

# Vapor Collection and Control Options for Storage and Transfer Operations in the Petroleum Industry

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FIRST EDITION, MARCH 1993



American Petroleum Institute  
1220 L Street, Northwest  
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## Measurement Coordination

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## FOREWORD

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## CONTENTS

|                                                                               | Page |
|-------------------------------------------------------------------------------|------|
| <b>SECTION 1—INTRODUCTION</b>                                                 |      |
| 1.1 Scope .....                                                               | 1    |
| 1.2 Purpose .....                                                             | 1    |
| 1.3 Definition of Vapor Collection and Control .....                          | 1    |
| <b>SECTION 2—APPLICATIONS OF VAPOR CONTROL</b>                                |      |
| 2.1 Storage Tank Vapor Control .....                                          | 1    |
| 2.1.1 Internal Floating Roofs .....                                           | 2    |
| 2.1.2 Vapor Control Systems .....                                             | 2    |
| 2.2 Truck and Rail Terminal Transfer Vapor Control .....                      | 3    |
| 2.2.1 Loading Methods .....                                                   | 3    |
| 2.2.2 Vapor Control .....                                                     | 3    |
| 2.3 Marine Terminal Vapor Control .....                                       | 4    |
| <b>SECTION 3—VAPOR COLLECTION SYSTEMS</b>                                     |      |
| 3.1 Vapor Balancing .....                                                     | 5    |
| 3.2 Vacuum-Assisted Vapor Collection Systems .....                            | 7    |
| <b>SECTION 4—VAPOR RECOVERY PROCESSES</b>                                     |      |
| 4.1 Carbon Adsorption .....                                                   | 9    |
| 4.2 Lean Oil Absorption .....                                                 | 11   |
| 4.3 Refrigeration .....                                                       | 12   |
| <b>SECTION 5—VAPOR DESTRUCTION PROCESSES</b>                                  |      |
| 5.1 Thermal Oxidation—Flares .....                                            | 13   |
| 5.2 Thermal Oxidation—Incineration .....                                      | 16   |
| 5.3 Catalytic Oxidation .....                                                 | 17   |
| <b>SECTION 6—HYBRID PROCESSES AND EMERGING TECHNOLOGIES</b>                   |      |
| 6.1 Absorption-Adsorption-Absorption .....                                    | 18   |
| 6.2 Vapor Recovery With Vapor Destruction .....                               | 18   |
| 6.3 Brayton Cycle .....                                                       | 19   |
| 6.4 Membrane Separation .....                                                 | 19   |
| 6.5 Refrigeration With Cogeneration .....                                     | 21   |
| <b>SECTION 7—CONSIDERATIONS FOR EVALUATING VAPOR CONTROL TECHNOLOGIES</b>     |      |
| 7.1 Data for Vapor Recovery Systems .....                                     | 22   |
| 7.2 Data for Vapor Destruction Systems .....                                  | 22   |
| <b>SECTION 8—REFERENCES</b>                                                   |      |
| 8.1 Referenced Publications .....                                             | 23   |
| 8.2 Suggested Further Reading .....                                           | 23   |
| <b>APPENDIX A—VAPOR CONTROL TECHNOLOGY CHECKLISTS</b> .....                   | 25   |
| <b>Figures</b>                                                                |      |
| 1—Storage Tank and Tank Truck Loading Hydrocarbon Concentration Profile ..... | 3    |
| 2—Typical Marine Vessel Loading System .....                                  | 4    |
| 3—Marine Vessel Loading Hydrocarbon Concentration Profile .....               | 5    |
| 4—Vapor Balancing System .....                                                | 6    |
| 5—Typical Carbon Adsorption Vapor Recovery System .....                       | 10   |

|                                                                   | Page |
|-------------------------------------------------------------------|------|
| 6—Typical Lean Oil Absorption Vapor Recovery System .....         | 11   |
| 7—Typical Refrigeration Vapor Recovery System .....               | 13   |
| 8—Typical Open Flare System .....                                 | 15   |
| 9—Typical Enclosed Flare System .....                             | 16   |
| 10—Typical Catalytic Oxidation System .....                       | 17   |
| 11—Typical Absorption-Adsorption-Absorption Recovery System ..... | 18   |
| 12—Typical Reverse Brayton Cycle Recovery System .....            | 20   |
| 13—Typical Membrane Vapor Separation System .....                 | 21   |
| 14—Typical Refrigeration/Cogeneration System .....                | 22   |
| Tables                                                            |      |
| 1—Vapor Recovery Process Comparison .....                         | 8    |
| 2—Vapor Recovery System Cost Estimates .....                      | 9    |
| 3—Vapor Destruction Process Comparison .....                      | 14   |
| 4—Flare System Cost Estimates .....                               | 15   |

