Compilation of Air Emission Estimating Methods for Petroleum Distribution and Dispensing Facilities

API PUBLICATION 1673
SECOND EDITION, JULY 2009

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Marketing Segment

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Compilation of Air Emission Estimating Methods for Petroleum Distribution and Dispensing Facilities

1 Introduction

1.1 Scope

This publication is a compilation of methods for estimating emissions associated with activities that may occur at typical petroleum distribution and dispensing facilities. Distribution facilities include bulk terminals, bulk plants, pipeline breakout stations, and pipeline pumping stations. Dispensing facilities are primarily retail service stations. Evaporative losses of volatile organic liquids (VOLs) from distribution and dispensing facilities occur primarily from transfer operations (i.e. refueling of motor vehicles, and the loading or unloading of tank trucks, railcars, and ships or barges), storage tanks, and equipment leaks (i.e. piping components such as valves and pumps).

Emission estimating methods have been developed to quantify total VOL emissions from these sources and to speciate these emissions. Speciation is the determination of the fraction of the total emissions that are attributable to given individual chemical compounds, or species.

Emission estimating methods change over time as more accurate methods are developed, emission controls change, and the compositions of petroleum products change in response to regulations and consumer needs.

1.2 Purpose

The purpose of this publication is to compile the most current and widely accepted emission estimating methods for petroleum distribution and dispensing facilities in one document.

Numerous studies have been conducted to estimate emissions from these facilities. As a result, more than one estimating method is sometimes available for a given emission-generating activity, with the different methods potentially having differing levels of complexity. There is a trade-off between accuracy and complexity of emission estimates. More accurate estimates require more information about the specific activity.

Section 3 of this publication provides the emission estimating methods. Emission estimating methods that can be stated briefly are provided in whole in Section 3; otherwise, the reader is referred to another document for the complete methodology. Section 3 contains three subsections: one for distribution facilities, one for dispensing facilities, and one for miscellaneous activities. Section 4 provides information on the properties of VOLs used to estimate emissions.

2 Definitions

40 *CFR* Part 63, Subpart BBBBBB [1], Section 63.11100, includes the following definitions related to gasoline distribution facilities.

2.1
bulk gasoline plant
Any gasoline storage and distribution facility that receives gasoline by pipeline, ship or barge, or cargo tank and has a gasoline throughput of less than 20,000 gal/day.

NOTE This differs from the definition implied by 40 *CFR* Part 60, Subpart XX [2], Section 60.501 and 40 *CFR* Part 63, Subpart R [3], Section 63.421. These rules do not define a bulk plant, but define a bulk terminal as any gasoline facility which receives gasoline by pipeline, ship or barge, and has a gasoline throughput greater than approximately 20,000 gal/day. This implies that a facility receiving only by cargo tank is a bulk plant, regardless of throughput.

2.2
bulk gasoline terminal
Any gasoline storage and distribution facility that receives gasoline by pipeline, ship or barge, or cargo tank and has a gasoline throughput of 20,000 gal/day or greater.

2.3
equipment
Each valve, pump, pressure relief device, sampling connection system, open-ended valve or line, and flange or other connector in the gasoline liquid transfer and vapor collection systems. This definition also includes the entire vapor processing system except the exhaust port(s) or stack(s).

2.4
gasoline cargo tank
A delivery tank truck or railcar which is loading gasoline or which has loaded gasoline on the immediately previous load.

2.5
pipeline breakout station
A facility along a pipeline containing storage vessels used to relieve surges or receive and store gasoline from the pipeline for re-injection and continued transportation by pipeline or to other facilities.

2.6
pipeline pumping station
A facility along a pipeline containing pumps to maintain the desired pressure and flow of product through the pipeline and not containing storage vessels.

40 *CFR* Part 63, Subpart CCCCCC [4], Section 63.11132, includes the following definition.

2.7
gasoline dispensing facility
GDF
Any stationary facility which dispenses gasoline into the fuel tank of a motor vehicle.

While the regulatory definitions listed above are specific to gasoline, this publication applies to distribution and dispensing facilities for VOLs and is not limited to gasoline.

3 Emission Estimating Methods

3.1 Distribution Facilities

3.1.1 Overview

AP-42, Section 5.2.1, gives an overview of the petroleum distribution system. Table 1 summarizes emission estimating methods for activities at distribution facilities.

3.1.2 Storage Tanks

3.1.2.1 Storing, Filling, and Emptying a VOL in a Storage Tank

EPA offers software (TANKS) to estimate emissions from storage tanks. TANKS is based on the emission estimating procedures from AP-42, Chapter 7, and is available at www.epa.gov/ttn/chief/software/tanks/index.html.

Limitations of the TANKS program are discussed in Annex A.

Table 1—Emission Estimating Methods for Activities at Distribution Facilities (Routine and Non-routine)

Activity	API 1673 Section	API Reference	EPA Reference
Storing a VOL (including filling and emptying) in the following types of storage tanks:			
a) fixed-roof tanks	3.1.2.1	API *MPMS* Ch. 19.1 [5]	AP-42 [6], Section 7.1.3.1
b) floating-roof tanks	3.1.2.1	API *MPMS* Ch. 19.2 [7]	AP-42, Section 7.1.3.2.1
c) closed-vent IFRTs	3.1.2.1	API 2569 [8]	
d) variable vapor space tanks	3.1.2.1		AP-42, Section 7.1.3.3
Landing a floating roof in a tank that stores a VOL	3.1.2.2	API 2567 [9]	AP-42, Section 7.1.3.2.2
Cleaning a storage tank that contained a VOL	3.1.2.3	API 2568 [10]	
Loading a VOL into a ship or barge (uncontrolled)	3.1.3.1	API *MPMS* Ch. 19.5 [11], Section 4.1	AP-42 [12], Section 5.2.2.1.1 and Tables 5.2-1, 5.2-2 and 5.2-6
Loading ballast water into a ship or barge that previously held crude oil (uncontrolled)	3.1.3.2	API *MPMS* Ch. 19.5, Section 4.2	AP-42, Section 5.2.2.1.2 and Table 5.2-4
Loading a VOL into a cargo tank (uncontrolled)	3.1.3.3		AP-42, Section 5.2.2.1.1 and Tables 5.2-1 and 5.2-5
Loading a VOL into a cargo tank (controlled)	3.1.3.4		AP-42, Section 5.2.2.1.1
Leaking a VOL from equipment	3.1.4	API 4653 [13], Table ES-2	EPA-453/R-95-017 [14], Tables 2-1 and 2-3
Spilling a VOL (pool exposed to wind)	3.1.5 a)		EPA 550-B-99-009 [15], Appendix B.2
Spilling a VOL (pool not exposed to wind)	3.1.5 b)		EPA EIIP Vol II, Ch 16 [16], Section 3.7.1
Miscellaneous activities	3.3	References for these activities are listed in Table 5	

3.1.2.1.1 Fixed-roof Tanks

API *MPMS* Ch. 19.1 and AP-42, Section 7.1.3.1, provide emission estimating methods for fixed-roof tanks. The method given in each document is the same.

3.1.2.1.2 Floating-roof Tanks with Open Vents (Freely Vented)

API *MPMS* Ch. 19.2 and AP-42, Section 7.1.3.2.1, provide emission estimating methods for floating-roof tanks with open vents. The emission estimating method for floating-roof tanks given in API *MPMS* Ch. 19.2 is the same as that given in AP-42, Section 7.1.3.2, with the following exceptions:

1) API *MPMS* Ch.19.2 specifies that the true vapor pressure of the stock is to be calculated from the average stock storage temperature (i.e. the liquid bulk temperature), whereas AP-42, Section 7.1.3.2, specifies that the true vapor pressure of the stock is to be calculated from the average liquid surface temperature;

2) API *MPMS* Ch.19.2 specifies a deck seam loss per unit seam length factor of 0.34, whereas AP-42, Section 7.1.3.2 specifies a deck seam loss per unit seam length factor of 0.14.

3.1.2.1.3 Closed-vent Internal Floating-roof Tanks (IFRTs) (Non-freely-vented IFRTs)

As discussed in API 2569, emissions from closed-vent IFRTs may be approximated as 5 % less than emissions from IFRTs with open vents determined in accordance with 3.1.2.1 b).

API 2569 compares emissions from closed-vent IFRTs with emissions from open-vent IFRTs and shows that closing the vents on IFRTs reduces emissions slightly. This reduction is a function of stock volatility, turnover rate, the rate at which vapors pass through the floating roof, tank height, pressure/vacuum vent settings, and stock temperature. API 2569 concludes that, given the high uncertainty associated with the methods evaluated, an assumption of a 5 % reduction in emissions from an IFRT due to use of closed vents would be a reasonable approach for estimating emissions from these tanks.

