

Marine Vapor Control Training Guidelines

API RECOMMENDED PRACTICE 1127
FIRST EDITION, NOVEMBER 1993

American Petroleum Institute
1220 L Street, Northwest
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Manufacturing, Distribution and Marketing Department

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FOREWORD

This recommended practice was developed under the direction of the API Marine Transportation Committee in cooperation with the Independent Liquid Terminals Association, The American Waterways Operators, and the American Institute of Merchant Shipping. This publication is intended to introduce uniformity in marine vapor control personnel training programs for tank ships, tank barges, and marine terminals required to operate vapor collection systems for the transfer of gasoline, crude oil, and benzene.

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Suggested revisions are invited and should be submitted to the director of the Manufacturing, Distribution and Marketing Department, American Petroleum Institute, 1220 L Street, N.W., Washington, DC 20005.

CONTENTS

	Page
SECTION 1—GENERAL	
1.1 Objective and Scope	1
1.2 Glossary	1
1.3 Referenced Publications	1
1.4 Introduction	1
1.5 System Overview	2
1.5.1 Enclosed Combustion	3
1.5.2 Open Flares	3
1.5.3 Carbon Adsorption Systems	3
1.5.4 Refrigeration Systems	3
1.5.5 Lean-Oil Absorption	3
1.5.6 Recycling to a Plant-Fuel Gas System	4
1.6 Hazards	4
1.6.1 Fire and Explosion	4
1.6.2 Over- or Underpressurization	4
1.6.3 Overfilling	4
1.6.4 Misconnection of Liquid and Vapor Lines	4
1.6.5 Condensation in the Vapor Line	4
1.6.6 Pyrophoric Iron Sulfide Deposits	4
1.6.7 Static Electricity Discharge	4
SECTION 2—VESSEL COMPONENTS AND SAFETY AND OPERATING CONCERNS	
2.1 Vessel Components	5
2.2 Safety Concerns	5
2.2.1 General	5
2.2.2 Overfilling the Vessel	5
2.2.3 Overpressuring the Vessel	8
2.2.4 Underpressuring the Vessel	9
2.2.5 Misconnection of Hoses and Loading Arms	10
2.3 General Operating Concerns	10
2.3.1 Cargo Contamination	10
2.3.2 Valve Positioning	11
2.3.3 Inspection	11
2.3.4 Static Electricity	12
2.3.5 Condensate in the Vapor Header	12
2.3.6 Vessel Filling Rate	12
2.3.7 System Emergency Shutdowns and Alarms: What Should Be Done?.....	12
2.3.8 Pretransfer Conference	13
2.3.9 Vapor Balancing During Lightering	14
SECTION 3—SHORE COMPONENTS AND SAFETY AND OPERATING CONCERNS	
3.1 Shore Components	15
3.2 Safety Concerns	15
3.2.1 General	15
3.2.2 Overfilling the Vessel	15
3.2.3 Overpressuring the Vessel	17
3.2.4 Underpressuring the Vessel	19
3.2.5 Preventing Flame Propagation and Detonation	20

	Page
3.2.6 Misconnection of Hoses and Loading Arms	25
3.3 General Operating Concerns	26
3.3.1 Vessel and Shore Cargo Connections	26
3.3.2 Cargo Hoses	26
3.3.3 Cargo Loading Arms	26
3.3.4 Vessel and Shore Insulating and Grounding	27
3.3.5 Static Electricity	28
3.3.6 Vessel Filling Rate	28
3.3.7 System Emergency Shutdowns and Alarms: What Should Be Done?	29
3.3.8 Routine System Monitoring	29
3.3.9 Pretransfer Conference	30
3.4 Before the Loading Begins	31
APPENDIX A—WHAT IS COMBUSTION?	33
APPENDIX B—DETONATIONS IN PIPING	35
APPENDIX C—EXAMPLES OF VESSEL AND SHORE COMPONENTS	37
APPENDIX D—GLOSSARY	55
APPENDIX E—BRIEF OUTLINE OF NATIONAL EMISSION STANDARD FOR HAZARDOUS AIR POLLUTANTS (NESHAP) REQUIREMENTS FOR THE DOCK OPERATOR	57
 Figures	
1—Marine Emission Control Schematic	2
2—Markings for Vapor Line and Vapor Hose	9
3—Vessel and Shore Vapor Connection	11
4—Insulating Flange Joint	27
C-1—High-Level or Overfill Alarm System Pin-and-Sleeve Device	39
C-2—Connector for an Intrinsically Safe Overfill System	40
C-3—Bidirectional Detonation Arrestor	40
C-4—Bidirectional Detonation Arrestor: Crimped Ribbon Style	41
C-5—Bidirectional Detonation Arrestor: Packed Style	42
C-6—Closed Sampling Device	42
C-7—Closed Gauging Device with Block Valve	43
C-8—Deck and Hatch Covers	44
C-9—Marine Sight Glass	45
C-10—Marine Spill Valves	46
C-11—Marine Spill Valve	47
C-12—Rupture Disk	48
C-13A—combination High-Level and Overfill Sensor	49
C-13B—Combination High-Level and Overfill Sensor (Continued)	50
C-14A—Magnetically Coupled Dipstick	51
C-14B—Magnetically Coupled Dipstick (Continued)	52
C-15—Magnetically Coupled Dipstick with Overfill Sensor	53
 Table	
1—Initial Fill Rate for Liquid Drop Lines	28

Marine Vapor Control Training Guidelines

SECTION 1—GENERAL

1.1 Objective and Scope

The objective of this recommended practice is to provide guidelines for developing marine vapor control (also referred to as marine emission control) shore and shipboard training programs in order to comply with U.S. Coast Guard regulations (33 *Code of Federal Regulations* Part 154.840 and 46 *Code of Federal Regulations* Part 39.10-11). These regulations outline vapor collection system safety requirements for the transfer of crude oil, gasoline, and benzene.

This recommended practice is not intended to be a comprehensive technical document. Where appropriate, training supervisors must expand on the facility-specific procedures to be followed. This recommended practice does review the U.S. Coast Guard regulatory requirements for safe operation of vapor control systems. Persons needing technical information on a particular marine vapor control system must not use this document but must refer to the appropriate manufacturer's technical documents or similar materials. Training supervisors must also be aware that state regulations may sometimes exceed federal guidelines. When this occurs, the state regulations must be followed.

1.2 Glossary

Definitions of the technical terms used throughout this document may be found in Appendix D.

1.3 Referenced Publications

The most recent editions of the following standards, codes, manuals, and specifications are cited in this recommended practice.

ABS¹

- Cargo Vapor Emission Control Systems on Board Tank Vessels*
- Rules for Building and Classing Steel Vessels*

API

- RP 1124 *Ship, Barge, and Terminal Hydrocarbon Vapor Collection Manifolds*
- RP 1125 *Overfill Control Systems for Tank Barges*
- RP 2003 *Protection Against Ignitions Arising Out of Static, Lightning, and Stray Currents*

DOT²

- 33 *Code of Federal Regulations* Parts 154, 155, and 156
- 46 *Code of Federal Regulations* Parts 1–69 and 90–139

EPA³

- 40 *Code of Federal Regulations* Part 60, Appendix A

IEEE⁴

- IEEE-45 *Recommended Practice for Electrical Installation on Shipboard*

ISA⁵

- RP 12.6 *Installation of Intrinsically Safe Systems for Hazardous (Classified) Locations*

1.4 Introduction

During the loading of crude oil, petroleum products, and benzene into vessels, the loaded liquid displaces the vapors inside the cargo tanks. These displaced vapors contain residual hydrocarbons left in the compartment at the beginning of the cargo transfer. As the transfer progresses, vapors are generated from the liquid entering the compartment. These hydrocarbons are mixed with air for noninerted vessels. For inerted cargo tanks, the hydrocarbons are mixed with nitrogen, inert exhaust stack gas, carbon dioxide, or some other type of inert gas. The vapors that exit the vessel contribute to air pollution if they are released directly into the atmosphere. The released hydrocarbon vapors may be hazardous to persons who breathe them or physically come in contact with them and may cause a fire or explosion if flammable vapors contact an ignition source.

