

Calculation Workbook For Oil and Gas Production Equipment Fugitive Emissions

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One of the most significant long-term trends affecting the future vitality of the petroleum industry is the public's concerns about the environment. Recognizing this trend, API member companies have developed a positive, forward-looking strategy called STEP: Strategies for Today's Environmental Partnership. This program aims to address public concerns by improving our industry's environmental, health and safety performance; documenting performance improvements; and communicating them to the public. The foundation of STEP is the API Environmental Mission and Guiding Environmental Principles.

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The members of the American Petroleum Institute are dedicated to continuous efforts to improve the compatibility of our operations with the environment while economically developing energy resources and supplying high quality products and services to consumers. The members recognize the importance of efficiently meeting society's needs and our responsibility to work with the public, the government, and others to develop and to use natural resources in an environmentally sound manner while protecting the health and safety of our employees and the public. To meet these responsibilities, API members pledge to manage our businesses according to these principles:

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- ❖ To counsel customers, transporters and others in the safe use, transportation and disposal of our raw materials, products and waste materials.
- ❖ To economically develop and produce natural resources and to conserve those resources by using energy efficiently.
- ❖ To extend knowledge by conducting or supporting research on the safety, health and environmental effects of our raw materials, products, processes and waste materials.
- ❖ To commit to reduce overall emission and waste generation.
- ❖ To work with others to resolve problems created by handling and disposal of hazardous substances from our operations.
- ❖ To participate with government and others in creating responsible laws, regulations and standards to safeguard the community, workplace and environment.
- ❖ To promote these principles and practices by sharing experiences and offering assistance to others who produce, handle, use, transport or dispose of similar raw materials, petroleum products and wastes.

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PREFACE

The purpose of this workbook is to provide a variety of methods for calculating fugitive hydrocarbon emissions from petroleum production equipment components. All of the methods use US EPA approved procedures to arrive at emission estimates. The methods vary in the amount of site-specific data required.

The American Petroleum Institute (API) co-sponsored three field monitoring programs to collect information from petroleum production operations, refining operations, and marketing terminal operations. The information included instrument screening data from petroleum production and marketing terminal operations, and leak quantification data from all three types of operations.

EPA used the API screening data and leak quantification data from petroleum production operations to develop "Screening Value Range Emission Factors" (see Chapter 4). EPA used leak quantification data from the three types of operations to develop "Default Zero Factors, Emission Correlation Equations, and Pegged Source Factors" (see Chapter 5). EPA used screening data from petroleum production operations and default zero factors, emission correlation equations, and pegged source factors to develop "Average Emission Factors" for petroleum production operations (see Chapter 3).

This workbook explains each of the three EPA emission estimation methods plus a fourth method that uses field quantification techniques to determine emissions from leaks. These methods use data currently available on the EPA Computer Bulletin Board. As with any EPA accepted methodologies and factors, future revisions are possible. If there are any questions about the acceptability of the methods contained in this workbook, contact the EPA or the local regulatory agency.

Chapter 1

AN INTRODUCTION TO FUGITIVE HYDROCARBON EMISSIONS

WHAT ARE FUGITIVE HYDROCARBON EMISSIONS?

Each petroleum production facility contains a number of equipment components such as valves, flanges, threaded connections, tubing connections, open-ended lines (also called open-ended valves), pump seals, and other items. Although these components are manufactured and installed in ways intended to prevent releases of hydrocarbon gases or liquids to the atmosphere, over time some of them will begin to leak.

Unintentional hydrocarbon emissions through seals, packings, joints, etc., are called "fugitive hydrocarbon emissions."

Typical examples of fugitive hydrocarbon emissions are: emissions out the end of a leaking sample valve, emissions from a cracked or improperly tightened gasket, and emissions from a loose tubing fitting.

WHAT ARE EMISSION FACTORS?

During the past 20 years, several organizations (such as the American Petroleum Institute and the US Environmental Protection Agency) have completed projects that determined the amount of fugitive hydrocarbons escaping from petroleum production facilities within the United States of America (USA). The facilities included onshore oil production sites, onshore gas production sites, onshore gas processing plants, and offshore platforms.

EPA used the information from these studies to determine the average amount of fugitive emissions from equipment components such as valves, flanges, etc. EPA published these averages as "Average Emission Factors for Petroleum Production Operations," (see Table 1 in Chapter 3). The factors are multiplied by the number of components at a site to calculate fugitive hydrocarbon emissions. For example, the EPA Average Emission Factor for valves in gas service is 0.24 pounds/component-day

(which can also be written as 2.4×10^{-1} lb/comp-day or 2.4E-01 lb/comp-day).

Therefore, if a site has three valves, the total fugitive hydrocarbon emissions from the valves would be calculated as:

$$3 \text{ valves} \times 0.24 \text{ lb/comp-day} = 0.72 \text{ lb/day.}$$

EPA developed average emission factors for the following six types of equipment components and four types of streams (described in Chapter 9):

Equipment Component Types

- Connectors (other than flanges)
- Flanges
- Open-ended lines (also called open-ended valves)
- Pump seals
- Valves
- Others (includes: compressors, diaphragms, drains, dump arms, hatches, instruments, meters, pressure relief valves, polished rods, and vents)

Stream

- Gas
- Heavy Oil
- Light Oil
- Water/Oil

WHAT ARE CORRELATION EQUATIONS?