3.1.2.1.4 Variable Vapor Space Tanks

Emissions from tanks with an expandable vapor storage capacity are addressed in AP-42, Section 7.1.3.3.

3.1.2.2 Landing a Floating Roof

The estimating method given in AP-42, Section 7.1.3.2.2, is the same as in API 2567. AP-42, Section 7.1.3.2.2, includes the stipulation of the saturation factor being set equal to 0.6 for calculating the upper-bound limit on standing-idle loss for drain-dry tanks, where the appropriate value for this factor is not as apparent in API 2567. The following clarifications may be helpful.

a) The same filling loss equation (API 2567, Equation 21) can be used for all tank configurations:

$$L_F = \left(\frac{PV_V}{RT}\right)M_V(C_{sf}\,S)$$

This equation includes the C_{sf} factor used in the filling loss equation for external floating-roof tanks and can be used in the filling loss equation for internal floating-roof and drain-dry tanks by setting its value equal to 1.0 for the latter two tank configurations so as to not change the estimated emissions.

b) The value of the saturation factor S used in the calculation of an upper-bound limit on standing-idle loss for drain-dry tanks is 0.6.

c) A more accurate expression from API *MPMS* Ch. 19.1 for the vapor space expansion factor K_E can be used as an alternate to the expression given for K_E in API 2567:

$$K_E = \frac{\Delta T_V}{T} + \frac{\Delta P}{P_a - P}$$

d) An upper-bound limit on the estimation of filling loss for tanks with a liquid heel may be determined from the initial amount of available liquid less the amount attributed to standing idle loss, plus the vapors generated by the incoming liquid upon refilling. This may be expressed as:

$$(5.9D^2 h_{le} W_l - L_S) + \frac{0.15PV_V M_V}{RT}$$

3.1.2.3 Tank Cleaning

API 2568 provides emission estimating methods for tank cleaning episodes.

3.1.3 Loading Ships, Barges, and Truck and Rail Cargo Tanks

The equation given in this edition of API 1673 for estimating emissions from the loading of VOLs is given as Equation 1 in AP-42, Section 5.2. This equation is a function of a saturation factor that depends upon the loading scenario.

The loading loss equation accounts for the vapor pressure and vapor molecular weight of the VOL being loaded, as well as for the temperature at which the loading occurs, but the use of emission factors does not accommodate accounting for these parameters. The Second Edition of API 2514A [17] specified emission factors for estimating emissions from the loading of marine vessels, but when this document was rewritten in 2009 (API *MPMS* Ch. 19.5, First Edition), these emission factors were converted into equivalent saturation factors so that the loading loss equation could be applied.

This edition of API 1673 is based on the use of the loading loss equation. Saturation factors given in this edition of API 1673 for the loading of cargo tanks were obtained from AP-42, Section 5.2, and saturation factors for the loading of marine vessels were obtained from API *MPMS* Ch. 19.5. There is an inconsistency between these sources in the manner in which the loading loss equation is applied, in that AP-42, Section 5.2, defines the temperature variable as the temperature of the bulk liquid loaded, whereas API *MPMS* Ch. 19.5 defines the temperature variable as the temperature of the ullage (i.e. the temperature of the vapor space). While the vapor pressure should be calculated at the temperature of the liquid, the temperature variable in the loading loss equation is the temperature used in calculating the vapor density, and thus it would seem that the temperature of the vapor space would be the more correct value for this variable.

3.1.3.1 Loading VOLs into Ships or Barges (Uncontrolled)

The loss from a liquid loading episode, L_L, is:

$$L_L \text{ lb/(thousand gallons loaded)} = 12.46\, K_S\, P_{VA}\, M_V/T_V$$

where

K_S is the saturation factor (API *MPMS* Ch. 19.5, Table 2);

P_{VA} is true vapor pressure of the liquid loaded (psia);

M_V is the molecular weight of the stock vapors (lb/lb-mol);

T_V is the absolute temperature of the ullage (the unfilled volume of a compartment) (°R).

There are a number of scenarios that may be described for the loading of petroleum liquids into marine vessels, with each having an associated saturation factor for the loading loss equation. Saturation factors for the loading of gasoline and crude oil into marine vessels are provided in API *MPMS* Ch. 19.5. Saturation factors for the loading of other petroleum liquids are provided in AP-42, Section 5.2. Furthermore, saturation factors for the loading of gasoline and crude oil can be calculated from the emission factors given in AP-42.

AP-42, Section 5.2.2.1.1, presents a method for estimating emissions from crude oil loading which separates the emissions into arrival and generated components. This methodology provides similar results to those given in API *MPMS* Ch. 19.5.

3.1.3.2 Loading Ballasting Water into Ships or Barges (Uncontrolled)

The loss for a ballast water loading episode, L_L, is:

$$L_L \text{ lb/(thousand gallons loaded)} = 12.46\, K_S\, P_{VA}\, M_V/T_V$$

where

K_S is the saturation factor (API *MPMS* Ch. 19.5, Table 3);

P_{VA} is the true vapor pressure of the crude oil unloaded (psia);

M_V is the vapor molecular weight of the crude oil unloaded (lb/lb-mol);

T_V is the absolute temperature of the ullage (the unfilled volume of a compartment) (°R).

If volume of the ballast water loaded into compartments that previously contained crude oil is unknown, it can be estimated as 17 % of the volume of the crude oil unloaded.

Table 2—Loading Loss Saturation Factor K_S
API *MPMS* Ch. 19.5

Marine Vessel Type [a]	Prior Cargo [b]	Compartment Condition Prior to Loading [c]	K_S (gasoline loading)	K_S (crude oil loading)	K_S (other petroleum liquids loading) [d]
Ship or ocean barge	Volatile	Uncleaned	0.2	0.2	0.2
Ship or ocean barge	Volatile	Ballasted	0.15	0.15	—
Ship or ocean barge	Volatile	Cleaned	0.10	0.10	—
Ship or ocean barge	Volatile	Gas freed	0.10	0.10	—
Ship or ocean barge	Nonvolatile	Uncleaned, ballasted, cleaned, or gas freed	0.10	0.10	—
Shallow draft barge	Volatile	Uncleaned	0.3	0.3 [e]	0.5
Shallow draft barge	Volatile	Cleaned or gas freed	0.15	—	—
Shallow draft barge	Nonvolatile	Uncleaned, cleaned, or gas freed	0.15	—	—

[a] Marine Vessel Type
shallow draft barge: marine vessels with compartment depths of approximately 10 ft to 12 ft.
ship or ocean barge: marine vessels with compartment depths of approximately 40 ft.

[b] Prior Cargo
volatile cargo: cargo with a true vapor pressure greater than 1.5 psia.
nonvolatile cargo: cargo with a true vapor pressure of 1.5 psia or less. Nonvolatile cargo includes fuel oils such as No. 2 fuel oil (diesel) and No. 6 fuel oil.

[c] Compartment Condition Prior to Loading
ballasted compartment: an uncleaned compartment that has been loaded with ballast water.
cleaned compartment: a compartment that has been water washed.
gas-freed compartment: a compartment that has been cleaned and air-blown, such that the compartment is suitable for entry and hot work such as welding.
uncleaned compartment: a compartment that has had no treatment except routine heel washing (washing restricted to the lower part of the compartment).
A barge may have more than one compartment and the compartments may have different conditions prior to loading.

[d] K_S for loading of other petroleum liquids into marine vessels is from AP-42, Table 5.2-1.

[e] K_S for loading of crude oil into a shallow draft barge is calculated from the emission factor given in AP-42, Table 5.2-6.

Table 3—Ballasting Loss Saturation Factor K_S
API *MPMS* Ch. 19.5

Marine Vessel Type	Prior Cargo	Compartment Condition Prior to Dockside Crude Oil Unloading [a]	K_S
Ship or ocean barge	Crude oil	Fully loaded	0.20
Ship or ocean barge	Crude oil	Lightered or previously short loaded	0.35

[a] Compartment Condition Prior to Dockside Crude Oil Unloading
fully loaded compartment: a compartment with a true ullage height of 5 ft or less prior to dockside crude oil unloading.
lightered or previously short-loaded compartment: a compartment with a true ullage height of more than 5 ft prior to dockside crude oil unloading.
Ships and barges may have more than one compartment and the compartments may have different conditions prior to loading. Vessels that have segregated ballast tanks that hold only ballast water have no emissions associated with ballasting.