In an effort to control the emission of these vapors, federal, state, and local environmental agencies have mandated the use of marine vapor control systems. These systems collect the vapors as they are generated during loading and either recover them or destroy them by such means as combustion.

²Department of Transportation. The *Code of Federal Regulations* is available from the U.S. Government Printing Office, Washington, D.C. 20402.

³Environmental Protection Agency. The *Code of Federal Regulations* is available from the U.S. Government Printing Office, Washington, D.C. 20402.

⁴Institute of Electrical and Electronics Engineers, 345 East 47th Street, New York, New York 10017.

⁵Instrument Society of America, 67 Alexander Drive, Box 12277, Research Triangle Park, North Carolina 27709.

¹American Bureau of Shipping, Two World Trade Center, New York, New York 10048.

The U.S. Environmental Protection Agency (EPA) currently has requirements for collecting emissions from benzene loading (see Appendix E). The EPA is developing additional regulations for collecting emissions from any cargo that is considered a volatile organic compound (VOC). Several states and local jurisdictions are proposing, or already have proposed, requirements for the control of emissions from the loading of gasoline or crude oil. The U.S. Occupational Safety and Health Administration (OSHA), while not requiring marine vapor control, does regulate personnel exposure to certain vapors, and such exposure is limited as a result of marine vapor control.

While the decision to require marine vapor control is made by environmental or health agencies, regulations for marine system safety are the sole responsibility of the U.S. Coast Guard. The U.S. Coast Guard published regulations on June 22, 1990, governing the safety of all aspects of marine vapor control systems, whether located on shore or on vessels. These regulations became effective July 23, 1990, and are applicable to all systems that recover or destroy emissions from the loading of vessels.

The regulations represent a set of minimum requirements for marine emission control installations. All facilities must meet these guidelines. However, some facilities may exceed the minimum standards.

As part of the regulations, the U.S. Coast Guard requires that both vessel and shore personnel are trained in the oper-

ation of marine emission control systems. This document provides guidelines for training those personnel.

1.5 System Overview

The process of loading a vessel with ballast or liquid hydrocarbons results in the displacement of the vapor from the compartment (see Figure 1). To prevent the release of vapors into the atmosphere, piping is installed to collect the vapors and direct them to a manifold on deck. As the cargo tanks are loaded with liquid, the vapors are displaced into the piping either by the positive pressure created by the rising liquid or by a negative pressure at the manifold created by a vacuum pump. The rate of vapor flow through the piping is set by the liquid loading rate.

Displaced vapors from the vessel move through the manifold, through a vapor collection hose or arm, through a series of safety devices and a piping system to the terminal's vapor control system. (See Figure 1 for a general system diagram.)

Several technologies are currently used to control hydrocarbon vapors generated from loading vessels, including the following:

- Combustion in an enclosed refractory-lined chamber.
- Combustion in an open, smokeless flare.
- Recovery by carbon adsorption.
- Recovery by refrigeration.
- Recovery by lean-oil absorption.
- Recovery and recycling to plant-fuel gas systems.

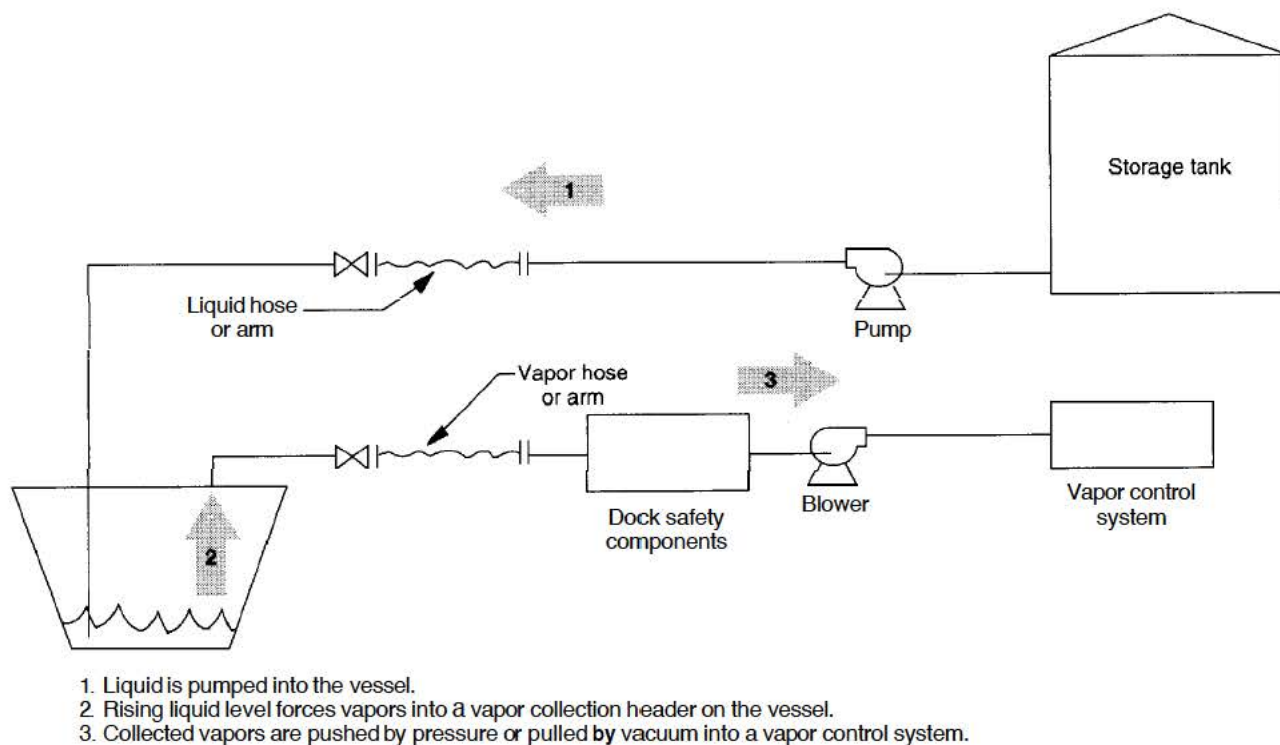


Figure 1 — Marine Emission Control Schematic

1.5.1 ENCLOSED COMBUSTION

Enclosed combustion systems are commonly used to reduce hydrocarbon emissions. All combustion and flare systems are referred to generically as destruction systems in the U.S. Coast Guard regulations. Enclosed combustion systems burn the collected vapors in a refractory-lined vessel. These systems completely hide the flame generated from the burning of hydrocarbons. Natural gas or other fuel is added to the stream to increase combustion efficiency, and combustion air is controlled to maintain high temperatures inside the combustion chamber.

Depending on the controls added to the system, combustion efficiency is as high as 99 percent. In addition, the emissions from the combustor are sampled before being emitted into the air.

Enclosed combustion systems are relatively inexpensive when compared to the recovery methods and have relatively low maintenance requirements. However, certain area regulations or a company policy prohibiting flames near loading docks may eliminate combustion systems from consideration.

1.5.2 OPEN FLARES

Open flares are the least expensive method for reducing hydrocarbon emissions. These systems burn the collected vapors at the top of a flare stack. The flame is completely open to the atmosphere and is not hidden from view.

