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American Petroleum Institute

STEP Strategies for Today's Environmental Partnership

Calculation Workbook For Oil and Gas Production Equipment Fugitive Emissions

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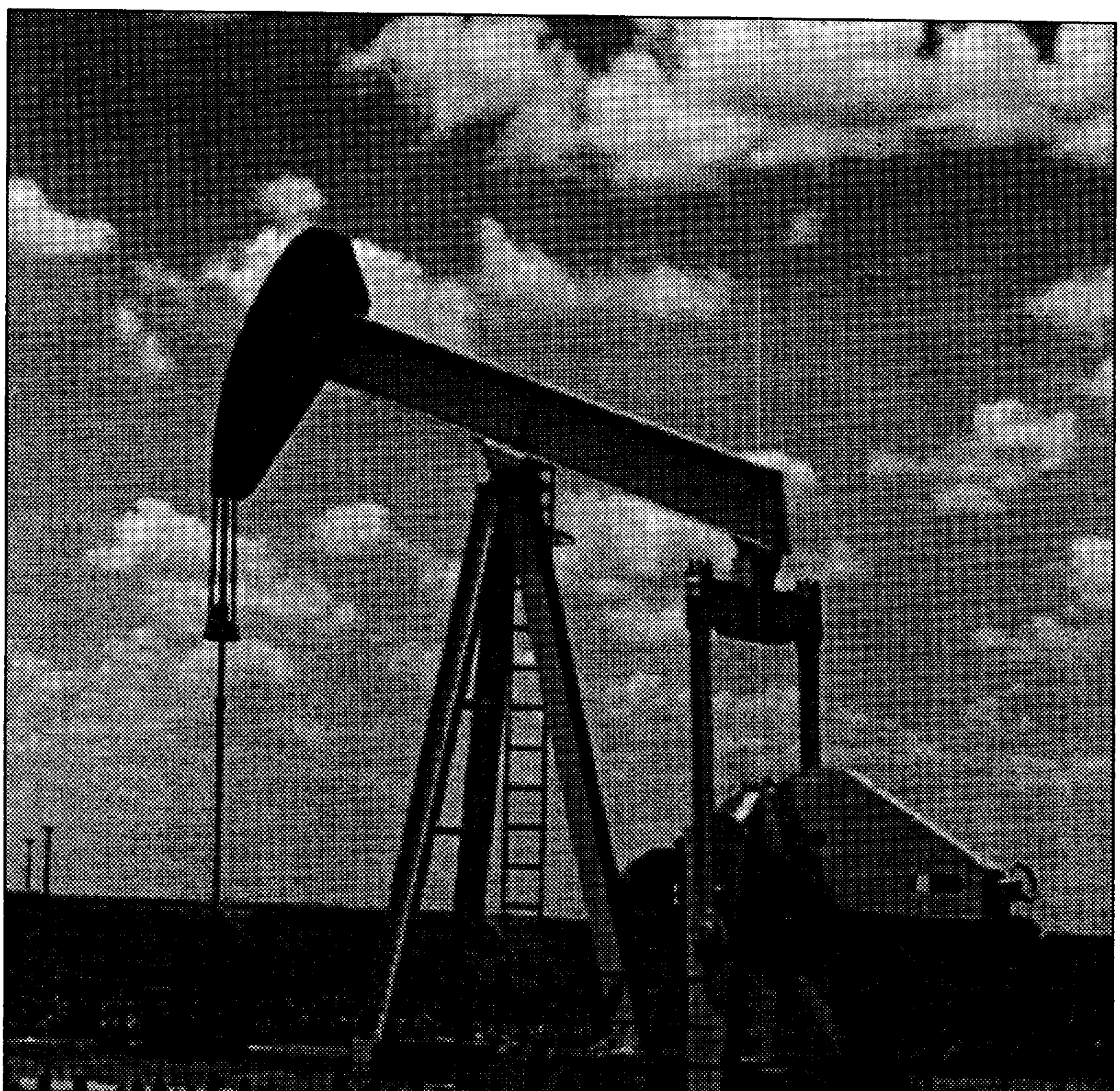

STEP
Strategies for Today's Environmental Partnership

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.

API ENVIRONMENTAL MISSION AND GUIDING ENVIRONMENTAL PRINCIPLES

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:

- To recognize and to respond to community concerns about our raw materials, products and operations.
- To operate our plants and facilities, and to handle our raw materials and products in a manner that protects the environment, and the safety and health of our employees and the public.
- To make safety, health and environmental considerations a priority in our planning, and our development of new products and processes.
- To advise promptly, appropriate officials, employees, customers and the public of information on significant industry-related safety, health and environmental hazards, and to recommend protective measures.
- 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.

