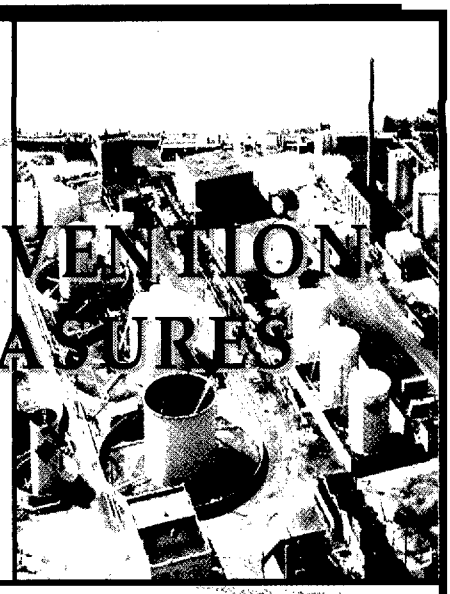
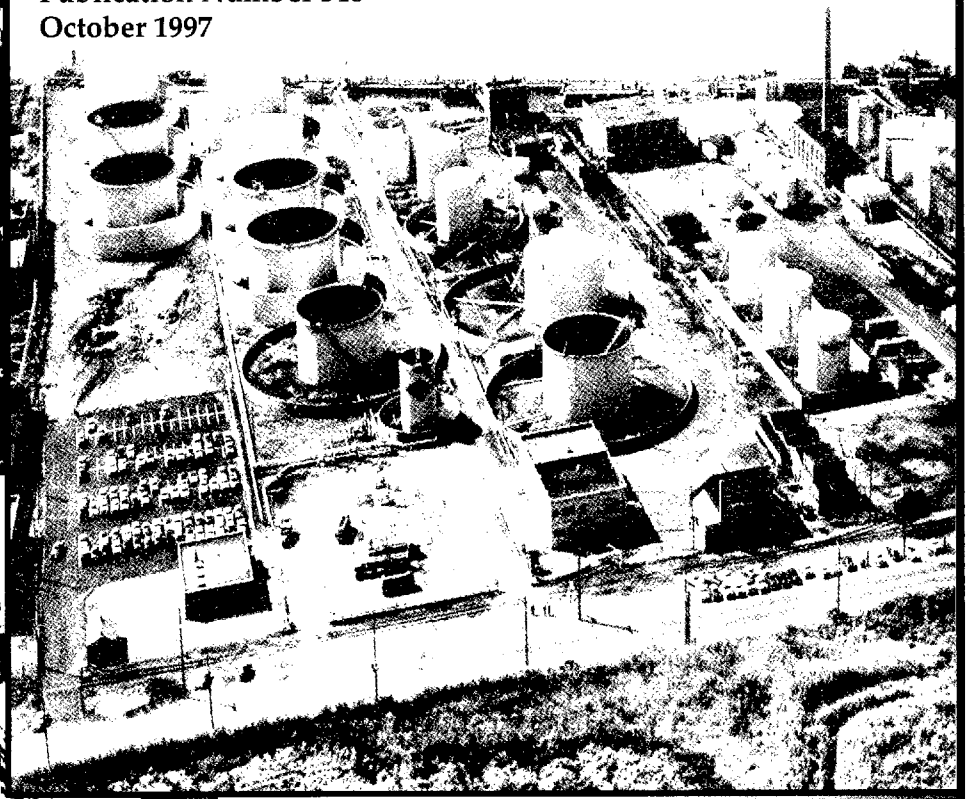
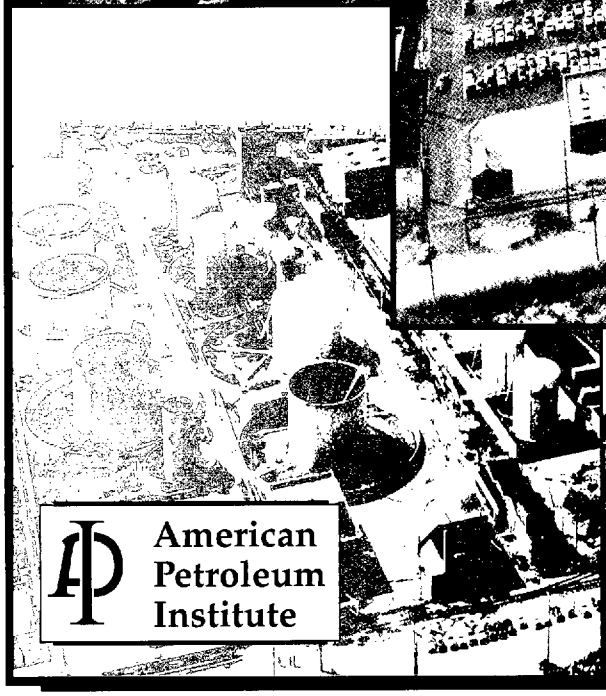
Liquid Release Prevention and Detection Measures for Aboveground Storage Facilities



Health and Environmental Affairs Department
Publication Number 340
October 1997





American Petroleum Institute

Liquid Release Prevention and Detection Measures for Aboveground Storage Facilities

Health and Environmental Affairs Department

API PUBLICATION NUMBER 340

PREPARED UNDER CONTRACT BY:

JOSEPH S. BURKE
SPEC CONSULTING SERVICES
10 WILDWOOD COVER
PO BOX 912
CLIFTON PARK, NEW YORK 12065

OCTOBER 1997

American Petroleum Institute

FOREWORD

API PUBLICATIONS NECESSARILY ADDRESS PROBLEMS OF A GENERAL NATURE. WITH RESPECT TO PARTICULAR CIRCUMSTANCES, LOCAL, STATE, AND FEDERAL LAWS AND REGULATIONS SHOULD BE REVIEWED.

API IS NOT UNDERTAKING TO MEET THE DUTIES OF EMPLOYERS, MANUFACTURERS, OR SUPPLIERS TO WARN AND PROPERLY TRAIN AND EQUIP THEIR EMPLOYEES, AND OTHERS EXPOSED, CONCERNING HEALTH AND SAFETY RISKS AND PRECAUTIONS, NOR UNDERTAKING THEIR OBLIGATIONS UNDER LOCAL, STATE, OR FEDERAL LAWS.

NOTHING CONTAINED IN ANY API PUBLICATION IS TO BE CONSTRUED AS GRANTING ANY RIGHT, BY IMPLICATION OR OTHERWISE, FOR THE MANUFACTURE, SALE, OR USE OF ANY METHOD, APPARATUS, OR PRODUCT COVERED BY LETTERS PATENT. NEITHER SHOULD ANYTHING CONTAINED IN THE PUBLICATION BE CONSTRUED AS INSURING ANYONE AGAINST LIABILITY FOR INFRINGEMENT OF LETTERS PATENT.

ACKNOWLEDGMENTS

THE FOLLOWING PEOPLE ARE RECOGNIZED FOR THEIR CONTRIBUTIONS OF TIME AND EXPERTISE DURING THIS STUDY AND IN THE PREPARATION OF THIS REPORT:

API STAFF CONTACT

F. Dee Gavora, Health and Environmental Affairs

MEMBERS OF THE STORAGE TANK TASK FORCE SUBCOMMITTEE

Jerry Boldra, Shell Oil Company

Jerry Engelhardt, Santa Fe Pacific Pipeline Company

Donald Gilson, Chevron Products Company

Donald Hitchcock, Texaco Refining and Marketing

George Loyd, Shell Oil Company

William Martin, ARCO Products Company

Gene Milunec, Mobil Oil Corporation

James Moore, AMOCO Oil Company

Philip Myers, Chevron Research and Technology

James Scott, 76 Products Company

Ned Seppi, Marathon Oil Company

Randy Steele, BP Oil Company

James Stevenson, Phillips Pipeline Company

John Thomas, Shell Oil Company

Alan Wolf, Exxon Research and Engineering Company

John Zimmer, Mobil Oil Corporation

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

EXECUTIVE SUMMARY

Preventing releases is an important aspect of day-to-day business for owners and operators of aboveground storage tank (AST) facilities. Over the years, operating practices have been developed and equipment has been designed to reduce the potential for releases and to protect the environment if a release occurs.

Data collected in a 1994 API survey of aboveground tank facilities indicated that the presence of groundwater contamination at aboveground storage tank facilities was mainly attributable to discontinued operating practices. Respondents reported significant reductions in releases (during the five-year period preceding the survey) because equipment, operating practices, and standards have improved. The 1994 survey focused on groundwater protection, but current practices at facilities address all facets of environmental protection. This report compiles information on current industry practices to prevent or detect releases, and to protect groundwater, surface water, and soil in the event of a liquid release. Air emissions are not addressed in this report.

Specifically, the report addresses facility tanks, piping, loading/unloading areas, ancillary equipment, as well as facility operating systems -- or the human factor. For each of these components, the report provides:

- A summary of the potential causes of liquid petroleum releases;
- An overview of the procedures and equipment available to operators to prevent, detect or provide environmental protection from such releases; and
- The advantages and disadvantages of various control measures including relative costs, as well as maintenance and operating parameters.

Much of the information presented in the document is taken from API standards and research reports. Additionally, current industry practices and industry examples are included.

The report is not intended to provide requirements; rather, it represents a compilation of the various methods that industry uses to prevent and detect releases. Effective operation of facilities and release prevention involve the evaluation and use of a wide range of control measures. Selection of appropriate measures must be made on a site-specific basis and then tailored to meet the needs of each location.

The approach taken by the report is illustrated in Table ES-1, which gives an overview of types of releases that can occur at facilities and lists some of the available control measures. The table, which is not intended to be comprehensive, shows that multiple methods are available to address each type of release. The objective of this report is to facilitate selection of an appropriate measure and to help the reader better understand the variety of methods that can be used to prevent releases or to protect the environment if releases occur.

Table ES-1 OVERVIEW OF LIQUID RELEASE CONTROL MEASURES

Source of Release	Type of Release	Examples of Control Measures[1] (Applicable Standard or Code)[2]
Aboveground Storage Tanks	Tank overfill	• Written procedures • Operator training • Overfill protection systems
	Bottom leaks	• Inspection & maintenance program (API 653) • Cathodic protection (API 651) • Floor coatings and liners (API 650, 651, and 652) • Release Prevention Barriers (API 650, Appx I)
	Tank shell or shell appurtenance release	• Inspection & maintenance program (API 653) • Secondary containment system • Use of API 650 design for new tanks
Piping Systems	Underground pressurized piping	• Cathodic protection (API 651) • Pipe coating (internal / external) • Proper piping system design (ASME / API) • Monitor pipe settlement • Inspection and maintenance program per API 2610 / 570
	Aboveground steel piping	• Visual inspection for defects • Pipe coating • Proper design (ASME / API) • Inspection and maintenance program per API 2610 / 570
	Underground gravity flow piping	• Pipe coating • Cathodic protection (API 651) • Special gaskets
Loading Areas	Loading/unloading	• Written procedures • Operator training • Monitor operations • Overfill protection systems • Pump emergency shutoff
Ancillary Equipment	Small equipment releases (e.g., pump, hose, flange leaks)	• Drip pans for equipment • Over-pressure protection
Operating Systems	Human error	• Written procedures • Operator training • Monitor shifts and workloads

[1] The control measures are not listed in prioritized order and are not intended to apply universally.
[2] See bibliography for source.

Section 1
INTRODUCTION

The prevention of liquid releases from aboveground tank facilities is of concern to facility owners and operators. Operating practices and equipment are designed to reduce the potential of such releases. This report outlines measures currently used by industry to prevent or detect releases and to protect the environment in the event of a release.

BACKGROUND

In 1992, API formed a steering group to evaluate the petroleum industry's approach to aboveground tank facility operation. The group chose two courses of action. The first involved a reassessment of the adequacy of API standards for terminal and tank operations. The second involved a survey of API members to evaluate the current status of facility operations and determine the frequency of groundwater contamination.

Under the steering group's direction, approximately 60 API standards and recommended practices were reviewed. This activity resulted in the revision of several existing standards and development of new ones. Most importantly, API members developed a comprehensive new standard, *Design, Construction, Operation, Maintenance, and Inspection of Terminal and Tank Facilities* (Standard 2610), which addresses the design, construction, operation, maintenance, and inspection of all petroleum terminal and tank facilities associated with marketing, refining, and transportation activities. The standard was designed to fill a need to combine terminal- and tank-related standards and good operating practices into one document.

In an effort to further define the extent of operational concerns relating to tank operations and to assess improvements, API conducted a survey of its members' aboveground storage tank facilities. At EPA's request, API members in the refining, marketing, and transportation sectors voluntarily participated in a survey of these facilities. Two purposes of the survey were to assess recent facility improvements and to determine the relative sources of groundwater contamination. The survey results indicated that the contribution to groundwater contamination from almost all sources decreased during the five-year period preceding the survey. Respondents in all three industry sectors reported significant reductions in releases because of improved equipment and operating practices.

The 1994 survey focused on groundwater protection, but current practices at facilities address all facets of environmental protection. This report summarizes the range of current industry practices used to prevent or detect liquid releases to groundwater, surface water, and soil.

SCOPE OF REPORT

This report outlines the range of available procedures, technologies, and equipment that can be used to prevent and/or detect liquid releases at existing aboveground storage tank facilities. It is intended to assist in the selection of appropriate options to prevent or detect releases and to protect the environment should a release occur. Additionally, the control measures have been identified according to their ability to prevent or detect types of releases and to protect the environment in the event of a release. Emphasis is given to release prevention measures.

The storage components addressed include: tankage, facility piping, loading and unloading areas, ancillary equipment (e.g., vapor processing, additive systems, sumps), and facility operating systems. These components are illustrated in Figure 1-1. For each of these components, the report:

- Provides a summary of the potential causes of liquid releases;
- Presents an overview of the procedures and equipment available to operators to prevent, detect or provide environmental protection from such releases; and
- Considers the advantages and disadvantages of various control measures including the relative costs, as well as maintenance and operating parameters.

Additionally, the report gives an indication of the relative costs required to install or implement the various measures. These costs are intended to be used only as a basis for comparing control measures. Actual installation and implementation costs will vary depending on site conditions, facility location, and regional cost factors.

Applicable federal and several state regulations were reviewed during preparation of this document. However, specific regulatory requirements or citations are not discussed, as they are subject to change and may not be universally applicable. Similarly, this report does not address regulatory requirements that may be required by local jurisdictions. Federal, state and local requirements should be taken into consideration in selecting a control measure.

At the time this report was prepared, new release prevention technologies were being developed. Most of these are not listed in the report because their performance has not been thoroughly validated; however, some emerging technologies have been highlighted in the tables for the reader's information. The reader should confirm the suitability and effectiveness of these new technologies prior to using them.

This report does ***not*** cover:

- Emergency response, cleanup, remediation, tank cleaning, and decommissioning
- Health, safety and fire prevention issues
- Air emissions

FACILITIES ADDRESSED

This report addresses aboveground storage tank and terminal facilities associated with the marketing, refining, and transportation of petroleum. The control measures discussed apply to the tank, piping, loading/unloading systems, ancillary equipment, and facility operating practices.

The report is ***not*** intended to be used for:

- Retail service stations
- Refinery process equipment and process areas
- Oil and gas production facilities, including offshore facilities and associated tanks
- Natural gas processing plants
- Production, pipeline, and truck crude oil gathering facilities

WHO SHOULD READ THIS REPORT?

This report is intended for use by managers, facility operators, and regulators, as well as engineers involved in the design and selection of facility components and prevention of liquid petroleum releases.

A NOTE OF CAUTION

The methods listed in this report do not represent a complete list of control measures. The reader is cautioned to fully investigate the appropriateness of a control measure and to determine its suitability to a particular facility. The retrofit cost, operating requirements, system modification

requirements, and effect on other systems are considerations when determining the suitability of a particular measure.

Application of the options discussed in this report should be based on sound engineering judgment and in accordance with relevant codes, standards, and manufacturers' recommendations. Potential health, safety, fire prevention, and fire protection requirements for each measure should be assessed as well.

In evaluating the options presented in this document, the risks posed by potential releases must also be considered, but a discussion of the risk assessment process is beyond the scope of this research effort. Rather, this report is designed to show the variety of precautions and technologies industry uses to prevent releases from occurring and to detect releases if they do occur.

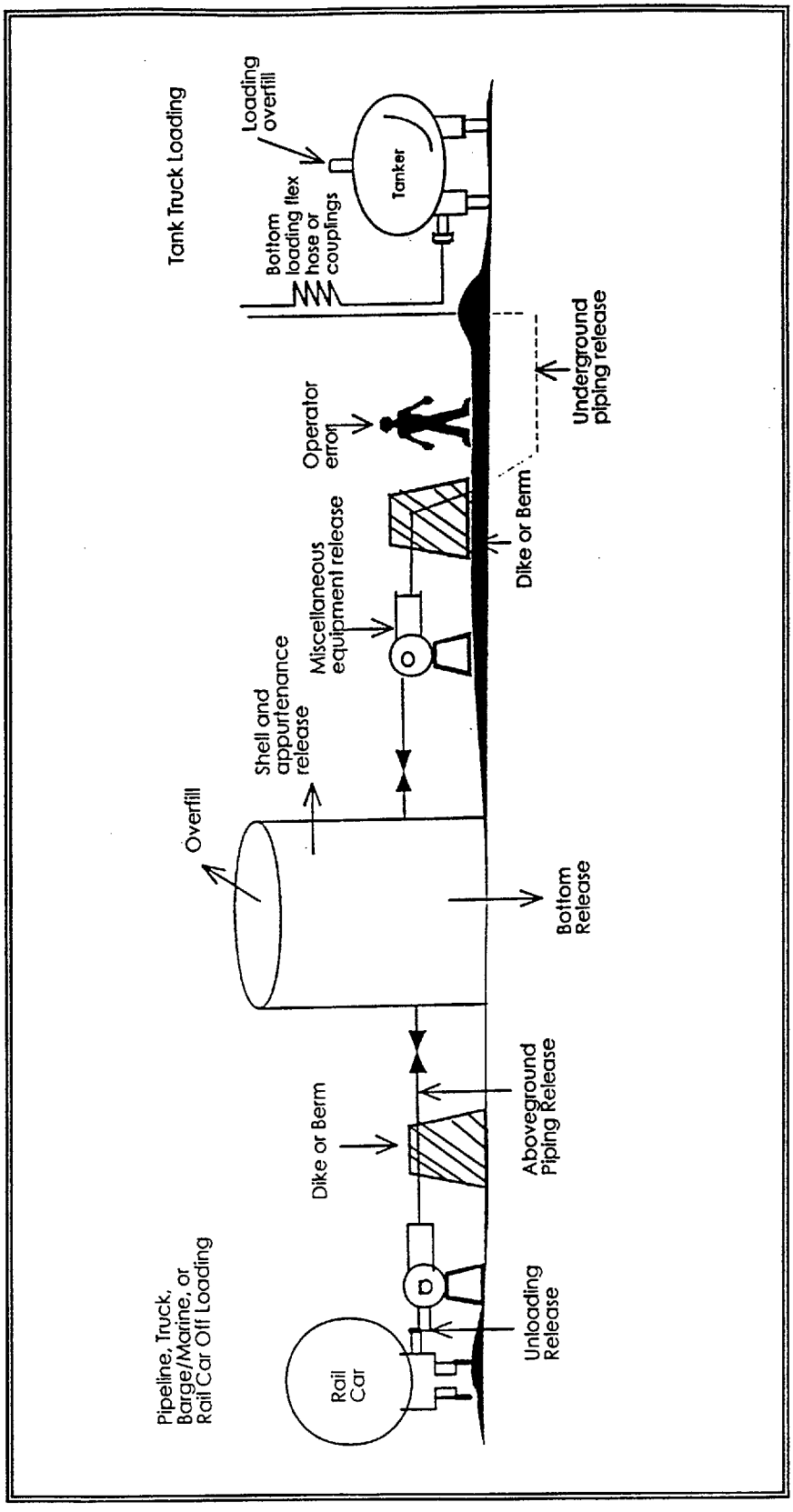


Figure 1-1. Sources of Potential Releases at AST Facilities

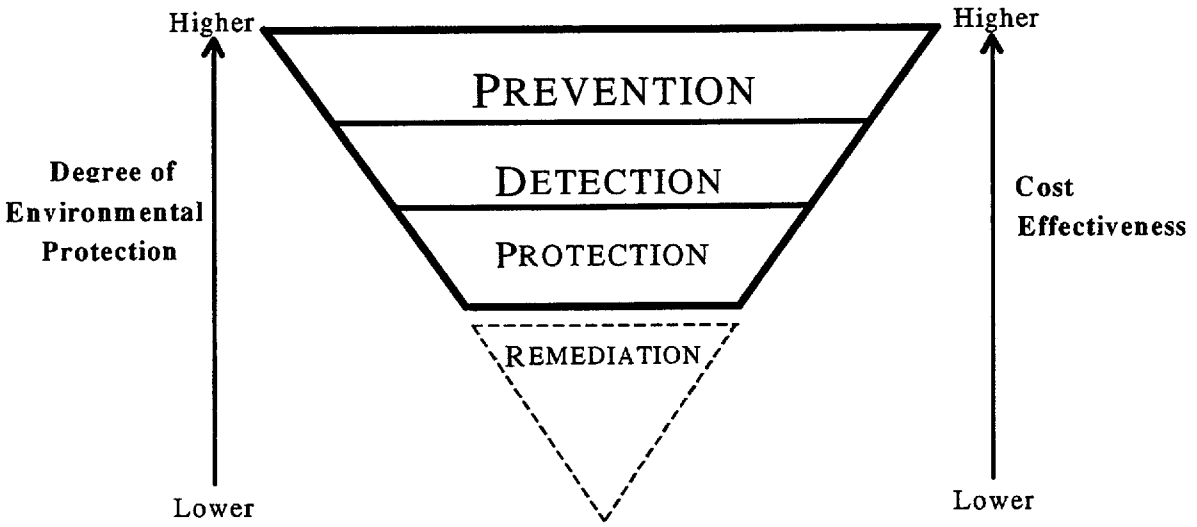
Section 2
SELECTION CRITERIA

GENERAL APPROACH

Preventing releases from aboveground storage facilities requires the evaluation of a range of control measures. Generally, measures that prevent releases are the most effective in terms of both cost and environmental protection. In operating storage facilities, the goal is to prevent releases and to keep the product in the tank.

