

LIQUID RELEASE PREVENTION AND DETECTION MEASURES FOR ABOVEGROUND STORAGE FACILITIES

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Liquid Release Prevention and Detection Measures for Aboveground Storage Facilities

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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/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.

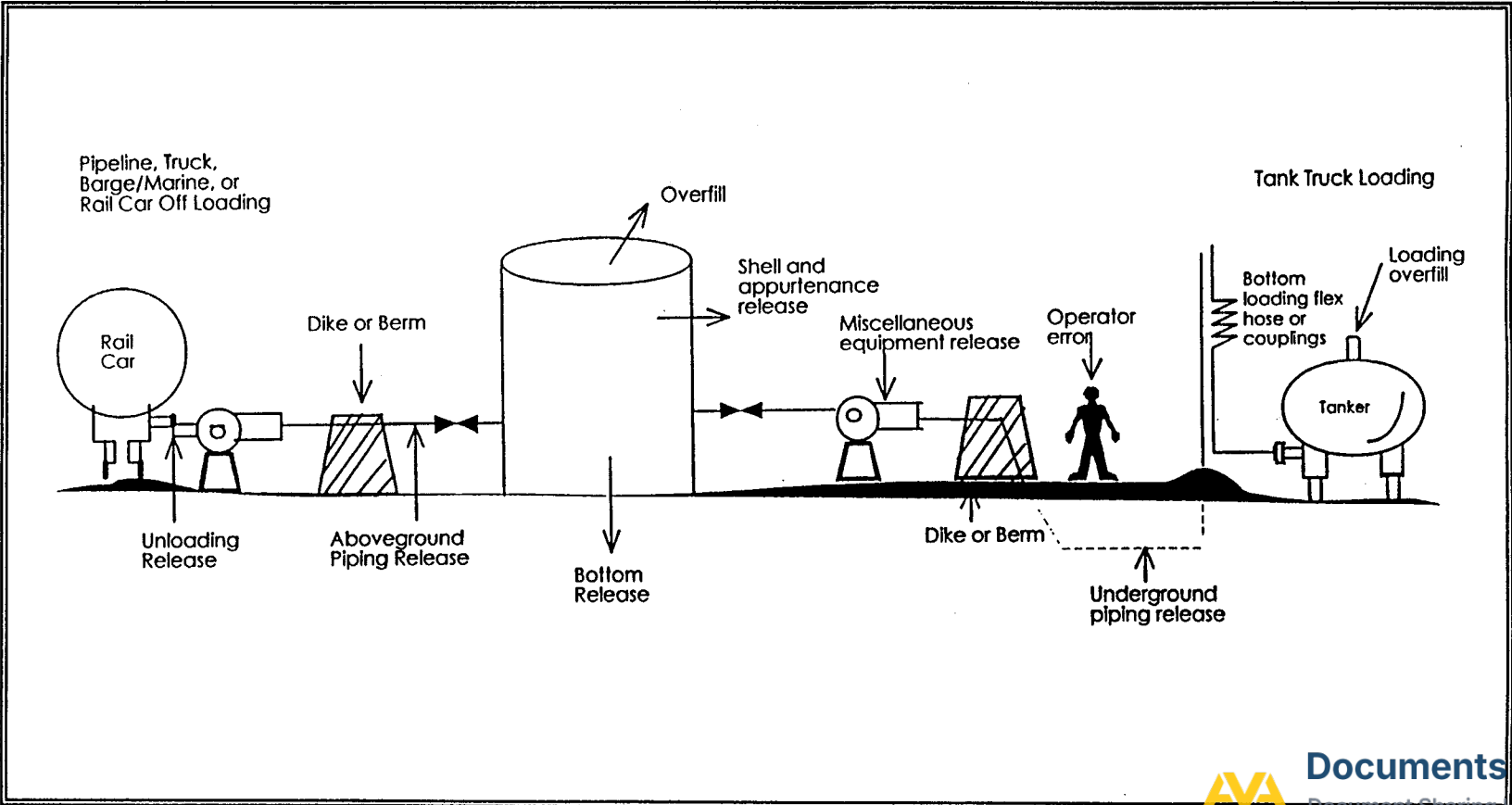
Application of the options discussed in this report should be based on sound engineering judgment and in accordance with relevant codes, standards, and manufacturers' recommendations.

