleum Releases*.

A.5.4.18.3 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.

A.6.1.6 Well-organized, accurate data will prove invaluable in subsequent efforts to solve the problem. *(See Annex C.)*

A.6.1.7.1 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.

A.6.2.3 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.

A.6.2.5(8) 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 might be suspect.

A.6.2.7(2) Saturated or darkened soil, stained concrete, or disintegrated asphalt indicates that repeated spills might have occurred and liquid accumulated underground.

A.6.2.11 Small spills do occur inadvertently and can appear to be larger than they really are. A small amount of liquid [e.g., 240 mL (8 oz) of fuel] spilled onto wet pavement will spread out over a relatively large area. Small spills that spread out over a large area will dissipate rapidly and are not typical sources of underground contamination.

Table A.4.1.11 Properties of Some Flammable and Combustible Liquids and Gases That Have Been Found in Underground Structures

Substance	Flash Point °C (°F)	Flammable Limits in Air, Percentage by Volume: Lower Limit	Upper Limit	Specific Gravity (Water = 1)	Vapor Density (Air = 1)
Acetone	−20 (−4)	2.5	12.8	0.8	2.0
Acetylene	Gas	2.5	100.0	—	0.9
Ammonia	Gas	15.0	28.0	—	0.6
Benzene	−11 (12)	1.2	7.8	0.9	2.8
Butadiene	Gas	2.0	12.0	—	1.9
Butane	Gas	1.9	8.5	—	2.0
Carbon disulfide	−30 (−22)	1.3	50.0	1.3	2.6
Carbon monoxide	Gas	12.5	74.0	—	1.0
Ethane	Gas	3.0	12.5	—	1.0
Ethyl chloride	−50 (−58)	3.8	15.4	0.9	2.2
Gas oil*	66 (150)	0.5	5.0	<1.0	—
Gasoline (values vary for different grades of gasoline)	−43 (−45)	1.4	7.6	0.8	3.0–4.0
Hydrogen	Gas	4.0	75.0	—	0.1
Hydrogen sulfide	Gas	4.0	44.0	—	1.2
Kerosene	38–72 (100–162)	0.7	5.0	<1.0	—
Methane	Gas	5.0	15.0	—	0.6
Methyl bromide (practically nonflammable)	Gas	10.0	16.0	—	3.3
Methyl chloride	Gas	8.1	17.4	—	1.8
Natural gas*	Gas	3.8–6.5	13.0–17.0	—	—
Petroleum ether	<−18 (<0)	1.1	5.9	0.6	2.5
Propane	Gas	2.1	9.5		1.6
Toluene	4 (40)	1.1	7.1	0.9	3.1

Note: Properties of other flammable materials can be found in NFPA 325. Although NFPA 325 has been officially withdrawn from the *National Fire Codes*, the information is still available in NFPA's *Fire Protection Guide to Hazardous Materials*.

*These liquids and gases are mixtures, and their properties can vary depending on the composition.

A.6.3.3 The decrease might not occur immediately; it can, in fact, take days or weeks for liquid that has accumulated underground to be removed or to dissipate.

A.6.3.4(2) Tracing will determine the actual extent of the release, its direction of flow, and any other potential impact. *(See Chapter 8.)*

A.7.1.1 Certain methods described in this chapter 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.

A.7.1.3 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.

A.7.2.1(1) Damaged fill pipes, poorly maintained tight-fill connections or hose couplings, driver carelessness, or even overfilling the tank can cause product to be spilled around the pipe when a delivery is made.

A.7.2.1(6) Presence of water can be determined using water-finding paste on the gauge stick. If possible, determine whether the water increases during periods of heavy rainfall and remains constant or diminishes during dry spells. Also, if possible, determine the depth of the water table by checking a monitoring well in the immediate area of the tank(s). Determine whether water is entering the tank(s) through a loose fill cap or through a vent line opening that is not protected against rainwater intrusion. The surface area around vent lines should be checked for evidence that water might be entering by this route (standing water over vent lines can be the source).

A.7.2.1(8) A release detected at a monitoring well typically indicates that a significant release has occurred.

A.7.2.1(11) Secondary containment–type tanks have a port or access opening for monitoring releases and should be one of the first areas checked to see if a release has occurred.

A.7.2.1(12) If submersible turbine pumps are used to pump the liquid, they can be accessed via a sump above the tank.

A.7.2.2 Presence of water in an aboveground tank does not necessarily indicate a leak in the bottom of the tank. It is not unusual for water to be present at the bottom of aboveground storage tanks due to condensation. Since groundwater is typically below the bottom of an aboveground tank, the presence of water is not typically cause for concern.