The effectiveness of prevention measures is illustrated graphically in Figure 2-1.

Figure 2-1. Hierarchy for Selection of Control Measures versus Remediation



The three categories of control measures addressed in this document (Prevention, Detection, and Protection) are shown as a triangular hierarchy. The left-hand axis represents the degree of environmental protection afforded by each control measure and increases at the top where the emphasis is on preventing releases. Similarly, the right-hand axis shows that the cost-effectiveness increases as one moves from measures designed to protect the environment in the event of a release to measures designed to prevent releases. A measure that is designed to minimize the impact of a release once it occurs may require some level of cleanup; thus, it may be more costly in the long run.

For example, an inspection and maintenance program designed to prevent a tank release can be more effective than installing an impermeable liner in the tankfield. The first approach prevents the release and thus is more protective of the environment and more cost-effective. In contrast, tankfield liners are prone to damage and generally have limited effectiveness in mitigating liquid releases.

In operating facilities and selecting control measures, emphasis is given to preventing releases. However, other categories of measures -- detection or protection measures -- may be required depending on the operating circumstances. Remediation is not considered a prevention, protection, or detection measure; thus, this report does not address the subject of remediation.

CONSIDERATION OF SELECTION CRITERIA

Selection of appropriate control measures is a complex process involving consideration of several criteria. These criteria vary from facility component to facility component; thus, the selection of appropriate control measures is site-specific and must be tailored to meet the needs of each location. Additionally, the selection process balances environmental concerns, operational considerations, and business objectives.

The following list gives some examples of factors that may be considered in selecting appropriate control measures for a facility:

Environmental & Health Factors

- Surrounding population, land and/or aquifer use and ecology
- Distance or depth to groundwater
- Aquifer location, gradient, and quality
- Proximity to navigable water
- Site geology, topography and drainage
- Permeability of soil
- Toxicological factors

Operational Factors

- Type and design of facility, tank or system
  - Condition of facility and equipment
  - Size and capacity
  - Staffed vs. unstaffed

- Maintenance practices
- Operator training and knowledge
- Extent of monitoring equipment and capabilities

- Remaining service life of the facility, tank or system
- Previous effectiveness of measure
- Type of product stored (toxicity, flammability, solubility, volatility, viscosity, etc..)
- Inventory turnover rate (duration of storage)
- Training, maintenance, and inspection program

Business Factors

- Initial cost
- Long-term operation and maintenance cost
- Inspection, maintenance, operating and testing requirements
- Company goals and objectives (e.g., anticipated change in service for a facility)

The range of factors listed above shows that operating conditions vary widely in terms of location, product handled, business objectives, and potential environmental risk. No single combination of control measures would be effective for all facilities, and any release prevention system selected should be commensurate with the risk involved.

Section 3
DESIGN OF THE TABLES

OVERVIEW

Sections 4 through 8 discuss the different components of aboveground storage facilities -- the tanks, piping, loading/unloading areas, ancillary equipment, and operating system. Each section contains two tables outlining:

- Release scenarios and available control measures
- References and advantages/disadvantages for the control measures

The information contained in the tables is presented in the following manner:

Release Scenarios -- Part One

The first table in each section lists the predominant sources of releases for the facility component and also gives the major causes. For example, tank overfill is a type of release that can occur in aboveground tanks. There are two primary causes of tank overfill: human error and equipment failure. The table lists various control measures available to prevent such releases and labels each measure according to its ability to prevent or detect a release or to protect the environment should the release occur. Additionally, the first table gives information on relative retrofit costs for existing facilities, as well as operation and maintenance costs for the control measures.

Control Measures -- Part Two

The second table provides more detailed information on the control measures listed in the first table. It lists available industry publications or standards that can be referenced for additional information. The more significant advantages and disadvantages of each control measure are given. The table also gives information on operation and maintenance considerations related to the application and/or installation of each control measure.

REFERENCES TO COST

The cost information in the tables is a relative indicator of the expense associated with the application of the particular control measure. It is provided to give the reader some understanding of costs when comparing the advantages and disadvantages of various control measures within each table.

When referring to the cost column in the table, the reader should note that:

- This document will be most widely used for existing AST facilities; therefore, references to installation costs refer to the cost of modifying an existing facility. Typically, installation costs for new facilities are less than the costs required to retrofit existing systems.

- Where new construction costs are substantially less than the cost required to retrofit an existing facility, a footnote is provided in the table.

- Operation and maintenance costs refer to the ongoing costs required for a control measure after installation.

- Costs for control measures are intended to represent relative ranges for comparable alternatives and are designated as low, medium, high, or very high. In general, a control measure referenced multiple times within a table will have the same relative cost. For example, in Table 4-1, Operator Training is listed as a control measure option for Slow Releases and Rapid Shell Failure; in both cases, the retrofit cost is *low* and the operations and maintenance cost is *medium.*[1]

[1] In Table 5-1, retrofit costs for identical control measures may differ substantially for aboveground piping versus below ground piping because of the difference in retrofit requirements.

Section 4
ABOVEGROUND STORAGE TANKS

INTRODUCTION

This section outlines potential release scenarios associated with the operation of aboveground storage tanks and lists the corresponding measures currently available to prevent or detect such releases. Selection of appropriate control measures is based on site-specific factors including: design, materials, operations, maintenance history, and environmental sensitivity.

OVERVIEW

New aboveground storage tank systems and most existing petroleum storage tanks are vertical cylinders, designed and field-erected in accordance with API Standard 650, *Welded Steel Tanks for Oil Storage*. The design of a tank system is dependent on a number of factors. These include the type and quantity of product stored; weather and soil conditions; and proximity to groundwater.

Tank Roof Vertical storage tanks may have either a fixed or floating roof or both. Generally, fixed-roof tanks have a cone or domed top to facilitate drainage. Roofing systems that move up and down with the product level are known as floating roofs. These systems may or may not be covered with a fixed roof. When covered, the system is referred to as an internal floating roof; those that are not covered are called external floating roofs.

Tank Floor A typical tank floor consists of a single layer of steel that rests on foundation material, the ground, a ring-wall foundation, and/or a concrete pad. Additionally, the bottom may be equipped with a Release Prevention Barrier (or RPB). A RPB may be a second steel bottom, synthetic liner materials, clay liners, or all other barriers or combinations of barriers placed in the bottom of, or under an aboveground storage tank. The RPB may prevent the escape of contained material and channel any released material for detection purposes. Methods for installing RPBs are discussed in API STD 650, Appendix I.

Tank Shell The tank shell is the vertical steel wall that contains the stored product. The required steel plate thickness increases with tank height, diameter, and product specific gravity. The shell exterior is usually painted and the interior is typically bare steel. Corrosion of the interior of the shell is not a problem, and if it is anticipated, it can be addressed with coatings, linings, or generally by using different construction materials.

Typical Appurtenances Attachments and appurtenances are fitted to tank parts for various purposes. These include shell attachments, bottom connections, cover plates, roof manholes, roof nozzles, water draw-off sumps, scaffold-cable supports, threaded connections, platforms, walkways, and stairways.

Floor attachments and appurtenances can include sumps and striker plates. Shell attachments and appurtenances can include nozzles and valves, thermowells, ground rods, anchor chairs, wind girders, level gauges, stairways, access hatches, relief vents, air vents, instrumentation, mixers, and pipe supports. Roof attachments and appurtenances can include stairs, walkways, gauge hatches, access hatches, and vents.

RELEASE SCENARIOS

Potential sources of releases from aboveground tanks include: tank overfill; slow releases from rapid shell failure, the bottom, the shell, or an appurtenance.

Tank Overfills A tank overfill occurs when the volume of product received exceeds the available tank storage capacity. In such cases, petroleum is released through tank vents.

Slow Releases Slow releases from a tank can occur from several sources: the bottom, the shell, or a tank appurtenance.

A tank bottom release involves a loss of product through the tank floor and may result from several factors including:

- Corrosion of the tank floor
- Structural failure caused by settlement, weld fracture or metal fatigue, damage caused by interior structures such as internal columns
- Improper fabrication or welding

Releases from the tank shell or tank fittings typically involve a defect or a minor failure in the tank shell or in a tank appurtenance. Examples of defects include a cracked pipe or fitting on an external gauge tube or a crack in a tank valve or manhole gasket failure. The in-service inspection requirements stipulated in API STD 653 and routine exterior tank inspections are effective means for preventing and detecting these types of releases.

Rapid Shell Failure Rapid tank shell failures may occur when:

- A tank is over-pressurized during filling
- Service (or use) of the tank is changed without ensuring that the tank is designed to accommodate the new conditions (e.g., changing the product stored, its temperature, or specific gravity)
- Construction, alteration or reconstruction not performed in accordance with API standards
- Earthquakes, floods, tornadoes, hurricanes, or other *acts-of-God* take place

RELEASE PREVENTION

A release prevention program is an integrated system that may include: proper equipment design, construction, operator training, operating procedures, periodic maintenance, periodic inspection, and management controls or practices. Such a program does not necessarily rely exclusively on the use of prevention measures, but also may employ release detection and environmental protection measures. Effective release prevention programs are designed to address site-specific risks.

The equipment and procedures used to maintain tank integrity form a Release Prevention System (RPS). The following standards and recommended practices cover internal inspections, lining the tank interior, installing cathodic protection and other facets of tank operation:

API Recommended Practice 575	*Inspection of Atmospheric and Low-Pressure Storage*
API Standard 620	*Design and Construction of Large, Welded, Low Pressure Storage Tanks*
API Standard 650	*Welded Steel Tanks for Oil Storage*
API Recommended Practice 651	*Cathodic Protection of Aboveground Storage Tanks*
API Recommended Practice 652	*Lining of Aboveground Petroleum Storage Tank Bottoms*
API Standard 653	*Tank Inspection, Repair, Alteration and Reconstruction*
API Standard 2610	*Design, Construction, Operation, Maintenance and Inspection of Terminal and Tank Facilities*
UL 142	*Steel Storage Tanks*

These documents provide a system for successfully operating and maintaining aboveground tanks and have been instrumental in fostering ongoing improvements in technologies associated with preventing and detecting tank releases.

API STD 653 provides specific inspection and testing requirements to ensure integrity of the tank. This standard includes information on inspector certification requirements. In-service and out-of-service tank inspections can be performed to detect potential problems.

Table 4-1 presents the different release scenarios and control measures associated with aboveground storage tanks, as well as the relative installation and operation-maintenance costs for each control measure. More detailed information on the individual control measures is presented in Table 4-2.

Table 4-1 Aboveground Storage Tank Release Scenarios[1]

Release Category	Cause	Control Measure Options	Type of Control Prevention Detection Protection	Control Measure Reference (see Table 2)	Retrofit Cost	O & M Cost
Overfill releases / Spill through tank vents	Human error	• Written operations procedures / schedule	P	5A	Low	Medium
		• Operator training	P	5A	Low	Medium
		• Overfill protection system alarms and instrumentation[2]	P	3B	Medium-High	Medium-High
		• Manual product level verification before & during receipt	P	3A	Low-Medium	Low-Medium
		• Automatic product level verification before & during receipt	P	3B	Medium-High	Medium-High
		• Tank farm secondary containment dike / berms	Pro	28	High	Low
		• Tank farm dike yard liners	Pro	29	Very High	Medium-High
	Equipment failure	• Planned and documented inspections in accordance with API STD 653	P	13A	N/A	Low
			P	13B	N/A	Medium
		• Automatic tank gauging system	D	21B	Medium	Medium
		• Manual product level verification before & during receipt	P	3A	Low-Medium	Low-Medium
		• Overfill protection system alarms and instrumentation[2]	P	3B	Medium- High	Medium-High
		• Programmed, preventative maintenance and testing	P	5B	Medium-High	Medium
		• Tank farm secondary containment dike / berms	Pro	28	High	Low
		• Tank farm dike yard liners	Pro	29	Very High	Medium-High
Slow Releases /Shell release	1. External corrosion 2. Corrosion under insulation 3. Internal corrosion	• External coating of steel tank	P	2B	Medium	Medium
		• Planned and documented inspections in accordance with API STD 653	P	13A	N/A	Low
			P	13B	N/A	Medium
		• Steel tank product side lining or coating	P	2A	Medium-High	Low-Medium
		• Routine walk around inspections	D	25	N/A	Low
		• Tank farm dike yard liners	Pro	29	Very High	Medium-High
		• Internal cathodic protection for internal corrosion	P	35	High	Low-Medium
	Weld crack	• Planned and document inspections in accordance with API STD 653	P	13A	N/A	Low
			P	13B	N/A	Medium
		• Routine walk around inspections	D	25	N/A	Low
		• Tank farm secondary containment dike / berms	Pro	28	High	Low

[1]Abbreviations used in this table are: N/A=Not Applicable, P=Prevention, D=Detection, P/D=provides Prevention and Detection, Pro=Protection Measure
[2]Cost effective control measure for new construction

Table 4-1 Aboveground Storage Tank Release Scenarios[1]

Release Category	Cause	Control Measure Options	Type of Control Prevention Detection Protection	Control Measure Reference (see Table 2)	Retrofit Cost	O & M Cost
Slow Releases /Bottom release	Top side corrosion	• Product side coating or lining	P	2A	Medium-High	Low-Medium
		• Planned and documented inspections in accordance with API STD 653	P	13A	N/A	Low
			P	13B	N/A	Medium
		• Non-destructive tank testing	P	7, 8,10-12	N/A	Low
			P	15	N/A	Low
		• Periodic precision tank testing	D	22	N/A	Low
			D	23	N/A	Low
		• Tank gauging system for inventory reconciliation	D	21A	Low-Medium	Low
		• Under tank monitor	D	20	High	Low
			D	24	High	Low
		• Groundwater monitoring wells	D	26	Medium-High	Low-Medium
		• Release prevention barrier in accordance with API STD 650	Pro/D	27A - 27C	Very High	Low
	Bottom side corrosion	• Cathodic protection system	P	1A & 1B	Medium-High	Low
		• Planned and documented inspections in accordance with API STD 653	P	13A	N/A	Low
			P	13B	N/A	Medium
		• Provide drainage for water away from tank	P	6	Low-Medium	Low
		• Non-destructive tank testing	P	7,8, 10-12	N/A	Low
		• Perform electronic floor scan	P	15	N/A	Low
		• Steel tank soil side coating or lining	P	2C	High	Low
		• Periodic precision tank testing	D	22	N/A	Low
			D	23	N/A	Low
		• Tank gauging system for inventory reconciliation	D	21A	Low-Medium	Low
		• Under tank monitor	D	20	High	Low
			D	24	High	Low
		• Groundwater monitoring wells	D	26	Medium-High	Low-Medium
		• Release prevention barrier in accordance with API STD 650	Pro/D	27A - 27C	Very High	Low

Table 4-1 Aboveground Storage Tank Release Scenarios[1]

Release Category	Cause	Control Measure Options	Type of Control Prevention Detection Protection	Control Measure Reference (see Table 2)	Retrofit Cost	O & M Cost
Slow Releases /Bottom release (continued)	Weld crack or Roof leg penetration	• Planned and documented inspections in accordance with API STD 653	P	13A	N/A	Low
		• Non-destructive tank testing	P	13B	N/A	Medium
			P	7,8,10-12,	N/A	Low
		• Steel striker plates installed under the roof legs	P	15	N/A	Low
		• Keep floating roof legs off bottom except during maintenance	P	9A	Low	Low
		• Vacuum box test of tank bottom welds	P	9B	Low	Low
		• Periodic precision tank testing	P/D	19	N/A	Medium
			D	22	N/A	Low
		• Tank gauging system for inventory reconciliation	D	23	N/A	Low
		• Soil vapor monitoring	D	21A	Low-Medium	Low
		• Groundwater monitoring wells	D	24	High	Low
		• Under tank monitor	D	26	Medium-High	Low-Medium
		• Release prevention barrier in accordance with API STD 650	D	20	High	Low
			Pro/D	27A - 27C	Very High	Low
	Tank settlement/ Foundation failure	• Planned and documented inspections in accordance with API STD 653	P	13A	N/A	Low
			P	13B	N/A	Medium
		• Periodic precision tank testing	D	22	N/A	Low
			D	23	N/A	Low
		• Tank gauging system for inventory reconciliation	D	21A	Low-Medium	Low
		• Under tank monitor	D	20	High	Low
			D	24	High	Low
		• Groundwater monitoring wells	D	26	Medium-High	Low-Medium
		• Release prevention barrier in accordance with API STD 650	Pro/D	27A - 27C	Very High	Low
Slow Releases /Tank fitting release from small diameter typically threaded or socket welded	Corrosion	• Planned and documented inspections in accordance with API STD 653	P	13A	N/A	Low
			P	13B	N/A	Medium
		• Routine walk around inspections	P/D	25	N/A	Low

Table 4-1 Aboveground Storage Tank Release Scenarios[1]

Release Category	Cause	Control Measure Options	Type of Control Prevention Detection Protection	Control Measure Reference (see Table 2)	Retrofit Cost	O & M Cost
Slow Releases /Tank fitting release from small diameter typically threaded or socket welded (continued)	Stress / metal fatigue and mechanical failure	• Design considerations, use of extra heavy pipe & fittings • Planned and documented inspections in accordance with API STD 653 • Routine walk around inspections	P P P P/D	14 13A 13B 25	Low N/A N/A N/A	Low Low Medium Low
	Operator error	• Operator training • Written operating procedures • Routine walk around inspections	P P D	5A 5A 25	Low Low N/A	Medium Medium Low
	Water draw off system release	• Operator training • Planned and documented inspections in accordance with API STD 653 • Routine walk-around inspections • Locked valves • Use of anti-freeze water drain valves • Written operating procedures	P P P D P Pro P	5A 13A 13B 25 17A 31 5A	Low N/A N/A N/A Low Low Low	Medium Low Medium Low Low Low Medium
	External floating roof drain	• Operator training • Planned & documented inspections in accordance with API STD 653 • Roof Inspections • Installation of fixed roof • Upgrade drain system	P P P/D P P	5A 13A 32 33 34	Low N/A N/A High Medium-High	Medium Low Low Low Low
	Vandalism	• Routine walk around inspections • Locked valves • Perimeter security fence • Lighting • Security cameras • Staffing surveillance	D P P P P P	25 17A 17B 17C 17D 17E	N/A Low Medium Medium Medium N/A	Low Low Low Low-Medium Medium-High High

Table 4-1 Aboveground Storage Tank Release Scenarios[1]

Release Category	Cause	Control Measure Options	Type of Control Prevention Detection Protection	Control Measure Reference (see Table 2)	Retrofit Cost	O & M Cost
Rapid shell failure	Collapse by vacuum / Tank fails inward	• Operator training	P	5A	Low	Medium
		• Control of delivery / suction	P	4C	Low	Medium
		• Written maintenance procedures	P	5A	Low	Medium
		• Vent tank in accordance with API RP 2000	P	4B	Low-Medium	Low
		• Pressure / vacuum vent design and maintenance	P	4A	Medium	Low
		• Tank farm secondary containment dike / berms	Pro	28	High	Low
		• Tank farm dike yard liners	Pro	29	Very High	Medium-High
	Tank settlement / Foundation failure	• Planned and documented inspections in accordance with API STD 653	P	13A	N/A	Low
			P	13B	N/A	Medium
			P	13C	Medium	Low
		• Secondary containment dike/ berms	Pro	28	High	Low
		• Dike yard liners	Pro	29	Very High	Medium-High
	Brittle shell failure	• Repairs, material selection, reconstruction and inspection in accordance with API STD 653	P	13B	N/A	Medium
			P	13C	Medium	Low
		• Hydrostatic test	P/D	18	N/A	Low-Medium
		• Tank farm secondary containment dike/ berms	Pro	28	High	Low
		• Tank farm dike yard liners	Pro	29	Very High	Medium-High
	Tank over pressurization	• Pressure / vacuum vent design and maintenance	P	4A	Medium	Low
		• Vent tank in accordance with API RP 2000 and API Std 650	P	4B	Low-Medium	Low
		• Planned and documented inspections in accordance with API STD 653	P	13A	N/A	Low
			P	13B	N/A	Medium
		• Tank farm secondary containment dike / berms	Pro	28	High	Low
		• Tank farm dike yard liners	Pro	29	Very High	Medium-High
	Earthquake / Weather related failures	• Planned and documented inspections in accordance with API STD 653	P	13A	N/A	Low
			P	13B	N/A	Medium
		• Emergency preparedness plans	Pro	16	Low	Low
		• Secondary containment dike	Pro	28	High	Low
		• Use of anchors, annular plates and other restraints	P	30	High	Low
		• Dike yard liners	Pro	29	Very High	Medium-High

Table 4-2 Aboveground Storage Tank Control Measures

Item	Control Measure / Type	Reference	Advantages	Disadvantages	Operation & Maintenance Comments
1A	Impressed Current Cathodic protection of Tank Bottom **(Prevention)**	API RP 651	• Provides protection of bare steel or coated steel on or in soil • Easily checked for proper function • Increases tank bottom life • Provides protection over a wide range of soil conditions • Able to provide protection to groups of tanks	• Requires a current source • Effectiveness can be compromised by hydrocarbon contamination, soil conditions, stray currents	• Maintain power supply; record rectifier readings periodically • Periodically measure soil potentials • Perform annual survey and evaluation • To ensure proper performance potential must be checked under the tank
1B	Galvanic Cathodic protection of Tank Bottom **(Prevention)**	API RP 651	• Provides protection of bare steel or coated steel on or in soil • Easily checked for proper function • Increases tank bottom life • Electrical power not required	• Effectiveness limited to soils of high resistivity • Effectiveness can be compromised by hydrocarbon contamination • Applicable to relatively small tanks	• Periodically measure soil potentials • Perform annual survey and evaluation • To ensure proper performance potential must be checked under the tank
2A	Steel tank product side coating or lining **(Prevention)**	API RP 652	• Protects the steel bottom product side • Provides a corrosion resistant barrier • Provides additional protection for welded seams • Reinforced coatings provide additional support for tank base, allowing for lower minimum remaining thickness (MRT) of floor	• Special preparation, installation & curing required • Must be compatible with product and temperature stored • Rigorous inspection of coating application required • Limits inspection of both surfaces	• Coating / lining should be visual inspected when tank is taken out of service • Coating / lining should have low voltage holiday test performed after major tank repair or alteration • Rigorous inspection during installation • Not suitable for all tanks • Reinforced coating may limit floor scanning and ultrasonic test results • Appropriate voltage must be used for holiday test • Refer to API STD 652 for thick & thin film discussion
2B	External coating of steel tank shell **(Prevention)**	SSPC Surface Prepar-ation	• Protects the steel tank shell • Provides a corrosion resistant barrier • Provides additional protection of riveted seams	• Special preparation, installation & curing required • Rigorous inspection & QA/QC of coating required	• Coating should be periodically inspected