Total hydrocarbon fugitive emissions can be measured with a portable hydrocarbon monitoring instrument. These instruments are like little vacuum cleaners that sweep the leaking hydrocarbons into a stream of air entering the instrument. The hydrocarbon/air stream is sent past a detector to determine the concentration of hydrocarbon in the stream which is then indicated on some type of readout device (dial face, digital readout, etc.) The instrument reading is often given in parts-per-million by volume (ppmv). This type of monitoring is often called "screening" and the reading obtained with the instrument is often called a "screening value" or SV.

There is a relationship between the amount of hydrocarbon leaking out of a component and the instrument screening value. This relationship can be written in the form of an equation which is referred to as a "correlation equation" (see Table 4 in Chapter 5).

The EPA correlation equation for valves (in any type of stream) is:

$$\text{Emissions (lb/day)} = 0.000121 \times (\text{SV}_{\text{ppmv}})^{0.746}$$

If a valve is found to have an instrument screening value of 500 ppmv, the total hydrocarbon emission rate is calculated to be:

$$\text{Emissions (lb/day)} = 0.000121 \times (500)^{0.746} = 0.012 \text{ lb/day.}$$

Correlation equations cannot be used for estimating fugitive hydrocarbon emissions that give instrument screening values that are the same as the readings for background air or for components whose emissions exceed the upper limit of the instrument. EPA has published "default zero" factors for components that have the same instrument screening values as background air. The default zero factor for valves is 0.00041 lb/comp-day (see Table 4 in Chapter 5). EPA has published "pegged source" factors for components whose emissions exceed the range of the monitoring instrument; these components are said to "peg" the instrument. There are two sets of pegged source factors: one for instruments with an upper limit of 10,000 ppmv and one for instruments with an upper limit of 100,000 ppmv. The two pegged source factors for valves are 3.4 and 7.4 lb/day, respectively (see Table 4 in Chapter 5).

HOW ARE FUGITIVE HYDROCARBON EMISSIONS QUANTIFIED?

Fugitive hydrocarbon emissions are quantified by pulling the leak into a known quantity of air or other carrier gas and measuring the hydrocarbon concentration in the resulting mixture. EPA recognizes three techniques for quantifying leaks: the Blow-Through Technique, the Vacuum Technique, and the High Flow System (see Chapter 8).

HOW DO I CALCULATE FUGITIVE HYDROCARBON EMISSIONS FROM MY SITE?

This Workbook contains four methods that can be used to calculate fugitive hydrocarbon emissions from equipment components at petroleum production facilities: the EPA Average Emission Factor Method (Chapter 3); the EPA Screening Value Range Emission Factor Method (Chapter 4); the EPA Default Zero Factor, Correlation Equation, and Pegged Source Factor Method (Chapter 5); and the Leak Quantification Method (Chapter 6).

The EPA Average Emission Factor Method is the simplest to use. All that is required is a count or estimate of the number of equipment components installed at the facility grouped by component type and stream (see Chapter 9 for definitions of component types and streams). The number of components in each component type/stream group is multiplied by the EPA Average Emission Factor for that group to calculate the emissions. This method requires the least amount of site-specific information, but it also gives the least site-specific emission estimates.

The EPA Screening Value Range Emission Factor Method requires that every component at the site be monitored ("screened") with a portable hydrocarbon monitoring instrument (see Chapter 7 for component screening procedures). The number of components with instrument screening values of less than 10,000 ppmv and the number of components with instrument screening of 10,000 ppmv or more is recorded. The components are grouped according to type and stream composition. Each group of components with screening values of less than 10,000 ppmv is multiplied by its appropriate EPA Screening Value Range Emission Factor to calculate emissions. Each group of components with screening values of 10,000 ppmv or more is multiplied by its appropriate EPA Screening Value Range Emission Factor. This method gives emission estimates that are more site-specific than the EPA Average Emission Factor Method.

The EPA Default Zero Factor, Correlation Equation, and Pegged Source Factor Method also requires that every component at the site be monitored with a portable hydrocarbon monitoring instrument. The difference between this method and the EPA Screening Value Range Emission Factor Method discussed in the preceding paragraph is that each individual instrument screening value is recorded, rather than just a count of the number of components with screening values above 10,000 ppmv and the number of components with screening values below 10,000 ppmv. The individual instrument screening values with EPA Default Zero Factors, Correlation Equations, and Pegged Source Factors are used to calculate the emissions. The emission estimates this method gives are more site-specific than those obtained with the EPA Screening Value Range Emission Factor Method.