Open flares include pilots (small igniting flames) at the top of the flare tip that are fueled by natural gas, propane, or some other available fuel. The pilot ignites the vapors as they exit the piping at the top of the flare. In addition, the open flares also include air blowers that inject air into the vapors as they exit the flare tip. The turbulent mixing of air into the vapors allows the vapors to burn without smoking.

Open flares are 98 percent efficient, as long as the heat content of the vapors being burned is maintained at or above 300 British thermal units per standard cubic foot (BTU/scf). This requires injection of natural gas or some other heat source into the stream before it is burned. For vapor collection systems that use enrichment to maintain the collected vapors above the upper flammability limit, the 300 BTU/scf limit is generally maintained by injection at the dock. For inerting or diluting systems, the fuel has to be added at the flare.

As with enclosed flares, local regulations or company policy may dictate that other means are used to reduce the hydrocarbon emissions.

1.5.3 CARBON ADSORPTION SYSTEMS

Carbon adsorption systems effectively recover certain hydrocarbons for return to the storage tanks from which they were taken. All carbon adsorption, refrigeration, lean-oil, and other similar systems are referred to generically as vapor recovery units in the U.S. Coast Guard regulations. These

systems have been used successfully in many gasoline truck loading facilities throughout the world.

The recovered vapors are passed through one of two or more carbon beds located at the vapor recovery system. The hydrocarbons are adsorbed by the carbon much like a sponge soaks up water. Like a sponge, at a certain point the carbon is no longer able to hold any additional hydrocarbons. When full capacity is reached, the vapors are directed to a different bed that has the capacity to hold them.

Beds that have reached their capacity to hold hydrocarbons are regenerated to restore their working capacity. This is normally done by subjecting the bed to a vacuum by using a vacuum pump that is a part of the system. The vacuum pump lowers the pressure in the carbon holding tank. The reduced pressure in the tank causes the carbon to "let go of" (desorb) the adsorbed hydrocarbons. The desorbed hydrocarbons are drawn into the vacuum pump and discharged into an absorption tower.

In the absorption tower, the vapors are absorbed into a liquid stream drawn from a storage tank. Therefore, the recovered vapors end up back in the storage tank from which they were originally taken or in another tank at the shore facility.

Carbon adsorption systems are 98 percent and greater efficient, depending on design parameters set by the company that provides the system. Carbon adsorption systems are more expensive to operate and maintain than combustion systems, but they do provide a payback from the hydrocarbons that are recovered.

Carbon adsorption systems have no hidden or open flames, which is an attractive feature to some companies.

1.5.4 REFRIGERATION SYSTEMS

In refrigeration systems, the recovered vapors are brought in contact with cooling coils. The recovered hydrocarbon is condensed and pumped back into the liquid storage tank from which it came.

The cooling coils are maintained at low temperatures by a refrigerant system similar to the air conditioning systems used in houses, except it operates at much lower temperatures. A refrigerant such as Freon^a is compressed, cooled, and then expanded. This process causes the temperature of the refrigerant to drop to the levels necessary for efficient condensation of the collected vapors.

Refrigerant systems are 98 percent and greater efficient, depending on the temperature of the refrigerant. Typical refrigerant systems are expensive to operate and maintain.

1.5.5 LEAN-OIL ABSORPTION

In a lean-oil absorption system, the collected vapors are brought in contact with an oil that absorbs the hydrocarbon from the vapors. The vapors contact the lean oil inside a column filled with a packing material. The purpose of the material is to expose a large surface area of oil to the vapors.

The efficiency of a lean-oil absorption system depends on the lean oil available. If the proper lean oil is selected and available at the dock, high efficiencies are achieved.

Lean-oil systems are relatively inexpensive to operate and maintain, but lean oils are typically not available in significant quantities at the dock. If the lean oil must be regenerated and used repeatedly, the operating costs of the system increase rapidly.

1.5.6 RECYCLING TO A PLANT-FUEL GAS SYSTEM

In a recycling system, the collected vapors are compressed and introduced into a plant-fuel gas system. This system can be very effective, especially for facilities with large plant-fuel gas consumption where the vapors will not significantly affect the plant-fuel gas characteristics.

The efficiency of this approach is high when all vapors can be absorbed by the plant-fuel gas system. Installed cost is also attractive. Treating the vapors with methods such as dehydration before mixing with plant-fuel gas may be required, and this will add to equipment cost.

Cleaner vapors such as gasoline or benzene are better suited to this recovery method.

1.6 Hazards

The hazards associated with operating marine vapor control systems are identified in 1.6.1 through 1.6.7. These hazards are addressed by the design and operating requirements of the U.S. Coast Guard regulations. A properly designed and operated system minimizes these hazards.

1.6.1 FIRE AND EXPLOSION

Marine vapor control systems involve the movement of vapors through a piping system that connects a vessel to shore equipment. An external ignition source or even the failure or malfunction of a marine vapor control system component may result in a fire and/or explosion. In the event of a fire or explosion, failure of in-line safety devices may result in personnel injury, including loss of life; environmental damage from oil spills; and financial loss from damage to the marine vapor control system and possibly to the vessel and terminal.

1.6.2 OVER- OR UNDERPRESSURIZATION

As with any closed loading operation, the possibility of overpressurization exists. Pressure increases are the result of any condition that causes the liquid loading rate to exceed the rate at which displaced vapors, including vapor growth, are vented. Overpressure occurs when the pressure increase exceeds the design operating pressure. If the vessel's pressure relief valves malfunction or are set too high, compartment warping, hull failure, and/or rupture occurs. These problems lead to spills, fire, or explosion.

Underpressurization occurs when vapors leave the cargo tank more rapidly than liquid enters the tank. This can occur with any system that utilizes in-line blowers or vacuum systems. Malfunction of the pressure relief valves or improperly high pressure relief set points can result in cargo tank warping, hull failure, and/or rupture. Spills, fire, or explosion then occur.

1.6.3 OVERFILLING

Since marine vapor systems involve closed loading operations, the ability of personnel on the vessel to visually observe the level of the liquid in a cargo tank may be limited. Therefore, personnel must have monitoring instrumentation, alarms, and overfill protection equipment such as automatic shutdown systems to prevent the overfilling of cargo tanks. Mechanical devices such as spill valves and rupture disks protect the vessel hull by permitting a controlled release of liquid. Failure of these devices leads to spills, tank rupture, fire, or explosion.

1.6.4 MISCONNECTION OF LIQUID AND VAPOR LINES

The proximity of the liquid and vapor lines raises the possibility these lines may be misconnected, even though they are configured differently. Misconnection of these lines leads to liquid entering a vessel through the vapor lines and to the possibility of static ignition of vapors due to free falling of liquid into an empty compartment. Misconnection of lines is addressed further in 2.2.5 and 3.2.6.

1.6.5 CONDENSATION IN THE VAPOR LINE

Hydrocarbons and water vapor condense into liquids. Such condensed liquids present a hazard in the form of liquid "slugs" that are propelled down a vapor line, potentially damaging system equipment. The presence of liquids in the vapor lines reduces the cross sectional area of the pipe, thereby increasing the pressure drop and causing increased back pressure on the vessel.

1.6.6 PYROPHORIC IRON SULFIDE DEPOSITS

The buildup of pyrophoric iron deposits and the potential for ignition of those deposits exist in systems that use inert gas or are loading high-vapor-pressure crude oils containing hydrogen sulfide. Detection and avoidance of this hazard are difficult; therefore, efforts to minimize the potential are important.

1.6.7 STATIC ELECTRICITY DISCHARGE

High initial loading rates, misconnection of liquid and vapor lines, and improper gauging are some of the sources of static discharge. If the vapor content within a tank or pipe is in the explosive range, fire or explosion may result.