Table 4-2 Aboveground Storage Tank Control Measures

Item	Control Measure / Type	Reference	Advantages	Disadvantages	Operation & Maintenance Comments
2C	Steel tank soil side coating or lining **(Prevention)**	SSPC Surface Preparation	• Protects the steel floor soil side • Provides a corrosion resistant barrier • Does not require separate cathodic protection system for protection of steel bottom	• Extremely difficult, if not impossible to retrofit an existing tank bottom • Special preparation, installation & curing required • Rigorous inspection & QA/QC of coating required	• None
3A	Manual product level verification before & during receipt **(Prevention)**	API RP 2350	• Aids in the prevention of tank overfills by establishing procedures to gauge the tank prior to and during a receipt • Provides accurate and reliable information that the receipt is properly set up and capable of taking product volume	• System may create a false sense of security • Tank must be properly calibrated • Requires operator training and oversight	• Check tank strapping charts for product volume • Establish tank safe fill heights • Confirm receipt volume, receiving tank and receiving tank capacity
3B	Instrumented overfill prevention system[2] **(Prevention)**	API RP 2350	• Aids in the prevention of tank overfills by alarming or automatically stopping or diverting a receipt • Provides accurate and reliable safety system for overfill prevention • System complexity, cost and configuration can be tailored to the specific operational needs	• System may create a false sense of security • System has to be periodically and properly calibrated • System calibration / maintenance can inadvertently disable protection • Requires a power backup or a fail safe operation in the event of power loss	• System operation should be checked periodically • System probes should be inspected and calibrated in accordance with vendor requirements • May involve phone line communications and backup systems
4A	Pressure vacuum vent **(Prevention)**	API STD 2000	• Regulates the tank venting during receipt and delivery • Decreases vapor losses • Prevents tank over pressurization or vacuum failure	• Limits the rate of delivery or suction • Requires routine inspection and maintenance to ensure proper operation • Vent pressure and vacuum setting must be set very low to ensure proper performance	• Perform routine inspection of vent to clear debris, corrosion, etc. from clogging vent • Must regulate delivery or suction within the relief vent design parameters • Vent pressure and relief set pressure must be set
4B	Vent tank in accordance with API RP 2000 **(Prevention)**	API STD 2000	• Regulates the tank venting during receipt and delivery • Prevents tank over pressurization or vacuum failure	• Limits the rate of delivery or suction • Requires routine inspection to ensure un-obstructed operation	• Perform routine inspection of vent to clear debris, corrosion, etc. from clogging vent • Must regulate delivery or suction within the relief vent design parameters

Table 4-2 Aboveground Storage Tank Control Measures

Item	Control Measure / Type	Reference	Advantages	Disadvantages	Operation & Maintenance Comments
4C	Control of delivery / suction **(Prevention)**		• Ensures tank fill / delivery rate does not exceed the tank vent design capacity		• Operating personnel to review offloading rates and vent capacity prior to receipt
5A	Operator training/ written operating procedures **(Prevention)**		See Item #1 and 4 of Table 8-2		
5B	Programmed, preventative maintenance and testing **(Prevention)**		See Item #8 of Table 8-2		
6	Provide drainage for water away from the tank **(Prevention)**	API STD 2610	• Prevents storm water from accumulating or collecting under the tank shell and chime area • Improves CP performance if under tank side is not repeatedly saturated • Minimizes corrosion with in the first 3' of the tank chime area • Improves tank settlement behavior	• Difficult to retrofit drainage on existing tanks if the tank has settled or if the tank bottom is at same elevation as the dike yard	• Operating personnel must review tank drainage • Re-direct drainage away from the tanks

Table 4-2 Aboveground Storage Tank Control Measures

Item	Control Measure / Type	Reference	Advantages	Disadvantages	Operation & Maintenance Comments
7	Tank bottom point ultrasonic test **(Prevention)**	API STD 653 API RP 575	• Detects potential defects or deficiencies in the tank bottom • Equipment easily accessible • Provides quick & accurate results • Non-destructive test • Data can be used to determine corrosion rates and time to next internal inspection	• Some linings prevent use or skew results • Provides limited sample of tank shell or bottom • The tank must be taken out of service • Measurement locations must be clean	• Operator must be properly trained in the specific instrument use and calibration • Instrument must be calibrated prior to use • Location of points measured must be recorded • Floor has to be cleaned at point of sampling • Used to best advantage in combination with other technologies
8	Automated ultrasonic thickness test **(Prevention)**	AP IRP 575	• Detects potential defects or deficiencies in the tank bottom • Provides a detailed profile of tank bottom condition • Allows for a relatively quick check of steel bottom condition • Non-destructive test which samples over 90% of the bottom • Data can be used to determine corrosion rates and time to next internal inspection	• Some linings prevent use or skew results • Tank must be taken out of service • Requires special equipment & training • Not suitable for all tank bottoms • Access and internal appurtenances will limit inspection • Measurement locations must be clean • Procedure is slow	• Operator must be properly trained in the specific instrument use and calibration • Instrument must be calibrated prior to use • Location of points measured must be recorded • Floor condition must be smooth **and** clean
9A	Steel striker plates installed under the roof legs **(Prevention)**	API STD 650	• Prevents damage to floor plate from repeated roof leg landings	• Difficult to retrofit, requires tank to be emptied, cleaned and certified gas free • If floor is coated, the coating has to be removed prior to installing plate and repaired after plate installation	• Install plates in accordance with API STD 650 • Inspect plates during normal internal tank inspection
9B	Keep floating roof legs off bottom except during maintenance **(Prevention)**		• Prevents damage to floor plate from repeated roof leg landings • Prevents inaccurate inventory readings due to loss of roof buoyancy • On liquid mounted roofs and seals, eliminates the risk associated with having a vapor space between product and roof.	• Facility operations and roof leg configuration may make it difficult to avoid roof leg landings • Reduces the maximum working capacity of the tank	• Maintain product level in tank above the lowest roof leg height

Table 4-2 Aboveground Storage Tank Control Measures

Item	Control Measure / Type	Reference	Advantages	Disadvantages	Operation & Maintenance Comments
10	Magnetic particle test **(Prevention)**	API STD 653	• Detects potential defects or deficiencies in the tank welds • Equipment & personnel readily available • Provides accurate results • Non-destructive test	• Tank must be taken out of service • Provides only a snapshot view of the tank condition • Does not test welds in loaded condition • Will only detect near surface defects	• Operator must be properly trained in the method • Location of defects must be marked
11	Dye penetrant test **(Prevention)**	API STD 653	• Detects potential defects or deficiencies in the tank welds • Equipment & personnel readily available • Non-destructive test	• Tank must be taken out of service • Does not test welds in loaded condition • Will only detect surface defects	• Operator must be properly trained in the method • Location of defects must be marked
12	Air pressure test on reinforcing & patch plates **(Prevention)**	API STD 653 API RP 575	• Detects potential defects or deficiencies in the seal weld • Equipment & personnel readily available • Non-destructive test	• Provides only a snapshot view of the tank condition • Does not test welds in loaded condition	• Operator must be properly trained in the method • Location of defects must be marked
13A	Planned & documented external inspection **(Prevention)**	API STD 653 API RP 575	• Provides assessment for continued service • Allows detection, prediction and correction of potential deficiencies not detected by operators • Provides database on various system performance which can be used to improve design, construction or maintenance	• Does not address potential internal problems	• Establish checklist forms and procedures for performing inspections • Inspector certification required

Table 4-2 Aboveground Storage Tank Control Measures

Item	Control Measure / Type	Reference	Advantages	Disadvantages	Operation & Maintenance Comments
13B	Planned & documented internal inspections **(Prevention)**	API STD 653 API RP 575	• Allows for internal inspection of steel, pitting, corrosion, sump, coating, areas of excessive wear, bottom welds, inspection of bottom, tank roof, columns, and measurements of bottom settlement • Provides assessment for continued service • Allows detection or correction of potential internal deficiencies • Data can be used to determine corrosion rates and time to next internal inspection • Inspection data can be used to schedule tank maintenance and repair • Provides database on various system performance which can be used to prioritize inspections of other tanks	• OSHA Confined space entry / and other personnel health and safety issues must be addressed • Tank sludge characterization, treatment or disposal issues • Air emission processing issues (in certain parts of the USA) • Tank availability and time out of service must be addressed	• Establish checklist forms and procedures for performing inspections • Have a contingency plan for tank if it becomes unavailable for an extended period of time • Inspector certification required
13C	Reconstructed Tank requirements **(Prevention)**	API STD 653	• Provides detailed requirements for reconstruction of existing storage tanks • Ensures consistent approach within industry for reconstructing tanks • Provides information on specific analysis and evaluations to be performed to maintain tank integrity	• Requires expertise to evaluate reconstruction requirements for the tank	• Follow requirements stipulated in API STD 653 • Requires personnel knowledgeable in reconstruction requirements
14	Design consideration/ use of extra heavy pipe and fittings **(Prevention)**	API STD 650	• Provides additional material to deter failure of shell piping appurtenances • Very economical on replacement items • Very easy to perform during internal inspections, replacements or retrofits	• Still susceptible to corrosion failure • Additional engineering may be required to assess weight suitability	• Install extra heavy pipe and fittings where facility management deems appropriate

Table 4-2 Aboveground Storage Tank Control Measures

Item	Control Measure / Type	Reference	Advantages	Disadvantages	Operation & Maintenance Comments
15	Use of electronic tank bottom floor scans **(Prevention)**	API STD 653 API RP 575	• Provides detailed coverage of most of the tank bottom • Can be performed reasonably quickly • Can detect areas of pitting or areas of accelerated corrosion • Non-destructive test	• Critical areas such as sumps, welds, bottom to shell joints and areas under tank columns are usually not addressed • Very dense corrosion may go undetected • Requires specialized equipment and trained personnel • Not suitable for all tank bottoms • Top side pitting and scale may prevent use • Thick coating liners may affect use • Very localized metal loss may go undetected • Method is only semi-quantitative; ultrasonic prove-up typically required	• Operator must be properly trained in the specific instrument use and calibration • Instrument must be calibrated prior to use • Location of areas of concern must be marked and recorded
16	Emergency preparedness plans **(Protection)**		• Provides a detailed plan for emergency conditions • Can minimize the effects of a release	• Requires coordinated implementation to be successful	• Use personnel familiar with local conditions in plan preparation • Periodically review and update plan • Periodically train local staff
17A	Facility Security - Locked tank water draw off valves and other tank valves **(Prevention)**	API STD 2610	• Discourages vandalism • Prevents inadvertent opening of valves	• Determined vandals can get around • Locks may corrode and require cutting to be removed • Cumbersome to use on valves that are routinely accessed	• Periodically inspect lock integrity • Train staff in proper monitoring
17B	Facility Security - Perimeter security fence **(Prevention)**	API STD 2610	• Discourages vandalism • Limits unauthorized access into tank farm or other areas	• Determined vandals can circumvent • Site layout and space restrictions may make fence difficult to install or ineffective	• Periodically inspect fence integrity • Train staff in proper monitoring

Table 4-2 Aboveground Storage Tank Control Measures

Item	Control Measure / Type	Reference	Advantages	Disadvantages	Operation & Maintenance Comments
17C	Facility Security - Tank farm lighting **(Prevention)**	API STD 2610 NFPA-70	• Provides area lighting to make detection of a release easier at night • Discourages vandalism • Provides adequate lighting for operations personnel performing loading, unloading and transfer operations thus minimizing the chance for a release	• Lighting should be located at all key transfer areas and around tank area, requiring significant commitment of resources • Issues of power availability, lighting pole locations, electrical area classifications must be addressed • Does not provide a large benefit for very remote, low volume operations which do not have night time activities	• Lighting design, layout and type should be performed by an experienced engineer • Lighting can be programmed to go on automatically • Periodically inspect fixtures for burned out bulbs
17D	Facility Security - Security cameras **(Prevention)**	API STD 2610	• Provides surveillance monitoring of remote areas • Decreases the frequency of the need for personnel to routinely check areas covered by cameras • Intent of using cameras is to detect very unusual conditions and discourage vandalism	• Often difficult and costly to install in remote areas of the facility • Provides only a partial picture or visual of areas • Determined vandals can get around • Requires staff to monitor TV screens	• Cameras should be positioned in critical areas of terminal such that the widest area of coverage is provided • Train staff to monitor camera location and to respond to releases or vandals
17E	Facility Security - Staffed facilities **(Prevention)**	API STD 2610	• Provides on-site personnel to monitor terminal • Provides on-site personnel to immediately respond to a release	• Costly to maintain • Requires personnel to be trained to respond to emergency • A release or act of vandalism may still go initially undetected	• Provide proper training in security and release response
18	Hydrostatic test of tank **(Prevention / Detection)**	API STD 650 API STD 653 API RP 575	• Provides a safety factor for products with specific gravity less than 1.0 • Demonstrates capability of tanks to hold the liquid weight for products with a specific gravity less than 1.0 • May induce stress in the tank shell and floor which can reveal defective construction prior to returning the tank to service • Decreases susceptibility to brittle fracture failure	• Handling, treatment and disposal of test water must comply with local requirements • Tank may need to be cleaned before and after testing • Sufficient water may not be available • Is not usually considered as a leak test • May be difficult to do in freezing temperatures	• Water supply and water quality must be ensured • Test water disposal must be arranged • Test duration must be performed in accordance with API Standards • Tank may require cleaning afterwards

Table 4-2 Aboveground Storage Tank Control Measures

Item	Control Measure / Type	Reference	Advantages	Disadvantages	Operation & Maintenance Comments
19	Vacuum box test of tank bottom welds **(Prevention / Detection)**	API STD 650 API STD 653 API RP 575	• Detects leaks in the tank welds or pitted areas by drawing a vacuum through a thin soap film • Equipment and personnel readily available • Provides accurate and reliable results • Easy method to perform • Non-destructive test	• Tank must be taken out of service • Time consuming • Non-leaking weld defects will not be found • Does not test welds in loaded condition • Does not detect all defective welds	• Operator must be properly trained in the method • Equipment must be designed for the specific use including viewing window and soft perimeter gasket • Location of defective points must be recorded • Operator must be diligent to ensure proper seal and proper coverage of all bottom welds or pitted areas
20	Under tank leak monitor using tell-tale pipe system **(Detection)**	API STD 650	• Uses tell-tale pipe to detect product release • Provides a means of detecting product release • Passive systems are inexpensive to install on new tanks • System design often incorporated into tank RPB or RPS design (see item 23A & 23B)	• May not detect a release • Site soil and groundwater conditions may effect system reliability • Tell-tale or monitor may provide a pathway for a release to go under the tank • No practical mechanism to confirm integrity of tell-tale pipe system	• Passive (tell-tale pipe) systems must be checked periodically
21A	Tank gauging system for inventory reconciliation **(Detection)**	API Publ 334	• Provides a method for detecting losses through a tank bottom • May facilitate tank inventory reconciliation • Provides periodic data without service disruption	• Accurate calibration and tank strapping required • Small volume releases may go undetected • Tank temperature changes may affect accuracy of results	• Operator must keep accurate records of receipt, volume stored, volume shipped and shrinkage volume in order to get accurate results • Manual gauges require periodic maintenance
21B	Automatic tank gauging system as backup system for overfill prevention **(Detection)**		• Provides redundant backup to overfill alarm system • Provides fast product measurement readings • Can be programmed to alarm separately • Can be interlocked to other control systems	• Accurate calibration and tank strapping required • Product measurement and annunciation must be at a location where an operator can respond • Sensor reliability varies widely • May require specialized maintenance	• Inspect and test sensors in accordance with vendor requirements • Training must be provided on how to respond to conflicting alarms (e.g. hi-level alarm does not annunciate but tank gauging system does alarm)

Table 4-2 Aboveground Storage Tank Control Measures

Item	Control Measure / Type	Reference	Advantages	Disadvantages	Operation & Maintenance Comments
22	Acoustic Leak Detection **(Detection)**	API Publ 334	• Setup and implementation readily achievable • Short test time • Minimal impact on operations • In-service test	• Limited acceptance • Requires close spacing of transducers • Sludge and water layers may affect accuracy of results • Test often performed at night because of background noise • Cannot have saturated soil under the tank • Leak simulation difficult • Detection threshold difficult to establish and is subject to technician interpretation • Specialized equipment and personnel required	• Test performance, isolation, standby and tank operation will have to be modified to perform the test • Requires specialized testing equipment • Operators must be specially trained
23	Mass / Volumetric Leak Detection **(Detection)**	API Publ 334	• Tank can be equipped with equipment permanently installed • Detection threshold can be determined • Suitable for periodic monitoring • In-service test	• Tank must be out of service for 0.5 to 4 days • Specialized equipment and personnel required	• Testing on a periodic basis • Contingency plan needed for tank out-of-service time • Typically requires blinding of valves • Requires specialized testing equipment • Operators must be specially trained
24	Under tank Soil Vapor/Liquid Monitoring **(Detection)**	API Publ 334	• Detects petroleum vapors in the vadose zone • Detects tracer or hydrocarbon vapor in the vadose zone • Some methods also have capability to detect dissolved liquid hydrocarbon/water • May compensate for some existing contamination • Methods using an added chemical marker have high detection sensitivity and low probability of false alarm • Various technologies can provide intermittent or continuous monitoring	• Limited by the site conditions; soil, backfill, water table • Release detection may be delayed • Background contamination may affect results for hydrocarbon detection systems	• Monitors must be inspected and calibrated in accordance with vendor requirements • Systems typically annunciate locally or remotely • System maintenance and analysis typically performed by manufacturer

Table 4-2 Aboveground Storage Tank Control Measures

Item	Control Measure / Type	Reference	Advantages	Disadvantages	Operation & Maintenance Comments
25	Routine walk around inspections **(Detection)**	API STD 653 API RP 575	• Slow or small releases may be readily detected and repaired • Potential problem areas can be detected and corrected prior to a release occurring • Provides positive proof of no visible releases • Local operator familiar with facility	• Time period between release and detection is dependent upon frequency of inspections • Relies upon human factors for detection	• Operator walks the tank farm area and all loading / unloading areas observing key equipment and all tanks for possible leaks
26	Groundwater monitoring wells **(Detection)**	Ground-water & Wells by Johnson	• Detects separate or dissolved phase product • Provides information on groundwater elevation, direction, background levels and quality	• Wells within the containment area may provide a leak path in the event of a release • Accuracy of information is limited by the site conditions, spacing, screened interval and groundwater elevation • Detection of a release will vary with soil conditions • Background levels may affect results • Not necessarily tank specific • Groundwater flow patterns and rain may complicate definitive detection	• Perform periodic monitoring of wells • Minimal maintenance required
27A	Release prevention barrier (i.e. steel bottom with under tank liner) **(Protection/ Detection)**	API STD 650	• Provides a barrier against a release to the subsurface • Allows the designer flexibility in design of the system • Provides secondary containment of tank bottom • Provides rapid detection of a release	• Very costly to retrofit • May cause leaks to develop in riveted or older welded steel tanks • For existing tanks - the tank will have to be taken out of service for long periods of time and will require substantial system modification • RPB can not be inspected practically • May complicate proper installation & effectiveness of cathodic protection • May trap moisture and cause accelerated corrosion of original steel bottom • Difficult to find and repair a leak	• Operation and maintenance varies by system • Periodically check leak detection tell-tale pipes

Table 4-2 Aboveground Storage Tank Control Measures

Item	Control Measure / Type	Reference	Advantages	Disadvantages	Operation & Maintenance Comments
27B	Release prevention barrier (i.e. Double steel bottom) **(Protection/Detection)**	API STD 650	• Provides a barrier for releases into the soil or groundwater from the tank • Provides a means of installing a new steel bottom • Provides detection / collection system of leaked product	• Very costly to retrofit • Requires cutting the shell of the tank • May cause leaks to develop in riveted or older welded steel tanks • Tank out of service for long period of time • Potential accelerated corrosion of new bottom if not properly protected • Lower bottom cannot be inspected or repaired • Cathodic protection for both bottoms may not be possible • Difficult to replace anodes in the future	• Periodically inspect the chime area, tell-tale pipes and cathodic protection system • Check the new bottom plate when the tank is out of service
27C	Release prevention barrier (i.e. un-bonded fiberglass sheet overlay on existing steel plate bottom) **(Protection/Detection)**	API STD 650	• Provides a barrier for releases into the soil or groundwater from under the tank • Can include a detection / collection system for product leaked past the sheet overlay • New fiberglass liner is applied over old steel bottom • Interstitial space is sealed	• Primary bottom can not be inspected • Integrity of old bottom will be difficult to monitor • Limited industry experience • Long term toughness and material durability is not known	• Very little industry experience with maintenance requirements • Monitor vacuum pressure
28	Tank farm secondary containment dike/berm **(Protection)**	NFPA 30	• Provides protection & containment of tanks from a catastrophic releases • Protects adjacent structures or tanks in the event of a fire	• Limits access to tanks • Space restrictions may make containment difficult • Penetrations or drainage system may provide a leak path • Storm water handling must be addressed • Product height limits effectiveness • Water accumulation can cause an empty tank to float	• Containment structure must be periodically inspected and necessary repairs made • Drainage is made through normally closed valves • Drainage is performed after inspection of accumulated water