The emission estimating method for loading ballast water into ships and barges given in this edition of API 1673 is the same as in API *MPMS* Ch. 19.5. AP-42 provides two methods, both of which provide similar results to API *MPMS* Ch. 19.5:

a) an equation (AP-42, Equation 4) that permits adjustments to account for the ullage height and the true vapor pressure of the crude oil that was unloaded from the vessel before ballasting, and

b) AP-42, Table 5.2-4 which has emission factors based on assumed values for these parameters.

3.1.3.3 Loading VOLs into Cargo Tanks (Uncontrolled)

The loss for a loading episode, L_L, is (AP-42, Section 5.2.2.1.1 Equation 1):

$$L_L \text{ lb/(thousand gallons loaded)} = 12.46\, K_S\, P_{VA}\, M_V / T$$

where

K_S is the saturation factor (Table 4);

P_{VA} is the true vapor pressure of the liquid loaded (psia);

M_V is the vapor molecular weight of the liquid loaded (lb/lb-mol);

T is the absolute temperature of the liquid loaded (°R).

Table 4—Cargo Tank Loading Loss Saturation Factor K_S
AP-42, Table 5.2-1

Cargo Tank Condition	Type of Loading	K_S [a]
Clean	Submerged loading	0.50
Dedicated normal service	Submerged loading	0.60
Dedicated vapor balance service	Submerged loading	1.00
Clean	Splash loading	1.45
Dedicated normal service	Splash loading	1.45
Dedicated vapor balance service	Splash loading	1.00

[a] AP-42, Table 5.2-1, applies these factors to petroleum liquids other than gasoline and crude oil. AP-42, Table 5.2-5, applies these factors to gasoline and crude oil, as well as to other products.

3.1.3.4 Loading VOLs into Cargo Tanks (Controlled)

For controlled loading operations, the emissions are estimated as:

$$L_{LC} = (\text{uncontrolled emissions } L_L)[1 - (\text{collection efficiency})(\text{control efficiency})]$$

When tank trucks are loaded at a bulk gasoline terminal, the vapors displaced from the cargo tanks are commonly routed to vapor control devices. The emissions associated with this control technology are due to the following.

1) Leakage from the tank truck during the loading process (collection efficiency). If the vapors are routed to the control device by means of a vacuum, no leakage is assumed to occur.

2) Inefficiency of the vapor control device (control efficiency). The control device efficiency is typically expressed as a percent reduction in the concentration of vapors from the inlet to the outlet of the control device.

Control efficiency depends upon the type of control device, which includes vapor combustion units (thermal oxidizers), flares, carbon adsorption, refrigeration, and internal combustion engines. Vapor control methods are discussed in API 2557 [18]. Control efficiencies may be obtained from vendor data or determined by performance tests. API 347 [19] provides VOC and hazardous air pollutant (HAP) control efficiencies for carbon absorbers and thermal oxidizers at gasoline loading racks.

Collection efficiency is a function of the leaktightness of the cargo tank being loaded. The leaktightness may be quantified in terms of a leaktightness test.

Table 5—Collection Efficiencies for Loading Cargo Tanks
AP-42, Section 5.2.2.1.1

Condition	Collection Efficiency
Tank trucks that are subject to an annual 1 in. pressure drop test	99.2 %
Tank trucks that are subject to an annual 3 in. pressure drop test	98.7 %
Tank trucks that are not subject to either of these leak tests	70.0 %
When a vacuum is used to collect the vapors	100 %

NOTE 1 The referenced pressure drop tests are pressure decay tests in which the cargo tank is pressurized to 18-in. of water column. The test criterion is the number of inches of water column that the pressure is allowed to drop in 5 minutes.
NOTE 2 The development of collection efficiency factors is discussed in detail below.

During the promulgation of the MACT rule for the gasoline distribution industry, EPA developed revised emission factors for leakage from tank trucks during loading at bulk gasoline terminals. The development of the revised factors is documented in Appendix A of the rule's final background information document (BID Volume II) [20]. BID Volume II uses the equation:

$$V_L = 0.5V\left(\frac{T}{t_p}\right)\left(1 - \frac{P_f}{P_i}\right)$$

where

V_L is the volume of leakage (L);

V is the capacity volume of the cargo tank (L);

T is the total time for loading (min) = V/R;

R is the loading rate (L/min);

t_p is the time limit for pressure test (min);

P_f is the final pressure for test (in. H_2O absolute);

P_i is the initial pressure for test (in. H_2O absolute).

EPA divided the volume of leakage (V_L) by the capacity volume of the cargo tank (V) in order to express leakage as a ratio of the volume loaded. This resulted in the following form of the equation:

$$\frac{V_L}{V} = 0.5\left(\frac{V}{R}\right)\left(\frac{1}{t_p}\right)\left(1 - \frac{P_f}{P_i}\right)$$

EPA selected the following values as being representative for the scenario of a tank truck just passing the 1-in. pressure decay test:

V = 32,200 L;

R = 2,270 L/min;

t_p = 5 min;

P_f = 424 in. H_2O absolute (17 in. H_2O gauge plus atmospheric pressure of 407 in. H_2O absolute);

P_i = 425 in. H_2O absolute (18 in. H_2O gauge plus atmospheric pressure of 407 in. H_2O absolute).

Substituting these values yields the following:

$$\frac{V_L}{V} = 0.5\left(\frac{32,200}{2270}\right)\left(\frac{1}{5}\right)\left(1 - \frac{424}{425}\right) = 0.0033$$

This means that the volume of leakage as a fraction of the volume loaded is equal to 0.0033 or 0.33 %.

Introducing a variable, W_V, as the density of vapors, we may rewrite the leak rate equation as follows:

$$\frac{V_L}{V}W_V = 0.5\left(\frac{V}{R}\right)\left(\frac{1}{t_p}\right)\left(1 - \frac{P_f}{P_i}\right)W_V$$

The term $\left(\frac{V_L}{V}\right)W_V$ is the leak rate, or emission factor, in terms of milligram per liter loaded. Defining a variable, L_L, to represent the emission factor:

$$L_L = \frac{V_L}{V}W_V = 0.5\left(\frac{V}{R}\right)\left(\frac{1}{t_p}\right)\left(1 - \frac{P_f}{P_i}\right)W_V$$

The density of vapors, W_V, is a function of the partial vapor pressure, temperature, and molecular weight of the vapors. EPA determined the density for the saturated vapor density by assuming values for the variables in the filling loss equation (Equation 1 from AP-42, Section 5.2), as demonstrated below:

$$\text{Density}\left(\frac{\text{lb}}{1000\ \text{gal}}\right) = 12.46\frac{S\ P\ M_V}{T}$$

Using values of S = 1, P = 5.35 psia, M_V = 66, and T = 520 °R (60 °F), EPA determined the resulting density, W_V, as approximately 8.46 lb/1000 gal, or 1014 mg/L.

Thus, EPA calculated a leak rate of:

$$L_L = \frac{V_L}{V}W_V = (0.0033)(1014\ \text{mg/L}) = 3.3\ \text{mg/L}$$

EPA solved the equation for several scenarios in order to obtain emission factors. As shown above, one of the scenarios evaluated was for tank trucks that are subject to the California pressure decay limit of 1-in. of water column over a 5-minute period, from an initial pressure of 18 in. of water column (now required nationwide of facilities that are subject to the gasoline distribution MACT rule). This resulted in the leak rate calculated above of 3.3 mg of emissions for every liter of gasoline that is loaded into the truck (3.3 mg/L).

EPA relied on data from the Bay Area Air Quality Management District to determine a failure rate of 3.8 % for tank trucks tested to the 1-in. pressure decay limit. A weighted average emission factor was then calculated, based on a leak rate of about 121 mg/L for the 3.8 % of tank trucks that fail the test and a leak rate of 3.3 mg/L for the tank trucks that pass the test. The resulting weighted-average emission factor that EPA determined for tank trucks that are subject to the 1-in. pressure decay limit is 8 mg/L.

Using this same methodology, EPA determined a weighted-average emission factor of 13 mg/L for tank trucks that are subject to a 3-in. pressure decay limit (as required by the new NSPS for bulk gasoline terminals, 40 *CFR* Part 60, Subpart XX). EPA's weighted average emission factors are summarized as follows:

Pressure Decay Limit (wc loss over 5 min.)	Passing Leak Rate	Failing Leak Rate	Percent Failure	Weighted Average Emission Factor	Collection Efficiency
1 in.	3.3 mg/L	121 mg/L	3.8 %	8 mg/L	99.2 %
3 in.	10 mg/L	121 mg/L	3.1 %	13 mg/L	98.7 %

The method documented above could be adapted to specific scenarios at facilities where passing and failing leak rates and failure percent is known for a given pressure drop test.