# Vapor Collection and Control Options for Storage and Transfer Operations in the Petroleum Industry

## SECTION 1—INTRODUCTION

### 1.1 Scope

Vapor collection and control, as it is discussed in this publication, includes the collection and treatment of volatile hydrocarbon vapors emitted during the storage and transfer of petroleum products and during loading operations. Passive vapor controls, which also can be effective at reducing emissions, are not covered in this publication. During loading operations, vapors from petroleum liquid will evaporate to reach equilibrium at ambient conditions to the degree allowed by the vapors' inherent vapor pressure. For example, vapors expelled while a rail car or truck is being filled with gasoline result from the exposure of hydrocarbon vapors to air and evaporation during transfer. Agitation of liquids and heating could cause additional vapor emissions during transfer operations. Vapor control devices collect emitted vapors and recover (for example, through refrigeration, absorption, or adsorption) or destroy (for example, by thermal or catalytic oxidation) them to prevent hydrocarbon vapors from releasing to the environment.

### 1.2 Purpose

This publication has been prepared to introduce vapor control technologies to individuals who are responsible for designing or purchasing vapor control devices for use on petroleum storage, transfer, and loading operations. The objectives of this publication are to acquaint readers with available vapor control technologies, provide general costing information, and supply a list of suggested reading for additional information on vapor emissions and control devices (see 8.2). Furthermore, vapor control technology checklists are provided in Appendix A to help readers effectively communicate their system needs to equipment vendors. The general issues that are discussed for each type of vapor control device include advantages and disadvantages; technical fea-

sibility; and situational factors that affect applicability. Tank, truck, rail, and marine (ship and barge) loading operations are the specific applications discussed because these are the most common petroleum product transfer operations.

This publication is not intended to recommend specific vendors or to cover all aspects of vapor control technology. Each application must be analyzed individually. Using this publication as a guide, readers may discuss with vendors general aspects of each technology with minimum background research. Furthermore, since this publication will likely be used by individuals in many geographic and regulatory areas, regulations concerning vapor controls and vapor recovery should be consulted in addition to this publication. A thorough understanding of local, state, and federal regulations is essential before proceeding with the design, selection, or use of any pollution control device.

### 1.3 Definition of Vapor Collection and Control

*Vapor collection and control* includes the collection and treatment of emissions containing volatile organic compounds (VOCs). The objective of vapor control is to reduce the volume and/or concentration of vapors escaping to ambient air. This publication examines both the devices that collect vapors emitted during transfer or loading operations and emission abatement processes. Two emission abatement processes are discussed: a) recovery devices that remove vapors from gaseous streams and return the vapors as liquids for reuse and b) destruction (oxidation) devices that destroy vapors in gaseous streams.

It should be noted that in any emission reduction strategy, opportunities for minimizing emission generation should always be considered; however, vapor formation minimization techniques to reduce emissions from storage tanks are not addressed in this publication.

## SECTION 2—APPLICATIONS OF VAPOR CONTROL

Three important applications of vapor control in the petroleum industry, in terms of the volume of vapor processed and number of installations, are storage tank vapor control, truck and rail terminal transfer vapor control, and marine terminal vapor control.

### 2.1 Storage Tank Vapor Control

The use of storage tanks is necessary in the production, refining, transportation, and distribution of petroleum products. Storage tanks are sources of evaporative emissions,

which are usually calculated using API Publications 2517 [1] and 2519 [2] and MPMS Chapter 19, Section 1 (formerly API Publication 2518) [3]. Vapor control is most commonly applied to fixed cone or dome roof tanks without internal floating roofs. Fixed-roof tanks with internal floating roofs can accommodate vapor control technology, but this is less frequently done. Collection and treatment of vapors from internal floating roof tanks is generally less cost-effective because hydrocarbon vapor concentrations are significantly lower. Vapor control techniques are not typically applied to an external floating roof tank because the outer roof of the tank sits directly on the liquid surface and only a small internal vapor space is created around the rim seal; however, an external floating roof tank can be modified to accommodate vapor control by retrofitting the existing tank with a self-supporting fixed roof. Spherical tanks used for pressurized storage of liquefied petroleum gas generally have no evaporative losses.