A.7.2.2(1) Aboveground tanks are typically filled by pressurized pumps. In addition to the items given in 7.2.1 for underground tanks, spills from overfills can also be observed close to normal and emergency vent openings and around the tank itself.

A.7.2.2(8) 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 7.2.4.)*

A.7.2.3.2 If the pump used in moving the liquid is aboveground 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 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 retail motor fuel dispensing, this can 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., the pump is running but not moving any liquid).

If any of those conditions indicates 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 are located in the pipe above the tank and can be inspected and repaired from the surface of the ground through a special extractor mechanism installed with the valve. If the valve is inside the tank, it might be necessary to dig down to the tank to check the valve or disconnect and seal off the pipe for a hydrostatic pressure test. In most cases, digging down to the check valve or tank should be delayed until other, more easily performed tests have failed to reveal the leak.

A.7.2.3.3(2) 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.

A.7.2.4.2 Any loss that is partially or totally explained by the causes listed in 7.2.4.1 cannot be considered as conclusive evidence that the site in question is not a source of the release. Records are often incorrect or inadequate. Unless another source is found and considered to be a solution to the problem, other tests should be performed to draw definite conclusions.

A.7.4.3 Certain test methods might allow additional product to be released from the system or might cause structural damage to the tank or piping during the test.

A.7.4.8 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.

A.7.5.3 Tracer or dye testing has the advantage of leaving the pipe system in service while the test is performed.

A.8.2.1 A USGS map or aerial photograph can serve as a useful base.

A.8.2.2(4) Special attention should be given to interviewing elderly and long-time residents. They will often provide valuable information about the area prior to its development.

A.8.4 Chromatographic and spectrographic analyses can detect a trace quantity of an element that is unique to a particular method of manufacture, thus identifying the source. They can also detect the amount of the element present. These procedures involve only a small sample taken at the point of discovery. However, these tests can be inconclusive because an 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.

A.8.5 See A.8.4.

A.9.1 Enclosed spaces and subterranean spaces have the potential to meet the criteria for a confined space. Where flammable or combustible liquids or flammable solids are to be removed from such spaces, then the requirements for control of ignition sources given in Chapter 4 of NFPA 326 should be considered.

A.9.3.2 Subways, tunnels, and mines are, in most cases, more prone to underground seepage than other subterranean structures such as basements.

A.9.3.2.3 For example, significant rainfall can cause groundwater to rise and carry with it more liquid.

A.9.3.4 In most cases, once further entry of volatile liquids has been stopped, such facilities can be purged of vapors with reasonable periods of ventilation.

A.9.4.2 The operator's special knowledge will be essential to selecting the procedures and techniques to be used.

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

This annex 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 that underlie developed residential and industrial areas where subsurface structures are not installed.

B.2 Fuel Gas.

B.2.1 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.

B.2.2 Since the oxygen content of each of these gases, when not mixed with air, is typically 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 their high carbon monoxide content.

B.2.3 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 concentration 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 business districts of 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 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.

B.6.1 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.

B.6.2 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 could 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. The action of such protective devices in shutting off current is very fast, typically 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.

Annex C Basic Principles and Concepts of Underground Flow

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

C.1 Porosity.

C.1.1 The principal characteristic that permits liquids to enter, accumulate, and flow through soil or rock is porosity — the space or voids that exist between the particles that make up the soil and topsoil. Porosity can be essentially zero, as in fine, dense clay. Rock almost never has large voids, but sandstones and limestones have voids similar to a fine sand.

C.1.2 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 pipes to very small irregular cracks that result in flows similar to what would be found in fine sand.

C.1.3 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 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 water, unless the liquid is water soluble. When these liquids escape into the ground, they will typically 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 like water in a bucket and establishes a definite top surface, called a water table. Figure C.3 shows that groundwater can occur in more than one layer underground. A porous layer between two impervious layers can 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 can be very deep at one location, they can be close to the surface at others. *(See Figure C.4.)*

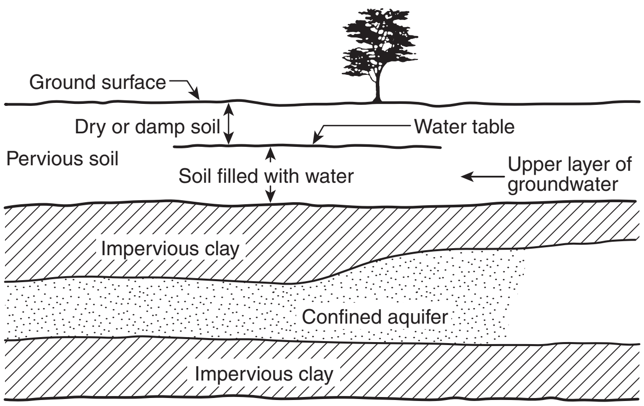

FIGURE C.3 Layering of Groundwater Between and Above Impervious Strata.