Some jurisdictions have adopted a value of 9 mg/L for tank truck leakage for trucks subject to the 3-in. pressure drop, rather than 13 mg/L. This is based on calculations that assume that the average passing leak rate is 5 mg/L and use this (rather than the upper limit passing leak rate of 10 mg/L) to determine the weighted average emission factor. However, the 9 mg/L factor is not recognized in AP-42.

3.1.4 Equipment Leaks

EPA's *Protocol for Equipment Leak Emission Estimates* provides the average emission factor method and three alternate approaches to estimating equipment leak emissions. The alternate approaches are potentially more accurate but require EPA Method 21 screening data from monitoring of the equipment for leaks. The average emission factor method, which does not require screening data, estimates the emission rate of a given type of equipment as:

$$E_{TOC} = F_A \times WP_{TOC} \times N$$

where

E_{TOC} is the total organic compound mass emission rate, including non-VOCs such as methane (CH_4) and ethane;

F_A is the average emission factor for the given piece of equipment;

WP_{TOC} is the weight percent of total organic compounds in the stream;

N is the number of pieces of equipment of the given type in the stream.

Available factors are summarized in Table 6.

EPA's EIIP Volume II: Chapter 4 [21], states that it is based on EPA's *Protocol for Equipment Leak Emission Estimates*. Unlike the *Protocol*, however, the EIIP document does not include average emission factors for terminals.

API 4653 average emission factors for equipment leaks are included in Table 6. API 4653 emission factors are based on a study of 33,588 equipment components at 10 U.S. pipeline facilities, including light crude oil, heavy crude oil,

Table 6—Average Emission Factors for Distribution Facility Equipment

Equipment Type [a]	Service [b]	EPA 453/R-95-017 Emission Factor (lb/hr/source) for Terminals [c]	API 4653 Emission Factor (lb/hr/source) for Pipelines [d]	EPA 453/R-95-017 Emission Factor (lb/hr/source) for SOCMI Units [e]
Valves	Gas	2.9×10^{-5}		1.32×10^{-2}
Valves	Light liquid	9.5×10^{-5}		8.89×10^{-3}
Valves	Heavy liquid			5.1×10^{-4}
Valves	Light crude		1.8×10^{-5}	
Valves	Heavy crude		1.7×10^{-5}	
Valves	Product		3.1×10^{-5}	
Pump seals	Gas	1.4×10^{-4}		
Pump seals	Light liquid	1.2×10^{-3}		4.39×10^{-2}
Pump seals	Heavy liquid			1.9×10^{-2}
Pumps	Light crude		5.089×10^{-3}	
Pumps	Heavy crude		1.740×10^{-3}	
Pumps	Product		4.609×10^{-3}	
Compressor seals	Gas	see others		5.03×10^{-1}
Fittings (connectors and flanges)	Gas	9.3×10^{-5}		
Fittings (connectors and flanges)	Light liquids	1.8×10^{-5}		
Connectors	All			4.04×10^{-3}
Fittings (threaded)	Light crude		1.7×10^{-5}	
Fittings (threaded)	Heavy crude		1.7×10^{-5}	
Fittings (threaded)	Product		1.8×10^{-5}	
Fittings (flanged)	Light crude		8×10^{-7}	
Fittings (flanged)	Heavy crude		8×10^{-7}	
Fittings (flanged)	Product		8×10^{-7}	
Open-ended lines	Light crude		3.3×10^{-5}	
Open-ended lines	Heavy crude		2.3×10^{-5}	
Open-ended lines	Product		1.49×10^{-4}	
Open-ended lines	All			3.7×10^{-3}
Sampling connections	All			3.31×10^{-2}
Pressure relief valves	Gas			2.29×10^{-1}
Others (compressors and any other than fittings, pumps, or valves)	Gas	2.6×10^{-4}		
Others (compressors and any other than fittings, pumps, or valves)	Light liquid	2.9×10^{-4}		
Others	Light crude		8.8×10^{-6}	
Others	Heavy crude		8.8×10^{-6}	
Others	Product		1.05×10^{-4}	

Table 6—Average Emission Factors for Distribution Facility Equipment (Continued)

Equipment Type [a]	Service [b]	EPA 453/R-95-017 Emission Factor (lb/hr/source) for Terminals [c]	API 4653 Emission Factor (lb/hr/source) for Pipelines [d]	EPA 453/R-95-017 Emission Factor (lb/hr/source) for SOCMI Units [e]

[a] Equipment
open-ended lines: open-ended lines are typically downstream from a valve and are open to the atmosphere. Lines closed at the end with flanged or threaded fittings are defined as fittings.
others: EPA 453/R-95-017, Table 4.3-2, identifies others as including instruments, loading arms, stuffing boxes, vents, dump lever arms, diaphragms, drains, hatches, meters, polished rods, and vents.

[b] Service
gas: material in a gaseous state at operating conditions.
light liquid: material in a liquid state in which the sum of the concentration of individual constituents with a vapor pressure over 0.044 psig at 68 °F is greater than or equal to 20 wt %.
heavy liquid: other than gas or light liquid.

[c] EPA 453/R-95-017, Table 2-3, is the source of terminals emission factors from EPA 453/R-95-017; units have been converted from kg/hr.

[d] API 4653, Table ES-2, is the source of emission factors from API 4653. In API 4653, emission factors are provided in lb/day/source; units have been converted from lb/day.

[e] EPA 453/R-95-017, Table 2-1, is the source of SOCMI units emission factors from EPA 453/R-95-017; units have been converted from kg/hr.

and product service. Concentrations were measured at these components and then emission factors were calculated using the EPA *Protocol for Equipment Leak Emission Estimates* correlation method.

API 4588 [22], presents an equipment leak study of four marketing terminals. This study provides emission factors for valves, pumps, connectors (which are also addressed by the EPA *Protocol*) as well as loading arm valves, pressure relief valves, and open-ended lines (which are not provided in the EPA *Protocol*). However, the results were not consistent with those in other studies and API 4588 states that the results are based on a “limited data set.”

Many regulations require a structured program of leak detection and repair (LDAR) as a means for reducing equipment leak emissions. The EIIP document presents control efficiencies for equipment monitored by an LDAR program at specified leak definitions and frequencies. Control efficiencies are presented for SOCMI units and for petroleum refineries, as shown in the tables below. The EIIP document indicates that the SOCMI factors are used for other industries as well.

Table 7—Control Effectiveness for an LDAR Program at a SOCMI Process Unit
EIIP Volume II, Chapter 4, Table 4.2-2

Equipment Type	Service	Control Effectiveness (%)		
		Monthly Monitoring 10,000 ppmv Leak Definition	Quarterly Monitoring 10,000 ppmv Leak Definition	HON [a]
Valves	Gas	87	67	92
Valves	Light liquid	84	61	88
Pumps	Light liquid	69	45	75
Compressors	Gas	[b]	[b]	93
Connectors	Gas	[b]	33	[b]
Connectors	Light liquid	[b]	33	[b]
Pressure relief devices	Gas	[b]	44	[b]

[a] Control effectiveness attributed to the requirements of the HON equipment leak regulation is estimated based on equipment-specific leak definitions and performance levels.

[b] Data are not available to estimate control effectiveness.

Table 8—Control Effectiveness for LDAR Component Monitoring Frequencies for Petroleum Refineries
EIIP Volume II, Chapter 4, Table 4.2-3

Equipment Type	Service	Control Effectiveness (%)		
		Monthly Monitoring 10,000 ppmv Leak Definition [a]	Quarterly Monitoring 10,000 ppmv Leak Definition [a b]	HON [a c]
Valves	Gas	88	70	96
Valves	Light liquid	76	61	95
Pumps	Light liquid	68	45	88
Compressors	Gas	[d]	33	[e]
Connectors	Gas	[f]	[f]	81
Connectors	Light liquid	[f]	[f]	81
Pressure relief devices	Gas	[d]	44	[e]

[a] Source: EPA, July 1992.

[b] Source: EPA, April 1982.

[c] Control effectiveness attributed to the requirements of the HON equipment leak regulation is estimated based on equipment-specific leak definitions and performance levels.

[d] Monthly monitoring of component is not required in any control program.

[e] Rule requires equipment modifications instead of LDAR.

[f] Information not available.

3.1.5 Spills Other Than from Vehicle Refueling

Emission estimating methods for spills other than from vehicle refueling are provided below. (Emission estimating methods for spills occurring during vehicle refueling at dispensing facilities are provided in 3.2.3.) For pools that are not replenished, the total emission cannot exceed the original weight of the pool.