Fixed-roof storage tanks are commonly used at refineries, pipeline tank farms, bulk plants, and transfer terminals for storage of low volatility liquids. Generally, each tank is equipped with a pressure-vacuum vent (P/V or conservation vent) valve designed to allow displaced air and vapor to escape during filling and to allow air or a vapor/air mixture to be introduced to the tank when product is being emptied. The vent prevents excessive pressures or vacuums from developing that could damage the tank. The design pressures of the tanks and all equipment must not be exceeded by the addition of a vapor collection system. Vapor emitted during filling is often referred to as the *working loss*.

Vapors can also escape from fixed-roof tanks when there is no product transfer activity. Daily temperature increases cause pressure buildup in a tank. Vapors are expelled through the P/V vent when pressure exceeds the setting on the vent valve, which is typically much less than 1 pound per square inch gauge. Pressure tolerance and vent valve setting vary depending on the tank design. Upon cooling, pressure can drop below the valve setting and air is introduced. Emissions that result from this process are often referred to as *breathing* or *standing loss*. In many cases, liquid stored in a fixed-roof tank has a low vapor pressure. The low hydrocarbon concentrations created by the low vapor pressure may not be cost effective to control.

### 2.1.1 INTERNAL FLOATING ROOFS

One approach to controlling evaporative emissions from fixed-roof tanks is to retrofit the existing tank with an internal floating roof. Internal floating roofs reduce evaporative storage losses by minimizing contact of petroleum products with air. The internal floating roof, or deck, is free to float on the surface of the stored liquid and rises or falls according to

the height of the stored liquid. Rim seals are fitted to the edge of the floating roof where it meets the internal wall of the tank. Internal floating roofs can generally be installed inside existing fixed-roof tanks if the tanks are free of internal obstructions that would limit travel of the floating roof and do not contain thick or viscous material, such as heavy asphalt.

### 2.1.2 VAPOR CONTROL SYSTEMS

Using vapor control systems is another approach to controlling emissions from existing fixed-roof tanks. Vapor control can also be used on internal floating roof tanks. Because the emission rate of hydrocarbon vapor around rim seals in internal floating roofs is low, vapor concentrations for vapor control applied to internal floating roof tanks are much lower than concentrations for vapor control applied to fixed-roof tanks without internal floating roofs. With vapor control, vapors vented as working or breathing losses are removed through a piping system connected at or near the roof and are transported to a vapor recovery or destruction device.

Sometimes, several storage tanks containing similar products can be manifolded together and vented to a single vapor control system. Thus, one control device can service a number of storage tanks. This can be economical if tanks are filled at low rates. Sharing the control device may be impractical if operations allow simultaneous filling of tanks requiring a large vapor processor. If a vapor control system is used, manifolded the vapor space of several tanks can also equalize pressure buildup or decrease in the tanks. Economies of scale can be realized by installing one large unit rather than several small ones. Manifolded systems must be carefully designed to minimize the potential for explosion propagation through the system. Product contamination and explosive mixture formation can be issues if vapor spaces of dissimilar products are connected. The actual design of the vapor control system must consider many operations and safety aspects. Storage tank vapor control designs are uniquely applied from one facility to another.

The choice of applying vapor control versus retrofitting tanks with internal floating roofs is not a clear one, and many factors must be considered. Cost-effectiveness of vapor control increases if the vapor from several tanks can be processed by a single vapor control system. The cost-effectiveness of adding internal floating roofs as opposed to vapor control varies with the size of the tank, Reid vapor pressure (RVP) of stock, and number of turnovers. In general, larger diameter tanks can be controlled by vapor control more cost effectively than smaller tanks, but the economics governing use of vapor control versus retrofitting internal floating roofs vary enough that the economics must be evaluated on a case-by-case basis.