Table 4-2 Aboveground Storage Tank Control Measures

Item	Control Measure / Type	Reference	Advantages	Disadvantages	Operation & Maintenance Comments
29	Dike yard liners - concrete - soil improvement - geo-composite, - geo-synthetic - other flexible membrane liners **(Protection)**	API Publ 315 & API Publ 328	• Reduces the permeability of the tank farm secondary containment • For very permeable tank farms, may aid in the recovery or clean up of a spill • Aids in the protection of groundwater and surface water outside of the tank containment area	• Difficult to reliably seal penetrations and seams • Subject to long-term deterioration • Requires special modifications for roadways / access into the containment • Difficult to install on steep slopes • Difficult to retrofit existing tank farms • Requires special handling of surface water • Inspection difficult • Integrity difficult to confirm	• Liner system specific maintenance required • Operating procedures and water management will require changes • Periodically liner should visually be inspected and deficiencies corrected • Access should be restricted within tank farm to roadways or walkways
30	Use of anchors, annular plates and other restraints **(Prevention)**	API STD 650	• Provides additional support for tank during extreme loading conditions caused by flood, earthquake, etc. • Provides a passive engineered solution to prevent releases	• Costly and difficult to retrofit • Must be designed by persons knowledgeable in tanks and the anticipated loading condition	• Periodically inspect during in-service and out-of-service tank inspections
31	Use of anti-freeze water drain valves **(Prevention)**		• Prevents freeze up and possible frost damage to AST water draw-off valves in cold weather service	• Difficult to retrofit	• Periodically inspect and operate valve during in-service and out-of-service tank inspections
32	Periodic roof inspections **(Prevention/ Detection)**	API STD 650	• Prevents a release from the water draw-off by detecting product on the roof during or after a rain event. Product on the roof can be indicative of a leak or defect in the components connecting the roof to the water draw-off	• Defects may not result in ponding of product on the roof and thus, inspections may not detect defects in the components connecting the roof to the water draw-off	• Perform periodic in-service inspection of the surface of the external floating roof

Table 4-2 Aboveground Storage Tank Control Measures

Item	Control Measure / Type	Reference	Advantages	Disadvantages	Operation & Maintenance Comments
33	Installation of fixed roof **(Prevention)**	API STD 650	• Eliminates the need to drain accumulated water from the floating roof by providing a fixed roof over the tank, thereby preventing the release of product from a floating roof drain valve	• Costly and difficult to retrofit • Must be designed by persons knowledgeable in tanks and the anticipated loading conditions including snow load	• Periodically inspect integrity of fixed roof during in-service and out-of-service tank inspections
34	Upgrade drain system **(Prevention)**	API STD 650	• Prevents releases by providing an improved and more durable system that connects the floating roof to the water draw-off	• Costly and difficult to retrofit; requires the tank to be taken out of service • Does not ensure that a release will not occur; still subject to breakdown	• Periodically inspect during out-of-service tank inspections
35	Internal cathodic protection for internal corrosion **(Prevention)**		• Prevents internal corrosion of steel bottom via installation of cathodic protection system that protects the product side	• Costly and difficult to retrofit • Suitable for heavy products, such as asphalt and residual oils • Must be designed by persons knowledgeable and experienced in cathodic protection system design	• Periodically inspect cathodic protection test station

Section 5

PIPING SYSTEMS

INTRODUCTION

This section addresses the potential causes of releases and available control measures for facility piping. The measures listed in this section address steel piping systems used to transport petroleum products built in accordance with ASME B31.4 or ASME B31.3 standards.[1] Gravity-flow piping systems, not intended to convey petroleum products, are also covered in this section. Gravity-flow piping has various configurations and may be built to a variety of standards.

The piping systems covered in this section include:

- Pipe
- Pumps, meters
- Valves
- Other piping appurtenances
- Fittings, flanges, and gaskets

OVERVIEW

Pressurized Piping Systems

Pressurized steel piping is the primary means of conveying liquid petroleum to and from storage tanks. Although most piping used to transport petroleum and petroleum products is pressurized by a pump, some piping is pressurized by the hydrostatic head from elevated tanks. Pressurized piping may be used aboveground or below ground:

- Aboveground piping systems are typically single-walled, appropriately supported, and externally coated or wrapped. Such piping systems are typically welded and flanged.

- Underground pipe is typically single-walled, butt-welded. It may also be externally coated or wrapped and cathodically protected. The use of flanges is usually minimized in new underground piping.

[1] Additional codes and standards may apply to marine piping systems.

Gravity-Flow Piping Systems

Underground gravity-flow piping is used at facilities for several different purposes: storm water drainage, spill containment area drainage, process sewer and tank water draw-offs, effluent wastewater drainage or line drainage.

Gravity-flow piping systems are not commonly used at aboveground tank facilities as a primary means of conveying petroleum products. Such systems are occasionally used to transport petroleum from proving meter vessels, tanker truck or rail tank cars, to temporary storage below ground. However, gravity-flow piping used to convey petroleum products is typically built to pressurized piping standards.

Pipe integrity and joint integrity is critical for gravity-flow piping systems conveying water that may have been in contact with petroleum or petroleum products. Such piping systems are made of a range of materials and have varying configurations. Material selection and piping layout are based on the use of the system and the facility. Typical materials and welding methods used for gravity-flow piping systems are:

MATERIAL	TYPE OF JOINT
Welded Steel Pipe (large diameter > 2")	Welded or flanged
Welded Steel Pipe (small diameter < 2")	Threaded or socket welded
Cast Iron Pipe (CIP) Precast Concrete Pipe (PCP) Vitrified Clay Pipe (VCP)	Coupling (with an elastomeric material located between the bell and spigot ends)
Ductile Iron Pipe (DIP)	Coupling or flanged connections
Polyvinyl Chloride (PVC) Pipe	Coupling, flanged connections, or solvent welded
Corrugated Metal Pipe (CMP) (typically used only for clean storm water)	Galvanized Collars
High Density Polyethylene (HDPE)	Coupling, flanged connections, or fusion welded
Fiber Reinforced Plastic Pipe (FRP)	Coupling or resin fusion

RELEASE SCENARIOS

Liquid releases from piping at aboveground storage tank facilities can be grouped into the following broad categories:

1. Underground pressurized piping releases
   - Corrosion (internal and external)
   - Pipe shear, compression or tensile failure
   - Flange or fitting failure
   - Mechanical damage from excavation
2. Underground gravity-flow piping releases
   - Corrosion (internal and external)
   - Pipe joint leak (settlement or gasket failure)
   - Mechanical damage from excavation
3. Aboveground piping releases
   - Corrosion (internal and external)
   - Pipe failure
   - Flange or fitting failure
   - Pipe or support settlement / failure
   - Pressure relief system
   - Mechanical damage (e.g., impact damage)
4. Operator Error
5. Environmental Factors (e.g., floods, hurricanes, earthquakes)

RELEASE PREVENTION

Proper design, corrosion protection and periodic inspection are the key elements in preventing piping system releases. API STD 2610, *Design, Construction, Operation, Maintenance, and Inspection of Terminal and Tank Facilities* addresses release prevention for aboveground tank facilities. API 570, *Piping Inspection Code: Inspection, Repair, Alteration and Rerating of In-Service Piping Systems*, provides guidance for inspection of process piping systems. Although this document was developed for the refining and chemical process sectors, portions of it may be

applicable to other aboveground tank facilities and may be helpful in developing a piping release prevention program. Similarly, Recommended Practice 574, *Inspection of Piping, Tubing, Valves, and Fittings*, a companion to API 570, was also written for the refining and chemical process sectors.

The following concepts and control measures can be used to form a release prevention program for piping systems:

- Design system in accordance with appropriate standards such as ASME B31.3 or ASME B31.4;
- Provide adequate pressure relief;
- Coat exterior pipe and maintain coating;
- Evaluate the use of cathodic protection for underground piping per API 570;
- Establish an inspection program that utilizes the appropriate concepts outlined in API STD 2610, *Design, Construction, Operation, Maintenance, and Inspection of Terminal and Tank Facilities* and/or API 570, *Piping Inspection Code*, or implement a programmed, preventive maintenance plan, that includes flanged connections or other mechanical systems connected to the pipe (e.g., valve stems, pump seals, air eliminators, etc.); and
- Protect piping from potential collision or impact, and monitor contractors working on or near buried piping systems.

These methods focus on preventing piping releases. Leak detection systems or pressure testing methods vary in cost, provide only a snapshot view of the system integrity, and are not predictive for preventing future releases; however, they may provide some benefit when properly integrated with other inspection programs.

Double-walled piping has been accepted for use in retail service station systems; however, there are significant differences between retail service stations and aboveground storage facilities. Most retail service stations use short lengths of small-diameter, low-pressure, non-metallic pipe. On the other hand, aboveground storage facilities have long runs of large-diameter pipe tied into other

pipe would be extremely difficult and costly. Additionally, double-walled pipe has several distinct disadvantages:

- Renders cathodic protection of the inner product pipe ineffective
- May accelerate the corrosion rate of the inner product pipe
- May allow accumulation of explosive vapors within the annular space and create a fire hazard
- Is difficult to install in existing systems and difficult to alter once installed

Pipe sleeves may be appropriate at dike penetrations for road crossings or as casing pipe for rail crossings.

Table 5-1 presents different release scenarios for facility piping systems. For each type of release, available control measures, relative costs to install the measure at an existing facility, as well as operation and maintenance costs are provided. Detailed information on individual control measures is presented in Table 5-2.

Table 5-1 Piping System Release Scenarios[1]

Release Category	Cause	Control Measure Options	Type of Control Prevention Detection Protection	Control Measure Reference (see Table 2)	Retrofit Cost	O & M Cost
Underground Pressurized Steel Pipe/Internal and external corrosion	• Coating or cathodic protection system failure • Soil conditions • Failure of unprotected steel • Internal corrosion • Dead legs • Soil / air interface • Change in service conditions (e.g. temperature, pressure, or product)	• Inspect in accordance with API STD 2610 / 570/ 574[2]	P	23	N/A	Low-Medium
		• Periodic monitoring of cathodic protection system	P	1C	N/A	Low
		• Soil resistivity measurements	P	1D	N/A	Low
		• Close interval cathodic protection surveys	P	25	N/A	Medium
		• Piping Risk Assessment	P	4B	N/A	Low
		• Periodic partial visual inspection	P	26	N/A	Medium-High
		• Use of heavier walled pipe[3]	P	3[6]	Very High	Low
		• Impressed current cathodic protection system	P	1A	Medium-High	Medium
		• Galvanic cathodic protection system	P	1B	Medium	Low
		• Corrosion inhibitor injection system	P	8	Medium	Medium
		• External pipe coating or pipe wrap[3]	P	2[6]	High	Low
		• Internal coatings / special gaskets[3]	P	18	High	Low-Medium
		• Management of change	P	4A	Low	Medium
		• Smart pig inspection[4]	P	32	Very High	High
		• Periodic visual inspection of surface for UG pipe	P/D	34	N/A	Low
		• Chemical tracer	D	46	N/A	Medium-High
		• Periodic leak detection	D	39	Low-Medium	Medium
		• Pipe pressure testing	D	41	Low-High	Low-Medium
		• Facility wide inventory reconciliation	D	42	Medium	Low-Medium
		• Groundwater monitoring wells	D	37	Medium-High	Low-Medium
		• Vapor monitors	D	36	Medium	Medium
		• Liquid / vapor hydrocarbon monitors	D	45	Medium-High	Low-Medium
		• On-line leak detection[4]	D	38	High	Low
		• Double walled piping[4]	Pro	57	Very High	Low
		• Dual pressure line test	D	48	N/A	Medium-High
		• Ground penetrating radar for leak detection[5]	D	50	N/A	Medium-High
		• Electrical Soil Conductivity[5]	D	51	N/A	Medium-High
		• Thermal conductivity[5]	D	53	N/A	Medium-High
		• Volumetric leak detection[5]	D	47	N/A	Medium-High
		• Acoustic leak detection[5]	D	49	N/A	Medium-High

[1]Abbreviations used in this table are: N/A=Not applicable, P=Prevention Measure, D= Detection Measure, P/D= provides Prevention & Detection, Pro= Protection Measure
[2]API 570 and API RP 574 are applicable to refining terminals only
[3]Cost effective control measure for new construction
[4]Technology which may not be practical to retrofit due to existing terminal configuration
[5]Designates an emerging technology. Currently, these methods are not proven or widely accepted
[6]Costs for this control measure vary based on release category

Table 5-1 Piping System Release Scenarios[1]

Release Category	Cause	Control Measure Options	Type of Control Prevention Detection Protection	Control Measure Reference (see Table 2)	Retrofit Cost	O & M Cost
Underground Pressurized Steel Pipe Pipe failure	• Differential settlement • Over-pressurization • Environmental factors such as flood & earthquake	• Inspect in accordance with API STD 2610 / 570 / 574[2]	P	23	N/A	Low-Medium
		• Design new piping systems in accordance with ASME B31.3 or B31.4	P	5	Low	Low
		• Piping risk assessment	P	4B	N/A	Low
		• Provide adequate flexibility for existing piping systems	P	6	N/A	N/A
		• Periodic walk around inspection	P/D	35	N/A	Low
		• Facility wide inventory reconciliation	D	42	Medium	Low-Medium
		• Groundwater monitoring wells	D	37	Medium-High	Low- Medium
		• Vapor monitors	D	36	Medium	Medium
		• Liquid and vapor hydrocarbon monitors	D	45	Medium-High	Low-Medium
		• On-line leak detection[4]	D	38	High	Low
		• Periodic leak detection	D	39	Low-Medium	Medium
		• Periodic partial visual inspection	P	26	N/A	Medium-High
		• Pipe pressure testing	D	41	Low-High	Low-Medium
Underground Pressurized Steel Pipe Flange leak	• Flange gasket or bolt failure • Differential settlement • Impressed current short circuit across an insulating flange • Improper pressure relief setting • Improper gasket installation or bolt-up	• Minimize or remove flanged connections from below ground	P	12	Medium-High	N/A
		• Written procedure for ensuring bolt torque and gasket integrity	P	7	Low	Low
		• Proper gasket material selection for suitability for service	P	22	Low	Low
		• Pipe pressure testing	D	41	Low-High	Low-Medium
		• Locate flanges with pig inspection	P	32	Very High	High
		• Periodic walk around inspection	P/D	35	N/A	Low
		• Facility wide inventory reconciliation	D	42	Medium	Low-Medium
		• Groundwater monitoring wells	D	37	Medium-High	Low-Medium
		• Vapor monitors	D	36	Medium	Medium
		• Liquid and vapor hydrocarbon monitors	D	45	Medium-High	Low-Medium
		• On-line leak detection[4]	D	38	High	Low
		• Periodic leak detection	D	39	Low-Medium	Medium
		• Periodic partial visual inspection	P	26	N/A	Medium-High
		• Install monitor at underground flanged connections	D	40, 47, 48	High	Medium

Table 5-1 Piping System Release Scenarios[1]

Release Category	Cause	Control Measure Options	Type of Control Prevention Detection Protection	Control Measure Reference (see Table 2)	Retrofit Cost	O & M Cost
Underground Pressurized Steel Pipe	• Driller / excavator damage	• Proper communication and notifications	P	13	N/A	Low
	• Mechanical damage	• Work permit	P	14	N/A	Low
		• Accurate as-built plans	P	15	Low-Medium	Low
		• On site inspection during contractor excavation	P	9	N/A	Medium
		• Radio waves for metal line location technology	P	56	Medium	N/A
Miscellaneous sources		• Buried warning tape	P	58	Medium-High	N/A
		• Buried mechanical protection	P	59	Medium-High	N/A
Aboveground Steel Pipe	• Corrosion at soil to air interface	• Inspect in accordance with API STD 2610 / 570 / 574[2]	P	23	N/A	Low-Medium
	• Coating breakdown / disbonding	• External pipe coating or pipe wrap	P	2[6]	Low-Medium	Low
		• Corrosion inhibitor injection system	P	8	Medium	Medium
	• Pipe penetration through dike	• Periodic visual inspection of pipe	P/D	34	N/A	Low
Corrosion	wall (soil/air transition)	• Perform ultrasonic thickness testing of pipe	P	33	N/A	Medium
	• Dead legs	• Monitor insulated pipe integrity	P	28	N/A	Low
	• Abrasion damage at pipe supports	• Magnetic flux exclusion	P	29	N/A	Medium
		• Radiography for Corrosion Under Insulation	P	30	N/A	Medium
	• Corrosion under insulation or pipe supports	• Tangential or through wall Radiographic Testing for internal pipe corrosion	P	31	N/A	Medium-High
		• Use of heavier walled pipe	P	3[6]	High	Low
Aboveground Steel Pipe	• Differential settlement of pipe or supports	• Inspect in accordance with API STD 2610 / 570 / 574[2]	P	23	N/A	Low-Medium
		• Design new piping systems in accordance with ASME B31.3 & B31.4	P	5	Low	Low
	• Over-pressurization	• Install pressure relief system	P	16	Medium	Low-Medium
	• Thermal expansion & contraction	• Monitor movement of aboveground pipe	P	27	N/A	Low
Pipe failure	• Inadequate support or excess equipment loading	• Perform periodic walk around inspections	P/D	35	N/A	Low
	• Extreme events - earthquake, hurricane, blast, etc.					

Table 5-1 Piping System Release Scenarios[1]

Release Category	Cause	Control Measure Options	Type of Control Prevention Detection Protection	Control Measure Reference (see Table 2)	Retrofit Cost	O & M Cost
Aboveground Steel Pipe Flange leak	• Improper installation • Flange gasket or bolt failure • Differential deflection • Material in-compatibility • Impressed current short circuit over an insulating flange *Note: Same procedures as for underground piping apply here (i.e., proper gasket material, bolting torque, pipe pressure testing)*	• Minimize the use of flanged connections outside containment areas • Check current potential across an insulating flange • Inspect flanged connections periodically in accordance with API STD 2610	P P D	12 10 23	Medium-High N/A N/A	N/A Low Low-Medium
Aboveground Steel Pipe Pressure relief system release	• Failure of relief valve • System over pressurization • Discharge line not properly routed • Improper valve lineup	• Proper design and installation • Operator training • Ensure pressure relief set pressure is properly set • Pressure relief discharge should be routed to product pipe or storage vessel equipped with proper alarms • Test Relief system periodically • Procedure to ensure isolation valves are open	P P P P P P	11 4C 16 16 16 16	Low Low Medium Medium Medium Medium	N/A Medium Low-Medium Low-Medium Low-Medium Low-Medium
Aboveground Steel Pipe Impact Damage	• Vehicle or equipment impact damage	• Work permit system • Monitor / inspect during work • Bollards {concrete filled pipes}[3] • Bumpers and guards[3] • Use of bright color paint on critical surfaces[3]	P P P P P	14 9 19 20 21	N/A Medium Low Low Low	Low Medium Low Low Low
Aboveground Steel Pipe Miscellaneous sources	• Vandalism • Sabotage	• Facility Security - Locked valves • Facility Security - Perimeter security fence • Facility Security - Lighting • Facility Security - Security Cameras • Facility Security - Staffed facilities	P P P P P	See item # 26A-26E of Table 4-2	Low Medium Medium Medium N/A	Low Low Low-Medium Medium-High High

Table 5-1 Piping System Release Scenarios[1]

Release Category	Cause	Control Measure Options	Type of Control Prevention Detection Protection	Control Measure Reference (see Table 2)	Retrofit Cost	O & M Cost
Underground Gravity flow (non - pressurized) piping Pipe leak from Corrosion of metal pipe	• Unprotected pipe • Failure of protection system (coating or cathodic protection) • Damage caused by excavation	• Periodic monitoring of cathodic protection system	P	1C	N/A	Low
		• Work / excavation permit procedures	P	14	N/A	Low
		• Use of heavier walled pipe	P	3[6]	High	Low
		• Steel pipe impressed current cathodic protection system	P	1A	Medium-High	Medium
		• Galvanic cathodic protection system [steel pipe only]	P	1B	Medium	Low
		• Develop and maintain accurate as-built drawings	P	15	Medium-High	Low-Medium
		• External pipe coating or pipe wrap	P	2[6]	High	Low
		• Falling head / stand pipe test	D	44	N/A	Low
		• Close interval cathodic protection surveys	P	25	N/A	Medium
		• Camera - TV inspection for specialized piping systems only	D	43	N/A	High
		• Groundwater monitoring wells	D	37	Medium-High	Low-Medium
		• Chemical tracer	D	46	N/A	Medium-High
		• Vapor monitors	D	36	Medium	Medium
		• Liquid and vapor hydrocarbon monitors	D	45	Medium-High	Low-Medium
		• Ground penetrating radar for leak detection[5]	D	50	N/A	Medium-High
		• Thermal conductivity	D	53	N/A	Medium-High
Pipe or Joint leak from damage (non-metal pipe)	• Improper installation • Settlement • Fatigue • Material Incompatibility • Damaged during excavation	•Work / excavation permit procedures	P	14	N/A	Low
		• Use of proper installation procedures	P	5	Low	Low
		• Internal coating or special gaskets	P	18	Medium-High	Low
		• Falling head / stand pipe test	D	44	N/A	Low
		• Pipe pressure test	D	36	Medium	Medium
		• Camera - TV inspection of pipe	D	43	N/A	High
		• Groundwater monitoring wells	D	37	Medium-High	Low-Medium
		• Vapor monitors	D	36	Medium	Medium
		• Liquid and vapor hydrocarbon monitors	D	45	Medium-High	Low-Medium
		• Chemical tracer	D	46	N/A	Medium-High
		• Electrical tracer[5]	D	52	N/A	Medium-High
Piping system appurtenance releases	Valve stem or pump seal leak	• Inspect in accordance with API STD 2610	P	23	N/A	Low-Medium
		• Programmed or preventative maintenance	P	4D	Low	Medium
		• Periodic visual inspections	P/D	24	N/A	Low
		• Liquid or vapor hydrocarbon monitor	D	45	Medium-High	Low-Medium
		• Drip pans	Pro	54	Low	Low
		• Spill containment system	Pro	55	Medium-High	Low