SECTION 2—VESSEL COMPONENTS AND SAFETY AND OPERATING CONCERNS

The following section addresses vessel components and safety and operating concerns associated with marine vapor control systems. Shore components and concerns are covered in Section 3.

2.1 Vessel Components

For many years, vessels of various configurations have been used to move a great variety of liquid products from port to port. These vessels have many types of components. Some of the more common ones are listed below:

- a. One or more compartments for holding liquid.
- b. A liquid loading header for connecting product loading hoses. This header system distributes the liquid throughout the vessel and has at least one pipe, or drop, that extends nearly to the bottom of each compartment. This drop reduces the splashing that occurs if the product is allowed to free-fall from the top of the compartment. By reducing splashing, the accumulation of static in the cargo liquid is reduced.
- c. Cargo tank hatches left open during loading to monitor the level in the compartment. After loading, all cargo hatches are closed during transit.
- d. A pressure relief valve and vacuum relief valve in each compartment to allow for expansion and contraction of the product due to thermal changes during transfer and transit.
- e. A cargo transfer system for loading and unloading the liquid cargoes.
- f. Inerting systems on some vessels to keep oxygen levels in the compartments at or below 8 percent by volume by filling the compartment with nitrogen, exhaust stack gas, carbon dioxide, or other inert gas.

Vessels that are to be connected to vapor collection systems will have some modifications. These modifications may include the following components, some of which are optional:

- a. A vapor collection header to collect vapors generated from each compartment during loading. The header sometimes includes valves to isolate one compartment from another. The header extends from the top of each compartment, comes together into a common line along the length of the vessel, splits at a tee junction, and terminates on both sides of the vessel near the liquid loading connection.
- b. Pressure relief and vacuum relief valves. These are sized to relieve vapors at a rate equivalent to the maximum loading rate of the vessel and to break vacuum at the maximum unloading rate of the vessel unloading pumps.
- c. On some vessels, closed inspection openings (see Figures C-8 and C-9) consisting of a glass viewing port, typically with an internal wiper blade and a cover to protect the glass

when not in use. All vessels must be fitted with a gauging system to aid in determining the cargo level (see Figure C-7).

- d. The vessels must be equipped with a type of overfill protection system. Four methods are currently accepted by the U.S. Coast Guard for preventing structural failure due to overfilling (see 2.2.2).

2.2 Safety Concerns

2.2.1. GENERAL

The addition of closed loading complicates the loading of a vessel. The main safety concerns associated with closed loading are as follows:

- a. Overfilling the vessel, since viewing the product level must now be done through smaller glass viewing ports or indirectly by mechanical means.
- b. Overpressuring the vessel due to the pressure drop in the vapor collection header on the vessel and the vapor collection system on shore.
- c. Underpressuring the vessel due to the addition of blowers, compressors, or eductors in the shore vapor collection system.

The addition of vapor connections on the vessel to accommodate closed loading creates the possibility of the following misconnections:

- a. Vapor lines incorrectly connected to liquid headers on the vessel.
- b. Liquid lines incorrectly connected to vapor headers on the vessel.

2.2.2 OVERFILLING THE VESSEL

2.2.2.1 General

In the past, vessels were loaded through an open cargo system. The vapors were allowed to vent through the compartment openings, and the vessel liquid level was easily determined by visual inspection through the open hatches.

With the introduction of vapor collection, all openings in the vessel must now be closed tightly to prevent fugitive vapor emissions to the atmosphere. Cargo liquid levels are watched through glass viewing ports (see Figures C-8 and C-9). To further aid in determining the cargo level, a ship's compartments are required to have a cargo gauging system that allows the operator to determine the liquid level in any compartment (see note).

Note: Barges that do not have an on-board liquid overfill protection system are required to provide a means of visually indicating the liquid level in the compartment during the final 3.3 feet (1.0 meter) (see Figures C-14A, C-14B, and C-15).

A variety of visual aids are being used. Some of these aids are as follows:

- a. Individual ladder rungs color coded to indicate approximate level. This method requires that the ladder is visible from the glass viewing port.
- b. Tabs or indicators fixed to the ladder or compartment wall to indicate approximate level.
- c. Hinged paddle floats with numbers inscribed on the paddle, so the number is visible if the paddle is raised.
- d. Gauge rods magnetically coupled to floats that rise as the level increases. The rods are sometimes color coded to give a better indication of the level in the compartment when viewed from a distance. The gauge rod may be part of a level alarm system if internal magnets are used to activate a proximity switch.
- e. Dip sticks.

The U.S. Coast Guard has recognized that it is increasingly difficult to determine the cargo level in closed vessels. In addition, it has recognized the increased likelihood of structural damage to the vessel because of the potential for an overfill. To further reduce the possibility of overfilling, U.S. Coast Guard regulations require the installation of one of the following four protection methods:

- a. Spill valves (see Figures C-10 and C-11)
- b. Rupture disks (see Figure C-12).
- c. On-board monitoring systems.
- d. Shore monitoring systems.

2.2.2.2 Spill Valves

2.2.2.2.1 General

A spill valve is a device located on the deck of each cargo compartment to prevent overpressurization of the compartment by opening to relieve pressure at a predetermined setting. The pressure relief set point of the spill valve must be greater than the pressure relief set point of the pressure relief valve of the vapor collection header. Spill valves typically are spring loaded, pressure weighted, or have some other means of allowing the valve to reclose once the pressure in the vessel is released. Spill valves must automatically reseal to prevent the release of vapors once the overfill pressure has been released. (See Figures C-10 and C-11 for examples of spill valves.)

2.2.2.2.2 Vessel Person-in-Charge Responsibilities

- a. The person in charge of transfer operations on the vessel (vessel PIC) must provide the person in charge of transfer operations on the shore (shore PIC) with information detailing the type of overfill system provided on the vessel.
- b. The vessel PIC must advise the shore PIC of the method to be used to indicate a spill valve has opened. Procedures to follow once a spill valve has activated must also be discussed.

- c. The vessel PIC must be familiar with the location of each spill valve.
- d. The vessel PIC must be familiar with the pressure set point that causes the spill valve to open.
- e. The vessel PIC must monitor the level indicators provided on the vessel to prevent overfills from occurring.
- f. If a spill valve opens, a spill to the atmosphere is likely to occur. The vessel PIC must be familiar with the procedure he is to follow as the result of a spill.
- g. If the spill valve is equipped to allow testing, it must be tested before each loading to make sure it is operating properly. If the spill valve is capable of being isolated or secured in a closed position, the vessel PIC must determine the valve is operational and not isolated.

2.2.2.3 Rupture Disks

2.2.2.3.1 General

A rupture disk is a thin metal membrane sandwiched between special flanged holders. (See Figure C-12 for an example of a rupture disk.) The disk is designed and tested to burst open at a set pressure to prevent the overpressurization of the cargo compartment as a result of being liquid-full. Once ruptured, the disk cannot reclose and must be replaced. The pressure relief set point of the rupture disk must be greater than the pressure relief set point of the pressure relief valve of the vapor collection header. Some installations will be isolated by valves to prevent rupture from liquid movement during transfer.

2.2.2.3.2 Vessel PIC Responsibilities

- a. The vessel PIC must provide the shore PIC with information detailing the type of overfill system provided on the vessel.
- b. The vessel PIC must advise the shore PIC of the method to be used to indicate a rupture disk has opened. Procedures to follow once a rupture disk has activated must be discussed.
- c. The vessel PIC must be familiar with the location of each rupture disk.
- d. The vessel PIC must be familiar with the pressure set point that causes the rupture disk to open.
- e. The vessel PIC must make sure replacement rupture disks are available aboard the vessel and must be familiar with the replacement procedure.
- f. The vessel PIC must monitor the level indicators provided on the vessel to prevent overfills from occurring.
- g. If a rupture disk opens, a spill to the atmosphere is likely to occur. The vessel PIC must be familiar with the procedure he is to follow as the result of a spill.
- h. If an isolation valve is provided to protect the rupture disk during transfer, the vessel PIC must make sure it is open prior to cargo transfer.