3.1.5.1 Pools Exposed to Wind

The evaporation rate, E_r, (lb/min) for a liquid pool exposed to wind is:

$$E_r = 0.0035 U^{0.78} M_w^{2/3} A \; P_{VA} / T$$

where

U is the wind speed (m/s);

M_w is the molecular weight of the liquid;

A is the surface area of the pool (ft^2);

P_{VA} is the vapor pressure of the liquid (mm Hg);

T is the absolute temperature of the liquid (K).

Background for the equation for estimating evaporation from spills exposed to wind is given in EPA 550-B-99-009, Appendix D.2.1.

3.1.5.2 Pools Not Exposed to Wind

The evaporation rate, E_r, (mass/time), for a liquid pool not exposed to wind is:

$$E_r = M_w^{2/3} A\ P_{VA} K_o M_o^{1/3} / (RT)$$

where

M_w is the molecular weight of the liquid;

A is the surface area of the pool;

P_{VA} is the vapor pressure of the liquid;

K_o is the mass transfer coefficient of a reference liquid (= 0.83 cm/s for water);

M_o is the molecular weight of a reference liquid (= 18.02 gm/gm-mol for water);

R is the ideal gas constant;

T is the absolute temperature of the liquid.

The equation above for evaporation from spills not exposed to wind is developed from the equations given in EPA's EIIP Volume II, Chapter 16, Section 3.7.1.

3.2 Dispensing Facilities

3.2.1 Overview

EPA's EIIP Volume III [23], Chapter 11, Section 2 gives an overview of emissions from gasoline marketing operations. Emissions from dispensing facilities are divided into Stage I emissions (occurring during the delivery of gasoline from tank trucks to storage tanks at service stations) and Stage II emissions (occurring during the pumping of gasoline from the service station storage tank into the fuel tank of the vehicle being refueled).

Table 9 summarizes emission estimating methods for activities at dispensing facilities.

Table 9—Emission Estimating Methods for Activities at Dispensing Facilities

Activity	API 1673 Section	Reference
Filling an underground storage tank with a VOL	3.2.2	AP-42, Section 5.2.2.2, CARB [a]
Storing a VOL in an underground storage tank	3.2.2	AP-42, Section 5.2.2.2, CARB
Refueling a vehicle with a VOL	3.2.3	EPA's MOBILE [24] model
Spilling a VOL while refueling a vehicle	3.2.3	EPA's MOBILE model

[a] CARB, *Emission Inventory Factors*, Section 4.10, "Gasoline Dispensing Facilities," May 1999 [25].

3.2.2 Underground Storage Tanks (USTs)

Filling and breathing losses from USTs are estimated in terms of emission factors applied to the gasoline throughput, as summarized in Table 10.

Table 10—Evaporative Emissions from Gasoline USTs (Stage I)

Activity	AP-42 [a]		CARB [b]
	mg/L Throughput	lb/1000 gal Throughput	lb/1000 gal Throughput
Filling a UST			
Submerged filling	880	7.3	
Splash filling	1380	11.5	
Balanced submerged filling	40	0.3	0.42
UST breathing			
Uncontrolled	120	1.0	0.84
Controlled [c]			0.10

[a] Source: AP-42 Table 5.2-7.

[b] Source: CARB, Section 4.10, “Gasoline Dispensing Facilities,” May 1999.

[c] The CARB reference states that “controlled” means both Stage I and Stage II controls are in effect.

3.2.2.1 Filling a UST

When a UST is filled, the incoming liquid displaces vapors in the tank. In balanced filling, the vapors are routed to the tank truck, and the only emissions are from any collection losses as the vapors go to the tank truck. Thus, for balanced submerged fill, the AP-42 emission rate is relatively low (40 mg/L). Although the emission rate might be expected to be a function of the leak tightness of the tank truck, AP-42 does not provide factors to make this distinction.

For filling operations that do not use vapor balancing, the vapors in the UST are vented to the atmosphere.

3.2.2.2 Breathing

Breathing losses from USTs are caused by vapor expansion due to diurnal heating, just as for aboveground storage tanks. However, underground tanks experience less daily temperature variation than aboveground tanks. UST breathing losses may be further reduced by equipping the vent pipe with a pressure/vacuum valve (vent valve). EPA does not distinguish between controlled and uncontrolled breathing losses for USTs, but emission factors for controlled scenarios are available from CARB.

Some dispensing facilities use aboveground storage tanks, for which breathing losses can be estimated using the same method as for aboveground storage tanks at distribution facilities [see standing storage loss for fixed-roof tanks in 3.1.2.1a)].

3.2.3 Vehicle Refueling

Vehicle refueling emissions include vapor displacement and spillage. EPA’s EIIP Volume III, Chapter 11, “Gasoline Marketing [26],” Section 3.1.1, recommends that the MOBILE model be used to estimate vehicle refueling emissions. Onboard refueling vapor recovery (ORVR) is increasingly used to reduce emissions and ORVR use is accounted for in the MOBILE model.

Information on estimating emissions that occur during vehicle refueling at dispensing facilities can be found in the following.

a) EPA’s MOBILE software. EPA’s EIIP Volume III, Chapter 11, Section 3.1.1 states:
“... MOBILE makes use of improved predictive equations to calculate refueling emission factors, including sensitivity to temperature and Reid vapor pressure (RVP), and these have not yet been incorporated into published AP-42 factors for refueling. Additionally, the user may provide information on local Stage II emission controls to develop an emission factor for controlled emissions.”

b) EPA's Technical Guidance, *Stage II Vapor Recovery Systems for Control of Vehicle Refueling Emissions at Gasoline Dispensing Facilities* [27], Section 4.4.3, provides guidance for determining in-use control efficiency for Stage II systems as a function of the population of Stage II facilities and inspection, maintenance and repair frequencies. Figure 4-15 shows the typical overall efficiency for Stage II to be about 84 % corresponding to annual inspection frequencies and exemptions for stations with throughputs of either less than 2000 gal/mo or less than 10,000 gal/mo.

c) CARB *Emission Inventory Factors*, Section 4.10, "Gasoline Dispensing Facilities," May 1999, provides loading, breathing, vehicle refueling, and spillage emission factors for uncontrolled and controlled scenarios at gasoline dispensing facilities.

d) AP-42, Section 5.2.2.3 provides emission factors for controlled and uncontrolled vehicle refueling and for spillage.

Refueling emissions may be controlled by a balance system or a vacuum-assist system. The balance system relies on the pressure created by the fuel entering the vehicle's tank to force the vapors through the hose and into the dispensing facility's storage tank. A vacuum-assist system uses a vacuum to pull the vapors from the vehicle's tank and move them to the storage tank.

Spillage includes the following.

a) Spitback, which occurs when the vehicle's tank is filled at a faster rate than vapors can escape from the tank. Federal rules limit spitback to 1 gm per vehicle refueling, which is equivalent to 26 mg/L assuming 10 gal per vehicle refueling.

b) Overfills, which can occur when the nozzle shut-off mechanism fails or the operator overrides it.

c) Post-fill drips from nozzles.

Spillage was estimated in several studies noted in the EPA Technical Guidance document, including API 4498 [28]. These studies measured spills for both uncontrolled and controlled vehicle refueling.

A summary of emission factors for vehicle refueling and spillage is presented in Table 11. A more reliable estimate of emissions would be obtained by using EPA's MOBILE software, which does account for ORVR controls.

Table 11—Evaporative Emissions from Gasoline Dispensing (Stage II)

Activity	AP-42 [a]		CARB [b]
	mg/L Throughput	lb/1000 gal Throughput	lb/1000 gal Throughput
Vehicle refueling			
Vapor displacement (uncontrolled)	1320	11.0	8.4
Vapor displacement (Stage II controls) [c]	132	1.1	0.74
Spillage [d]	80	0.7	0.42

[a] Source: AP-42, Table 5.2-7.

[b] Source: CARB *Emission Inventory Factors*, Section 4.10, "Gasoline Dispensing Facilities," May 1999.

[c] These emission factors do not account for reductions that would result from ORVR controls.

[d] The CARB reference gives the value shown of 0.42 lb/(1000 gal) for gasoline dispensing operations with Stage II vapor recovery controls. A value of 0.64 lb/(1000 gal) is given for gasoline dispensing operations without Stage II vapor recovery controls.

3.2.4 The Future of Stage II Controls at Dispensing Facilities

Dispensing gasoline into a motor vehicle's onboard tank displaces the vapors in the tank, resulting in VOC emissions unless these vapors are captured. The Clean Air Act (CAA) has required two methods for controlling these emissions.