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

1-5



Section 2

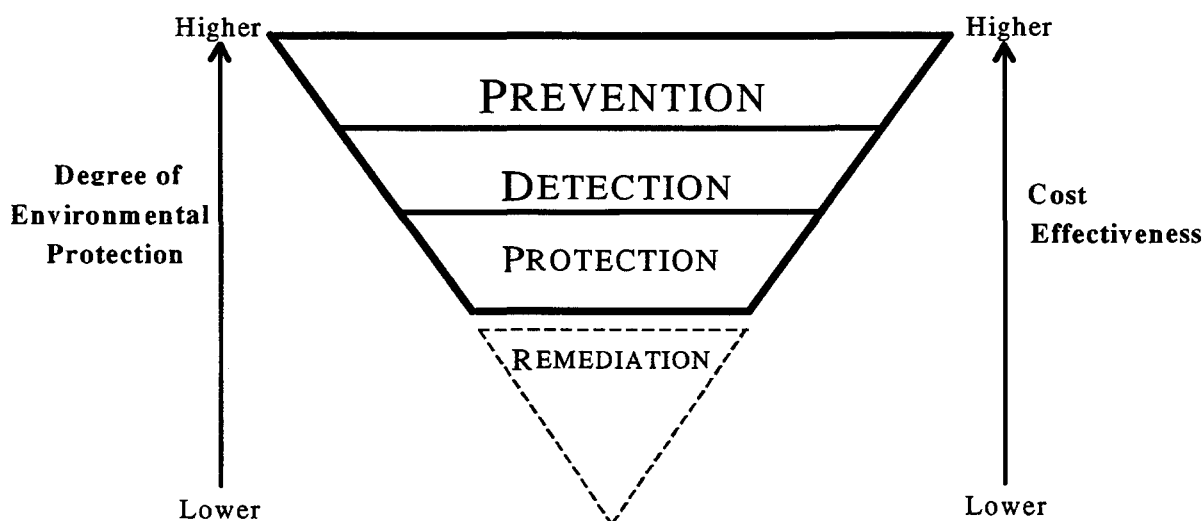
SELECTION CRITERIA

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 overflow; slow releases from rapid shell failure, the bottom, the shell, or an appurtenance.

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

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 Scenarios¹

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 - Operator training - Overfill protection system alarms and instrumentation² - Manual product level verification before & during receipt - Automatic product level verification before & during receipt - Tank farm secondary containment dike / berms - Tank farm dike yard liners	P	5A	Low	Medium
			P	5A	Low	Medium
			P	3B	Medium-High	Medium-High
			P	3A	Low-Medium	Low-Medium
			P	3B	Medium-High	Medium-High
			Pro	28	High	Low
			Pro	29	Very High	Medium-High
	Equipment failure	- Planned and documented inspections in accordance with API STD 653 - Automatic tank gauging system - Manual product level verification before & during receipt - Overfill protection system alarms and instrumentation² - Programmed, preventative maintenance and testing - Tank farm secondary containment dike / berms - Tank farm dike yard liners	P	13A	N/A	Low
			P	13B	N/A	Medium
			D	21B	Medium	Medium
			P	3A	Low-Medium	Low-Medium
			P	3B	Medium-High	Medium-High
			P	5B	Medium-High	Medium
			Pro	28	High	Low
Slow Releases /Shell release	1. External corrosion 2. Corrosion under insulation 3. Internal corrosion	- External coating of steel tank - Planned and documented inspections in accordance with API STD 653 - Steel tank product side lining or coating - Routine walk around inspections - Tank farm dike yard liners - Internal cathodic protection for internal corrosion	P	2B	Medium	Medium
			P	13A	N/A	Low
			P	13B	N/A	Medium
			P	2A	Medium-High	Low-Medium
			D	25	N/A	Low
			Pro	29	Very High	Medium-High
			P	35	High	Low-Medium
	Weld crack	- Planned and document inspections in accordance with API STD 653 - Routine walk around inspections - Tank farm secondary containment dike / berms	P	13A	N/A	Low
			P	13B	N/A	Medium
			D	25	N/A	Low
			Pro	28	High	Low

¹Abbreviations used in this table are: N/A=Not Applicable, P=Prevention, D=Detection, P/D=provides Prevention and Detection, Pro=Protection Measure

²Cost effective control measure for new construction



Table 4-1 Aboveground Storage Tank Release Scenarios¹

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 - Planned and documented inspections in accordance with API STD 653 - Non-destructive tank testing - Periodic precision tank testing - Tank gauging system for inventory reconciliation - Under tank monitor - Groundwater monitoring wells - Release prevention barrier in accordance with API STD 650	P	2A	Medium-High	Low-Medium
			P	13A	N/A	Low
			P	13B	N/A	Medium
			P	7, 8,10-12	N/A	Low
			P	15	N/A	Low
			D	22	N/A	Low
			D	23	N/A	Low
			D	21A	Low-Medium	Low
			D	20	High	Low
			D	24	High	Low
	Bottom side corrosion	- Cathodic protection system - Planned and documented inspections in accordance with API STD 653 - Provide drainage for water away from tank - Non-destructive tank testing - Perform electronic floor scan - Steel tank soil side coating or lining - Periodic precision tank testing - Tank gauging system for inventory reconciliation - Under tank monitor - Groundwater monitoring wells - Release prevention barrier in accordance with API STD 650	D	26	Medium-High	Low-Medium
			Pro/D	27A - 27C	Very High	Low
			P	1A & 1B	Medium-High	Low
			P	13A	N/A	Low
			P	13B	N/A	Medium
			P	6	Low-Medium	Low
			P	7,8, 10-12	N/A	Low
			P	15	N/A	Low
			P	2C	High	Low
			D	22	N/A	Low
	Bottom side corrosion	- Cathodic protection system - Planned and documented inspections in accordance with API STD 653 - Provide drainage for water away from tank - Non-destructive tank testing - Perform electronic floor scan - Steel tank soil side coating or lining - Periodic precision tank testing - Tank gauging system for inventory reconciliation - Under tank monitor - Groundwater monitoring wells - Release prevention barrier in accordance with API STD 650	D	23	N/A	Low
			D	21A	Low-Medium	Low
			D	20	High	Low
			D	24	High	Low
			D	26	Medium-High	Low-Medium
			Pro/D	27A - 27C	Very High	Low