2.2.2.4 On-Board Monitoring Systems

2.2.2.4.1 General

On-board monitoring systems use level sensors that are permanently installed in each vessel compartment (see Figures C-13A and C-13B). The level sensors have two alarm points, one that is considered a high-level alarm and another that is considered an overfill alarm. The high-level alarm occurs at no less than 95 percent of the compartment capacity. The overfill alarm sounds early enough to allow the persons in charge of transfer operations to stop the transfer before the cargo tank overfills.

The high-level alarm causes an audible and visual alarm on the vessel. The overfill alarm also causes an audible and visual alarm on the vessel, which signals the persons in charge of transfer operations to stop the loading of the vessel. This shutdown may be automatic or manual.

For many vessels, these systems are totally self-contained, and need no power from the shore. Other systems require power from shore, and a shore connection must be provided. If the shore facility cannot provide power for the overfill system and no other means of preventing overfill is available on the vessel, the loading cannot proceed while collecting vapors. If power to the overfill system fails or if the electrical circuitry to the tank level system fails, the alarm system must activate.

The level monitoring system must be provided with a mechanical means to test the overfill system in each compartment of the vessel.

2.2.2.4.2 Vessel PIC Responsibilities

- a. The vessel PIC must provide the shore PIC with information detailing the type of overfill system provided on the vessel.
- b. If the vessel has an on-board system requiring power from the shore, the shore PIC must provide a 120 volt power source utilizing an approved explosion-proof receptacle. If power is not available from shore and there are no other means on the vessel to prevent overfill, the vessel may not be loaded while collecting vapors.
- c. The vessel PIC must familiarize the shore PIC with the on-board alarm system to ensure that the shore PIC recognizes when a high-level alarm or an overfill alarm occurs.
- d. During the pretransfer conference, the vessel PIC must direct the shore PIC in what is expected of him in the event of a high-level alarm and an overfill alarm.
- e. Before beginning the loading, the vessel PIC must conduct a functional test of the level alarms in each compartment. The shore PIC must witness and verify that each alarm-level system is operational. If an overfill alarm does not function, the compartment with the level switch that is not working must not be loaded with cargo, unless an additional means of preventing overfill is provided.

2.2.2.5 Shore Facility Monitoring Systems

2.2.2.5.1 General

Shore facility monitoring systems use level sensors that are permanently installed in each compartment of the vessel. Unlike an on-board system, these level sensors are monitored by a signal generated from an overfill control panel located on shore. This panel is maintained and operated by the shore facility.

Before loading, a connection must be made between the vessel and the shore facility overfill control panel. This connection must be made by specific cable set aside for use with the overfill system. The connectors for this system meet the requirements of the International Electrotechnical Commission⁵ for systems carrying 50 volts or less (see Figures C-1 and C-2). This prevents the accidental connection to other sources, such as 120 or 240 volts. In the case of the overfill control system, the U.S. Coast Guard regulations require these systems to be intrinsically safe. Intrinsically safe basically means the system does not have sufficient energy to create an incendiary spark; therefore, the system carries considerably less than 50 volts at very low currents.

The level sensor system on the vessel is designed for a capacitance and inductance specified in the U.S. Coast Guard regulations [46 *Code of Federal Regulations* Part 39.20-9(b)(4)]. The shore facility overfill control panel and its connectors are also designed to work with a certain capacitance and inductance. The capacitance and inductance of the equipment on the vessel must not exceed the design limits of the overfill control panel. The capacitance and inductance of both the vessel overfill system and the facility overfill control panel must be posted near the level sensor system connectors.

The level sensors must have at least one alarm point that is considered an overfill alarm. The overfill alarm occurs early enough to allow the shore PIC to stop the transfer operation prior to 100 percent filling of the vessel. The overfill alarm causes both an audible and visual alarm and an automatic shutdown of the shore facility loading system.

As an option, the overfill panel is equipped so that the level sensors in each compartment cause a high-level alarm. This alarm is typically set to provide adequate warning that an overfill condition is nearing. The high-level alarm causes both audible and visual alarm signals. The vessel PIC must have a set procedure to follow when the vessel's high-level alarm set point is tripped. Generally, the vessel PIC must proceed to the position on the vessel where liquid loading is controlled and provide an indication to the shore PIC to either slow down or stop the liquid loading process.

⁵International Electrotechnical Commission, Bureau Central de la Commission, Electrotechnique Internationale, 1 rue de Varembe, Genève, Suisse.

2.2.2.5.2 Vessel PIC Responsibilities

- a. The vessel PIC must provide the shore PIC with information detailing the type of overfill system provided on the vessel.
- b. The vessel PIC must connect the sensing cable to the connection point provided on the vessel. The vessel PIC must make sure the capacitance and inductance of the vessel is compatible with the capacitance and inductance of the overfill control panel.
- c. The shore PIC must familiarize the vessel PIC with the shore alarm system, so the vessel PIC recognizes when a high-level alarm or an overfill alarm occurs.
- d. During the pretransfer conference, the vessel PIC and shore PIC must discuss what each is expected to do in the event of a high-level alarm and an overfill alarm.
- e. Before beginning the loading, the vessel PIC and shore PIC must conduct a functional test of the level alarms in each compartment. Each overfill alarm must work properly. If an overfill alarm does not function, the compartment with the level switch that is not working must not be loaded with product. If a high-level alarm does not work but the overfill alarm in the same compartment does work, the compartment may be filled if the shore PIC chooses. If the overfill system is not functional and no other means of preventing overfill of the vessel is available, the vessel must not be loaded.

2.2.3 OVERPRESSURING THE VESSEL

2.2.3.1 General

As the vessel is filled, the vapors are collected into the vapor piping header. The header is generally a simple piping system connecting the vessel's compartments. On some vessels the various compartments are isolated by ordinary pipeline valves, and in others the vapor header is a continuous length of pipe with no isolation valves.

The individual compartment headers join to a common line running the length of the vessel. This line ends at a manifold connection located near the liquid loading manifold. Vessels generally have vapor connection manifolds on both sides. For identification purposes, the manifold is color coded with red and yellow. The word "VAPOR" is stenciled in black letters on the yellow band of paint (see Figure 2).

The vapor header piping is connected by vapor hose or vapor arm to the shore facility vapor connection. This routes the vapors from the vessel compartments to the shore and then to either a recovery system or a combustion system. The shore facility vapor collection system varies in length depending on the location of the recovery or combustion system and the general space available at the dock.

The combination of the piping length and the components in the piping creates a pressure drop through the system when vapors flow. The back pressure created by the system generates the operating pressure inside the vessel compart-

ments. This piping configuration of a closed loading system increases the possibility of overpressuring the vessel.

Operating procedures and precautionary devices added to the shore facility monitor the operating pressure of the system and alarm or shut down vapor collection when the pressure presents a danger to the vessel. These safety devices and operating practices include the following:

- a. A high-pressure alarm set to cause an audible and visual alarm if the pressure in the vessel reaches 80 percent of the vessel's pressure relief valve set point. The high-pressure alarm must be tested within the 24 hours prior to loading of the vessel to make sure it is operational.
- b. A high high-pressure alarm set to cause an audible and visual alarm and close the remotely operated vapor block valve if the pressure reaches 2 pounds per square inch gauge at the vapor collection header or a lesser setting agreed to by the vessel PIC and shore PIC. This pressure may be set lower if necessary to protect the vessel. The high high-pressure alarm must be tested within the 24 hours prior to loading of the vessel to make sure it is operational.
- c. A pressure relief valve installed at the shore facility that is set to relieve if the pressure reaches 2 pounds per square inch gauge or less at the vapor collection header.