The first approach, called Stage II controls, was required by CAA § 182(b)(3) in the late 1970s for areas classified as moderate, serious, severe, and extreme ozone non-attainment areas. Stage II controls capture gasoline vapors displaced from the motor vehicle's fuel tank with a flexible bellows that surrounds the gasoline dispensing nozzle, and directs the vapors into the underground gasoline storage tank. Later, these vapors are displaced from the underground tank into the tank truck during filling of the underground tank as a Stage I control. According to EPA's Office of Transportation and Air Quality, by 2006, 27 states and the District of Columbia implemented Stage II controls in 275 counties. Some states, such as California, require Stage II controls statewide; other states limit Stage II controls to ozone non-attainment areas.

The second approach, called ORVR, was promulgated on April 16, 1994 (59 *FR* 16262) under CAA § 202(a)(6), and was phased in between 1998 and 2006 as a requirement for new vehicles. ORVR-equipped vehicles have a seal in the tank fill pipe that forms around the dispensing nozzle, and vapors are directed to an activated carbon canister onboard the vehicle. When the vehicle is started, air is pulled through the canister, directing the vapors to the engine where they are burned.

CAA § 202(a)(6) authorizes the EPA Administrator to waive the Stage II requirements for serious, severe, or extreme ozone non-attainment areas when the Administrator determines that ORVR systems are in "widespread use" throughout the motor vehicle fleet. CAA § 202(a)(6) also states that Stage II controls no longer apply to moderate ozone nonattainment areas. However, ozone non-attainment areas may need to continue Stage II controls to satisfy other air quality requirements.

The CAA gives the Administrator discretion in defining widespread use. As of 2008, the Administrator has not yet determined that ORVR systems are in widespread use, and EPA's website says this determination will be made "probably sometime after 2010." [29]

3.3 Miscellaneous Activities

Emission estimating methods for miscellaneous activities are summarized in Table 12. Emissions from some of these activities include air pollutants other than VOCs such as particulates, nitrogen oxides (NO_x), sulfur oxides (SOx), and carbon monoxide (CO).

3.3.1 Crude Oil Storage Tank Flashing

Produced crude oil typically passes through a separator to remove dissolved gas, but may still contain some gas that is maintained in solution under pressure until the crude oil enters an atmospheric storage tank. The gas does not remain in solution at the lower pressure of atmospheric conditions, and thus bubbles out of the crude oil, much like carbon dioxide (CO_2) bubbling out of a carbonated beverage when the container is opened. This release of gas is referred to as flashing. There are several methods for estimating flashing emissions as follows.

a) E&P TANK Program—API and the Gas Research Institute jointly developed the E&P TANK program to estimate flashing, working, and standing losses from petroleum production field storage tanks for either black oil or gas condensate systems. Flashing emissions are based on the Peng-Robinson equation of state, and require site-specific information on separator oil composition, separator temperature and pressure, sales oil API Gravity and RVP, sales oil production rate, ambient temperature and pressure, and various tank parameters. API 4697 [30] addresses the method and includes the program.

b) Vasquez-Beggs Correlation Equation—This equation determines flashing loss for black oil systems as a function of separator temperature, separator pressure, gas specific gravity, the crude oil's API Gravity (between 16 and

Table 12—Emission Estimating Methods for Other Activities

API 1673 Section	Activity	Estimating Method
3.3.1	Crude oil storage tank flashing	API 4697 Vasquez-Beggs correlation equation EC/R equation GOR
3.3.2	Abrasive blasting	AP-42, 13.2.6
3.3.3	Electric arc welding	AP-42, Section 12.19.2
3.3.4	Particulates from unpaved roads	AP-42, Section 13.2.2
3.3.5	Engines for fixed facility pump drivers and emergency generators and portable gasoline-driven equipment	AP-42, Chapter 3
3.3.6	Solvent machines	AP-42, Section 4.6
3.3.7	Vacuum truck loading	EPA-453/R-94-080A
3.3.8	Natural gas-fired process heaters (boilers and furnaces)	AP-42, Section 1.4
3.3.9	Routing to flares [highly volatile liquid (HVL) pipelines: segment blow downs and other routing to flares]	AP-42, Section 13.5
3.3.10	Oil/water separators	AP-42, Section 5.1
3.3.11	Motor vehicle emissions	MOBILE model

58), tank throughput, molecular weight of the gas, and weight fraction of VOC in the gas. A spreadsheet for the method is given at: www.deq.state.ok.us/aqdnew/resources/Calculations11.xls.

c) Environmental Consultants and Research, Inc. (EC/R) Equation—The EC/R equation estimates flashing losses for gas condensate systems given the separator pressure, the tank throughput, the API Gravity of the crude oil, and crude oil's vapor pressure. It is limited to liquid streams with a vapor pressure between 23.5 and 75 psia. The EC/R equation is provided and explained in EPA's EIIP Volume II, Chapter 10 [31], Section 4.3.2.

d) Gas-to-oil Ratio (GOR)—The GOR and the components of the oil can be determined by gas chromatography analysis of a pressurized crude oil sample collected upstream of the storage tank. The GOR is a gas volume per liquid volume, so for a given oil volume, the uncontrolled gas emission can be determined as the GOR times the oil volume assuming all of the gases are released upon depressurization. An extended hydrocarbon (HC) analysis of the flash gas from the sample should also be conducted to identify the concentrations of the individual components of the tank's flash emissions. The Gas Processors Association (GPA) Standard 2174-93 [32] gives details on the procedure for collecting the pressurized oil sample.

3.3.2 Abrasive Blasting

Abrasive blasting is used to prepare metal surfaces of objects such as storage tanks or pipes for paint or other coatings. AP-42, 13.2.6 [33] provides particulate emission estimates for abrasive blasting.

3.3.3 Electric Arc Welding

Particulate matter (PM) and particulate-phase HAPs are the major emissions from welding processes. Only electric arc welding generates these pollutants in substantial quantities. AP-42, Table 12.19-1 [34], presents PM-10 emission factors from shielded metal arc welding (SMAW), gas metal arc welding (GMAW), flux cored arc welding (FCAW), and submerged arc welding (SAW) processes for commonly used electrode types. AP-42, Table 12.19-2, presents similar factors for hazardous metal emissions.

Table 13—Particulate Emission Factors For Abrasive Blasting [a]
AP-42, Table 13.2.6-1

Source	Particle Size	Emissions (lb/1000 lb Abrasive)
Sand blasting of mild steel uncontrolled (SCC 3-09-002-02)	Total PM 5 mph wind speed 10 mph wind speed 15 mph wind speed PM-10 [b] PM-2.5 [b]	 27 55 91 13 1.3
Abrasive blasting of unspecified metal parts, controlled with a fabric filter [c] (SCC 3-09-002-04)	Total PM	0.69

[a] SCC = Source Classification Code.
[b] Emissions of PM-10 and PM-2.5 are not significantly wind-speed dependent.
[c] Abrasive blasting with garnet blast media.

3.3.4 Particulates from Unpaved Roads

AP-42, Section 13.2.2.2 [35], estimates emissions for vehicles traveling on unpaved surfaces at industrial sites as:

$$E = k(s/12)^a(W/3)^b$$

where

E is the size-specific emission (lb/vehicle-mile traveled);

s is the surface material silt content (%) for silt contents from 1.8 % to 25.3 % and surface moisture content 0.03 % to 13 %;

W is the mean vehicle weight (ton) for weights from 2 tons to 290 tons, 4 to 17 mean number of wheels;

k, a, and b are determined from Table 14.

Table 14—AP-42, Table 13.2.2-2

Constant	PM-2.5	PM-10	PM-30 [a]
k (lb/VMT)	0.15	1.5	4.9
a	0.9	0.9	0.7
b	0.45	0.45	0.45

[a] Assumed equivalent to total suspended particulate matter (TSP).

3.3.5 Engines for Fixed Facility Pump Drivers and Emergency Generators and Portable Gasoline-driven Equipment

Various fixed and portable equipment such as pumps and emergency generators may be used at pipeline facilities. Often the equipment is electric-driven, but natural gas, gasoline, and diesel-fueled internal combustion engines may be used instead, especially in remote or off-shore locations.

AP-42, Chapter 3 [36], discusses the emissions from these engines. Most emissions from these engines are in the exhaust. However, some VOCs escape from the crankcase as a result of blowby (gases that are vented from the oil pan after they have escaped from the cylinder past the piston rings) and evaporation from the fuel tank and carburetor. Nearly all of the VOCs from diesel engines enter the atmosphere from the exhaust. Evaporative losses are insignificant in diesel engines due to the low volatility of diesel fuels.