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.

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.

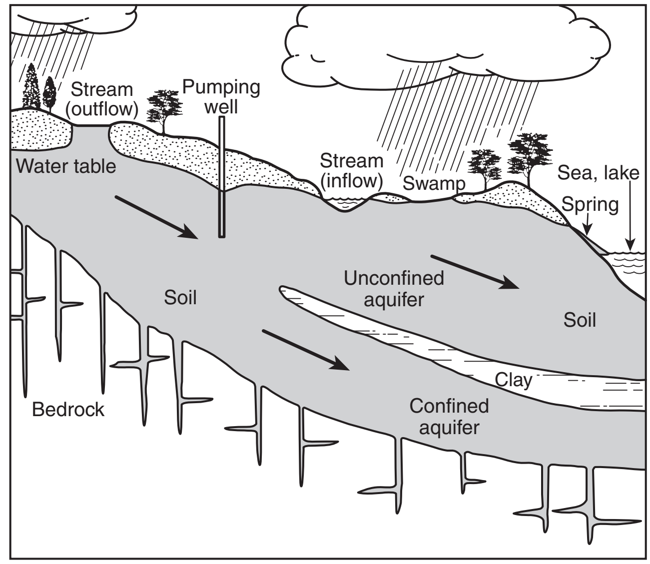

FIGURE C.4 Hypothetical Groundwater System Showing Significant Features.

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 feet per day to 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.

C.8.1 Figure C.8.1(a) and Figure C.8.1(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 both figures, a four-story building lies midway between two streets that are 120 m (400 ft) apart. A 5 percent grade from left to right places the street on the right about 6 m (20 ft) higher than the street on the left.

C.8.2 In Figure C.8.1(a), the underground strata follow 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 vapor was found in the subbasement of the building, the source of that gasoline would probably be from the service station to the right, at the higher elevation, or from other tanks farther up the hill.

C.8.3 In Figure C.8.1(b), the situation is such that the service station downhill is the most probable source. The water-bearing strata of sand and gravel slope 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.

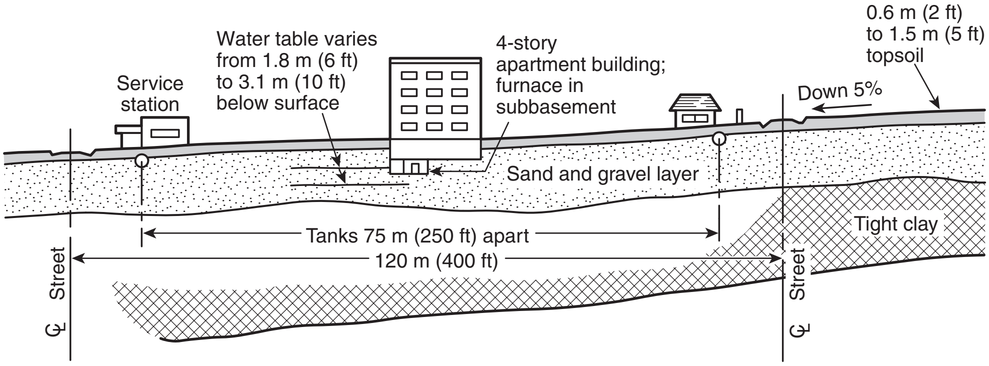

FIGURE C.8.1(a) Effects of Slope of Underground Strata on Groundwater Flow I.

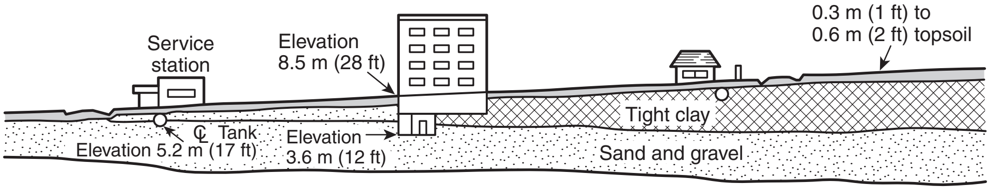

FIGURE C.8.1(b) Effects of Slope of Underground Strata on Groundwater Flow II.

C.8.4 One other condition shown in Figure C.8.1(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 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 stratum 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. If the wells were not present, discovery would be delayed, probably until the release reached the ground on the other side of the hill, possibly miles away.