In addition to the shore facility safety features, all vessels are outfitted in accordance with 46 *Code of Federal Regulations* Part 39.20-11(a)(1), which requires a pressure relief valve that has a capacity of 1.25 times the maximum loading rate in the vapor collection header and opens at a pressure that protects the vessel from structural failure. This pressure relief valve must also include a means for testing that it opens freely and closes again after opening.

Vessels must also be equipped with an additional safety feature to prevent overpressuring the vessel (see note below). This is a high-pressure alarm that senses the pressure in the vapor collection header. The device includes a pressure indicator for pressure monitoring. The set point is no more than 90 percent of the lowest pressure relief valve setting in the cargo tank venting system.

Note: Barges are not required to have this equipment, but some may have a pressure indicator.

It is very important to make sure the vessel's compartments are never isolated from the vapor header and relief valves during loading.

2.2.3.2 Vessel PIC Responsibilities

- a. The vessel PIC must make sure all valves in the vapor collection header are open to allow unobstructed flow. The shore PIC shares this responsibility.
- b. The vessel PIC must check the pressure relief valve in the vapor collection header to make sure it opens freely and closes after opening. If the relief valve does not open prop-

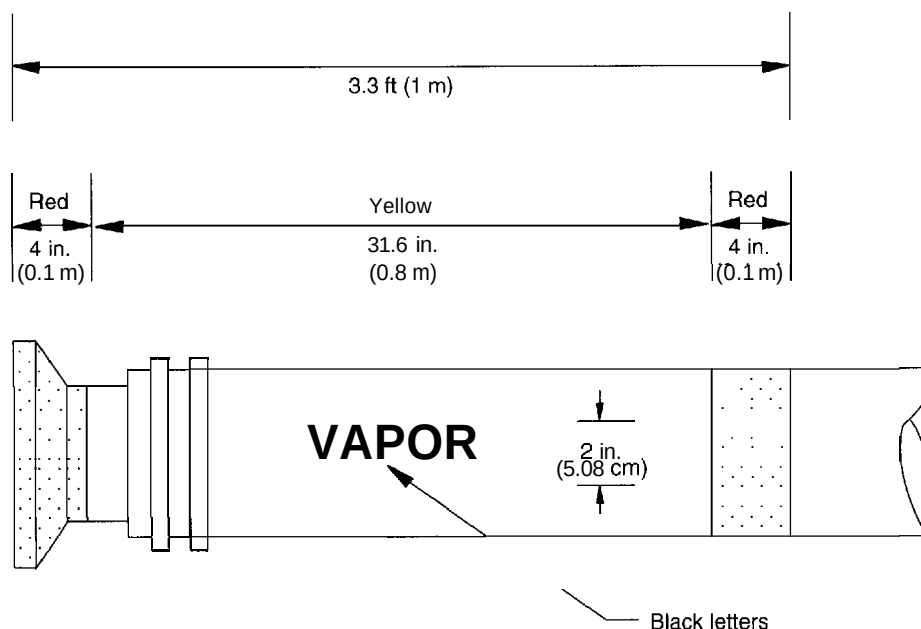


Figure 2 — Markings for Vapor Line and Vapor Hose

erly, it must be repaired before loading is allowed to proceed. Some valves may not be built to allow for testing; if so, this step can be bypassed.

c. The vessel PIC must inform the shore PIC of the pressure setting for the pressure relief valve during the pretransfer conference. This allows the shore PIC to verify the proper setting for the high-pressure alarm at the shore facility vapor connection.

d. The vessel PIC must discuss with the shore PIC the procedures to be followed in the event of a high-pressure alarm, a high high-pressure alarm, or the opening of a relief valve. Liquid flow must stop whenever a shutdown of the vapor collection header occurs.

e. The vessel PIC must routinely monitor the vapor header pressure if pressure indicators are provided.

2.2.4 UNDERPRESSURING THE VESSEL

2.2.4.1 General

There are two common types of vapor collection systems located on shore, as follows:

- One uses the pressure in the vessel to push the vapors to a recovery or combustion system.
- In the other, the pressure drop in the piping from the vessel to the recovery or combustion system is high enough to require a vapor booster, eductor, or blower in the vapor line.

Systems that use devices to move the vapors introduce a new hazard to the vessel. If the device is allowed to run un-

controlled with no liquid flowing into the vessel, it could create a vacuum on the vessel. If the device has vacuum capacity greater than 1.0 pounds per square inch gauge, it could cause structural failure.

Another cause of underpressurization on the vessel is condensation that occurs in long vapor lines with little or no flow. In this case, the vapors in the line condense and form liquid. Since the liquid takes up less space than the vapor from which it was formed, a vacuum begins to form in the line. If the line is allowed to continue to cool and condense for a long period of time, excessive vacuum occurs.

Shore facilities must have operating procedures and precautionary devices to monitor the vacuum of the system and to alarm or shut down vapor collection when the vacuum presents a danger to the vessel. These safety devices and operating practices include the following:

- A low-pressure alarm set to cause an audible and visual alarm if the vacuum in the vessel reaches 80 percent of the vessel's vacuum relief valve set point. The low-pressure alarm must be tested within the 24 hours prior to loading of the vessel to make sure it is operational.
- A low low-pressure alarm set to cause audible and visual signals and close the remotely operated vapor shutoff valve if the vacuum reaches -1.0 pounds per square inch gauge at the vapor collection header or a higher setting agreed to by the vessel PIC and shore PIC. This pressure may be set higher if necessary to protect the vessel. The low low-pressure alarm must be tested within the 24 hours prior to loading of the vessel to make sure it is operational.

c. A vacuum relief valve installed at the shore facility and set to relieve if the vacuum reaches -1.0 pounds per square inch gauge or higher at the vapor collection header.

In addition to the shore facility safety features, all vessels are outfitted with a vacuum relief valve in the vapor collection header that has a capacity at either maximum cargo or vapor withdrawal to protect the vessel from structural failure. This vacuum relief valve must also include a means for testing that it opens freely and closes again after opening, if installed after July 23, 1991 [see 46 *Code of Federal Regulations* Part 39.20-11(b)(2)].

Vessels must also be equipped with at least one low-pressure alarm that senses the pressure in the vapor collection system or header (see note below). The alarm includes a pressure indicator for pressure monitoring. The set point varies depending on the condition of the cargo, as follows:

- a. Inerted cargo. The low-pressure alarm must not be less than 4 inches water gauge.
- b. Noninerted cargo. The low-pressure alarm must not be less than the lowest vacuum relief setting in the cargo tank venting system.

Note: Barges are not required to have this equipment.

2.2.4.2 Vessel PIC Responsibilities

- a. The vessel PIC must make sure all valves in the vapor collection header are open to allow unobstructed flow. The shore PIC shares this responsibility.
- b. The vessel PIC must check the vacuum relief valve in the vapor collection header to make sure it opens freely and closes after opening. If the vacuum relief valve does not open properly, it must be repaired before loading is allowed to proceed.
- c. The vessel PIC must inform the shore PIC of the vacuum setting for the vacuum relief valve during the pretransfer conference. This allows the shore PIC to verify the correct setting for the low-pressure alarm at the shore facility vapor connection.
- d. The vessel PIC must discuss with the shore PIC the procedures to follow in the event of a low-pressure alarm, a low low-pressure alarm, or the opening of a relief valve.
- e. The vessel PIC must routinely monitor the vapor header pressure if pressure indicators are provided.