The primary pollutants from internal combustion engines are NO_X, VOCs, CO, and particulates, both visible (smoke) and invisible. NO_X formation is directly related to high pressures and temperatures during the combustion process and to the nitrogen content, if any, of the fuel. The other pollutants are primarily the result of incomplete combustion. Ash and metallic additives in the fuel also contribute to the particulate content of the exhaust. SO_X [mainly sulfur dioxide (SO_2)] in the exhaust are directly related to the fuel's sulfur content.

The appropriate section in AP-42 is as follows:

AP-42 Section	Source
3.1	Stationary gas turbines
3.2	Natural-gas fired reciprocating engines
3.3	Gasoline and diesel industrial engines
3.4	Large stationary diesel (greater than 600 hp) and all stationary dual-fuel engines

40 *CFR* Part 60, Subpart JJJJ [37], limits emissions of NO_X, CO, and VOCs from new stationary spark ignition engines. It applies to those manufactured or ordered after January 18, 2008 and manufactured after July 1, 2007 for engines greater than or equal to 500 hp and after July 1, 2008 for engines with less than 500 hp, and to engines that begin modification or reconstruction after June 12, 2006. 40 *CFR* Part 63, Subpart ZZZZ [38], limits air toxics emissions from new and reconstructed stationary reciprocating internal combustion engines that either are located at smaller-emitting sources of air toxics emissions called area sources, or that have a site rating of less than or equal to 500 hp and are located at larger emitting, or major sources of air toxics emissions. Emissions from engines subject to these rules are likely to be less than those cited in AP-42, which is based on older engines.

Similarly, 40 *CFR* Part 60, Subpart KKKK [39], limits NO_X and SO_2 from certain stationary combustion turbines that commence construction, modification, or reconstruction after February 18, 2005.

3.3.6 Solvent Machines

Solvents are occasionally used to clean and degrease parts at distribution facilities. Solvent cleaning may be done by wiping a part with a rag wetted with solvent, by spraying a part with solvent, or by placing a part in a solvent machine. AP-42, Section 4.6, provides emission estimating methods for continuous solvent degreasing operations.

For solvent that evaporates only partially, such as in solvent machines, Raoult's Law can be used to determine the composition of the solvent vapor from the composition of the liquid solvent.

3.3.7 Vacuum Truck Loading

Vacuum trucks may be used to collect volatile liquids that cannot be pumped, such as liquids that have been spilled or liquid remaining in the bottom of the tank that cannot be pumped out through the normal suction line. Vacuum trucks include two types: those with an evacuated compartment that pulls liquid into the compartment by means of a vacuum without an exhaust for vapors, and those that have an exhaust.

Emissions from vacuum trucks without an exhaust are from any leakage from the truck, similar to the controlled loading of VOLs into cargo tanks (see 3.1.3.4). EPA's *Air Emissions Models for Waste and Wastewater* [40] gives the emissions from vacuum trucks with an exhaust as:

$$E_i = VX_iP_iM_i/(P_oV_GT/273)$$

where

E_i is the air emissions of compound i (g);

V is the vacuum truck volume (m^3);

X_i is the mole fraction of compound i in the liquid phase;

P_i is the vapor pressure of compound i (mm Hg);

M_i is the molecular weight of compound i;

P_o is the atmospheric pressure (mm Hg);

V_G is the volume of 1 g-mol of gas at standard temperature and pressure = 0.0224 m^3/g-mol;

T is the operating temperature K.

3.3.8 Natural Gas-fired Process Heaters (Boilers and Furnaces)

Heaters may be used to reduce the viscosity of liquids, drive out moisture, or reach an ideal temperature and pressure for metering. AP-42, Section 1.4 [41], “Natural Gas Combustion,” states:

> “The emissions from natural gas-fired boilers and furnaces include nitrogen oxides (NO_x), carbon monoxide (CO), and carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), volatile organic compounds (VOCs), trace amounts of sulfur dioxide (SO_2), and particulate matter (PM).”

AP-42, Section 1.4, provides natural gas combustion emissions in pounds per million standard cubic feet (lb/10^6 scf) for NO_x, CO, CO_2, lead, N_2O, PM, SO_2, TOCs, CH_4, and VOCs.

3.3.9 Routing to Flares (HVL Pipelines: Segment Blow Downs and Other Routing to Flares)

49 *CFR* Part 195, Section 195.2 [42], defines HVLs as “hazardous liquid which will form a vapor cloud when released to the atmosphere and which has a vapor pressure exceeding 276 kPa (40 psia) at 37.8 °C (100 °F).” When pipelines handling these liquids are opened to the atmosphere, the liquid evaporates; these emissions may be controlled using flares. Emission estimating methods for flares are given in AP-42, Section 13.5.

3.3.10 Oil/Water Separators

AP-42, Table 5.1-2, provides emission factors for oil/water separators as shown in Table 15.

Table 15—Fugitive Emission Factors for Petroleum Refineries
AP-42, Table 5.1-2

Units	Uncontrolled Emissions	Controlled Emissions	Control Technology
kg/10^3 L waste water	0.6	0.024	covered separators and/or vapor recovery systems
lb/10^3 gal waste water	5	0.2	covered separators and/or vapor recovery systems

3.3.11 Motor Vehicle Emissions

MOBILE6, an emission factor model for predicting gram per mile emissions of HC, CO, NO_x, CO_2, PM, and toxics from cars, trucks, and motorcycles under various conditions, is available at: www.epa.gov/oms/m6.htm.

4 Properties of Volatile Organic Liquids

4.1 Properties

Several properties of VOLs are needed to estimate emissions. Table 16 provides references for these properties.

Table 16—References for Properties of VOLs

Substance	Property	Reference
Petrochemicals	CAS registry no. Molecular weight Liquid density Vapor pressure as a function of temperature Normal boiling point	API 19.4 [43], Table 3
Liquid Mixtures	Vapor molecular weight, M_v Liquid molecular weight, M_l Condensed vapor density, W_{vc} Liquid density, W_l Vapor pressure, P, as a function of temperature	API 19.4, Table 2

Properties of many chemical compounds can be obtained from the NIST Standard Reference Database Number 69, available at http://webbook.nist.gov/chemistry/.

4.2 Speciation

API *MPMS* Ch. 19.4 provides three methods for speciating emissions:

1) Section 5: calculating vapor composition based on liquid composition using Raoult's Law,

2) Section 6.1: determining vapor composition based on a vapor composition developed for representative stocks,

3) Section 6.2: direct measurement of vapor composition.

The liquid composition must be known in order to use the first method above (calculating vapor composition based on the liquid composition). The table below provides references for liquid compositions of various VOLs. Usually, the compounds of interest are those that EPA has identified as HAPs, toxic release inventory (TRI) compounds, or polycyclic aromatic compounds (PACs), also known as polycyclic aromatic hydrocarbons (PAHs).

Table 17—References for Compositions of VOLs

Substance	Concentration of:	Reference
Crude oil, petroleum products	Some HAP and TRI compounds	API *MPMS* Ch. 19.4, Table 4
Crude oil, petroleum products	TRI compounds	EPA 745-B-00-002 [44], Table 3-4
Crude oil, petroleum products	Some PACs	API *MPMS* Ch. 19.4, Table 5
Crude oil, petroleum products	Total PACs	EPA 260-B-01-03 [45], Table 2-2
Refinery streams	18 HAPs and 6 other compounds	API 4723 [46]

The more volatile compounds in a liquid mixture comprise a greater share of the mixture's vapor phase than its liquid phase. API *MPMS* Ch. 19.4 states that the most practical and commonly used method to determine the concentration of given compounds in the vapor phase of a mixture is to apply Raoult's Law to the concentration of these compounds in the liquid phase of the mixture. The liquid concentration of all the compounds that comprise the mixture is not needed to use this method—only the liquid concentration, molecular weight, and vapor pressure of the compounds and the vapor pressure and molecular weight of the mixture and its vapor are needed.

EPA and state regulations occasionally require changes in the properties of fuels. The reformulated gasoline (RFG) program that EPA introduced in phases from 1995 to 2000 required, among other things, that RFG (used for about 30 % of the gasoline in the United States) contain no more than 1.0 % benzene by volume. This program also required that conventional gasoline (CG) sold in the rest of the country shall not have higher levels of pollutants than 1990 gasoline.

The program further requires that gasoline refiners and importers report gasoline properties to EPA. The compilation of these reports given in *Fuel Trends Report: Gasoline 1995 – 2005* [47] provides information on the properties of reformulated and conventional gasoline, including RVP and benzene volume percent. For 2005, the average benzene content was 0.67 % by volume in RFG and 1.16 in CG.