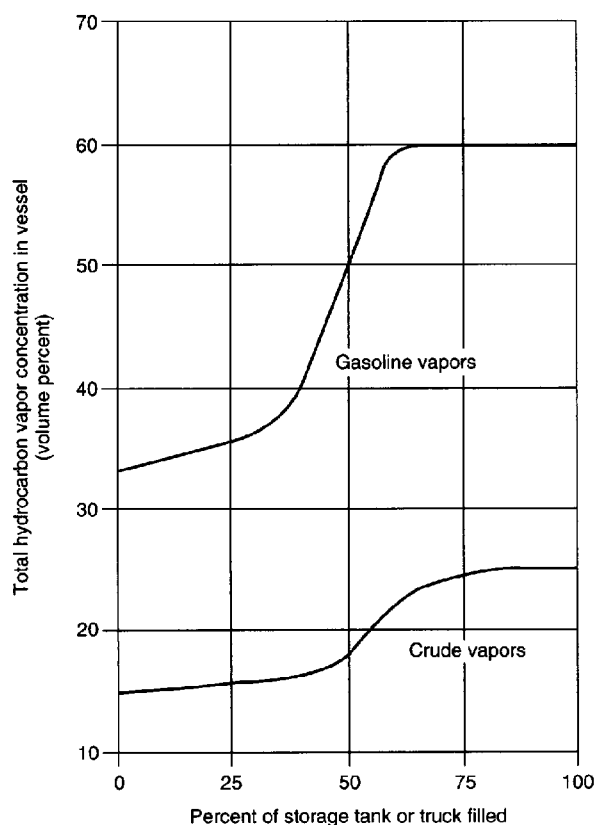


Figure 1—Storage Tank and Tank Truck Loading Hydrocarbon Concentration Profile

## 2.2 Truck and Rail Terminal Transfer Vapor Control

At bulk plants and transfer terminals, petroleum products are transferred into tank trucks and rail cars through metered loading racks. Finished products, such as gasoline and diesel, are generally transported by tank trucks; chemicals and intermediates are generally transported by rail cars. Loading racks can contain pumps, meters, piping, and movable loading arms with flexible hoses and check valves that connect to the delivery tank trucks. In addition, safety considerations require grounding, fire suppression equipment, and overfill alarms. A typical loading rack design has four to ten rack positions or bays. Since each rack position typically has three loading arms (each dedicated to one product), many loading arms are available for loading operations. Loading rack equipment does not vary significantly from small to large facilities; however, the number of loading positions increases.

The design loading rate of the nominal truck loading arm is about 650 gallons per minute (2,460 liters per minute). A truck loading, including hookup and disconnect, typically

takes 10 to 20 minutes. During short peak periods of loading, all of the loading arms may be used simultaneously; however, standard use of the facility would be approximately two to four trucks at any given time.

### 2.2.1 LOADING METHODS

Without vapor control, emissions from truck and rail terminal transfer occur when the product being loaded displaces the vapors in the delivery vessel and forces the vapors to the atmosphere. The amount and hydrocarbon content of these emissions can be influenced by the loading method. Loading may be performed using the splash, submerged, or bottom fill method. In the splash method, the fill pipe dispenses the gasoline from the top of the truck and is only partially lowered into the cargo tank. Significant turbulence and air-liquid contact occurs during splash loading; this results in high levels of vapor generation and loss.

Loading product by using a fill pipe extended (submerged) inside the truck from the top to the bottom or loading product directly at the bottom of the truck reduces vapor generation. Most tank trucks are bottom loaded, and most rail cars are top loaded with the fill pipe extending to about 1 to 2 feet (0.3 to 0.6 meters) above the bottom of the tank. For both submerged loading methods, the fill pipe opening is below the liquid level during a majority of the loading time. The submerged loading method significantly reduces the liquid turbulence and air-liquid contact. Therefore, vapor emissions are reduced by 60 to 65 percent compared to splash loading [4]. In typical submerged fill gasoline loading operations, the vapor inside the tank truck contains about 30–60 percent hydrocarbon. Figure 1 shows an example of typical hydrocarbon concentration profiles for a storage tank or tank truck filling with either gasoline or crude. (Note that saturation levels of an actual profile will be largely dependent on RVP of stock and loading conditions.)

Tank trucks dedicated to a single service are generally not cleaned or vented between trips. An empty tank truck or rail car in dedicated gasoline service will retain a significant concentration of vapors generated by the evaporation of residual gasoline product. The vapors in the empty tank truck or rail car that arrives at the next transfer facility may be saturated with hydrocarbon. The saturation level will be greater for trucks that deliver to facilities employing vapor balancing. The residual vapors are expelled along with newly generated vapors during the subsequent loading operation.

### 2.2.2 VAPOR CONTROL

Vapor control at tank truck loading facilities is not a new concept. In 1990, approximately 70 percent of all bulk terminals in the United States had some type of vapor processor. In an operating vapor recovery system, the vapors