Calculation Workbook for Oil and Gas Production Equipment Fugitive Emissions

Health and Environmental Sciences Department

API PUBLICATION NUMBER 4638

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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 $2.4x10^{-1}$ 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 valves x 0.24 lb/comp-day = 0.72 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 read-out, 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:

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

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 ≥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.

METHOD 4. THE LEAK QUANTIFICATION METHOD

This is the most expensive and most labor intensive of the four methods but it gives the most site-specific results. All components at the site have to be screened with portable hydrocarbon monitoring instruments (just like with the EPA Screening Value Range Emission Method or EPA Default Zero Factor, Correlation Equation, and Pegged Source Factor Method). Instrument screening values in ppmv are recorded for all equipment components screened. Emissions are then calculated for all components with instrument screening values less than 10,000 ppmv using either the EPA Screening Value Range Emission Factors or the EPA Default Zero Factors and Correlation Equations. However, emissions from components with screening values of 10,000 ppmv or more are not calculated using EPA Screening Value Range Emission Factors or EPA Pegged Source Factors. Instead, 20 or more of the leaking components are actually quantified on-site to determine an average emission rate for all of the components with instrument screening values of 10,000 ppmv or more.

Chapter 8 contains descriptions of three leak quantification techniques that can be used: the Vacuum Technique; the Blow-Through Technique; and the High Flow System. Each of these techniques requires some additional equipment (small pumps, flow meters, bagging material). One technique, the High Flow System, also requires the purchase or construction of a dilution system using a medium sized air handler (pump or enclosed fan). Quantifying leaks also takes time, although the High Flow System takes much less time than the other two techniques. The High Flow System also has the advantage of giving real-time quantification of the leaks without the use of laboratory equipment. The other two techniques require laboratory analysis of collected fugitive hydrocarbon samples before the quantifications can be calculated. The Environmental Protection Agency completed a successful laboratory and field test of a High Flow System (HFS) in 1994 (see Chapter 8). A final report (EPA-600-R-95-167) was published in November 1995, entitled *EPA Evaluation of the High Volume Collection System ((HVCS) for Quantifying Fugitive Organic Vapor Leaks* .

COMPARISON OF RESULTS

Although the four calculation methods vary in expense and time requirements, in some cases, the simplest method (EPA Average Leak Factor Method) may give exactly the same answer as the most sophisticated method (Leak Quantification Method). This would occur if the site has an average leak frequency and average leak rates similar to those found in API's studies. In other cases, the simplest method may give higher or lower results than the most sophisticated method. But in all cases, the results obtained using the Leak Quantification Method are the most reliable.

The EPA Average Emission Factor Method is the least site-specific of the four methods. It assumes that the average leak rate of <u>all installed components</u> within the USA is the same. The EPA Screening Value Range Emission Method is more site-specific, but it still assumes that the average leak rates of <u>all components with instrument screening values less than 10,000 ppmv and all components with screening values of 10,000 ppmv or more</u> within the USA are the same, respectively. The EPA Default Zero Factors, Correlation Equations, and Pegged Source Factor Method is site-specific for non-pegged sources (<10,000 ppmv or <100,000 ppmv depending on the range of the screening instrument used), but it still assumes that the average leak rate of <u>all Pegged Sources</u> within the USA is the same. The Leak Quantification Method is the most site-specific method since most emissions are calculated from actual on-site leak measurements.

The cost and labor involved in using the EPA Average Emission Factor Method are lower than the other three methods; the cost and labor of either the EPA Screening Value Range Emission Method or EPA Default Zero Factor, Correlation Equation, and Pegged Source Factor Method are substantially more, and the cost and labor involved in using the Leak Quantification Method are highest of all.

In general, a facility with an above average leak prevention program will have the highest calculated emission rate when using the EPA Average Emission Factor Method, lower calculated emission rates when using the EPA Screening Value Range Emission

Method or EPA Default Zero Factor, Correlation Equation, and Pegged Source Factor Method, and the lowest calculated emission rate when using the Leak Quantification Method.

Chapter 3

METHOD 1 -- USING EPA AVERAGE EMISSION FACTORS TO CALCULATE FUGITIVE HYDROCARBON EMISSIONS

The easiest way to calculate total hydrocarbon fugitive emissions is to multiply the number of components at a site by the EPA Average Emissions Factors. Table 1 shows the EPA Average Emissions Factors. They are the average emissions rates of total hydrocarbon to be assumed for all components in hydrocarbon service installed at a site. The factors are current as of June 15, 1996 and are given in pounds per component-day (lb/comp-day).