The Energy Policy Act of 2005 repealed EPA's minimum requirement for RFG of 2.0 % oxygen by weight, which refiners often met by using 11 % MTBE by volume. Consequently, by late 2006, most U.S. gasoline refiners ceased using MTBE as an oxygenate. The liquid compositions of some fuels given in the references cited in this edition of API 1673 do not yet reflect the effects of the latest regulations.

Annex A

TANKS 4.09D Limitations

A.1 Fixed-roof Tank Working Loss

When temperatures are well above 63 °F, TANKS tends to overestimate emissions from unheated fixed-roof tanks (and conversely, underestimates emissions when temperatures are well below 63 °F). This is because TANKS uses an algorithm for estimating working losses that incorporates a temperature of 63 °F, rather than treating the temperature as a variable.

API, in cooperation with EPA, has developed a more general form of the working loss equation that treats temperature as a variable. API included this general form of the equation in the Third Edition of API *MPMS* Ch. 19.1, and EPA revised AP-42, Section 7.1, in 2006 to include it. This improvement to the method for estimating working loss, however, has not been incorporated into EPA's TANKS program.

A.2 Liquid Bulk Temperature

TANKS does not accommodate tanks that receive warmer-than-ambient stock, but which are not heated. Such tanks should have the elevated stock temperature entered for the liquid bulk temperature, and then the AP-42 equations applied in order to determine the vapor space and liquid surface temperature ranges. In order to enter an other-than-ambient temperature in TANKS, however, the tank must be designated as heated, which introduces additional problems in TANKS as noted below (and the heated-tank routine in TANKS is not even available for floating-roof tanks).

A.3 Heated Fixed-Roof Tanks

TANKS contains several default routines that hinder it from properly applying the equations of AP-42 to heated fixed-roof tanks. These include the following.

— TANKS requires the breather vent settings of heated tanks to be set at zero (i.e. as if the tank were freely vented). This obviously introduces error for those tanks which have vent settings at other than zero.

— TANKS caps the calculated stock true vapor pressure at the value corresponding to 100 °F when it uses vapor pressure Option 1, regardless of how high the temperature is that the user enters. For example, if the user selects "Residual oil no. 6" as the stock, and enters a temperature of 300 °F, TANKS will calculate the same true vapor pressure as at 100 °F. This is obviously not correct.

— TANKS does not compute the vapor space and liquid surface temperature ranges for heated tanks—the user must enter these values. In order to properly determine these values, however, the user should perform calculations as indicated in AP-42. These calculations are quite tedious, and the user is often not familiar with them. The user then enters "best-guess" values, and gets "best-guess" results.

— TANKS automatically sets the vapor space temperature range for a heated tank equal to the liquid surface temperature range. This may be a reasonable assumption for tanks that are not only heated, but which also are insulated and have high vent settings (so that there is limited communication of the vapor space with ambient air, which TANKS does not even allow to be modeled, in that it requires the vent settings to be set at zero). This temperature range assumption, however, introduces significant error for tanks that are designated as heated, but which are not both insulated and equipped with high vent settings (in that the methodology of AP-42 results in a calculated vapor space temperature range that is twice that of the liquid surface temperature range, see AP-42, Figure 7.1-17).

A.4 Fixed-roof Tank Working Capacity

TANKS calculates the tank capacity, and thereby the number of turnovers, on the basis of the shell height at the maximum liquid level. Most tanks, however, have a heel of liquid remaining in the bottom of the tank when emptied. The resulting overstatement of the tank capacity, and associated understatement of the number of turnovers, causes TANKS to overstate the turnover factor for fixed-roof tanks with a high turnover rate.

A.5 Monthly Emission Estimates

TANKS applies monthly ambient temperature data when calculating monthly emissions, but the annual average value for the liquid bulk temperature. It would be more appropriate to calculate the liquid bulk temperature on a monthly basis as well.

NOTE Because of this error, EPA does not allow the use of TANKS for calculating the maximum true vapor pressure to be used for rule applicability determinations, per ADI 0500035.

A.6 Guidepole

TANKS allows defaulting the guidepole configuration (with the default assumption being an uncontrolled, unslotted guidepole). The potential emissions from a guidepole in an EFRT, however, are such that any default for this fitting may result in a large error in the overall estimate of emissions.

A.7 Recalculate Deck Fittings

When a change has been made to the tank diameter, TANKS only recalculates deck fitting quantities if the deck fittings are shown as “typical.” Furthermore, if a change is made to the type of deck, TANKS only adjusts the deck fitting selections if “typical” is shown. If a change has been made to any deck fitting (such as changing the control status from ungasketed to gasketed), then none of the deck fitting quantities will recalculate with a change in tank diameter, and none of the deck fitting selections will adjust with a change in the deck type.

A.8 IFRT Deck Support Legs

TANKS allows changing the IFRT deck support legs from “roof leg or hanger well” to “roof leg (3-in. diameter)” without explaining that the latter is only appropriate for EFRT-type deck legs [the 3-in. diameter is not the critical parameter, it is the 30-in. long or longer leg housing of an EFRT-type deck (vs the 12-in. long housing typical of an IFRT-type deck leg) that matters].

A.9 EFRT Deck Support Legs

TANKS does not explain that deck legs for double-deck EFRTs are similar to the center-area legs of pontoon EFRTs (i.e. an assumed 48-in. housing length), and thus the factors for “center area, sock” may be used when a double-deck EFRT is equipped with leg socks (API *MPMS* Ch. 19.2, Table 6).

A.10 Current Emission Factors

The following changes were made to emission factors in the September 2003 Edition of API *MPMS* Ch. 19.2, and EPA revised AP-42, Section 7.1, in 2006 to include them, but these changes have not been incorporated into TANKS:

Deck Fitting	Old Factor	New Factor
Uncontrolled ladder well	76	98
Uncontrolled column well	47	51

NOTE The higher factor for the uncontrolled ladder well can be approximated in TANKS by including both a gasketed ladder well (emission factor = 56) and an uncontrolled slotted guidepole (emission factor = 43), rather than selecting an uncontrolled ladder well. This would also be appropriate for a ladder well that has a gasketed cover, but also has a slotted pipe for one leg of the ladder with no control of the slotted pipe.

A.11 Default Speciation Profiles

Version 4.09D of TANKS intended to change the name of the chemical previously listed as 2,2,4 trimethylpentane to iso-octane. An error in how this change was programmed, however, corrupted the default speciation profiles for mixtures that include iso-octane. EPA has issued a page of instructions for correcting this, which is available at the link for "errors and fixes in 4.09D" at the EPA TANKS 4.09D website.

A.12 Solar Absorptance Factors

TANKS has not been updated to include the solar absorptance factors added in the Third Edition of API *MPMS* Ch. 19.1, which include additional paint colors as well as a value for mill-finish aluminum (for use with aluminum geodesic domes). In the absence of these factors, the user has to pick from a menu of factors which may not apply to the tank in question.

A.13 Bolted Decks with Dimensions Other Than Those Listed

TANKS does not automatically calculate the length of bolted deck seams unless the sheet width or panel dimensions match one of the options listed. For sheets or panels with differing dimensions, the user must calculate the total length of deck seam, then select an option that does not match the actual dimensions and override the length of deck seams calculated by TANKS.

A.14 Fixed-roof Tank Volume

TANKS has an entry box for the working volume, even though the user has already entered the liquid height and diameter (for which an issue was noted above with respect to accounting for the liquid heel). Working volume is automatically calculated by TANKS, if the user enters data in the order anticipated by TANKS. If the user makes a change to a previously entered data entry, however, TANKS does not always recalculate the volume. If TANKS then does not like the value entered for volume, it gives an error message that the "volume, maximum shell height, and diameter" do not agree within 10 %. This is confusing, because the error message is actually based on the maximum liquid height, not the shell height—so adjusting the volume to match the shell height will not make the error message go away.

A.15 Saving Changes

TANKS prompts the user for whether changes are to be saved when closing a tank record. This allows the user to run "what-if" scenarios without overwriting the existing tank record, as long as the user does not save the changes—or so the user may think. In actuality, if the user runs a report of the what-if scenario, then TANKS automatically saves the changes to that tank record. The user may then click "No" to the "Save changes?" prompt and think that the original tank record has been preserved, when in fact it has been overwritten.

A.16 Monthly Emissions

TANKS does not account for the actual number of days in each month, but rather simply divides the annual period by 12. This causes emissions for February to be overestimated by about 10 %, with smaller errors in the other months.

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