Table 4-1 Aboveground Storage Tank Release Scenarios¹

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 - Non-destructive tank testing - Steel striker plates installed under the roof legs - Keep floating roof legs off bottom except during maintenance - Vacuum box test of tank bottom welds - Periodic precision tank testing - Tank gauging system for inventory reconciliation - Soil vapor monitoring - Groundwater monitoring wells - Under tank monitor - Release prevention barrier in accordance with API STD 650	P	13A	N/A	Low
			P	13B	N/A	Medium
			P	7,8,10-12,	N/A	Low
			P	15	N/A	Low
			P	9A	Low	Low
			P	9B	Low	Low
			P/D	19	N/A	Medium
			D	22	N/A	Low
			D	23	N/A	Low
			D	21A	Low-Medium	Low
			D	24	High	Low
			D	26	Medium-High	Low-Medium
			D	20	High	Low
	Tank settlement/ Foundation failure	- Planned and documented inspections in accordance with API STD 653 - Periodic precision tank testing - Tank gauging system for inventory reconciliation - Under tank monitor - Groundwater monitoring wells - Release prevention barrier in accordance with API STD 650	P	13A	N/A	Low
			P	13B	N/A	Medium
			D	22	N/A	Low
			D	23	N/A	Low
			D	21A	Low-Medium	Low
			D	20	High	Low
			D	24	High	Low
			D	26	Medium-High	Low-Medium
	Corrosion	- Planned and documented inspections in accordance with API STD 653 - Routine walk around inspections	P	13A	N/A	Low
			P	13B	N/A	Medium
			P/D	25	N/A	Low

Table 4-1 Aboveground Storage Tank Release Scenarios¹

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	14	Low	Low
			P	13A	N/A	Low
			P	13B	N/A	Medium
			P/D	25	N/A	Low
	Operator error	- Operator training - Written operating procedures - Routine walk around inspections	P	5A	Low	Medium
			P	5A	Low	Medium
			D	25	N/A	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	5A	Low	Medium
			P	13A	N/A	Low
			P	13B	N/A	Medium
			D	25	N/A	Low
			P	17A	Low	Low
			Pro	31	Low	Low
			P	5A	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	5A	Low	Medium
			P	13A	N/A	Low
			P/D	32	N/A	Low
			P	33	High	Low
			P	34	Medium-High	Low
	Vandalism	- Routine walk around inspections - Locked valves - Perimeter security fence - Lighting - Security cameras - Staffing surveillance	D	25	N/A	Low
			P	17A	Low	Low
			P	17B	Medium	Low
			P	17C	Medium	Low
			P	17D	Medium	Medium-High
			P	17E	N/A	High

Table 4-1 Aboveground Storage Tank Release Scenarios¹

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 • Control of delivery / suction • Written maintenance procedures • Vent tank in accordance with API RP 2000 • Pressure / vacuum vent design and maintenance • Tank farm secondary containment dike / berms • Tank farm dike yard liners	P P P P P Pro Pro	5A 4C 5A 4B 4A 28 29	Low Low Low Low-Medium Medium High Very High	Medium Medium Medium Low Low Low Medium-High
	Tank settlement / Foundation failure	• Planned and documented inspections in accordance with API STD 653 • Secondary containment dike/ berms • Dike yard liners	P P P Pro Pro	13A 13B 13C 28 29	N/A N/A Medium High Very High	Low Medium Low Low Medium-High
	Brittle shell failure	• Repairs, material selection, reconstruction and inspection in accordance with API STD 653 • Hydrostatic test • Tank farm secondary containment dike/ berms • Tank farm dike yard liners	P P P/D Pro Pro	13B 13C 18 28 29	N/A Medium N/A High Very High	Medium Low Low-Medium Low Medium-High
	Tank over pressurization	• Pressure / vacuum vent design and maintenance • Vent tank in accordance with API RP 2000 and API Std 650 • Planned and documented inspections in accordance with API STD 653 • Tank farm secondary containment dike / berms • Tank farm dike yard liners	P P P P Pro Pro	4A 4B 13A 13B 28 29	Medium Low-Medium N/A N/A High Very High	Low Low Low Medium Low Medium-High
	Earthquake / Weather related failures	• Planned and documented inspections in accordance with API STD 653 • Emergency preparedness plans • Secondary containment dike • Use of anchors, annular plates and other restraints • Dike yard liners	P P Pro Pro P Pro	13A 13B 16 28 30 29	N/A N/A Low High High Very High	Low Medium Low Low Low 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 Preparation	- 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 unobstructed 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

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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 <u>and</u> 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