2.2.5 MISCONNECTION OF HOSES AND LOADING ARMS

2.2.5.1 General

The vessel PIC now has to be concerned with different types of hoses for vapor and liquid. There is the possibility of connecting the vapor hose to the liquid loading line or the liquid hose to the vapor collection line. If this happens, the following two problems can occur:

- a. Liquid loaded through the vapor header, which does not have drop lines into the bottom of the vessel, free-falls into the tank creating a static electricity buildup.
- b. Vapor drawn through the liquid header is taken from the bottom of the vessel compartments through the drop lines. Liquid loaded in the compartments covers the line and causes a pressure drop or pulls liquid into the vapor collection header.

The U.S. Coast Guard regulations provide the following safety measures to prevent the misconnection of hoses:

- a. Each vapor connection on the shore and on the vessel is color coded with a band 3.3 feet (1.0 meter) long painted red and yellow. The yellow band has the word "VAPOR" stenciled in black letters 2 inches (5.08 centimeters) tall (see Figure 2).
- b. Each vapor hose has the same red and yellow color coding and markings as the vapor connections.
- c. The shore vapor connection and the vessel vapor connection each have a metal lug [approximately $\frac{1}{2}$ inch (1.27 centimeters) in diameter and 1 inch (2.54 centimeters) long] welded at the top of the flange (see Figure 3).
- d. Each flange connection of the vapor hose has a hole drilled between the bolt holes [approximately $\frac{3}{8}$ inch (1.59 centimeters) in diameter] that matches the metal lug on the vapor connections.

2.2.5.2 Vessel PIC Responsibilities

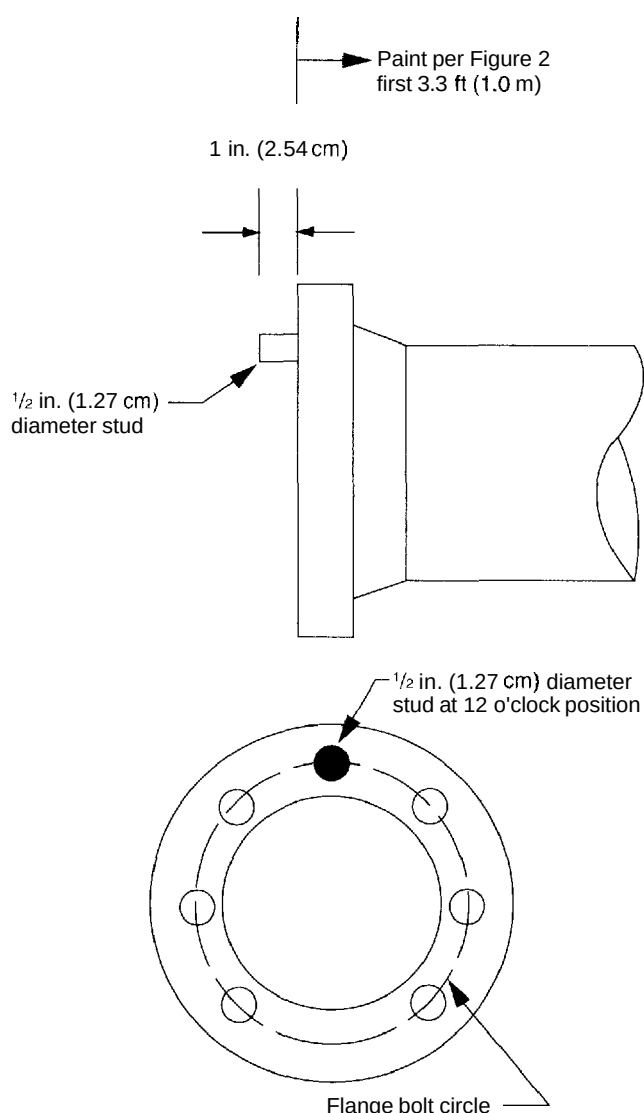
- a. The vessel PIC must identify the vapor connections on the vessel by the red and yellow color coding.
- b. If the vessel is providing the vapor collection hose, the vessel PIC must be sure the hose or loading arm is attached at the proper shore facility connection.
- c. If the shore facility is providing the vapor collection hose, the vessel PIC must be sure the hose is attached to the proper connection on the vessel.
- d. The vessel PIC must only connect hoses to the vapor collection system that are properly color coded and labeled as vapor collection hoses.
- e. The vessel PIC must inspect the vapor hose to make sure it is properly supported to prevent kinking. In addition, the hose must be inspected for cuts or other damage.

2.3 General Operating Concerns

2.3.1 CARGO CONTAMINATION

2.3.1.1 General

Many vessels carry more than one type of cargo on a voyage. Contamination can occur through the vapor header line if different cargos are not properly isolated by valves. Vessels may be subjected to wave action that causes significant sloshing of the product and results in commingling of product and/or vapors.



Note: The stud may be located on a flanged valve instead of on the piping flange.

Figure 3—Vessel and Shore Vapor Connection

2.3.1.2 Vessel PIC Responsibilities

- The vessel PIC must be aware of the products that are to be carried in the vessel's compartments.
- When products are incompatible or are different grades of the same product, the isolation valves in the vapor header must be closed to prevent contamination.

2.3.2 VALVE POSITIONING

2.3.2.1 General

Another concern associated with closed loading is the accidental loading of a compartment that has the vapor header valves closed. The vessel PIC must pay particular attention

to any valves or other devices that hamper removal of vapors from the compartment.

2.3.2.2 Vessel PIC Responsibilities

- The vessel PIC must make sure all isolation valves in the vapor collection header from a compartment are completely open before loading the compartment. The shore PIC shares this responsibility.
- The vessel PIC on a vessel that has an inert gas system must make sure the system is isolated from the compartment during the collection of vapors [46 Code of Federal Regulations Part 39.30(j)].

2.3.3 INSPECTION

2.3.3.1 General

The new components associated with the collection of vapors must be routinely inspected to make sure they are operational. In addition to those steps discussed in previous sections, the items listed in 2.3.3.2 must be considered.

2.3.3.2 Vessel PIC Responsibilities

- Each flame screen attached to a relief valve must be inspected frequently. The flame screen must be free of rust, dirt, or other forms of plugging. If the screen is plugged, it must be cleaned with a wire brush or, if necessary, removed and replaced. If the flame screen has been punctured, torn, or otherwise damaged, it must be replaced.
- During freezing weather conditions, each flame screen must be inspected for icing before the vessel is loaded. Ice must be removed, if present, and the flame screen must be monitored frequently for ice formation during the loading.
- Hoses must be inspected for external damage before beginning the loading. Inspection must determine that the following conditions are met:
 - Hoses must be free of kinking.
 - Hoses must be supported properly to prevent kinking during the loading.
 - Hoses must be monitored during the loading and adjusted as the vessel level lowers.
 - Hoses must not have unrepaired loose covers, bulges, or soft spots.
 - Hoses must not have gouges, cuts, or slashes that penetrate the first layer of hose reinforcement.
 - Hoses must not have external deterioration and, as viewed from each end, must not have internal deterioration.
- Hoses must be pressure tested yearly at one and one-half times the maximum allowable working pressure. Vapor hoses have at least a maximum allowable working pressure of 5.0 pounds per square inch gauge and must be capable of withstanding 2.0 pounds per square inch gauge vacuum without collapsing.

- e. Liquid high-level alarm and overfill sensors must be tested before each loading is started.
- f. Pressure and vacuum relief valves must be tested yearly for proper operation.
- g. Devices added to the vessel, such as temperature and pressure indicators, must be tested yearly to determine whether they work properly.

2.3.4 STATIC ELECTRICITY

2.3.4.1 General

Some products are known accumulators of static electricity. Therefore, it is necessary practice to follow guidelines that minimize the chances of static discharges when loading these products. (See API Recommended Practice 2003 and the *International Safety Guide for Oil Tankers and Terminals*⁶ (ISGOTT), Chapters 7.4 and 19, for additional information.)