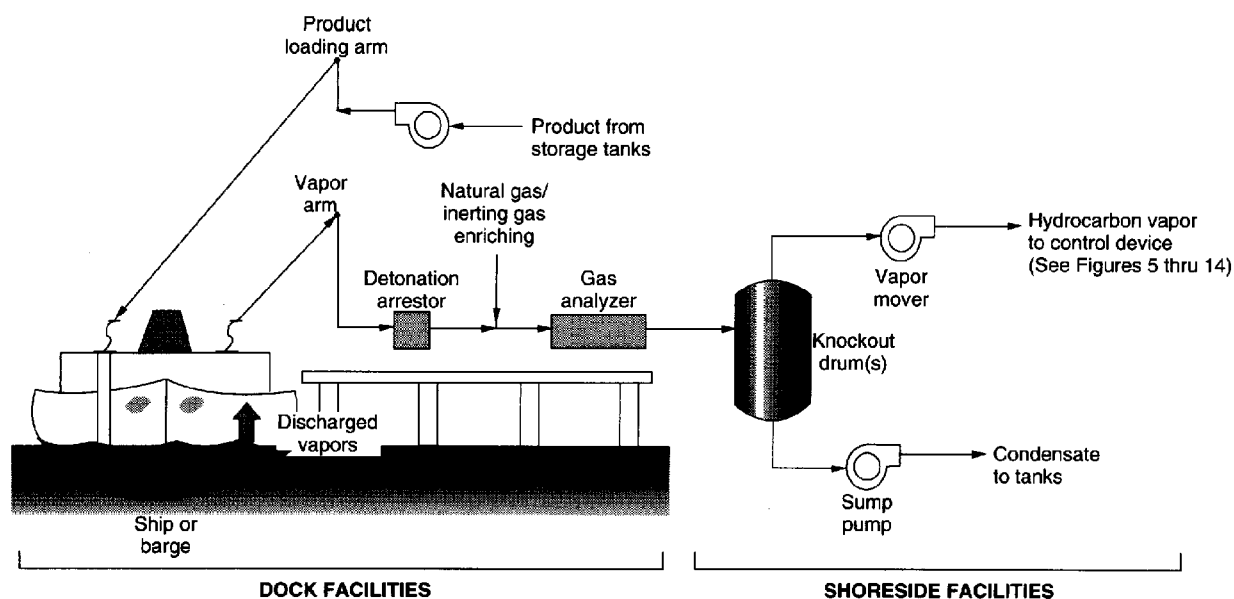


Figure 2—Typical Marine Vessel Loading System

displaced from the cargo tanks during loading are collected in a vapor header on the cargo carrier and returned to tanks being discharged (vapor balancing) or to a vapor recovery or destruction unit.

Vapor control has not been commonly applied at rail loading facilities mainly because gasoline is not generally loaded onto rail cars in the United States. Also, vapor recovery has not generally been applied to truck loading of diesel and heavier products. The low vapor pressure of such products produces a lower concentration of VOC, making recovery less effective. The vapors may also be potentially dangerous because they are not rich enough to exceed the upper explosive limit (UEL) and can be flammable.

### 2.3 Marine Terminal Vapor Control

Hydrocarbon vapors displaced from the cargo hold of marine vessels during vessel loading historically have been the largest single source of hydrocarbon emissions at storage terminals. Evaporative emissions from marine vessels are usually calculated using API Publication 2514A [5]. It is not uncommon to find that uncontrolled releases of hydrocarbon during gasoline loading onto a single ship or large barge can amount to as much as several tons of VOCs.

To collect and control the release of hydrocarbon vapors from marine loading activities, vessels must be designed or retrofitted to accommodate marine vapor collection. Ship safety is an important aspect of the design and implementation of a marine vapor recovery system. Regulations for marine system safety in the United States are the responsibility of the U.S. Coast Guard. Due to the international nature of the shipping industry, operating and safety concerns are also

being addressed by the Oil Companies International Marine Forum (OCIMF) [6], and draft standards are proposed by the International Maritime Organization (IMO) [7]. Shipboard equipment required by the U.S. Coast Guard includes vapor collection piping and manifold connections (vapor header) that join the vapor space of all vessel cargo compartments. On some ships, the inert gas system header may serve as an appropriate vapor header.

In addition, all open vents or manholes on ships or barges must be sealed off to allow closed loading and prevent escape of cargo vapors. This in turn requires certain safety precautions, such as remote tank gauging and overfill alarms, because the product level in the vessel can no longer be viewed directly. Of primary concern for the safety of the ship is protection against overpressuring or underpressuring the vessel. To protect against overpressuring or underpressuring, P/V valves must be installed in vent lines or on individual vessel tanks.

Shipdock and shoreside components of a marine vapor recovery system are shown in Figure 2. Vapor from the ship's compartments is either displaced under slight positive pressure by the rising product in the vessel or evacuated under a vacuum created by a shoreside vapor mover, which can be either a vacuum pump, blower, or fan. A movable vapor collection hose or vapor arm is attached to the ship's vapor manifold to carry the vapors to the dock. On the dock, the U.S. Coast Guard requires detonation arrestors; hydrocarbon or oxygen analyzers; and vapor enriching, inerting, or diluting systems in the vapor piping for fire safety [8]. Sufficient controls must be installed to shut down the system if the hydrocarbon and oxygen mixture falls within the flammable range.