Table 5-1 Piping System Release Scenarios[1]

Release Category	Cause	Control Measure Options	Type of Control Prevention Detection Protection	Control Measure Reference (see Table 2)	Retrofit Cost	O & M Cost
Piping system appurtenance releases (continued)	Pressure surge / water hammer	• Proper system hydraulic design • Pressure relief systems • Use of surge suppressors	P P P	11 16 17	Low Medium High	N/A Low-Medium Medium
Operator error during maintenance, installation or operation	• Inadequate training • Inadequate supervision	• Develop operating and maintenance procedures • Operator training • Management of Change Procedure	P P P	4C 4C 4A	Low Low Low	Medium Medium Medium

Table 5-2 Piping System Control Measures

Item	Control Measure	Reference	Advantages	Disadvantages	Operation & Maintenance Comments
1A	Impressed current cathodic protection system **(Prevention)**	NACE RP0169	• Provides reliable protection of steel buried in the earth • Easily checked for proper function • Provides uniform protection along entire length of pipe especially when soil potentials vary considerably	• High initial cost • Requires a current source • Easily damaged by subsequent activity • Effectiveness may be affected by stray current interference and soil conditions • Effectiveness can be compromised by hydrocarbon contamination • Requires anode replacement • Improper design or installation could accelerate corrosion	• Record rectifier readings periodically • Periodically measure soil potentials • Perform annual survey and evaluation
1B	Galvanic cathodic protection system **(Prevention)**	NACE RP0169	• Does not require a current source • Lower initial cost • Will not accelerate corrosion rate if improperly designed or installed	• Portions can be unknowingly compromised • Effectiveness can be compromised by hydrocarbon contamination • Easily damaged during installation • Requires anode replacement • May have gaps in protection if not properly designed	• Periodically check continuity • Perform annual survey and evaluation
1C	Periodic monitoring of cathodic protection system **(Prevention)**	NACE RP 0169 API RP 651	• Assures CP system is continuing to function properly	• Portions of system can be unknowingly compromised and go undetected by testing	• Periodically check continuity • Perform annual survey and evaluation
1D	Soil Resistivity measurements **(Prevention)**	NACE ASTM G57 ASTM G51	• Determines soils potential to cause galvanic corrosion of piping system • Detects differences in soil resistivity over long distances • Determines required inspection intervals in accordance with API 570	• Soil resistivity can be affected by the introduction of contaminants such as salt • Soil resistivity can vary substantially with small areas and is affected by changes in soil moisture	• Soil resistivity measurements must be performed by trained personnel utilizing appropriate equipment
2	External pipe coating or pipe wrap **(Prevention)**	Steel Structures Painting Council Manual	• Protects the exterior steel pipe from corrosion • Provides a corrosion resistant barrier • Provides additional protection of welded joints	• Special preparation, installation and curing required • Must be compatible with service conditions (soil, moisture, temperature, product) • Rigorous inspection and QA/QC of coating and coating repair	• Coating should be visually inspected prior to burial • Non-paint coatings should have holiday test performed at critical joints or repair locations

Table 5-2 Piping System Control Measures

Item	Control Measure	Reference	Advantages	Disadvantages	Operation & Maintenance Comments
3	Use of heavier walled pipe or fittings **(Prevention)**	ASME B31.3 and B31.4 ASTM Section 0101	• Provides a heavier walled pipe which provides a corrosion allowance for under ground piping • More durable pipe for aboveground piping	• Still susceptible to corrosion failure • Analyze piping systems to determine if stiffer pipe adversely affects piping system flexibility stresses, necessitating piping design changes	• Practical when installing or replacing existing piping
4A	Management of Change Procedure **(Prevention)**		See Item #3 of Table 8-2		
4B	Piping risk assessment **(Prevention)**		• Establishes required control measures and necessary redundancy for control measure selection • Identifies applicable risk	• All risks may not be quantifiable • Risk is a facility specific issue	• Personnel performing risk assessment have to be familiar with the site specific issues and the methodology for performing risk assessment
4C	Operator training / SOPs **(Prevention)**		See Item #1 and 4 of Table 8-2		
4D	Programmed or preventative maintenance **(Prevention)**		See Item #8 of Table 8-2		
5	Design new piping systems in accordance with ASME B31.3 & B31.4 **(Prevention)**	ASME B31.3 & B31.4	• Provides a proven system for design of petroleum piping systems • Establishes detailed requirements for specific system components		• Perform periodic maintenance of piping systems
6	Provide adequate flexibility of existing piping systems **(Prevention)**	ASME B31.3 & B31.4	• Diminishes high pipe stress caused by pipe expansion / contraction or settlement	• Requires corrective action at high stress areas such as bends, pipe anchors, branches, etc.	• Critical areas may need periodic visual inspection of piping system
7	Written procedure for bolt torque and gasket integrity **(Prevention)**		• Provides detailed requirements to ensure that bolts are properly tightened	• Installation errors may still occur	• Personnel performing the installation have to follow the procedure and utilize proper tools for tightening bolts

Table 5-2 Piping System Control Measures

Item	Control Measure	Reference	Advantages	Disadvantages	Operation & Maintenance Comments
8	Corrosion inhibitor injection system **(Prevention)**		• Provides an additive into the product which inhibits corrosion of the pipe from the inside • May be able to receive product with inhibitor already injected or inject inhibitor during receipt or delivery	• Inhibitors must not affect petroleum quality • Significant facility upgrade required for installation of injection system at the facility	• Perform periodic maintenance and inspection of injection system • Install and monitor corrosion coupons • Perform periodic confirmation of underground facilities
9	On-site inspection during excavation **(Prevention)**		• Provides knowledgeable and trained personnel to assure that the excavation work does not damage facility piping	• Requires a significant commitment of personnel	• Facility personnel must be trained in how to inspect work and must be knowledgeable in the piping layout • Requires good documentation of underground facilities
10	Check current potential over an insulating flange **(Prevention)**	NACE	• Detects shorts in an impressed current cathodic protection system at the insulating flange	• Provides only a snap shot view	• Personnel performing the test must be properly trained and have the appropriate equipment
11	Proper system hydraulic design **(Prevention)**	Mechanical Engineers Handbook by McGraw Hill	• Properly designed systems are less likely to cause a release from improper flow control or pressure • Establishes a detailed analysis of the system hydraulics including line size, pumping system and flow control system • Avoids hydraulic pressure surges	• System modifications can quickly make the hydraulic design out of date • Provides only a passive method of release prevention	• Operations and maintenance personnel must not adjust the system hydraulic configuration without consulting the organization who performed the hydraulic design
12	Minimize or remove flanged connections **(Prevention)**		• Improves system reliability • Provides a one time fix, no follow up required • Work is performed in accordance with applicable codes & standards	• Typically work must be performed during down times • Repair work must be performed to minimize spills • May reduce future pipeline expansion flexibility	• No maintenance required
13	Proper communication & notifications **(Prevention)**	API RP 750 API RP 2220	• Protects pipe from potential damage which may result in a release • Keeps community involved • Provides a system of checks to prevent releases	• Requires on-site personnel, training and equipment • Requires detailed record keeping • May require pipeline markers	• Maintain records and line markers • Perform training and maintain lines of communication
14	Excavation work permit system **(Prevention)**	API RP 750 API RP 2220	• Establishes a procedure and method of control where by work can not be performed with out a work permit • Allows review of work requirements and work areas prior to work	• Does not eliminate human errors • Does not provide oversight	• Facility staff review the work activities, work area, tools, equipment, MSDS, excavation areas, hot work, drawings etc. with the contractor and/or internal work crew prior to issuing a work permit

Table 5-2 Piping System Control Measures

Item	Control Measure	Reference	Advantages	Disadvantages	Operation & Maintenance Comments
15	Develop and maintain accurate as-built plans **(Prevention)**		• Provides accurate information of the as-built conditions and locations of piping system • Often provides ties to the location of underground piping and elbows	• Accurate information is often unavailable • As-built drawings must be revised as modifications are performed • Increased engineering costs	• Facility staff, engineering staff or contractor is responsible for preparation of as-built drawings • Facility staff check the accuracy of as-built information
16	Install pressure relief system on pressurized piping **(Prevention)**		• Reduces flange and gasket leaks caused by over-pressurization • Protects idled lines and closed valves, check valves and flow control valves from over pressurization due to temperature rise	• Improperly designed, maintained or installed systems will not function • Training required to ensure operators use system correctly • Provides an additional area for leaks due to small gauge pipe and common use of threaded connections	• Periodically test pressure relief valve • Periodically inspect for leaks • Establish safeguards to ensure relief flow path is open
17	Use of surge suppressors **(Prevention)**		• Reduces flange and gasket leaks caused by over-pressurization • Protects idled lines and closed valves, check valves and flow control valves from over-pressurization due to temperature increase	• Improperly designed, maintained or installed systems will not function • Training required to ensure operators use system correctly	• Periodically test pressure relief valve • Periodically inspect for leaks
18	Internal coatings / special gaskets **(Prevention)**	API RP 1132 API RP 1626 API RP 1627	• Applicable for products in aggressive corrosive service or products with corrosive components • Effectively mitigates internal corrosion	• Difficult to retrofit • Not beneficial for most services at terminal facilities • Difficult to inspect and maintain	• Periodically perform visual inspection of representative areas of piping system
19	Bollards / imbedded concrete filled pipes **(Prevention)**		• Provides a barrier against accidental damage to above ground piping systems or piping supports • Easy and economical to install • Provides a deterrent	• Bollards could damage tank trucks causing a release from a loaded vessel • Require additional space for installation	• Maintain brightly colored paint on bollards
20	Bumpers & guards **(Prevention)**		• Provides impact resistance and protection for aboveground piping systems • Easy and economical to install	• May not prevent damage to piping system	• Periodically inspect condition of guards and bumpers, replace or alter as necessary
21	Use of bright color paint on critical surfaces **(Prevention)**		• Uses bright colored paint to call attention to critical areas • Easy and economical to install and maintain	• Strictly a passive protection measure	• Maintain paint

Table 5-2 Piping System Control Measures

Item	Control Measure	Reference	Advantages	Disadvantages	Operation & Maintenance Comments
22	Proper gasket material selection for suitability for service **(Prevention)**	API RP 1132 API RP 1626 API RP 1627	• Ensures gaskets are compatible with the material stored • Prevents leaks from critical equipment	• Temperature, material and pressure will affect material performance and selection	• Review gasket selection with manufacturer to ensure proper application to service conditions
23	Inspect in accordance with API STD 2610 or equivalent practice **(Prevention)**	API STD 2610 API RP 574 API 570	• Provides a systemized inspection approach • Establishes detailed requirements for specific system component inspection • Provides guidance on inspection intervals and areas to inspect • Allows flexibility in development of program or practice that has equivalent requirements to those referenced in API 570	• Does not involve 100% inspection • For underground or insulated pipe, inspection is limited to small samples which may not be representative of the pipe condition • Only addresses anticipated degradation mechanisms	• Qualified inspection personnel and procedures required • Perform periodic inspection of piping systems
24	Periodic visual inspections **(Prevention/Detection)**	API STD 2610 API RP 574 API 570	• Provides a periodic check of the system performance to detect potential areas of concern or to detect small drips from flanges, valve stems, and pump seals	• Effectiveness varies depending upon the operator, weather conditions and other activities occurring at the facility	• Personnel must be attentive to potential abnormal noises as well as visual information
25	Close interval cathodic protection surveys **(Prevention)**	API 570 API RP 574	• Measures potential along a pipeline system to detect potential hot spots and areas of accelerated corrosion	• Requires near by impressed current systems to shutdown their rectifiers or install interrupters in adjacent systems	• Surveys must be performed periodically by trained personnel with appropriate equipment
26	Periodic partial visual inspection of Underground pipe **(Prevention)**	API 570 API RP 574	• Provides direct assessment of outside condition of pipe at area excavated • May permit local assessment of pipe internal condition	• May not accurately predict the conditions elsewhere along the pipe • Creates the opportunity for a mechanical failure • May have regulatory and soil management issues associated with excavation	• Excavation operations require careful supervision • Excavation must be protected and backfilled with compacted fill
27	Monitor movement of above ground pipe **(Prevention)**	API 570 API RP 574	• Provides data on pipe movement which may be indicative of over stressing of the piping system • Appropriate for detecting critical pipe movement over long periods of time	• Information may be difficult to interpret • Of limited value on underground piping systems	• Personnel must be trained in the use of leveling instrumentation • Local benchmark must be established • Exact points must be located and re-surveyed periodically to detect long term trends

Table 5-2 Piping System Control Measures

Item	Control Measure	Reference	Advantages	Disadvantages	Operation & Maintenance Comments
28	Monitor insulated pipe integrity **(Prevention)**	API RP 574 API 570	• Several technologies provide complementary assessment of insulated pipe external and internal corrosion	• Most of these provide only localized data • Some technologies are only indirect indicators of integrity	• Specialized equipment and personnel are necessary
29	Magnetic flux exclusion (from pipe exterior) **(Prevention)**	API 570 API RP 574	• Detects internal pipe metal loss or deficiencies in the pipe • Provides a detailed profile of pipe condition	• Provides only a snapshot view of the pipe condition • Requires special equipment & training • Not suitable for all piping systems • Access will limit inspection	• Specialized equipment and personnel are required • Scaffolding and manlift may be required
30	Radiography for corrosion under insulation **(Prevention)**	API 570 API RP 574	• Qualitative and quantitative assessment for external metal loss without insulation removal • Can be performed while piping is in service	• Provides localized information only, snapshot view of area inspected	• Issue of radiation safety must be addressed • Personnel must be specially trained and specialized equipment is required
31	Tangential or through wall radiographic testing for internal pipe corrosion **(Prevention)**	API 570 API RP 574	• Quantitative assessment for internal metal loss • Can be performed while piping is in service	• Provides localized information only, snapshot view of area inspected	• Issue of radiation safety must be addressed • Personnel must be specially trained and specialized equipment is required
32	Smart pig / pigging **(Prevention)**	API RP 574	• Provides quantitative information on pipe condition over the length of pipe surveyed • Can be performed while piping is in service • Has been shown to be an effective technology in cross country pipelines; however it is not suitable for the majority of the existing station pipings • Can have limited use on straight sections of terminal piping	• Launchers / receivers required • Not suitable for most pipe geometries and configurations at existing tank facilities • Most inspection tools cannot traverse short radius bends • Difficult to retrofit on systems not designed for pigging	• Requires considerable maintenance support

Table 5-2 Piping System Control Measures

Item	Control Measure	Reference	Advantages	Disadvantages	Operation & Maintenance Comments
33	Ultrasonic thickness measurements of Above ground Pipe **(Prevention)**	API RP 574 API 570	• Detects pipe thinning by use of a ultrasonic probe which determines steel thickness • Provides precise thickness measurements • Detects uniform thinning of pipe	• Critical pipe areas may be obstructed from inspection by insulation, supports or other equipment • Provides point data which is interpolated between test points • Localized corrosion may not be detected • Provides a limited sample of the piping system area • Measurement surface must be clean	• No maintenance cost associated with this method • Areas may have to be prepared prior to inspection • Test frequency depends upon critical and remaining life • Holes must be cut in insulation
34	Visual inspection of above ground pipe & surface inspection for underground pipe **(Prevention/ Detection)**	API RP 574 API 570	• Detects potential areas of corrosion or pipe stress • Relatively easy to perform • Can be performed at greater frequencies for areas of concern • May show ground discoloration	• Critical piping areas may be obstructed from view by pipe supports, insulation of attached equipment	• No maintenance required for this inspection • Test frequency in accordance with API 570 or local regulatory requirements • Personnel must have suitable training
35	Periodic walk around inspections **(Prevention/ Detection)**	API STD 2610 API 570 API RP 574	• Slow or small releases may be readily detected and repaired • Potential problem areas can be detected and corrected prior to a release occurring	• Relies upon human factors for detection • Time period between release and detection is dependent upon frequency of inspections	• Properly trained operator walks the tank farm area and all loading / unloading areas observing key equipment and all piping systems for possible leaks • Properly trained operators required to maximize effectiveness
36	Vapor monitors (Point Sensor Sampling) **(Detection)**	API Publ 334	• Detects petroleum vapors in the vadose zone • Detects tracer or hydrocarbon vapor in the vadose zone • Tracer methods have high sensitivity and low probability of false alarm • Same system can provide on-line monitoring • Various technologies can provide intermittent or continuous monitoring	• Limited by the site conditions; soil, backfill, water table • Release detection may be delayed • Background contamination may affect results for hydrocarbon detection systems	• Monitors must be inspected calibrated in accordance with vendor requirements • Systems typically sound locally or remotely • System maintenance and analysis typically performed by manufacturer

Table 5-2 Piping System Control Measures

Item	Control Measure	Reference	Advantages	Disadvantages	Operation & Maintenance Comments
37	Groundwater monitoring wells **(Detection)**	Ground-water and Wells by Johnson	• Detects free phase or dissolved phase product • Provides information on groundwater elevation, direction, background levels and quality	• Limited by the site conditions • Ability to detect release varies with soil condition • Background levels may affect results • Not necessarily pipe specific • Groundwater flow patterns and rain may complicate definitive detection	• Periodic inspection of wells • Minimal maintenance required
38	On-line leak detection - software based **(Detection)**		• Responds quickly to leaks • Some systems can locate leak source	• May be difficult to retrofit • No one system will detect all leak situations • Specialized hardware requires routine and thorough maintenance • Some systems have limited capabilities during transients • Small corrosion leaks may be undetected	• Train personnel in system operation • Perform manufacturer specified maintenance and periodic testing
39	Periodic leak detection **(Detection)**	API 570	• Can provide accurate tightness assessment • Is usually easier to retrofit than on-line leak detection	• Is not indicative of future line integrity • Results may be ambiguous or difficult to interpret • Line may need to be temporarily removed from service	• Train personnel in proper test performance • Ensure equipment is appropriate for the intended use
40	Install monitor at underground flanged connections **(Detection)**		• Can provide early detection of a flange release for underground flanges	• May be difficult to retrofit existing underground flanges • Existing contamination may complicate data interpretation • May be cost prohibitive	• Periodic inspection and maintenance of cables are necessary
41	Pipe pressure test **(Detection)**	API STD 2610 API RP 1110 API 570	• Detects potential defects in a line by applying a pressure greater than the normal operating pressure • Commonly accepted method • Demonstrates that the line holds the product • Leak tests can be performed at normal operating pressure	• Temperature, isolation, etc. could effect the accuracy of the results • Could cause a release • Only provides information on integrity of line at the time the line is tested • If water is used as the test medium it often presents product quality, operational, and water disposal problems	• Blinds must often be inserted if valve integrity is uncertain • Test frequency is in accordance with regulatory or operational requirements • Line to be tested requires positive isolation and may require draining to use a low flash product or water • If product is used as the test medium, refer to API STD 2610 for proper testing procedures

Table 5-2 Piping System Control Measures

Item	Control Measure	Reference	Advantages	Disadvantages	Operation & Maintenance Comments
42	Facility wide inventory reconciliation **(Detection)**	API Publ 334	• Does not interfere with piping system normal operations • Can provide both short- and long-term information	• Difficult to determine source area of leak • Significant quantities may be lost before detection occurs • Requires sophisticated and costly hardware for instrumented systems • Requires extensive record keeping	• Specialized hardware may require periodic maintenance • Operations personnel must perform necessary record keeping
43	Camera TV inspection of pipe **(Detection)** Note: Typically used for gravity flow underground piping built to storm or septic sewer standards only		• Provides a visual picture of the actual condition of the pipe and its joints • Suitable for piping systems designed to septic or storm sewer standards	• Results are qualitative - detecting small defects or misalignment of joints is difficult • Pipe will have to be drained, isolated and cleaned • Some pipe defects may go unnoticed • Special equipment and personnel are required • Does not leak test pipe • Pipe diameter must be large enough to accommodate cameras • Pipe configuration must not have sharp bends	• Special setup conditions and extensive line cleaning will be required • Test is typically performed if the line appears obstructed, damaged or other tests indicate a potential breach
44	Falling head / standpipe test **(Detection)** Typically used on underground gravity flow pipe to detect pipe or joint leaks	AWWA Std C-600 ASTM C924 UNI - B - 6	• Detects pipe leaks in underground gravity flow piping by plugging one end and flooding the pipe while placing a small head of water and observing any change in height of water • Relatively simple test to perform • Will detect moderate to large leaks • Can be performed with on-site personnel	• Minor leaks may go unnoticed • Test may require retrofit of existing systems • A high water table may influence the results • Draining pipe may be difficult	• Special setup required with this test to create a pressure dam • The test is performed typically after new construction and in accordance with local regulatory or operational requirements

Table 5-2 Piping System Control Measures

Item	Control Measure	Reference	Advantages	Disadvantages	Operation & Maintenance Comments
45	Liquid / Vapor hydrocarbon monitors (cable-based system) **(Detection)**	API Publ 334	• Continuous monitoring detects relatively small leaks • Detects a free phase hydrocarbon release in a single walled or double walled pipe • Most systems are not affected by water	• Some technologies have difficulties with existing contamination • Expensive to retrofit • Results can be difficult to interpret because of location and fluctuation of the groundwater table • System design and layout depends on permeability of soil and backfill • Encompasses wide range of technologies with varying effectiveness • Background contamination may make system unreliable • Site conditions including soil permeability, groundwater elevation and rate of leak may affect system effectiveness	• Some systems can be monitored off-site • Maintenance costs are low • Personnel must be trained in the required maintenance and operation of the leak monitor
46	Chemical tracer **(Detection)**	API 570	• High sensitivity • Minimal interference with operations • Identifies leak location	• Soil conditions affect results • Product quality issues • Requires special equipment	• Must know exact pipe locations • Regulatory requirements may restrict use
47	Volumetric leak detection **(Detection)**		• Shorter test time than conventional pressure testing • Some methods compensates for temperature	• Requires special equipment • Blinding required • Does not identify leak location • Will not detect leaks below a set threshold--possibility of missed detection and false positives	• Mechanical maintenance required for this test • Test frequency is in accordance with regulatory or operational requirements • Line to be tested requires positive isolation and may require draining to use a low flash product or water
48	Dual pressure line test **(Detection)**		• Shorter test time than conventional pressure testing • Compensates for temperature variation	• Requires special equipment • New technology • Blinding required • Does not identify leak location • Will not detect leaks below a set threshold--possibility of missed detection and false positives	• Mechanical maintenance required for this test • Test frequency is in accordance with regulatory or operational requirements • Line to be tested requires positive isolation and may require draining to use a low flash product or water
49	Acoustic leak detection (Detection)		• Minimal access to pipe required • Relatively low cost • May identify leak location	• Detection threshold unknown • Effects of backfill on results is uncertain • Requires special equipment and personnel • Background noise may reduce effectiveness	• Blinding may be required