Table 1. EPA Average Emission Factors for Total Hydrocarbon (THC) Emissions from Oil and Gas Production Operations (lb/component-day)

	Gas	Heavy Oil (<20 API Gravity)	Light Oil (≥20 API Gravity)	Water/Oil**
Connector	1.1E-02	4.0E-04	1.1E-02	5.8E-03
Flange	2.1E-02	2.1E-05	5.8E-03	1.5E-04
Open-End	1.1E-01	7.4E-03	7.4E-02	1.3E-02
Other*	4.7E-01	1.7E-03	4.0E-01	7.4E-01
Pump	1.3E-01	Not Available	6.9E-01	1.3E-03
Valve	2.4E-01	4.4E-04	1.3E-01	5.2E-03

* The "other" category includes: compressors, diaphragms, drains, dump arms, hatches, instruments, meters, pressure relief valves, polished rods, and vents

** Water/Oil emission factors apply to water streams in oil service with a water content greater than 50%, from the point of origin to the point where the water content reaches 99%. For water streams with a water content greater than 99%, the emission rate is considered negligible.

SOURCE: US EPA Bulletin Board (Leaks_OG.WP5; 8/9/1995).

The only information needed for this method is a count or estimate of the number of flanges, connectors (other than flanges), open-ended lines, pumps, valves, and "other" components at the site grouped by stream (gas, light oil, heavy oil, water/oil). The number of components can be determined by either counting them in the field or, in the case of remote sites or facilities not yet built, by estimating them.

The most accurate way of using EPA Average Emission Factors is to actually go into a facility and count all of the equipment components. Example 1 shows the calculation of fugitive emissions using actual in-field component counts.

In some instances an in-field component count cannot be performed, either because it is a remote site, the time and resources for an in-field count are not available or perhaps the facility does not exist yet. In these and similar cases, a good approximation of the number of components can be obtained by counting or estimating the number of valves and pumps at the facility and then calculating the probable number of flanges, connectors, open-ended lines, and other components from the number of valves. During a recent field study of petroleum production operations, API found that the number of flanges at a petroleum production site is usually about the same as the number of valves, while the number of connectors (threaded pipes and tubing fittings) is about three times the number of valves (Star Environmental, Inc., 1993, and Star Environmental, 1995.) API also found that about 10% of all valves have one side that can be opened to the atmosphere (open-ended lines) and that the number of "other" components at a site is approximately 5% of the number of valves. No correlation was found between the number of valves and the number of pumps. Example 2 shows the calculation of fugitive emissions using estimated component counts.

Hydrocarbon emissions calculated using EPA Average Emission Factors are total hydrocarbon emissions; they include methane and all heavier hydrocarbons. Sometimes it is important to know what fraction of the total emissions are of a specific type, for example non-methane, or propane and heavier, or air toxics. Table 2 shows speciation fractions for total hydrocarbon emissions based on stream type. The values in Table 2 were calculated using methodology similar to that described in Appendix A (Chapter 3) of API Publication Number 4589 (Star Environmental, Inc., 1993.)

Example 3 shows how to speciate total fugitive hydrocarbon emissions calculated using EPA Average Emission Factors.

Table 2. Speciation Fractions for Total Hydrocarbon (THC) Emissions Calculated Using EPA Average Emission Factors

	Gas	Heavy Oil	Light Oil	Water/Oil
Methane	0.687	0.942	0.612	0.612
Non-methane	0.313	0.058	0.388	0.388
VOC	0.171	0.030	0.296	0.296
C6+ *	0.00693	0.00752	0.02300	0.02300
Benzene	0.00069	0.00935	0.00121	0.00121
Toluene	0.00038	0.00344	0.00105	0.00105
Ethyl-Benzene	0.00003	0.00051	0.00016	0.00016
Xylenes	0.00009	0.00372	0.00033	0.00033

* The C6+ fraction can be used to calculate an upper limit for n-hexane

EXAMPLE 1 -- <u>Using EPA Average Emission Factors and Actual Component Counts to Calculate Total Hydrocarbon Emissions</u>

Example 1 shows the calculation of total hydrocarbon emissions from a typical light crude oil production operation. Column A of the table shows the actual count of components grouped by component type and stream; Column B of the table shows EPA Average Emission Factors repeated from Table 1; Column C shows calculated total hydrocarbon emissions found by multiplying the respective sub-columns in Columns A and B. The calculated total hydrocarbon emissions are 34.6 lb/day from gas service components, 360 lb/day from light oil service components, and 1.3 lb/day from water/oil service components for a total of 396 lb/day.