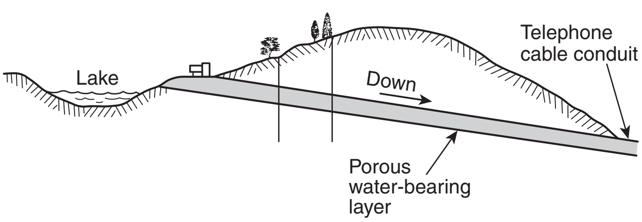

FIGURE C.9 Effects of Slope of Underground Stratum on Groundwater Flow III.

C.10 Rising and Falling Water Table.

C.10.1 Figure C.10.1(a) and Figure C.10.1(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.10.1(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.

C.10.2 Figure C.10.1(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.

C.10.3 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 0.3 m (1 ft) of the surface during wet periods but falls to a level below the bottom of the tank evacuation during dry periods.

C.10.4 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.

C.10.5 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. It will not necessarily enter the sewer pipe in the street. It can 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.

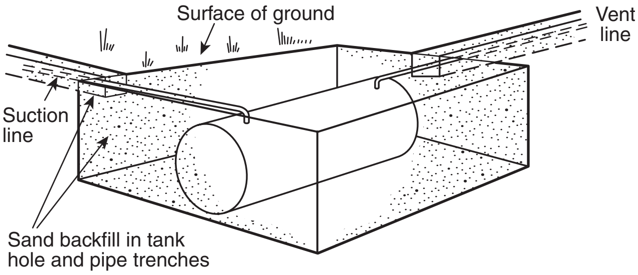

FIGURE C.10.1(a) Excavation in Clay and Backfilled with Sand.

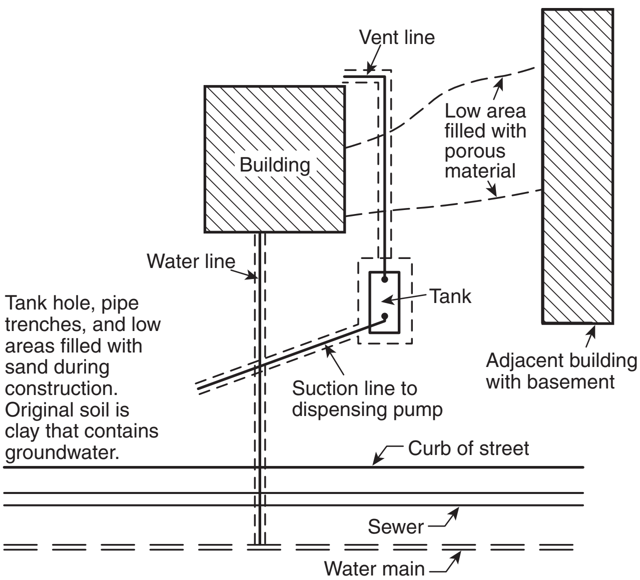

FIGURE C.10.1(b) Tank Installed Next to a Building with a Basement.

C.10.6 Another condition, illustrated by Figure C.10.1(b), is the potential for the contaminating liquid to move without the presence of groundwater. If a serious leak occurs in the suction piping, pure liquid can flow along the trenches.

C.11 Summary. The principles and concepts discussed in this annex 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.

Annex D Sources of Damage to Storage Containers and Lines

This annex 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 can 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 can 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.

Annex E Inventory Control Procedures

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

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

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

E.1.1.1 When liquid is added to the underground tank, the tank volume should be gauged both before and after the delivery. The operator should also check the tank for presence of water to the nearest 3 mm (⅛ in.), using, for example, water-finding paste or other means. This procedure, however, is not applicable to water-miscible liquids. Water that is detected should be accounted for in the inventory procedures, and any accumulation greater than 13 mm (½ in.) should be removed.

E.1.1.2 At the close of the business day (or the end of the shift), tank volume should again be gauged and meter totalizer readings recorded. The difference between the opening and closing totalizer readings is the sales for the inventory period. All readings that are recorded as part of this procedure should be kept in a safe location and retained for a minimum of one year. Detailed instructions covering tank gauging, water gauging, meter calibration checks, and record keeping are contained in API 1621, *Bulk Liquid Stock Control at Retail Outlets.*

E.1.2 Daily Reconciliation. Inventory reconciliation consists of comparing the measured closing inventory to the book inventory, which is obtained by adding deliveries and subtracting sales and on-site usage from the measured inventory. Due to variables inherent in the process, this reconciliation will rarely balance exactly, and small daily overages or shortages are to be expected. By observation of daily variances, the operator is able to identify trends over time; daily fluctuations tend to cancel out over the long term.