Table 5-2 Piping System Control Measures

Item	Control Measure	Reference	Advantages	Disadvantages	Operation & Maintenance Comments
50	Ground penetrating radar for leak detection **(Detection)**		• Detects disturbed soil • Non-intrusive method is used external to the pipe • Identifies area of possible leak	• Limited use in wet soil conditions • Results are qualitative and subjective • Requires specialized equipment	• No maintenance cost • Minimal impact on operations and maintenance • Specialized equipment and personnel must be used
51	Electrical soil conductivity **(Detection)**		• Detects unusual soil conductivity • Identifies possible leak location	• Limited use in wet or saturated soils • Results are qualitative and subjective • Requires specialized equipment	• May require dams in gravity fed pipe • Specialized equipment and personnel must be used
52	Electrical tracer **(Detection)**		• Detects electrical continuity between product and ground • Identifies holes Not Leaks • Identifies locations of holes • Primarily for gravity feed piping water systems	• Backfill affects results • Set up may be difficult • Not suitable for metal pipes	• May require dams in gravity fed pipe • Specialized equipment and personnel must be used
53	Thermal conductivity **(Detection)**		• Identifies leaks by unusual thermal gradient • Non-intrusive • Identifies possible leak locations	• Requires temperature differential between product and ground • Backfill affects results • Performance is improved with greater temperature difference between ground and product • Not appropriate under concrete	• May require dams in gravity fed pipe • Specialized equipment and personnel must be used
54	Drip pans **(Protection)**	API STD 2610 API Publ 4602	• Very effective and economical method for collecting small drips or potential areas of drips such as pump seals and flanged connections	• Can only accommodate small quantities; requires periodic emptying • Should only be used as a temporary method for existing leaks until repairs can be made • Limited effectiveness depending on precipitation	• Drip pans should checked periodically for accumulated water or petroleum to prevent over filling
55	Spill containment system **(Protection)**	API STD 2610 API Publ 4602	• Provides secondary containment of critical system components such as air eliminators and pumps which are more likely than welded steel pipe to experience a release	• Not practical for the most above ground or underground piping	• Containment area should be checked periodically for accumulated water or petroleum

Table 5-2 Piping System Control Measures

Item	Control Measure	Reference	Advantages	Disadvantages	Operation & Maintenance Comments
56	Radio waves for metal line location technology **(Protection)**		• Reliable and easy to use for metallic piping • Can be performed on in service piping • Can be used on land and some in water • Minimizes excavation	• Difficult under reinforced concrete • Less reliable for non-metallic pipe • Requires specialized equipment and specially trained personnel • Difficult in complex pipe fields	• Operations personnel have to be available to assist line location personnel • Must identify correct technology for specific application
57	Double walled pipe **(Protection Measure)**		• Provides an extra barrier for containment of leaked product	• May convey a hazardous / explosive air mixture within the double walled pipe • Extremely difficult to retrofit • Virtually impossible to inspect condition of space between double walled pipe • May accelerate corrosion of primary containment pipe • Prevents use of cathodic protection of primary containment pipe • May be prohibited by local jurisdictions	• Special line tie-in and monitoring of explosive environment required during system modification • If interstitial monitor is installed, maintenance of this unit will be required
58	Buried warning tape **(Prevention)**		• Provides an indicator to the presence of buried lines • Prevents releases by warning personnel performing excavation activities of the presence of buried lines	• Costly, difficult and impractical to retrofit on existing buried systems • Tape must be located at least 6" above the pipe or line to be protected • Tape can go unnoticed during unsupervised excavations	• No routine operation or maintenance required. If the tape is damaged during excavation, repair or replace
59	Buried mechanical protection **(Prevention)**		• Provides an active indicator of the presence of buried lines • Prevents releases by warning personnel performing excavation activities of the presence of buried lines	• Costly, difficult and usually impractical to retrofit on existing buried systems • Equipment must be located above line to be protected in accordance with manufacturer's recommendations	• No routine operation or maintenance required. If the tape is damaged during excavation, repair or replace

Section 6
LOADING AND UNLOADING SYSTEMS

INTRODUCTION

The practices and control technologies available to prevent and detect releases during loading and unloading operations vary depending on the product being transferred and the mode of transport used by the facility. The four primary methods of petroleum transport are tank truck, rail tank car, marine vessel, and pipeline. Because pipeline transfers occur within a closed system, they are not addressed in this section. (Section 5 - Piping Systems gives information on control measures for pipeline transfers).

The probability of a release occurring is minimal for many facets of a transfer operation; therefore, when selecting control measures, the selection process should evaluate the most likely sources of releases.

OVERVIEW

Product transfer operations occur at all aboveground tank facilities and involve either the receipt of product (unloading) or the distribution of product (loading). Depending on the facility location, tank trucks, rail tank cars, or marine vessels may be used to deliver product to storage facilities. Tank trucks are the primary means of distributing product from the facility. Typically, transfers to and from tank trucks and rail cars take place at loading/unloading racks, which contain the equipment needed for the transfer. Such transfer operations involve the use of connective couplings, loading arms, hoses, control devices, and meters located at the point of transfer. Marine vessels are generally equipped with pumps and hoses for transferring product to on-shore facilities.

Pipeline transfers -- which take place in a closed system -- do not involve loading and unloading operations and are not covered in this section.

RELEASE SCENARIOS

Product releases can occur during either loading or unloading operations.

The primary release mechanisms during *loading* include:

- Overfill of the tank truck, rail tank car, or marine vessel
- Loading connection leak or failure
- Leak or spill when breaking the loading connection
- Tank truck or marine vessel damage to the loading system
- Failure of the spill containment system or spill collection system
- Container shell failure due to over-pressurization of the receiving container

The primary release mechanisms during *unloading* include:

- Overfill of the receiving tank (refer to Section 4 - Aboveground Storage Tanks)
- Vacuum failure of the vessel being unloaded
- Unloading connection leak or failure
- Leak or spill when breaking the unloading connection
- Tank truck or marine vessel damage to loading system
- Failure of the spill containment pad or spill collection system

RELEASE PREVENTION

There are several measures available to address potential releases for each facility. However, when loading or unloading petroleum products, the following are key elements to consider:

- Using automatic shut-off based on meter count
- Using high-level alarms or high-level shut down systems
- Ensuring the receiving vessel is capable of holding the volume being transferred
- Monitoring transfers
- Maintaining written procedures and ensuring operators are trained
- Using proper connections and ensuring their integrity

Additionally, an ongoing preventive maintenance program is an important element in preventing releases. Such a program addresses:

- Integrity of fittings, pumps and connectors
- Loading and unloading hose / arm inspection and testing
- Loading rack spill containment system integrity
- Tank truck container or rail car vessel integrity inspection and testing
- Loading rack control system interlock maintenance and testing
- Overfill protection system maintenance and testing
- Pressure relief system testing

The facility operator plays a central role in the prevention or minimization of releases during loading and unloading. Having trained facility personnel familiar with the equipment and prepared to respond in the event of a release is important.

Table 6-1 presents different release scenarios for loading and unloading systems based on the method of product transfer. This table also includes a list of available control measures and the relative costs to install, operate, and maintain the measure at an existing facility. More detailed information on each individual control measure is presented in Table 6-2.

Table 6-1 Loading & Unloading Systems Release Scenarios[1]

Release Category	Cause	Control Measure Options	Type of Control Prevention Detection Protection	Control Measure reference (see Table 2)	Retrofit Cost	O & M Cost
Loading Spill	• Loading connection leak	• Dripless or dry break coupling	P	3	Low	Low
		• Elastomer (O-rings and seals) compatibility and selection	P	7	Low	Low-Medium
		• Programmed or preventative maintenance	P	1	Medium-High	Medium
		• Written operating procedures	P	14A	Low	Medium
		• Operator training	P	14B	Low	Medium
		• Periodic / planned and documented inspections	P	14C	Low-Medium	Low
		• Drip pans	Pro	21	Low	Low
		• Spill pad[2]	Pro	20	Medium-High	Low
		• Secondary containment system[2]	Pro	26	High	Medium
	• Overfill of tank truck or rail tank car	• High-level shutoff on tank truck or rail tank car	P	4	Low	Low
		• Presets on metering system	P	17	Medium	Low-Medium
		• Written operating procedures	P	14A	Low	Medium
		• Operator training	P	14B	Low	Medium
		• Review of pump design	P	15	Low	N/A
		• Attended Loading	D/Pro	29	N/A	Medium
		• Surveillance cameras	D	19	Medium	Medium-High
		• Emergency shutdown system	Pro	28	Medium	Low
		• Spill pad[2]	Pro	20	Medium-High	Low
		• Secondary containment system[2]	Pro	24	High	Low-Medium
		• Coatings applied to concrete	Pro	25	Medium	Low-Medium
		• Spill containment tank	Pro	26	High	Medium
	• Control valve malfunction resulting in an overfill	• Operator training	P	14B	Low	Medium
		• Written operating procedures	P	14A	Low	Medium
		• Appropriate use of strainers	P	11	Low	Low
		• Review of pump design	P	15	Low	N/A
		• Overfill protection system	P	8	Medium	Low
		• Attended Loading	D/Pro	29	N/A	Medium
		• Emergency shutdown system	Pro	28	Medium	Low
		• Spill pad	Pro	20	Medium-High	Low
		• Secondary containment system [2]	Pro	24	High	Low-Medium
		• Coatings applied to concrete	Pro	25	Medium	Low-Medium
		• Spill containment tank	Pro	26	High	Medium

[1]Abbreviations used in this table are: N/A=Not Applicable, P=Prevention, D=Detection, P/D=provides Prevention and Detection, Pro=Protection Measure
[2]Cost effective control measure for new construction

Table 6-1 Loading & Unloading Systems Release Scenarios[1]

Release Category	Cause	Control Measure Options	Type of Control Prevention Detection Protection	Control Measure reference (see Table 2)	Retrofit Cost	O & M Cost
Loading Spill (continued)	• Overfill of marine vessel or barge	• Overfill protection system[2]	P	8	Medium	Low
		• Written operating procedures	P	14A	Low	Medium
		• Operator training	P	14B	Low	Medium
		• Communications plan [Ship to Shore]	P	2	Low	Low
		• Attended loading	D/Pro	29	N/A	Medium
		• Emergency shutdown system	Pro	28	Medium	Low
	• Failure due to over pressurization of tank vehicle	• Written operating procedures	P	14A	Low	Medium
		• Operator training	P	14B	Low	Medium
		• High level shutoff on tank truck or rail tank car	P	4	Low	Low
		• Programmed or preventative maintenance	P	1	Medium-High	Medium
		• Periodic / planned and documented inspections	P	14C	Low-Medium	Low
		• Pre-sets on metering system	P	17	Medium	Low-Medium
		• Appropriately designed pressure/vacuum relief system	P	16	Low-Medium	Low
		• Emergency shutdown system	Pro	28	Medium	Low
		• Secondary containment system[2]	Pro	24	High	Low-Medium
		• Coatings applied to concrete	Pro	25	Medium	Low-Medium
		• Spill containment tank	Pro	26	High	Medium
	• Mechanical system leak	• Minimize use of piping connectors [e.g. flanges][2]	P	5	Medium-High	Low
		• Elastomer (O-rings and seals) compatibility and selection	P	7	Low	Low-Medium
		• Programmed or preventative maintenance	P	1	Medium-High	Medium
		• Periodic / planned and documented inspections	P	14C	Low-Medium	Low
		• Proper system design, alteration & maintenance	P	9	Low	Low
		• Proper material selection	P	10	Low-Medium	Low
		• Pressure testing [Loading & Unloading System]	D	18	N/A	Low-Medium
		• Drip pans	Pro	21	Low	Low
		• Spill pad[2]	Pro	20	Medium-High	Low
	• Damage to loading system from vehicle or vessel	• Operator training	P	4B	Low	Medium
		• Surveillance camera	D	19	Medium	Medium-High
		• Break-away couplings or hoses	P	13	Low	Low
		• Brake interlocks on tank vehicles	P	12	Medium	Low-Medium
		• Emergency shutdown system	P	28	Medium	Low
		• Impact guards / Bollards / Dolphins / Spars / Bumpers[2]	Pro	27	Low-Medium	Low
		• Secondary containment system[2]	Pro	24	High	Low-Medium
		• Coatings applied to concrete	Pro	25	Medium	Low-Medium
		• Spill containment tank	Pro	26	High	Medium

Table 6-1 Loading & Unloading Systems Release Scenarios[1]

Release Category	Cause	Control Measure Options	Type of Control Prevention Detection Protection	Control Measure reference (see Table 2)	Retrofit Cost	O & M Cost
Unloading Spill Includes pump-back, oxygenate & additive unloading area	• Connection leak	• Dripless or dry break coupling	P	3	Low	Low
		• Programmed or preventative maintenance	P	1	Medium-High	Medium
		• Written operating procedures	P	14A	Low	Medium
		• Operator training	P	14B	Low	Medium
		• Periodic / planned and documented inspections	P	14C	Low-Medium	Low
		• Elastomer (O-rings and seals) compatibility and selection	P	7	Low	Low-Medium
		• Attended unloading	D/Pro	29	N/A	Medium
		• Drip pans	Pro	21	Low	Low
		• Spill pad[2]	Pro	20	Medium-High	Low
	• Mechanical system leak	• Minimize use of flanged connections[2]	P	5	Medium-High	Low
		• Elastomer (O-rings and seals) compatibility and selection	P	7	Low	Low-Medium
		• Programmed or preventative maintenance	P	1	Medium-High	Medium
		• Periodic inspection	P	14C	Low-Medium	Low
		• Pressure testing [Loading & Unloading System]	D	18	N/A	Low-Medium
		• Attended unloading	D/Pro	29	N/A	Medium
		• Drip pans	Pro	21	Low	Low
		• Spill pad[2]	Pro	20	Medium-High	Low
	• Damage to unloading system from tank vehicle or vessel	• Operator training	P	14B	Low	Medium
		• Brake interlocks on tank vehicles	P	12	Medium	Low-Medium
		• Surveillance camera	D	19	Medium	Medium-High
		• Impact guards / Bollards / Dolphins / Spars / Bumpers[2]	Pro	27	Low-Medium	Low
		• Break-away couplings or hoses [2]	Pro	13	Low	Low
		• Spill pad [2]	Pro	20	Medium-High	Low
		• Coatings applied to concrete	Pro	25	Medium	Low-Medium
		• Secondary containment system [2]	Pro	24	High	Low-Medium
	• Vacuum vent failure on tank truck	• Written operating procedures	P	14A	Low	Medium
		• Operator training	P	14B	Low	Medium
		• Proper system design, alteration and maintenance	P	9	Low	Low
		• Review of pumping system design	P	15	Low	N/A
		• Appropriately designed pressure/vacuum relief system	P	16	Low-Medium	Low
		• Programmed or preventative maintenance	P	1	Medium-High	Medium
		• Periodic / planned and documented inspections	P	14C	Low-Medium	Low
		• Attended unloading	D/Pro	29	N/A	Medium
		• Emergency shutdown system	Pro	28	Medium	Low
		• Spill pad [2]	Pro	20	Medium-High	Low
		• Secondary containment system[2]	Pro	24	High	Low- Medium

Table 6-1 Loading & Unloading Systems Release Scenarios[1]

Release Category	Cause	Control Measure Options	Type of Control Prevention Detection Protection	Control Measure reference (see Table 2)	Retrofit Cost	O & M Cost
Miscell-aneous loading / unloading area releases	• Own use truck fueling system release	• Written operating procedures	P	14A	Low	Medium
		• Operator training	P	14B	Low	Medium
		• Periodic / planned and documented inspections	P	14C	Low-Medium	Low
		• Dispensing nozzle with automatic shutdown	P	6	Low	Low
		• Proper system design, alteration and maintenance	P	9	Low	Low
		• Emergency shutdown system	Pro	28	Medium	Low
		• Shear valve on dispenser product and vapor lines	Pro	22	Low	Low
		• Own use fuel dispenser containment sump	Pro	23	Medium-High	Low
		• Spill pad [2]	Pro	20	Medium-High	Low
		• Secondary containment system [2]	Pro	24	High	Low-Medium
		• For UST systems follow regulatory authority having jurisdiction	Pro	No reference	Medium-High	Low
	• Spill pad / containment system integrity	• Proper system design, alteration and maintenance	P	9	Low	Low
		• Proper material selection	P	10	Low-Medium	Low
		• Programmed or preventative maintenance	P	1	Medium-High	Medium
		• Coatings applied to concrete	Pro	25	Medium	Low-Medium

Table 6-2 Loading & Unloading Systems Control Measures

Item	Control Measure / Type	Reference	Advantages	Disadvantages	Operation & Maintenance Comments
1	Programmed or preventative maintenance **(Prevention)**	API RP 750	• Equipment is maintained in proper functioning order to prevent releases • Program addresses repetitive equipment maintenance items • Maintenance can be pre-planned	• Requires detailed knowledge of equipment and maintenance requirements • Detailed record keeping is necessary	• Use equipment manufacturers recommended maintenance lists • Develop and adhere to maintenance program • Follow preventative maintenance program
2	Communica-tions Plan [Ship to shore] **(Prevention)**		• Assures adequate voice communication during product transfers • Provides a scripted procedure for product transfers	• Human error is a factor • Communications can be interrupted at critical times	• Train personnel in use of the communications plan • Provide proper equipment and periodically check equipment operation • Periodically audit compliance with plan
3	Dripless or dry break coupling **(Prevention)**	API RP 1004	• Provides a tight and secure connection to vessel being loaded • Minimizes drips when hose is disconnected • Easy to use and maintain	• Coupling may leak if not properly maintained • Compatible hoses and fittings are necessary	• Perform routine maintenance and inspection of coupling • Train personnel in proper use of coupling
4	High-level shut off on tanker truck or rail tank car **(Prevention)**		• Provides automatic interlock to discontinue product receipt when a predetermined product level is reached	• Pressure surges may cause premature shutdown • System hydraulics may be insufficient to shut down control valve	• Inspect & maintain probes and interlocks in accordance with the vendor specifications • Test system operation routinely
5	Prudent use of flanges **(Prevention)**	ASME B16.5	• Minimizes potential leaks by reducing the number of flanged connections • Flanges are located in contained areas	• May make equipment installation, modification and maintenance more difficult • May not be feasible or possible to locate flanges in contained areas or to minimize the number of flanges	• No special maintenance or operation requirements
6	Dispensing nozzle with automatic shutdown **(Prevention)**	API RP 1650	• Stops flow of petroleum when receiving tank is sensed to be full • No special training required for system to operate • System functions automatically and independent of other systems providing redundant control	• System can not be exclusively relied upon to prevent a release	• Periodically check nozzle operation • Perform maintenance in accordance with vendor requirements

Table 6-2 Loading & Unloading Systems Control Measures

Item	Control Measure / Type	Reference	Advantages	Disadvantages	Operation & Maintenance Comments
7	Elastomer (O-rings and seals) compatibility and selection **(Prevention)**	API RP 1132 API RP 1627 API RP 1626	• Assures that gaskets, packing and other elastomers are compatible with the petroleum product • Prevents releases caused by gasket, seal or packing degradation	• Elastomers have to accommodate the various products stored, temperature conditions, and routine changes in service • Change in product formulation can limit suitability and cost of gaskets	• Ensure that petroleum is compatible with elastomer • Repair or replace unsuitable or failed elastomers
8	Overfill protection system **(Prevention)**	API RP 2350	• Aids in the prevention of vessel overfills by activating alarms or automatically stopping a receipt • Provides accurate and reliable system for overfill prevention • System complexity, cost and configuration can be tailored to the specific operational needs	• System should not become relied upon as a routine method to terminate loading • Use of audible / visual alarms require operator action to prevent a release • System has to be properly and periodically calibrated • System calibration / maintenance can inadvertently disable protection	• System operation should be checked periodically • System probes should be inspected and calibrated in accordance with vendor requirements • Provide training in system operation, maintenance and response
9	Proper system design, alteration and maintenance **(Prevention)**	API STD 2610	• Prevents loading losses by ensuring system is designed for the specific service • Ensures system alteration does not cause a release by providing insufficient pressure to regulating valves or provides over pressurization of off-loaded tanks	• System design requirements may vary substantial for differing services • Not all contingencies can be incorporated into the design	• Review system design prior to change in service
10	Proper material selection **(Prevention)**	API RP 1132 API RP 1627 API RP 1626	• Assures that loading materials are compatible and suitable for the intended service	• Differing service conditions may require different materials • Material selection may be affected by differing service conditions and products	• No special operation or maintenance requirements
11	Appropriate use of strainers to prevent flow control valve failure **(Prevention)**	National Institute for Standards & Technology	• Prevents particulate material from clogging, disabling or disrupting critical equipment such as meters, flow control valves and connectors	• May require retrofit in areas where accessibility is difficult • Requires periodic maintenance • Imposes additional system head loss • Has a lower limit on particle size which can be effectively screened	• Periodically clean strainer basket