EXAMPLE 1. Table of Calculated Values

	(A) Count				**(B) THC Emission Factors (lb/comp-day)**			**(C) Calculated THC Emissions (lb/day)**			
	Gas	Lt Oil	Water/Oil	Total	Gas	Lt Oil	Water/Oil	Gas	Lt Oil	Water/Oil	Total
Connectors	291	5,332	69	5,692	1.1E-02	1.1E-02	5.8E-03	3.20	58.7	0.40	62.3
Flanges	107	1,756	28	1,891	2.1E-02	5.8E-03	1.5E-04	2.25	10.2	0.00	12.4
Open-Ends	10	176	3	189	1.1E-01	7.4E-02	1.3E-02	1.10	13.0	0.04	14.2
Others	6	98	1	105	4.7E-01	4.0E-01	7.4E-01	2.82	39.2	0.74	42.8
Pump Seals	0	5	0	5	1.3E-01	6.9E-01	1.3E-03	0.00	3.5	0.00	3.5
Valves	105	1,811	24	1,940	2.4E-01	1.3E-01	5.2E-03	25.20	235.4	0.12	260.8
ALL	519	9,178	125	9,822				34.6	360.0	1.30	396.0

EXAMPLE 2 -- Using EPA Average Emission Factors and Estimated Component Counts to Calculate Total Hydrocarbon Emissions

Example 2 shows the calculation of total hydrocarbon emissions from a proposed heavy crude oil production operation that will co-produce natural gas. The following three assumptions were made for the proposed operation:

Assumption 1. The facility will have 400 valves.

Assumption 2. The facility will have only submerged pumps which have no emissions to atmosphere.

Assumption 3. Three-fourths of the valves (and associated components) will be in heavy crude service, the other one-fourth will be in gas service.

Step 1 -- Estimating the total number of components;

Number of Valves	=	400
Number of Pumps (with emissions to atmosphere)	=	0
Number of Flanges = (Number of Valves)	=	400
Number of Connectors = (3X Number of Valves)	=	1,200
Number of Open-ends = (0.10X Number of Valves)	=	40
Number of "Others" = (0.05X Number of Valves)	=	20

Step 2 -- Calculating the Emissions

Column A in the following table shows the estimated count of components grouped by component type and stream; Column B of the table shows EPA average emissions factors repeated from Table 1; Column C shows calculated total hydrocarbon emissions found by multiplying the respective sub-columns in Columns A and B. The calculated total hydrocarbon emissions are 32.9 lb/day from gas service components and 0.74 lb/day from heavy oil service components for a total of 33.6 lb/day.

EXAMPLE 2. Table of Calculated Values

	(A) Count			(B) THC Emission Factors (lb/comp-day)		(C) Calculated THC Emissions (lb/day)		
	Gas	Hvy Oil	Total	Gas	Hvy Oil	Gas	Hvy Oil	Total
Connectors	300	900	1,200	1.1E-02	4.0E-04	3.30	0.36	3.7
Flange	100	300	400	2.1E-02	2.1E-05	2.10	0.01	2.1
Open-Ended	10	30	40	1.1E-01	7.4E-03	1.10	0.22	1.3
Others	5	15	20	4.7E-01	1.7E-03	2.35	0.02	2.4
Pump Seals	0	0	0	1.3E-01	Not Available	0.00	0.00	0.0
Valves	100	300	400	2.4E-01	4.4E-04	24.00	0.13	24.1
ALL	515	1,550	2,065			32.9	0.74	33.6

EXAMPLE 3 -- Speciation of Total Hydrocarbon Emissions Predicted with EPA Average Emission Factors

Table 2 (page 15) is a speciation table for separating total hydrocarbon emissions calculated using EPA Average Emission Factors into individual groups of hydrocarbons. The table shows speciation fractions for eight groups of hydrocarbons: methane only, non-methane, VOC (propane and heavier), C6+ (which can also be used as the upper limit of the n-hexane fraction), benzene, toluene, ethyl-benzene, and xylenes. Speciation fractions are shown for four streams: Gas, Heavy Oil, Light Oil, and Water/Oil.

Example 3 shows how total hydrocarbon emissions from the proposed heavy crude production site used in Example 2 are speciated into the eight groups. Column A of the table shows the speciation fractions taken from Table 2; Column B of the table shows the total hydrocarbon emissions from each stream type in Example 2 (32.9 lb/day from gas service components and 0.74 lb/day from heavy oil service components, see Column C in Example 2); Column C in the table for Example 3 shows the speciated emissions obtained by multiplying the respective sub-columns in Columns A and B. The example shows that the VOC fraction of the emissions is calculated to be 5.6 lb/day and the benzene fraction of the emissions is calculated to be 0.030 lb/day.