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

E.1.3.1 For a facility that stores more than one variety of liquids, such as a retail service station, the operator should compare inventory records for the various tank systems. This comparison will mitigate the effect of the temperature-induced errors on the inventory accounting. Since the impact of temperature should be roughly the same, a significant difference in the inventory variance from one product to the next can indicate a leak. The first step in investigating this would be to check the meter calibrations on the dispenser system.

E.1.3.2 At the end of each month, the operator should again review the daily inventory accounting and perform a monthly reconciliation. According to U.S. Environmental Protection Agency regulations, a leak is suspected if, for two consecutive months, the monthly inventory shortage exceeds 1 percent of the system throughput plus 492 L (130 gal). The operator should look closely to see if the negative variance is a one-time fluctuation or if there is a consistent negative trend throughout the inventory period.

E.2 Tanks Without Metered Dispensing.

E.2.1 For these systems, the inventory review is complicated by the fact that all withdrawals can only be measured by gauging the tank. For tanks of 7570 L (2000 gal) or less, manual tank gauging can be used to determine if a release has occurred.

E.2.2 Tank liquid level measurements are taken at the beginning and ending of at least a 36-hour period during which no liquid is added to or removed from the tank. Level measurements are based on an average of two consecutive gauge readings at both the beginning and the end of the period.

E.2.3 According to U.S. Environmental Protection Agency regulations, a leak is suspected if the weekly or monthly standards exceed the values shown in Table E.2.3.

Table E.2.3 Standard Deviations for Inventory Reconciliation

Nominal Tank Capacity (gal)	Weekly Standard (One Test) (gal)	Monthly Standard (Average of Four Weekly Tests) (gal)
550 or less	10	5
551–1000	13	7
1001–2000	26	13

For SI units, 1 gal = 3.785 L.

E.2.4 For tanks larger than 7570 L (2000 gal), tank levels should be accurately gauged and recorded before and after any input or withdrawal. To determine if the storage system is losing liquid, the operator should compare the volume before an input or withdrawal with the measured volume after the previous input or withdrawal.

E.2.5 This loss or gain figure for each period of tank inactivity should be carried forward and cumulative variance maintained by adding the gain or subtracting the loss from the previous number.

E.2.6 Since tank gauging errors are completely random, they should tend to cancel out from one measurement to the next. A consistent and increasing negative or positive trend indicates a potential leak that should be investigated.

E.2.7 For additional information on the subject, see the following:

(1) API 1621, *Bulk Liquid Stock Control at Retail Outlets*
(2) "Analysis of Factors Affecting Service Station Inventory Control," report prepared for the API by the Radian Corporation

Annex F Informational References

F.1 Referenced Publications. The documents or portions thereof listed in this annex are referenced within the informational sections of this recommended practice and are not part of the recommendations of this document unless also listed in Chapter 2 for other reasons.

F.1.1 NFPA Publications. National Fire Protection Association, 1 Batterymarch Park, Quincy, MA 02169-7471.

NFPA 30, *Flammable and Combustible Liquids Code,* 2015 edition.

NFPA 326, *Standard for the Safeguarding of Tanks and Containers for Entry, Cleaning, or Repair*, 2015 edition.

Fire Protection Guide to Hazardous Materials, 14th edition, 2010.

F.1.2 Other Publications.

F.1.2.1 ACGIH Publications. American Conference of Governmental Industrial Hygienists, 1330 Kemper Meadow Drive, Cincinnati, OH 45240.

Threshold Limit Values (TLV) for Chemical Substances and Physical Agents and Biological Exposure Indices, 2013 edition.

F.1.2.2 API Publications. American Petroleum Institute, 1220 L Street, N.W., Washington, DC 20005-4070.

API Recommended Practice 1621, *Bulk Liquid Stock Control at Retail Outlets*, 5th edition, 1993 (reaffirmed 2000).

API Publication 1628, *A Guide to the Assessment and Remediation of Underground Petroleum Releases*, 3rd edition, 1996.

"Analysis of Factors Affecting Service Station Inventory Control," report prepared for the API by the Radian Corporation, July 1984.

F.1.2.3 U.S. Government Publications. U.S. Government Printing Office, Washington, DC 20402.

NIOSH *Pocket Guide to Chemical Hazards*, 2007 edition.

Title 29, Code of Federal Regulations, Part 1910.1000, Subpart Z, "Air Contaminants."

Title 29, Code of Federal Regulations, Part 1910.1200(g), "Safety Data Sheets."

F.2 Informational References. (Reserved)

F.3 References for Extracts in Informational Sections. (Reserved)