2.3.4.2 Vessel PIC Responsibilities

- a. The vessel PIC and the shore PIC shall determine the initial fill rate for the vessel and the amount of initial fill required before the loading rate is increased (see note). During the initial fill, the vessel PIC must not allow the vessel to be loaded faster than its initially agreed-upon fill rate. The maximum design loading rate is initiated once all splashing and surface turbulence have been eliminated and the load pipes in the compartments are covered.

Note: The start of the maximum loading rate varies according to vessel and/or corporate operating policies.

- b. During loading of static accumulating products and for 30 minutes after completing the loading, no metallic dipping, ullaging, or sampling equipment may be introduced into a noninerted tank. These items must not be allowed to remain in the tank during loading. Only nonconducting equipment with no metal parts may be used at any time.
- c. The vessel PIC must make sure that any metallic dipping, ullaging, or sampling equipment is firmly grounded to the vessel structure before introduction into the tank. Ropes made of polymer material are often conductive and must not be used without determining whether they are conductive. It is generally recommended that grounded steel cables or ropes made of natural fibers be used.
- d. The vessel PIC must inspect compartments for items such as floats that have broken off level sensors or for other solid material. Floating items act as static accumulators and arc if they come in contact with the compartment sides.

2.3.5 CONDENSATE IN THE VAPOR HEADER

2.3.5.1 General

During the design and layout of the vessel vapor collection header, drainage for condensate must be considered. However, in many cases a low point in the vapor header cannot be avoided. If the vapor header has a low point, it must also include a means of removing any condensate or a means of preventing condensate from forming.

If condensate is allowed to build up in the low spots of the vapor header, a back pressure is created on the vessel that could cause the vapor header relief valve to open.

2.3.5.2 Vessel PIC Responsibilities

- a. If a low point exists in the vessel vapor header, the PIC must monitor the low point for condensate
- b. When condensate collects, the vessel PIC must remove by whatever means has been included in the vessel

2.3.6 VESSEL FILLING RATE

2.3.6.1 General

The vapor piping on the vessel and the vapor piping and components on the shore are all designed for an expected maximum loading rate. The vessel design rate and the shore design rate most likely do not match, since they were developed independently. If the maximum loading rates are exceeded, the increase in flow develops a greater back pressure than the systems are designed for. This increased back pressure must be sensed by the pressure monitoring systems in the shore vapor collection system or in the vessel pressure alarms. If the pressure monitoring systems fail, or are isolated, loading the vessel too rapidly could overpressure it and cause structural failure.

2.3.6.2 Vessel PIC Responsibilities

- a. The vessel PIC must know the maximum design loading rate for the vessel vapor collection system.
- b. During the pretransfer conference, the vessel PIC must advise the shore PIC of the design loading rate for the vessel.
- c. During the loading of the vessel, the maximum loading rate must be the lesser of the vessel design rate and the shore design rate. It is the shore PIC's responsibility to set and maintain this flow rate.

2.3.7 SYSTEM EMERGENCY SHUTDOWNS AND ALARMS: WHAT SHOULD BE DONE?

2.3.7.1 General

There are many reasons a marine emission control system experiences a shutdown or an alarm condition. A shutdown provides an audible and visual signal as well as automatically

⁶Published by Witherby and Co. Ltd., 32/36 Aylesbury Street, London, EC1R0ET, England, 1988.

stops the operation of the system, whereas an alarm is generally only an audible and visual signal. Some systems have unique shutdowns and alarms that are not required by the U.S. Coast Guard but make operation safer for the particular vessel's operation. In general, some simple guidelines must be followed for any shutdown or alarm condition. The vessel PIC must be familiar with emergency procedures to be followed in the event of vessel or shore facility shutdown alarms.

2.3.7.2 Vessel PIC Responsibilities

- a. If an automatic shutdown occurs, the vessel PIC must stop the flow of liquid to the vessel as soon as possible.
- b. When an automatic shutdown or alarm occurs on the vessel, the vessel PIC immediately determines the cause.
- c. If an automatic shutdown occurs, the vessel PIC must notify the shore PIC of the cause, and a joint decision must be made either to close the manual isolation valves on the vessel or to restart the system.
- d. If an alarm condition occurs, the vessel PIC must notify the shore PIC of the problem. The vessel PIC must take appropriate steps to eliminate the alarm condition as outlined in the marine vapor control procedural manual.
- e. If the shutdown occurs from the shore facility monitoring system, the shore PIC must determine the cause and notify the vessel PIC. The shore PIC must take appropriate measures as outlined in the shore facility marine vapor control procedural manual.

2.3.8 PRETRANSFER CONFERENCE

2.3.8.1 General

The vessel PIC and the shore PIC must hold a pretransfer conference before the transfer of any product begins. During the pretransfer conference, the following topics must be discussed before the vessel PIC and the shore PIC sign the Declaration of Inspection (DOI):

- a. The identity of the product to be transferred.
- b. The sequence of transfer operations.
- c. The initial, maximum, and topping-off transfer rates.
- d. The name, title, and location of each person participating in the transfer operation.
- e. Details of the transferring and receiving systems.
- f. Critical stages of the transfer operation.
- g. Federal, state, and local rules that apply to the transfer of the product.
- h. Emergency procedures.
- i. Discharge containment procedures.
- j. Discharge reporting procedures.
- k. Watch or shift arrangement.
- l. Transfer shutdown procedures.

In addition to discussing the above topics, the following steps must be taken:

- a. The electrical insulating flange must be checked to make sure it is fitted between the vapor hose and the shore facility vapor connection. The insulated flange must not be short-circuited by items such as chains touching both flanges.
- b. The pressure relief set point and the vacuum relief set point for the vessel must be discussed and high- and low-pressure alarm set points calculated for the vapor collection system.
- c. The vessel's Certificate of Inspection must be reviewed to make sure the vessel has the proper endorsement for connection to a vapor collection system.
- d. If the vessel is to load benzene vapors, the vessel must have aboard a certificate of leak tightness dated within the last year. If the certificate is not available, the vessel is either loaded under vacuum or the shore facility conducts a leak check of the vessel during the final 20 percent of the loading. If leaks are detected, the vessel must not be loaded again until it provides a certificate of leak tightness or an endorsement that the modifications to make the vessel leak tight cannot be made until the vessel is placed in dry dock.
- e. The compartment condition of the vessel must be determined as either inerted or noninerted.

2.3.8.2 Vessel PIC Responsibilities

- a. The vessel PIC must be familiar with both the product being loaded and any safety precautions necessary. If there is any doubt concerning safety measures, the vessel PIC must obtain and read the material safety data sheets.
- b. The sequence of transfer operations must now include any steps required to accommodate the vapor collection system. Since vacuums are now implied on vessels by some systems, the vessel PIC must determine the correct time to open the manual vapor block valves on the vessel.
- c. The vessel PIC must give the transfer rate for the vessel to the shore PIC. The shore facility transfer rate is compared to the vessel transfer rate. Whichever is less sets the transfer rate during vessel loading.
- d. The vessel PIC and shore PIC must review the details of the transfer operation and any critical stages. Such items as what to do during shutdown conditions, high-level or overflow alarms, and other details of the system must be discussed.
- e. The vessel PIC must be familiar with shutdown procedures, including modifications resulting from the use of the vapor collection system. Requirements for purging of hoses and mandatory wait periods for static reduction or other purposes must be followed.
- f. The vessel PIC must provide the following information to the shore PIC in order to determine the initial fill rate:
 1. The number of compartments open initially.
 2. The size of the drop lines in the compartment.
 3. The length of time or amount of product required to satisfy the initial fill period.