EXAMPLE 3. Table of Calculated Values

	(A) Speciation Fraction		(B) THC Emissions (lb/day)		(C) Speciated Emissions (lb/day)		
	Gas	Heavy Oil	Gas	Heavy Oil	Gas	Heavy Oil	Total
Methane	0.687	0.942	32.9	0.74	22.6	0.697	23.3
Non-methane	0.313	0.058	32.9	0.74	10.3	0.0429	10.3
VOC	0.171	0.030	32.9	0.74	5.6	0.0222	5.6
C6+	0.00693	0.00752	32.9	0.74	0.228	0.005	0.233
Benzene	0.00069	0.00935	32.9	0.74	0.023	0.007	0.030
Toluene	0.00038	0.00344	32.9	0.74	0.013	0.002	0.015
Ethyl-Benzene	0.00003	0.00051	32.9	0.74	0.001	0.00038	0.001
Xylenes	0.00009	0.00372	32.9	0.74	0.003	0.003	0.006

Chapter 4

METHOD 2 -- USING EPA SCREENING VALUE RANGE EMISSION FACTORS TO CALCULATE FUGITIVE HYDROCARBON EMISSIONS

In order to use EPA Screening Value Range Emission Factors, all equipment components must first be monitored with portable hydrocarbon monitoring instruments that have been calibrated with methane-in-air standards. This activity is generally referred to as "screening the components." Chapter 7 contains detailed procedures for screening components.

As the components are screened, keep track of the number that have screening values of less than 10,000 ppmv, and of the number that have screening values of 10,000 ppmv or more. The components need to be grouped according to the following types: connectors other than flanges, flanges, open-ended lines, pump seals, valves, and "other" components. The "other" category includes such things as: compressors, diaphragms, drains, dump arms, hatches, instruments, meters, pressure relief valves, polished rods, and vents. Information on the streams inside the components (gas, heavy oil, light oil, water/oil) must also be collected.

For each type of component/stream, combine those with screening values of less than 10,000 ppmv into one set, and those with screening values of 10,000 ppmv or more into another set. The numbers of components in each set are multiplied by the factors in Table 3 to calculate total hydrocarbon emissions.

Example 4 shows the calculation of THC emissions using Screening Value Range Emissions Factors. THC emissions predicted with the EPA Screening Value Range Emission Factor Method can be speciated using speciation fractions given in Chapter 3 (Table 2; Example 2).

Table 3. Screening Value Range Emission Factors for Oil and Gas Production Operations (Total Hydrocarbons* in pounds per component-day)

Component Type	Stream	<10,000 ppmv Emission Factor	≥10,000 ppmv Emission Factor
Connectors	Gas	5.3E-04	1.4
	Heavy Oil	4.0E-04	NA
	Light Oil	5.1E-04	1.4
	Water/Oil***	5.3E-04	1.5
Flanges	Gas	3.0E-04	4.3
	Heavy Oil	2.1E-05	NA
	Light Oil	1.3E-04	3.9
	Water/Oil***	1.5E-04	NA
Open End	Gas	7.9E-04	2.9
	Heavy Oil	3.8E-04	1.6
	Light Oil	7.4E-04	2.3
	Water/Oil***	1.9E-04	1.6
Others**	Gas	6.3E-03	4.7
	Heavy Oil	1.7E-03	NA
	Light Oil	5.8E-03	4.4
	Water/Oil***	3.1E-03	3.7
Pump Seals	Gas	1.9E-02	3.9
	Heavy Oil	NA	NA
	Light Oil	2.7E-02	5.3
	Water/Oil***	1.3E-03	NA
Valves	Gas	1.3E-03	5.2
	Heavy Oil	4.4E-04	NA
	Light Oil	1.0E-03	4.6
	Water/Oil***	5.1E-04	3.4

* These factors are for total organic compound emission rates, including non-VOCs such as methane and ethane, and apply to light crude, heavy crude, gas plant, gas production, and offshore facilities. "NA" indicated that not enough data were available to develop the indicated emission factor.

** The "other" category includes: compressors, diaphragms, drains, dump arms, hatches, instruments, meters, pressure relief valves, polished rods, and vents.

*** Water/Oil emission factors apply to water streams in oil service with a water content greater than 50%, from the point of origin to the point where the water content reaches 99%. For water streams with a water content greater than 99%, the emission rate is considered negligible.

SOURCE: US EPA Protocol for Equipment Leak Emission Estimates (EPA-453/R-95-017), *November, 1995*

EXAMPLE 4 -- Using EPA Screening Value Range Emission Factors to Calculate Total Hydrocarbon Emissions

Step 1 -- Screen all of the Components

All components at an offshore gas production platform were screened with the following results:

Results of Screening at a Gas Production Platform

Component Type	Number Screened	Number of Component (SV <10,000 ppmv)	Number of Components (SV ≥ 10,000 ppmv)
Connector	3,588	3,571	17
Flange	1,225	1,223	2
Open-Ended	96	81	15
Other	55	49	6
Pump	27	27	0
Valve	1,197	1,121	76
TOTAL	6,188	6,072	116

Step 2 -- Calculate Fugitive Hydrocarbon Emissions Using EPA Screening Value Range Emission Factors from Table 3

Column two of the following tables shows the number of components found for each type of component. Column three in these tables shows the EPA emission factors. Column four shows the calculated total hydrocarbon (THC) emissions found by multiplying columns two and three.