The Leak Quantification Method is similar to the EPA Screening Value Range Emission Factor Method and EPA Default Zero Factor, Correlation Equation, and Pegged Source Factor Method. The difference is that instead of using the $\geq 10,000$ ppmv Factor or Pegged Source Factors to predict emissions from components with screening values of 10,000 ppmv or more, the fugitive hydrocarbon emissions from 20 or more of these components are actually quantified using one of the leak quantification techniques described in Chapter 8. This is the most labor intensive of the four methods, but the emission estimates it gives are the most site-specific.

The Workbook presents each of these methods in a separate chapter with one or more example calculations. The examples are all based on one very large database collected for API, therefore the calculated emissions for an example site are essentially the same for most of the methods from the simplest to the most sophisticated. This will not usually be the case when the different methods are used to predict emissions from a specific facility.

Chapter 2

METHODS OF CALCULATING FUGITIVE HYDROCARBON EMISSIONS

This workbook contains four methods for calculating fugitive hydrocarbon emissions: the EPA Average Emission Factor Method (see Chapter 3), the EPA Screening Value Range Emission Factor Method (see Chapter 4), the EPA Default Zero Factor, Correlation Equation, and Pegged Source Factor Method (see Chapter 5), and the Leak Quantification Method (see Chapter 6). Each method has its advantages and disadvantages.

METHOD 1. THE EPA AVERAGE EMISSION FACTOR METHOD

This method is the easiest and cheapest to use. A count or estimate is made of the number of equipment components by type (flanges, connectors, valves, open-ended lines, pumps seals, and "others"); then they are divided into groups by stream type (gas, heavy oil, light oil, water/oil) and each group is multiplied by the appropriate EPA Average Emission Factor (see Chapter 3 for example calculations). One disadvantage of this method is that it assumes that every facility has the same leak frequency (number of leaks per 100 installed components) and average leak size (amount of fugitive hydrocarbon per leak) as the facilities studied by API during the past 5 years. If a facility has a different leak frequency or average leak size than the API sites, this method may not give the correct prediction of fugitive hydrocarbon emissions.

Another disadvantage of the method is that it always gives the same prediction of fugitive hydrocarbon emissions for a constant number of components. Emissions calculated with this method will not be affected if leaking components are replaced with non-leaking components or if maintenance activities are increased. The only way this method will show a reduction in emissions is if some components are eliminated.

METHOD 2. THE EPA SCREENING VALUE RANGE EMISSION FACTOR METHOD

This method is more expensive and time consuming than the EPA Average Emission Factor method. Each component at the site must be monitored before a calculation can be made. It requires the purchase of one or more portable hydrocarbon monitoring instruments and the calibration gases needed for the instruments.

One advantage of this method is that it is site-specific. Another advantage of this method is that it will reflect any changes made to equipment or operational procedures that either reduce or increase the number of components with instrument screening values of 10,000 ppmv or more.

One disadvantage is there is no guarantee that the average leak rate of screening value range emission factors at every facility is the same as the average screening value range emission factors calculated by EPA from the API data.

This method is used by counting the number of components with instrument screening values less than 10,000 ppmv and the number that have instrument screening values of 10,000 ppmv or more. The number of components with instrument screening values of less than 10,000 ppmv is multiplied by an EPA <10,000 ppmv Factor which is fairly small. The number of components that have instrument screening values of 10,000 ppmv or more is multiplied by an EPA $\geq 10,000$ ppmv Factor. If all the components have instrument screening values of less than 10,000 ppmv, the calculated emissions for that site will be low. If there are only a few components with instrument screening values of 10,000 ppmv or more, the calculated emissions will be slightly higher. If many components with instrument screening values of 10,000 ppmv or more are found, the calculated emissions will be high.

METHOD 3. THE EPA DEFAULT ZERO FACTOR, CORRELATION EQUATION, AND PEGGED SOURCE FACTOR METHOD

This method is very similar to the Screening Value Range Emission Method because all components must be screened with portable monitoring instruments. The difference is that instead of merely counting the components with instrument screening values less than 10,000 ppmv and multiplying the number by a Screening Value Range Emission Factor, each individual screening value is recorded, up to at least 10,000 ppmv, and emissions are calculated for each component.

Components with instrument screening values that are the same as the background reading of ambient air are called "Default Zeros" and their emission rates are calculated with EPA Default Zero Factors. Emissions from components with instrument screening values higher than background but below the upper limit of the monitoring instrument are calculated using EPA Correlation Equations. Components with fugitive emission rates that exceed the upper limit of the monitoring instrument are called "Pegged Sources" and their emission rates are calculated with EPA Pegged Source Factors.

This method reflects changes in leak frequency and, to some extent, changes in leak size resulting from equipment changes and changes in operational procedures.

The EPA Correlation Equations used in this method are only valid for small and medium-sized leaks. Larger leaks, which often account for 80 to 95% of the total emissions from a site, are estimated using Pegged Source Factors. These factors were developed from data collected at various sites within the USA by API during the past 5 years. However, there is no guarantee that the average leak rate of pegged sources at a specific facility is the same as the average leak rate of pegged sources found in the API studies. If the average leak rate of pegged sources is significantly different from the EPA Pegged Source Factors, the emissions calculated using this method may vary from the site's actual emissions.