Table 6-2 Loading & Unloading Systems Control Measures

Item	Control Measure / Type	Reference	Advantages	Disadvantages	Operation & Maintenance Comments
12	Brake interlocks on tank vehicles **(Prevention)**	See manufacturer's information	• Vehicle cannot move during product transfer operations • Prevents truck from driving away with connections attached	• System must be inspected and maintained for proper operation • Trucks may require retrofit • May create a reliance on system instead of procedures to prevent truck movement	• Inspect and test system operation • Maintain in accordance with vendor requirements
13	Break-away couplings or hoses **(Prevention)**	See manufacturer's information	• Provides a connection designed to fail in the event the system is hit or the tanker moves while still connected • Minimizes the damage to the loading position and amount of product spilled	• Damage may still be extensive • Damage may occur to loaded vessel and may result in loss of contents from loaded vessel • Proper installation critical	• Inspect and maintain in accordance with vendor specifications
14A	Written operating procedures **(Prevention)**		Refer to Item #4 of Table 8-2		
14B	Operator training **(Prevention)**		Refer to Item #1 of Table 8-2		
14C	Periodic / planned and documented inspections **(Prevention)**		Refer to Item #14 of Table 8-2		
15	Review of pump design **(Prevention)**		• Assures that pumping rate will not exceed vent relief design on loaded or unloaded vessel	• Will not prevent damage if a vent is blocked	• No special operation or maintenance requirements
16	Appropriately designed pressure / vacuum relief system **(Prevention)**	API STD 2000	• Prevents a tank structural failure	• Vent system must be designed for maximum possible flow rate • Vents may become blocked • Difficult to assure adequacy of third party carrier's systems	• Periodically inspect vent system

Table 6-2 Loading & Unloading Systems Control Measures

Item	Control Measure / Type	Reference	Advantages	Disadvantages	Operation & Maintenance Comments
17	Presets on metering system **(Prevention)**	See manufacturer's information	• Helps prevent an overfill by limiting the volume of product loaded • Provides redundant spill protection system with high-level shut off	• Pre-set volume must be properly entered and must be less than the compartment size • Pre-set system failure can occur • Pre-set provides an output signal only to shut the control valve	• Periodically inspect and test pre-set system • Provide training in system operation and maintenance
18	Pressure test [Loading / Unloading system] **(Detection)**	API RP 1110	• Detects potential defects in a loading or unloading position by applying a pressure greater than the normal operating pressure • Demonstrates system integrity	• Could cause a release if petroleum is test media • All equipment must be suitable for pressure testing • Isolation of pipe and connectors will be required • If water is used as test media it often presents product quality, operational and waste disposal problems	• Position to be tested has to be positively isolated and may require draining to use low flash product
19	Surveillance camera **(Detection)**	API STD 2610	• Provides surveillance monitoring of loading and unloading areas • Can detect unusual operations or inappropriate operating practices	• Often difficult and costly to install • Provides only a limited area of coverage • Requires staff to monitor cameras/VCRs/tapes	• Train staff in proper operation, monitoring and maintenance
20	Spill Pad **(Protection)**	API STD 2610 ACI 318	• Protects the surrounding area from being impacted by a small release • Provides a barrier for drips and leaks	• May not incorporate pad drainage and storm water / product handling • Does not provide containment of releases • Pad integrity has to be maintained	• Spill pad area must be routinely checked and drips or spills cleaned up
21	Drip pans **(Protection)**	API STD 2610	• Easy to install and isolate areas of potential drips at loading or unloading connections • Protects the surrounding area from being impacted by drip releases	• Does not provide a large amount of containment capacity • Mixed water and product must be managed • Must have periodic observation to prevent overflow	• Perform periodic inspection and drainage of accumulated water or petroleum from pans • Remove cover from pan when performing loading or unloading operations
22	Shear valve on own-use fuel dispenser **(Protection)**	API RP 1650	• Prevents product loss if the dispenser is sheared from its base	• Proper installation critical	• No special operation or maintenance required

Table 6-2 Loading & Unloading Systems Control Measures

Item	Control Measure / Type	Reference	Advantages	Disadvantages	Operation & Maintenance Comments
23	Own-use fuel dispenser containment sump **(Protection)**	API RP 1650	• Provides containment of dispenser base and piping connections • Can be fitted with a leak monitor	• Provides containment of only small releases	• Periodically inspect sump for accumulated water or product if leak detection system is not used
24	Secondary containment system **(Protection)**	API STD 2610	• Protects areas outside of loading and unloading positions from accidental releases • Provides containment of the planned release • Typically has curbing or a rapid drainage system to collect and contain the release	• Storm water which enters the containment area and becomes mixed with petroleum has to be managed • May be difficult to maintain the integrity of the containment area because of cracks, joints and penetrations	• Perform periodic inspection of containment integrity • Perform periodic drainage of accumulated water or petroleum
25	Coatings applied to concrete **(Protection)**	NACE RP-0892-92	• Helps protect the soil and groundwater beneath loading and unloading areas by providing an additional barrier against a release • Seals concrete which has become heavily cracked or has numerous penetrations or joints	• Coating must be compatible with intended service and petroleum • Has to seal effectively to provide protection • Has to bond to secondary containment material to be effective • Difficult to detect defects or holes in coating Must rely on visual inspection	• Perform periodic inspection of coating integrity • Repair coating as necessary
26	Spill containment tank **(Protection)**	API STD 2610	• Protects area outside of a loading position by collecting spilled product • Provides a large volume holding capacity for spill • Allows for gravity drainage of spill • Provides quick product drainage away from loading area thereby reducing the fire hazard	• May require additional compliance with local or state agency underground storage tank requirements • Requires monitoring, testing, instrumentation and inspection of sump • Must be kept clean and free of accumulated storm water • Storm water which enters the tank has to be managed	• Comply with local or state record keeping, inspection and testing requirements • Routinely check level in sump for accumulations of storm water or petroleum

Table 6-2 Loading & Unloading Systems Control Measures

Item	Control Measure / Type	Reference	Advantages	Disadvantages	Operation & Maintenance Comments
27	Impact guards, bollards, dolphins, spars and bumpers **(Prevention)**		• Provides protection of loading and unloading equipment from inadvertent vehicle, equipment or vessel damage • Reasonably easy to retrofit • Provides impact resistance • Provides a deterrent	• May cause damage to the tanker which hits the bollard causing a release • Requires additional space for installation	• Maintain brightly colored paint • Maintain bumper integrity • No special operations required
28	Emergency shutdown system **(Protection)**		• System types vary and can include pump kill switches, flow control valve shutdown systems, in line valve shutdown, or main power disconnect systems • Provides an emergency means of shutting down product flow • Systems are often located at the loading positions and remotely at an office location Remote shutdowns provide a means for stopping the loading operation without exposing personnel Remote shutdowns are important for vehicle accidents involving damage to the loading rack	• Requires manual activation under difficult conditions • Shutdown system has to be conveniently located and easily operated • Has to be properly designed to prevent equipment damage	• Periodically check proper operation of shutdown system • Train all loading personnel in the proper system use including when system should be activated
29	Attended loading or unloading **(Detection/ Protection)**		• Provides monitoring of loading and unloading process • Provides staff to respond to a release or potential for a release	• Requires staff to monitor system • Staff must be attentive, properly trained and experienced with the system being monitored • Improper staff action can be the cause of a release	• Train staff in proper operation, response, monitoring and maintenance

Section 7

ANCILLARY FACILITY EQUIPMENT

INTRODUCTION

The major facility components are discussed in Sections 4 through 6, covering tank and associated piping, as well as loading and unloading systems. A typical facility has several other kinds of equipment or systems that are not easily categorized. This equipment is referred to as *ancillary facility equipment.* As with all equipment, ancillary equipment may be a potential source of a release under certain conditions.

OVERVIEW

Release sources and offsetting control measures associated with ancillary equipment are presented in Table 7-1, which also gives the relative costs for installing and maintaining the control measures. More detailed information on each control measure is presented in Table 7-2.

The ancillary equipment presented in this section includes:

- Vapor processing units
- Water treatment equipment
- Storm water equipment
- Additive systems
- Terminal maintenance garages
- Truck wash facilities
- Product sampling facilities
- Laboratory facilities
- Liquid phase remediation treatment systems
- Tank cleaning operations

Some facilities also conduct specialized operations. For purposes of this report, these specialized functions have been grouped with the ancillary equipment and include:

- Asphalt processing
- Lube blending and packaging
- Aviation fuel handling

RELEASE SCENARIOS

Because of the variety of equipment covered by this section and because the cause of a release may vary depending on the equipment involved, release scenarios are not listed. However, available control measures for typically used ancillary equipment are listed in Table 7-2.

RELEASE PREVENTION

An effective release prevention program focuses on those features that are unique to the specific equipment. However, preventing releases from ancillary equipment does not necessarily create redundant systems. For example, equipment used to inject additives may be a potential source of releases at loading rack boards. Installation of drip pans below the boards may be a prudent and effective control measure. On the other hand, if the injector boards are located inside the secondary containment system of the truck loading area, drip pans are normally unnecessary. Therefore, the release prevention programs covered in Sections 4 through 6 may also apply to ancillary equipment at many facilities.

Table 7-1 Ancillary Facility Equipment Release Scenarios[1]

Release Category	Source of Release	Control Measure Options	Type of Control Prevention Detection Protection	Control Measure reference (see Table 2)	Retrofit Cost	O & M Cost
Spill or Release	Vapor processing unit [liquid petroleum release]	• Loading rack vapor check valves or motor operated valves	P	2A	Low-Medium	Low
		• Periodic inspection of vapor processing equipment	P	6C	Low	Low
		• Overfill alarm / interlock system	P/D	13	Low-Medium	Low
		• Block valves in product piping	Pro	18	Medium	Low
		• Knockout tank	Pro	16	Medium	Low
		• Containment system[2]	Pro	17	Medium-High	Low
	Water treatment • Oil/water separator overfill • Petroleum contact water • Remediation	• Truck overfill prevention interlocks	P	2B	Low	Low-Medium
		• Operator training	P	3A	Low	Medium
		• Periodic planned and documented inspections	P	14	Low-Medium	Low
		• Written operating procedures	P	3B	Medium	Low
		• Programmed or preventative maintenance	P	3C	Medium-High	Medium
		• Proper sizing including flow control regulation for O/W separator	P	1	Medium-High	Low-Medium
		• Overfill alarm / interlock system	P/D	13	Low-Medium	Low
		• Containment system[2]	Pro	17	Medium-High	Low
	Storm water discharge	• Visual inspection prior to release	P/D	4	N/A	Low
		• Control measures as required to meet discharge requirements	P	No Reference	Varies	Varies
	Additive system release	• Refer to section 4 for tank control measures • Refer to section 5 for piping control measures • Refer to section 6 for additive unloading control measures • Drip pans located beneath injector boards, pumps and loading connections	Pro	19	Low	Low
	Terminal maintenance garage	• Operator training in proper waste management procedures	P	3A	Low	Medium
		• Written operating procedures in waste management / waste minimization	P	3B	Medium	Low
		• Periodic planned and documented inspections	P/D	14	Low-Medium	Low
		• Spill pads / drip pans	Pro	19	Low	Low
		• Dedicated used oil / glycol collection, storage and handling system [2]	Pro	20	Medium	Medium
	Truck wash water	• Operator training	P	3A	Low	Medium
		• Written operating procedures	P	3B	Medium	Low
		• Periodic planned and documented inspections	P/D	14	Low-Medium	Low
		• Dedicated wash water handling, treatment and disposal system[2]	Pro	21	High	Medium
		• Containment system [truck wash]	Pro	17	Medium-High	Low

[1]Abbreviations used in this table are: N/A=Not Applicable, P=Prevention, D=Detection, P/D=provides Prevention and Detection, Pro=Protection Measure
[2]Cost effective control measure for new construction

Table 7-1 Ancillary Facility Equipment Release Scenarios[1]

Release Category	Source of Release	Control Measure Options	Type of Control Prevention Detection Protection	Control Measure reference (see Table 2)	Retrofit Cost	O & M Cost
	Sampling facility (Product only)	• Operator training	P	3A	Low	Medium
		• Written operating procedures	P	3B	Medium	Low
		• Waste containers / waste handling procedures	P	9	Low-Medium	Low
		• Closed loop sampling systems	P	7	Medium	Low
		• Periodic planned and documented inspections	P/D	14	Low-Medium	Low
		• Weather protection shed / spill pad[2]	Pro	23	Medium-High	Low
	Laboratory facility	• Operator training	P	3A	Low	Medium
		• Written operating procedures	P	3B	Medium	Low
		• Waste containers / waste handling procedures	P	9	Low-Medium	Low
		• Proper management of laboratory reagents and product samples	P	8	Medium	Low
		• Periodic planned and documented inspections	P/D	14	Low-Medium	Low
	Asphalt facilities	• Top loading release prevention procedures	P	5	Low	Low
		• Periodic inspection program for corrosion under insulation	P	6A	N/A	Medium
		• Periodic inspection for accelerated corrosion within piping and tanks	P	6B	N/A	Medium
	Lube oil facilities exclusive of packaging facilities	• Operator training	P	3A	Low	Medium
		• Written operating procedures	P	3B	Medium	Low
		• Periodic integrity inspections of hoses	P	10	Low-Medium	Low
		• Periodic inspection program for corrosion under insulation	P	6A	N/A	Medium
		• Periodic inspection for accelerated corrosion within piping and tanks	P	6B	N/A	Medium
		• Top loading release prevention procedures	P	5	Low	Low
		• Spill pads / containment system [for blending areas][2]	Pro	22	High	Low
	Aviation fueling facilities exclusive of hydrant or aircraft refueling systems	• Operator training	P	3A	Low	Medium
		• Written operating procedures	P	3B	Medium	Low
		• Spill pads / containment system [for fuel filter equipment][2]	Pro	22	High	Low
	Liquid phase remediation treatment systems	• Operator training	P	3A	Low	Medium
		• Written operating procedures	P	3B	Medium	Low
		• Ensure proper material compatibility	P	11	Low	Low
		• Overfill prevention devices for recovered product	P	12	Low	Low-Medium
		• System malfunction alarms	D	15	Low	Low
		• Spill pads / containment system [for remediation equipment] [2]	Pro	22	High	Low

Table 7-1 Ancillary Facility Equipment Release Scenarios[1]

Release Category	Source of Release	Control Measure Options	Type of Control Prevention Detection Protection	Control Measure reference (see Table 2)	Retrofit Cost	O & M Cost
	Tank cleaning operations	• Operator training • Written operating procedures • Waste containers / waste handling procedures • Periodic planned and documented inspections	P P P P/D	3A 3B 9 14	Low Medium Low-Medium Low-Medium	Medium Low Low Low

Table 7-2 Ancillary Facility Equipment Control Measures

Item	Control Measure / Type	Reference	Advantages	Disadvantages	Operation & Maintenance Comments
1	Proper sizing including flow control regulation for oil / water separator **(Prevention)**	API Publ 4602	• Ensures that separator can handle design flows without discharge of oil or overflow release • Flow control via a lift station or line restriction prevents flows greater than separator can handle • Provides for procedures and controls to manage the water when the rain event exceeds the design storm or facility alteration increases the amount of water	• May cause impoundment of water upstream • Requires detailed analysis of tank farm hydrology	• Periodically inspect oil/water separator for accumulated product • Periodically check discharge flow for sheen and flow rate
2A	Loading rack vapor check valves or motor operated valves **(Prevention)**		• Prevents damage to vapor hoses and connections at truck loading rack from truck movement • Prevents release of product or vapor	• Does not address accumulation of condensed petroleum in vapor lines	• Periodically inspect and test interlock system
2B	Truck overfill prevention interlocks **(Prevention)**		• Prevents possible accumulation of petroleum in vapor lines due to loading overfill	• Does not address accumulation of condensed petroleum in vapor lines	• Periodically inspect and test interlock system
3A	Operator training **(Prevention)**	Refer to Item 1 of Section 8	*Refer to Item #1 of Table 8-2		
3B	Written operating procedures **(Prevention)**	Refer to Item 4 of Section 8	*Refer to Item #4 of Table 8-2		
3C	Programmed or preventative maintenance **(Prevention)**	Refer to Item 8 of Section 8	*Refer to Item #8 of Table 8-2		

Table 7-2 Ancillary Facility Equipment Control Measures

Item	Control Measure / Type	Reference	Advantages	Disadvantages	Operation & Maintenance Comments
4	Visual inspection prior to release **(Prevention/ Detection)**	API Publ 4602	• Verifies water quality prior to discharges by having operating personnel confirm that no visible sheen is present on accumulated storm water	• Releases occurring after visual inspection could be discharged	• Visual inspected accumulated water prior to discharge
5	Top loading release prevention procedures **(Prevention)**	API STD 2610	• Provides written procedures instead of engineered control measures to prevent over fills from heavy product top loading	• Procedures have to be strictly followed • Personnel have to be nearby to respond quickly	• Follow operating procedure • Train all personnel performing top loading in procedures and policies regarding the performance of top loading
6A	Periodic inspection program for corrosion under insulation **(Prevention)**	API RP 574 API 570	• Small sections of insulation on pipe or tank is removed to visual inspect metal corrosion condition	• Only addresses a very small sample of the insulated pipe • Conditions can vary substantially in localized areas	• Perform visual inspection on weak or disturbed insulation or at areas likely to accumulate water (i.e. pipe supports, attachments, lower ring of tank) • Document results and recommend necessary repairs
6B	Periodic inspection for accelerated corrosion within piping and tanks **(Prevention)**	API RP 574 API 570	• Addresses the concern of accelerated corrosion from heated petroleum products • Internal inspection of pipe and tank will detect general degradation or isolated areas of corrosion attack	• Very difficult to perform • Often requires extensive cleaning of metal surface • Usually inspection is limited to small areas which are considered to be representative of the entire system	• Pipe or vessel has to be isolated, emptied and cleaned • Perform visual inspection of representative areas • Document results and recommend necessary repairs
6C	Periodic inspection of vapor processing equipment **(Prevention)**		• Provides verification of system integrity	• May require removal of unit from service • Internal inspections require entry into confined space	• Perform periodic inspection of vapor unit • Properly train inspection personnel including appropriate safety training
7	Closed loop sampling system **(Prevention)**		• Prevents drips and spills caused by open sampling taps • Provides a totally closed system for sampling	• Sampling facilities have to be located near lines to be sampled	• Perform periodic inspection of lines and valves

Table 7-2 Ancillary Facility Equipment Control Measures

Item	Control Measure / Type	Reference	Advantages	Disadvantages	Operation & Maintenance Comments
8	Proper management of laboratory reagents & product samples **(Prevention)**	API RP 1638	• Prevents improper product and waste disposal or release • Special facilities and waste handling containers provided	• System is dependent upon lab technician for proper performance	• Perform training and periodically audit technicians
9	Waste containers / waste handling procedures **(Prevention)**	API RP 1638 API Publ 4602	• Ensures that wastes generated during tank cleaning operations are properly managed including storage, labeling, characterization and disposal	• Tank sludge has to be carefully placed inside containers and containers have to be protected prior to disposal	• Follow company procedures for handling and protecting waste containers
10	Periodic integrity inspections of hoses **(Prevention)**		• Visual inspection of hoses will often detect defects in hose prior to rupture	• Some defects are often hidden from view due to dirt, sleeves or hose guards • Some defects may be too small to visually detect	• Perform periodic visual inspection of hoses
11	Ensure proper material compatibility **(Prevention)**	API RP 1132	• Ensures that critical materials such as gaskets, pipe material, seals, etc. are compatible with the petroleum product to be encountered	• Systems designed for unlikely concentrations of petroleum may be difficult to construct • Systems designed for low-level concentrations or which encounter large concentrations of a single constituent may cause a release	• Ensure that all critical materials are compatible with the products and concentrations to be encountered
12	Overfill prevention devices for recovered product **(Prevention)**	API RP 2350	• Prevents tank overfill by restricting flow into tank, shutting a valve or shutting down a pump	• System requires monitoring	• Periodically inspect and/or test overfill prevention system • Train operators in system operation and maintenance

Table 7-2 Ancillary Facility Equipment Control Measures

Item	Control Measure / Type	Reference	Advantages	Disadvantages	Operation & Maintenance Comments
13	Overfill alarm / interlock system **(Prevention /Detection)**	API RP 2350	Refer to Items #3A & 3B of Table 4-2		
14	Periodic planned and documented inspections **(Prevention /Detection)**		Refer to Item #14 of Table 8-2		
15	System malfunction alarms **(Detection)**		• Alerts operator	• Requires operator action • May foster operator complacency	• Operator has to be trained in the nature of the alarm and required response • Periodically test and inspect alarm system
16	Knockout tank **(Protection)**		• Contains an accidental overfill • Contains condensed product	• Requires routine inspection • Must be designed in accordance with flow-through process tank requirements	• Inspect tank contents routinely • Pump out accumulated product
17	Containment System **(Protection)**	API STD 2610	• Suitable for containment of small drips or leaks from pumps, filters, air eliminators, valves, compressors, etc. • Prevents soil / water contamination	• Need to keep liquid tight • Need to handle accumulations • Need to handle storm water • Special handling procedures for product contaminated solids	• Install to allow maintenance of equipment • Inspect and drain routinely
18	Block valve in product piping **(Protection)**	API RP 574	• Provides isolation of petroleum lines from the vapor unit	• May not prevent a release from occurring	• Ensure block valves are properly identified and are in the proper position [open or closed]

Table 7-2 Ancillary Facility Equipment Control Measures

Item	Control Measure / Type	Reference	Advantages	Disadvantages	Operation & Maintenance Comments
19	Spill Pads / Drip pans **(Protection)**	API STD 2610	• Effective and economical method for collecting small drips in areas under pump seals, flanges or hose connections	• Can only accommodate small quantities • Should only be used as a temporary method for controlling existing leaks until repairs can be made	• Periodically check drip pans for accumulated water or petroleum • Empty as necessary • Properly manage petroleum / water mixes
20	Dedicated used oil / glycol collection, storage and handling system **(Protection)**		• Provides a secure location to store materials • Provides capability to recover or recycle glycol or oil • Ensures products are properly recovered	• Requires two separate and distinct storage areas • Storage areas have to be managed to prevent releases • Have to develop a recycling or disposal program	• Schedule and perform periodic recycling of collected oil / glycol; or • Schedule pickup of collected oil / glycol with outside vendor
21	Dedicated wash water handling, treatment and disposal system **(Protection)**	API RP 1638	• Contains, collects and properly manages wash water which may contain emulsified oil and grease • Maintains integrity and isolation from other facility waste water handling system by preventing the introduction of possible emulsifying agents • Recover and recycle operations can decrease the volume of makeup water required to wash vehicles	• System has to be sized to accommodate the anticipated number and size of vehicles • System requires periodic maintenance and inspection • Sludge and wash water may require special handling and disposal	• Follow operating procedure for system use • Ensure that wash water does not enter into yard storm water or facility waste water system unless the system was designed to handle
22	Spill pads / containment system **(Protection)**	API STD 2610	• Protects the surrounding area from being impacted by a release • Provides a barrier for drips or leaks or containment of larger volume releases • Contains the release in a controlled area	• Mixed water / petroleum products have to be properly managed • Spill pads do not provide significant containment volume • Containment areas have to be sized to handle the anticipated release volume	• Periodically inspect for spilled product or accumulated water • Remove accumulated petroleum and properly manage accumulated water

Table 7-2 Ancillary Facility Equipment Control Measures

Item	Control Measure / Type	Reference	Advantages	Disadvantages	Operation & Maintenance Comments
23	Weather protection shed / spill pad **(Protection)**		• Prevents contaminated storm water runoff from lab area	• May develop a hazardous vapor concentrations in shed • May requires ventilation and explosion-proof electrical system	• Perform periodic inspection of floor slab

Section 8

OPERATING SYSTEMS

INTRODUCTION

Previous sections of this document outlined engineered and non-engineered controls available to facility owners and operators. This section addresses the human factor -- or operating systems -- involved in conducting sound facility operations. Employee performance, as well as policies and procedures, act as control measures. In many instances, the use of such controls is as effective as strict reliance on engineered controls. Conversely, misapplication or lack of an effective operating system can be the direct or indirect cause of a release.