Emissions from Components with SV <10,000 ppmv

Component Type	Number Found	Factor (lb/component day)	THC Emissions lb/day
Connector	3,571	5.3E-04	1.9
Flange	1,223	3.0E-04	0.4
Open-Ended	81	7.9E-04	0.1
Other	49	6.3E-03	0.3
Pump	27	1.9E-02	0.5
Valve	1,121	1.3E-03	1.5
SUB-TOTAL	6,072		4.6

Emissions from Components with SV ≥10,000 ppmv

Component Type	Number Found	Factor (lb/component-day)	THC Emissions (lb/day)
Connector	17	1.4	23.8
Flange	2	4.3	8.6
Open-Ended	15	2.9	43.5
Other	6	4.7	28.2
Pump	0	3.9	0
Valve	76	5.2	395.2
SUB-TOTAL	116		499

TOTAL (4.6 + 499) = 504

Chapter 5

METHOD 3 -- USING EPA DEFAULT ZERO FACTORS, CORRELATION EQUATIONS, AND PEGGED SOURCE FACTORS TO CALCULATE FUGITIVE HYDROCARBON EMISSIONS

Most components will have screening values (SV) the same as the background reading of the ambient air. EPA has found that some of these components do have emissions even though the instrument does not detect them. For this reason, EPA has developed "Default Zero Factors" that give the average emission rates of these components.

Some of the components will have fugitive emission rates that will cause the screening instrument to "peg" at its maximum. EPA has developed "Pegged Source Factors" that give the average emission rates of these components. Because some instruments have a maximum range of 10,000 ppmv and others have a maximum range of 100,000 ppmv, EPA has developed two sets of Pegged Source Factors: one for 10,000 ppmv and one for 100,000 ppmv.

EPA has also developed "Correlation Equations" which relate instrument screening values to mass emission rates for all those components which give instrument screening values higher than background but lower than the maximum range of the monitoring instrument. Table 4 shows the EPA Default Zero Factors, Correlation Equations, and Pegged Source Factors given in pounds of total hydrocarbon (THC) emissions per component-day. The factors and equations are divided by component types (connectors, flanges, open-ended lines, pump seals, valves, and others) but not by stream composition.

Table 4. EPA Default Zero Factors, Correlation Equations, and Pegged Source Factors (lb/component-day)

Component	Default Zero	Correlation Equation	Pegged at 10,000 ppmv	Pegged at 100,000 ppmv
Connector	0.00040	THC = 8.10E-05(SV)$^{0.735}$	1.5	1.6
Flange	0.00002	THC = 2.44E-04(SV)$^{0.703}$	4.5	4.4
Open-end	0.00011	THC = 1.16E-04(SV)$^{0.704}$	1.6	4.2
Other*	0.00021	THC = 7.20E-04(SV)$^{0.589}$	3.9	5.8
Pump Seal	0.00127	THC = 2.66E-03(SV)$^{0.610}$	3.9	8.5
Valve	0.00041	THC = 1.21E-04(SV)$^{0.746}$	3.4	7.4

*The "other" category includes: compressors, diaphragms, drains, dump arms, hatches, instruments, meters, pressure relief valves, polished rods, and vents

SOURCE: USEPA Bulletin Board (Leaks_OG.WP5; 1995).

<u>EXAMPLE 5</u> -- <u>Using EPA Default Zero Factors, Correlation Equations, and 100,000 ppmv Pegged Source Factors to Calculate Total Hydrocarbon Emissions</u>

Example 5 shows the calculation of fugitive emissions from a gas processing plant that has been screened using a portable monitoring instrument with an upper limit of 100,000 ppmv. The example shows how to use EPA Default Zero Factors, Correlation Equations, and 100,000 ppmv Pegged Source Factors.

Step 1 -- Screen all of the Components

All components at a gas production plant were screened with a monitoring instrument having an upper limit of 100,000 ppmv. The first table shows the number of components falling in each of three categories: screening value the same as background (use Default Zeros); screening value between background (BG) and 100,000 ppmv (use Correlation Equations); and components that peg the instrument at its 100,000 ppmv limit (use 100,000 ppmv Pegged Source Factors). The second table shows the individual screening values for the 15 components with screening values between background and 100,000 ppmv.

Number of Components Screened in each Category				
	Total Number Screened	Screening Value Same as Background	Screening Value between BG and 100,000 ppmv	Pegs Instrument at 100,000 ppmv
Connector	632	626	2	4
Flange	228	226	1	1
Open-end	3	2	1	0
Other	13	10	2	1
Pump Seal	0	0	0	0
Valve	228	212	9	7
TOTAL	1,104	1,076	15	13

Individual Screening Values of 15 Components Found to have Instrument Screening Values between BG and 100,000 ppmv							
Component	ppmv		Component	ppmv		Component	ppmv
Connector	1,500		Other	8,500		Valve	28,000
Connector	5,000		Valve	12,000		Valve	30,000
Flange	7,500		Valve	15,000		Valve	35,000
Open-End	80,000		Valve	18,000		Valve	50,000
Other	2,000		Valve	25,000		Valve	55,000

Step 2-- Calculate Contribution of Components with Screening Values the Same as Background (use Default Zero Factors from Table 4 on the previous page)

Column two of the following table shows the number of components found for each type of component. Column three in this table shows the EPA emission factors. Column four shows the calculated total hydrocarbon (THC) emissions found by multiplying columns two and three.

	Number of Default Zeros	Default Zero Factor (lb/comp-day)	Emissions (lb/day)
Connector	626	0.00040	0.250
Flange	226	0.00002	0.00452
Open-end	2	0.00011	0.00022
Others	10	0.00021	0.002
Pump Seal	0	0.00127	0.000
Valve	212	0.00041	0.0869
SUB-TOTAL	1,076		0.344

Step 3 -- Calculate Contribution of Components with Instrument Screening Values Between Background and 100,000 ppmv (use Correlation Equations from Table 4, p. 24)

Column two of the following table shows the instrument screening value for each type of component. Column three shows the correlation equation for each type of component. Column four shows the calculated total hydrocarbon (THC) emissions found by substituting the instrument screening value (SV) in column two into the correlation equation.

Component	SV (ppmv)	EPA Correlation Equation	Emissions (lb/day)
Connector	1,500	$THC = 8.10E\text{-}05(SV)^{0.735}$	0.0175
Connector	5,000	$THC = 8.10E\text{-}05(SV)^{0.735}$	0.0424
Flange	7,500	$THC = 2.44E\text{-}04(SV)^{0.703}$	0.129
Open-Ended	80,000	$THC = 1.16E\text{-}04(SV)^{0.704}$	0.328
Other	2,000	$THC = 7.20E\text{-}04(SV)^{0.589}$	0.063
Other	8,500	$THC = 7.20E\text{-}04(SV)^{0.589}$	0.149
Valve	12,000	$THC = 1.21E\text{-}04(SV)^{0.746}$	0.134
Valve	15,000	$THC = 1.21E\text{-}04(SV)^{0.746}$	0.158
Valve	18,000	$THC = 1.21E\text{-}04(SV)^{0.746}$	0.181
Valve	25,000	$THC = 1.21E\text{-}04(SV)^{0.746}$	0.231
Valve	28,000	$THC = 1.21E\text{-}04(SV)^{0.746}$	0.251
Valve	30,000	$THC = 1.21E\text{-}04(SV)^{0.746}$	0.265
Valve	35,000	$THC = 1.21E\text{-}04(SV)^{0.746}$	0.297
Valve	50,000	$THC = 1.21E\text{-}04(SV)^{0.746}$	0.387
Valve	55,000	$THC = 1.21E\text{-}04(SV)^{0.746}$	0.416
SUB-TOTAL			3.05

Step 4-- Calculate Contribution of Components that Peg Instrument at 100,000 ppmv (use 100,000 Pegged Source Factors from Table 4, p. 24)

Column two of the following table shows the number of components found for each type of component. Column three shows the EPA emission factors. Column four shows the calculated total hydrocarbon (THC) emissions found by multiplying columns two and three.

Component	Number Pegged at 100,000 ppmv	EPA 100,000 Pegged Source Factor	Emissions (lb/day)
Connector	4	1.6	6.4
Flange	1	4.4	4.4
Other	1	5.8	5.8
Valve	7	7.4	51.8
SUB-TOTAL	13		68.4

Step 5-- Calculate Total Emissions by Adding Contributions from Default Zeros, Components with Screening Values Between Background and 100,000 ppmv, and Components that Peg the Instrument at 100,000 ppmv

SUB-TOTAL (From Default Zeros)	0.34 lb/day
SUB-TOTAL (From SV between Background and 100,000 and ppmv)	3.05 lb/day
SUB-TOTAL (From Sources Pegged at 100,000)	68.4 lb/day
TOTAL	71.8 lb/day

<u>EXAMPLE 6</u> -- <u>Using EPA Default Zero Factors, Correlation Equations, and 10,000 ppmv Pegged Source Factors to Calculate Total Hydrocarbon Emissions</u>

If the same gas processing plant used in Example 5 were to be screened using a monitoring instrument with an upper limit of 10,000 ppmv (instead of 100,000 ppmv as used in Example 5) the calculation procedure would change slightly. Example 6 shows the calculation using EPA Default Zero Factors, Correlation Equations, and 10,000 ppmv Pegged Source Factors.