OVERVIEW

Personnel at an aboveground tank facility perform a range of activities. Facility personnel job activities may be grouped as shown below:

CATEGORY	RESPONSIBILITIES
Operations	Operation of storage facilities, pipeline facilities, or marine transfer systems; loading and unloading of vessels, railroad tank cars, and tank trucks
Maintenance	Facility maintenance and repair
Other Activities	Construction, maintenance, system upgrades, environmental and waste management services, and facility housekeeping.

Operations and maintenance personnel may be employees of the operating company or contract employees.

Facility staffing requirements vary widely and are generally based on the facility size, location, amount of product stored, degree of automation and other factors. In many instances, a continuous staff is not required, and release prevention and detection is handled by a combination of continuously automated systems with periodic human review. For facilities with minimal staffing requirements, the observations of this section may not always be applicable.

An effective program addresses training, knowledge, skills, and ability for all personnel activity. The facility operator can ensure that personnel:

- Are trained in appropriate work practices and procedures
- Adhere to established operational and maintenance procedures and policies
- Perform periodic physical inspections
- Operate and maintain systems in a manner consistent with established procedures
- Support or augment engineered controls
- Are actively involved in preventive maintenance
- Are involved in an established system for reviewing, approving, and documenting changes to process equipment prior to construction or return to service
- Are trained and prepared to respond to a release

RELEASE SCENARIOS

Releases resulting from an operating system failure can be grouped into the following broad categories:

Operational Practices: Releases may be attributable to errors or omissions by facility personnel. Examples of such errors include tank overfills or incorrect use of equipment. Facility personnel errors and omissions also may be related to inattention to policies and procedures.

Maintenance Practices: Releases may be attributable to errors or omissions in facility maintenance practices. Proper maintenance ensures operationally sound equipment, controls, and alarm systems.

RELEASE PREVENTION

Use of the operating system to prevent releases is based on the following elements:

- Management commitment
- Defined job duties and responsibilities
- Documented operating procedures
- Personnel training programs
- Supervisory oversight
- Evaluation and feedback for personnel

Management controls and appropriate staffing by trained personnel can be the central components of an effective operating system.

Causes of potential releases and available control measures associated with the facility operating system are presented in Table 8-1, which also gives the relative costs for installing and maintaining the control measures. Information on the application of the various control measures is presented in Table 8-2.

Table 8-1 Operating Systems Release Scenarios[1]

Release Category	Cause	Control Measure	Type of Control Prevention Detection Protection	Control Measure Reference (see Table 2)	Retrofit Cost	O & M Cost
Spill / Release	• Operator error • Deficient facility supervisory systems • Management policy and procedures deficiencies	• Operator training and operating procedures	P	1	Low	Medium
		• Inventory control & reconciliation	P/D	2	Low	Medium
		• Management of change procedure	P	3	Low	Medium
		• Documented operating procedures	P	4	Medium	Low
		• Evaluate operator schedule	P	5	Medium	Medium
		• Permit review meetings	P	6	Medium	Medium
		• Spill prevention plans / best management practice plans	P	7	Medium	Medium
		• Programmed or preventative maintenance	P	8	Medium-High	Medium
		• Fail safe engineered systems	P	9	High	Low-Medium
		• Visual inspection of containment water prior to discharge	P/D	10	Low	Low
		• Personnel attended dike water discharges	P/D	11	Low	Low
		• Attended product transfers	P/D	12	Low	Low
		• Daily walk around visual inspections	P/D	13	Low	Low
		• Periodic/ planned & documented inspections	P/D	14	Low-Medium	Low
		• Periodic audits	P/D	15	Medium-High	Medium
		• Spill response plans	Pro	16	Medium	Low

[1]*Abbreviations used in this table are: N/A=Not Applicable, (P)=Prevention Measure, (d)=Detection Measure, (P/D)=provides Prevention & Detection, (Pro)=Protection Measure*

Table 8-2 Operating Systems Control Measures

Item	Control Measure / Type	Reference	Benefits	Considerations	Routine Tasks
1	Operator training **(Prevention)**	API RP 750	• Provides personnel knowledge and skills necessary to perform their duties • Reinforces proper procedures and operation • Validates job performance	• Time to perform training • Ensure procedures will be followed by auditing performance • Regular review level of operator training	• Periodically review and update training process • Monitor training frequency • Test for understanding • Document training
2	Inventory control & reconciliation **(Prevention/ Detection)**		• Manages facility wide inventory by proven method • Provides documentation of the integrity of the system • Readily detects large or steady releases	• Closely track inventory • Adequate time to perform inventory reconciliation	• Periodically review records • Follow up on inventory inconsistencies
3	Management of change procedure **(Prevention)**	API RP 750 API STD 2610	• Documents change of procedure • Promotes safe process changes	• Operators commitment • Potential for inconsistent application - oversight essential to success	• Regular review necessary • Documentation and record keeping
4	Documented operating procedures **(Prevention)**	API RP 750 API STD 2610	• Provides written procedures and checklists to serve as road maps for job performance • Provides appropriate training for equipment operation • Reinforces job procedures & duties • Refreshes operators' knowledge of proper work performance	• Update procedures periodically to keep current • Inspect to see that procedures are followed • Recognize that it does not prevent human error • Requires appropriate job skills and training • Need system in place to develop, update and review procedures • Training must be performed routinely to be effective	• Review procedures & training periodically • Periodically perform training • Update procedures when equipment is changed
5	Evaluate operations schedule **(Prevention)**	API STD 2610	• Allows for alteration and adjustment of schedules to accommodate human factors • Allows response to changing work requirements and job demands	• Allocate proper amount of time to perform job tasks in conformance with the required operating procedures • Evaluate schedule rotations and shift lengths • Use knowledgeable and experienced person to evaluate schedules • Use job task analysis to gain understanding of the knowledge, skills and abilities required to perform the job	• Regular evaluation of each operating section

Table 8-2 Operating Systems Control Measures

Item	Control Measure / Type	Reference	Benefits	Considerations	Routine Tasks
6	Permit review meetings **(Prevention)**		• Provides personnel with knowledge and information regarding essential government requirements • Underscores facilities compliance requirements • Ensure permit changes are communicated to staff	• Meeting is facilitated by person knowledgeable in applicable regulatory requirements • Staff time is allocated for meetings • Staff is provided with important facts and requirements and is allowed to ask questions	• Periodically schedule meetings • Review and prepare for meetings
7	Spill prevention plans / Best Management Practice plans **(Prevention)**		• Provides an overall plan to prevent liquid releases • Focuses on preventing a release and identifying potential sources of a release • Ensures periodic review of facility prevention and protection measures on a periodic basis	• Allocate staff and resources to develop plan, train staff, and audit performance • The plan has to be kept relevant and up to date as the facility is modified or staff changes • May be part of a response plan, see item 6	• Conduct periodic plan reviews • Update plan as necessary to correct & identify deficiencies or changes to facility
8	Programmed or preventative maintenance program **(Prevention)**	API RP 750	• Identifies potential problems • Elevates awareness • Reduces unplanned maintenance • Maintenance is budgeted up-front	• Monitor maintenance performance • Maintenance scheduling	• Maintenance performed per schedule • Monitor status of record keeping & documentation
9	Fail safe engineered systems **(Prevention)**	API RP 750	• Reduces operator error • Provides redundancy approach • Dependable • Provides 24-hour protection	• Keep well maintained to avoid equipment failure • Need to budget for installation • New equipment may develop unique problems which need to be investigated / fixed • Plan for replacement with better and more dependable equipment when new technology becomes available	• Perform regular maintenance • Practice contingency planning
10	Visual inspection of containment water prior to discharge **(Prevention/ Detection)**	API Publ 4602	• Serves as a last review to prevent inadvertent discharge of visible petroleum • Prevents discharge of visibly contaminated water	• Train operators to prevent discharge of water with petroleum sheen • Operating staff to periodically check on discharging water • Allocate time to perform this task	• Inspect accumulated water prior to discharge • Periodically inspect discharge water

Table 8-2 Operating Systems Control Measures

Item	Control Measure / Type	Reference	Benefits	Considerations	Routine Tasks
11	Personnel attended dike water discharges **(Prevention/ Detection)**	API STD 2610	• Provides knowledgeable staff available at the site during dike water discharges to ensure that a release is not discharged	• Train staff in proper procedures and response • Allocate time for performance of this task	• Staff are on site and available during all dike water discharges • Staff periodically inspect the dike discharge water for liquid petroleum or petroleum sheen
12	Attended product transfers **(Prevention/ Detection)**		• Provides knowledgeable staff available at the site during petroleum receipts to properly setup a receipt, respond to alarms and take appropriate corrective actions	• Allocate staff for performance of this task • Staff training in job duties, responsibilities, notifications and corrective actions • Staff necessary to detect alarms or overfill conditions	• Staff are on site and available during all receipts • Staff periodically inspect the receiving tank evidence of alarms or overfill
13	Daily walk around visual inspections **(Prevention/ Detection)**	API STD 653	• Provides a daily visual and auditable check of the tanks, loading and unloading areas for potential releases • Detection of small releases	• Allocation of time • Staff training in job duties, responsibilities, what to look and listen for, documentation, notification and corrective actions • Periodic verifications to be sure daily inspections are being performed • Awareness of the possible release sources and locations • Requires timely resolution of noted defects	• Perform periodic visual inspection • Document inspection • Provide documentation and notification of items requiring correction
14	Periodic / planned & documented inspections **(Prevention/ Detection)**	API RP 574 API STD 653 API RP 750	• Provides a documented routine review of critical components and operations • Documents regulatory compliance • Maintains a sense of heightened awareness throughout the facility • Helps avoid complacency • Provides a periodic check of system performance	• Be aware that such inspections provide only a snap shot view of the system integrity • Requires evaluation of the results and corrective actions to be effective • Promptly act on inspection findings	• Perform periodic inspections • Monitor program and system effectiveness

Table 8-2 Operating Systems Control Measures

Item	Control Measure / Type	Reference	Benefits	Considerations	Routine Tasks
15	Periodic audits **(Prevention / Detection)**	API STD 750	• Identifies potential problems • Allows for periodic review and corrective actions to be taken • Raises awareness of the concern for release prevention and system integrity	• Allocate time and staff for performance • Use of outside staff or management oversight provides heighten importance and provides an outsiders review to the process • The focus of the audit is on detecting practices, procedures or equipment which may result in a release • The audit results include recommended corrective actions and a time table for audit comment resolution	• Schedule audit cycle with third party participation • Close out findings within a reasonable time
16	Spill response plans **(Protection)**		• Ensures facility is prepared to respond to anticipated release scenarios or other emergencies • Focuses on the priority tasks for rapid response to a release • Provides for integration of response activities with outside agencies such as fire department or coast guard	• Allocate staff and resources to develop plans, train staff, coordinate with outside agencies and perform joint drills • Provide staff for spill plan and emergency response • The plan has to be kept relevant and up to date as the facility is modified or staff changes • Provide a spill plan coordinator	• Conduct periodic plan reviews and training exercises • Update plan as necessary to correct deficiencies or changes to facility

BIBLIOGRAPHY

American Concrete Institute (ACI)
P.O. Box 19150; Detroit, MI 48219; (313)532-2600

318 *Building Code Requirements for Reinforced Concrete*

American Petroleum Institute (API)
1220 L Street, NW, Washington, D.C. 20005; (202)682-8000

Publ 315 *Assessment of Tankfield Dike Lining Materials and Methods*
Publ 328 *Laboratory Evaluation of Candidate Liners for Secondary Containment of Petroleum Products*
Publ 334 *A Guide to Leak Detection for Aboveground Storage Tanks*
API 570 *Piping Inspection Code*
RP 574 *Inspection of Piping, Tubing, Valves, and Fittings*
RP 575 *Inspection of Atmospheric and Low-Pressure Storage Tanks*
Std 650 *Welded Steel Tanks for Oil Storage* (ANSI/API Std 650)
RP 651 *Cathodic Protection of Aboveground Petroleum Storage Tanks*
RP 652 *Lining of Aboveground Petroleum Storage Tank Bottoms*
Std 653 *Tank Inspection, Repair, Alteration and Reconstruction* (ANSI/API Std 653)
RP 750 *Management of Process Hazards*
RP 1004 *Bottom Loading and Vapor Recovery for MC-306 Tank Motor Vehicles*
RP 1110 *Pressure Testing of Liquid Petroleum Pipelines*
Publ 1132 *Effects of Oxygenated Fuels & Reformulated Diesel Fuels on Elastomers and Polymers in Pipeline/Terminal Components*
RP 1004 *Bottom Loading & Vapor Recovery for MC-306 Tank Motor Vehicles*
RP 1626 *Storing and Handling Ethanol and Gasoline-Ethanol Blends at Distribution Terminals and Service Stations*
RP 1627 *Storing and Handling of Gasoline-Methanol/Cosolvent Blends at Distribution Terminals and Service Stations*
RP 1638 *Waste Management Practices for Petroleum Marketing Facilities*
RP 1650 *Set of Six API Recommended Practices on Underground Storage Tank Management*
Std 2000 *Venting Atmospheric and Low-Pressure Storage Tanks: Nonrefrigerated and Refrigerated*
RP 2220 *Improving Owner and Contractor Safety Performance*
RP 2305 *Overfill Protection for Petroleum Storage Tanks*
STD 2610 *Design, Construction, Operation, Maintenance and Inspection of Terminal and Tank Facilities* (ANSI/API 2610)
Pub 4602 *Minimization, Handling, Treatment and Disposal of Petroleum Products Terminal Wastewaters*

American Society of Mechanical Engineers (ASME)
345 East 47th Street; New York, NY 10017; (212) 705-7722

B16.5 *Pipe Flanges and Flanged Fittings*
B31.3 *Process Piping*
B31.4 *Liquid Petroleum Transportation Piping Systems*

American Society for Testing and Materials (ASTM)
100 Barr Harbor Dr.; West Coshohocken, PA 19428; (610)832-9585

ASTM G57 *Field Measurement of Soil Resistivity Using the Wenner Four Electrode Method*
ASTM G51 *Measuring pH of Soil for Use in Corrosion Testing*

American Water Works Association (AWWA)
6666 W. Quincy Avenue; Denver, CO. 80235; (303) 794-7711

STD C-600 *Installation of Ductile Iron and Their Appurtenances*

American Welding Society (AWS)
550 LeJeune Rd., NW; Miami, FL 33126; (305) 443-9353

D-1.1 *Welding in Building Construction*

Driscoll, F. 1986. *Groundwater and Wells*, 2nd ed. Published by Johnson Division, St. Paul, MN.

National Association of Corrosion Engineers (NACE)
PO Box 218340, Houston, TX 77218: (713) 492-0535

RP0169 *Control of External Corrosion on Underground or Submerged Metallic Piping Systems*
RP0193 *Cathodic Protection of On Grade Metallic Storage Tank Bottoms*
RP0285 *Control of External Corrosion of Metallic Buried, Partially Buried, or Submerged Liquid Storage Systems*
RP0575 *Design, Installation, Operation and Maintenance of Internal Cathodic Protection Systems in Oil Treating Vessels*
RP0892 *Linings Over Concrete For Immersion Service*

National Fire Protection Association (NFPA)
One Batterymarch Park; P.O. Box 9101; Quincy, MA 02269

30 *Flammable and Combustible Liquids Code*
70 *National Electric Code*

Steel Structures Painting Council (SSPC)
4516 Henry St; Pittsburgh, PA 15213; (412) 687-1113

SP1 *Solvent Cleaning*
SP2 *Hand Tool Cleaning*
SP3 *Power Tool Cleaning*
SP5 *White Metal Blast Cleaning*
SP6 *Commercial Blast Cleaning*
SP7 *Brush-off blast Cleaning*
SP10 *Near-White Metal Blast Cleaning*

Underwriters Laboratories (UL)
333 Pfigsten Rd. Northbrook, IL 60062-2069; (708) 272-8800

UL-142 *Steel Storage Tanks*

UNI-BELL PVC Pipe Association
2655 Villa Creek Dr., Suite 155; Dallas, TX 75234; (214) 243-3902

UNI-B-6-90 *Low-Pressure Air Testing of Installed Sewer Pipe*

Appendix A

ABBREVIATIONS

A/G	Aboveground
AST	Aboveground storage tank
CIP	Cast iron pipe
CIPCP	Cast in place concrete pipe
CMP	Corrugated metal pipe
D	Detection control measure
DIP	Ductile iron pipe
FRP	Fiber reinforced plastic
HDPE	High-density-poly-ethylene
P	Prevention control measure
P/D	Prevention and detection control measure
PCP	Pre-cast concrete
PRO	Protection control measure
PVC	Poly-vinyl chloride
RPB	Release Prevention Barrier
RPS	Release Prevention System
SPCC	Spill Prevention Controls and Countermeasures
U/G	Underground
UST	Underground Storage Tank
VCP	Vitrified clay pipe
WSP	Welded steel pipe

Appendix B

DEFINITIONS

Terms used within this report have the following meaning:

Aboveground Storage Tank (Vertical and Horizontal).

An atmospheric vertical or horizontal, cylindrical, closed-top or open-top, steel or fiberglass aboveground storage containers of various sizes and capacities over 1100 gallons (4164 liters) and whose entire bottom is supported uniformly on the ground, completely on saddles, or other supports

Control Measure

The available practices, procedures, technologies, and equipment that can be used in AST facilities to prevent or detect a liquid release or protect the outside environment from a release.

Detection

Any device, equipment, procedure, or operating practice whose primary function is to identify a release or the potential of a release of liquid petroleum outside the primary containment system.

Dead Legs

A section of unused liquid-filled petroleum piping that branches off the main pipe. Dead legs are often the inadvertent result of piping system alterations.

Engineered Control

Any control measure that involves use of equipment whose function is to serve as a release prevention, detection or environmental protection measure.

Facility

Refers to the physical property, equipment, buildings, structure, pipelines or other physical features associated with aboveground storage tanks referred to in this report.

Liquid Release

The abnormal discharge, spill, leak or release of liquid petroleum products outside their primary containment system.

Non-Engineered Control or Procedural Control

Any control measure that involves the use of policies, procedures or personnel to prevent, detect or protect the environment from a release.

Operator

The person responsible for the performance of the specific task. For example, the driver performing the loading or unloading operation is the operator.

Practice or Procedure

Refers to operating, maintenance, testing, and inspection methods or policies that are used to prevent, detect or protect the environment from a liquid petroleum release.

Prevention

Any device, equipment, procedure, or operating practice whose primary function is to avert a release of liquid petroleum outside of the primary containment system.

Primary Containment

The system such as a tank or piping whose purpose is to hold liquid petroleum.

Protection

Any device, equipment, procedure, or operating practice whose primary function is to minimize the impact of a release on the surrounding soil, groundwater or surface waters.

Release Scenario

Various potential sources or causes for the discharge or the potential of discharging liquid petroleum outside the primary containment system.

Release Prevention Barrier (RPB)

Refers to the items covered in the non-mandatory Appendix I of API Standard 650 and includes steel bottoms, synthetic materials, clay liners and all other barriers and combination of barriers placed in the bottom of or under an aboveground storage tank that have these functions: (a) preventing the escape of contaminated material, and (b) containing or channeling release material for leak detection. Application of RPBs is limited to aboveground storage tanks only.

Release Prevention System (RPS)

Refers to API Standards designed to maintain aboveground storage tank integrity, thus protecting the environment. These standards cover such things as frequency of internal inspections, lining the bottom of the tank interior, fitting the tank with RPBs, installing cathodic protection or some combination of these measures, depending on the operating

environment and service of the tank. Application of RPSs is limited to aboveground storage tanks only.

Secondary Containment

The means available to retain a release of petroleum from impacting the soil, groundwater or surface water adjacent to the facility in the event a release of petroleum occurs from a tank, vessel, loading, unloading or piping area. This may involve the use of dikes, remote impoundment, drainage, knockout tanks or other means that will hold the anticipated volume of petroleum. The requirements for secondary containment vary based upon the regulatory jurisdiction and applicable code. For detailed requirements on secondary containment, refer to NFPA 30, the Uniform Fire Code, the Federal SPCC Regulations (29 CFR 112), the Oil Pollution Act of 1990 and the specific state regulations where the facility is located.

Vadose zone

The subsurface soil area of aeration above the atmospheric groundwater table. The vadose zone includes the area where the soil is less than 100 percent saturated and the capillary water area where water is held against the soil by capillary forces.

American Petroleum Institute
1220 L Street, Northwest
Washington, D.C. 20005
202-682-8000
http://www.api.org

Order No. J34000