Step 1 -- Screen all of the Components

All components at a gas production plant were screened with a monitoring instrument having an upper limit of 10,000 ppmv. The first table shows the number of components falling in each of three categories: screening value the same as background (use

Default Zeros); screening value between Background and 10,000 ppmv (use Correlation Equations); and components that peg the instrument at its 10,000 ppmv limit (use 10,000 ppmv Pegged Source Factors). The second table shows the individual screening values for the five components with screening values between Background and 10,000 ppmv.

Table of Screening Values

	Total Number Screened	Screening Value Same as Background	Screening Value between Background and 10,000 ppmv	Pegs Instrument at 10,000 ppmv
Connector	632	626	2	4
Flange	228	226	1	1
Open-end	3	2	0	1
Other	13	10	2	1
Pump Seal	0	0	0	0
Valve	228	212	0	16
TOTAL	1,104	1,076	5	23

Individual Screening Values of 5 Components Found to Have Instrument Screening Values Between Background and 10,000 ppmv.

Component	ppmv		Component	ppmv		Component	ppmv
Connector	1,500		Flange	7,500		Other	8,500
Connector	5,000		Other	2,000			

Step 2 -- Calculate Contribution of Components with Screening Values the Same as Background (use Default Zero Factors from Table 4, p. 24)

Column two of the following table shows the number of components found for each type of component. Column three of the table shows the EPA emission factors. Column four shows the calculated total hydrocarbon (THC) emissions found by multiplying columns two and three.

	Number of Default Zeros	Default Zero Emission Factor (lb/comp-day)	Calculated Emissions (lb/day)
Connector	626	0.00040	0.250
Flange	226	0.00002	0.00452
Open-end	2	0.00011	0.00022
Others	10	0.00021	0.0021
Pump Seal	0	0.00127	0.000
Valve	212	0.00041	0.0869
SUB-TOTAL	1,076		0.344

Step 3 -- Calculate Contribution of Components with Instrument Screening Values Between Background and 10,000 ppmv (use Correlation Equations from Table 4, p. 24)

Column two of the following table shows the instrument screening value for each type of component. Column three of the table shows the correlation equation for each type of component. Column four shows the calculated total hydrocarbon (THC) emissions, found by substituting the instrument screening value (SV) into the correlation equation.

Component	SV (ppmv)	EPA Correlation Equation	Emissions (lb/day)
Connector	1,500	$THC = 8.10E\text{-}05(SV)^{0.735}$	0.0175
Connector	5,000	$THC = 8.10E\text{-}05(SV)^{0.735}$	0.0424
Flange	7,500	$THC = 2.44E\text{-}04(SV)^{0.703}$	0.129
Other	2,000	$THC = 7.20E\text{-}04(SV)^{0.589}$	0.0633
Other	8,500	$THC = 7.20E\text{-}04(SV)^{0.589}$	0.149
SUB-TOTAL			0.401

Step 4 -- Calculate Contribution of Components that Peg Instrument at 10,000 ppmv (use 10,000 Pegged Source Factors from Table 4, p. 24)

Column two of the following table shows the number of components found for each type of component. Column three of the table shows the EPA emission factors. Column four shows the calculated total hydrocarbon (THC) emissions found by multiplying columns two and three.

Component	Number Pegged at 10,000 ppmv	10,000 Pegged Source Factor	Emissions (lb/day)
Connector	4	1.5	6.0
Flange	1	4.5	4.5
Open-Ended	1	1.6	1.6
Other	1	3.9	3.9
Valve	16	3.4	54.4
SUB-TOTAL	23		70.4

Step 5 -- Calculate Total Emissions by Adding Contributions from Default Zeros, Components with Screening Values Between Background and 10,000 ppmv, and Components that Peg the Instrument at 10,000 ppmv

SUB-TOTAL (From Default Zeros)	0.34 lb/day
SUB-TOTAL (From SVs between Background and 10,000 ppmv)	0.40 lb/day
SUB-TOTAL (From Sources Pegged at 10,000)	70.4 lb/day
TOTAL	71.1 lb/day

<u>EXAMPLE 7</u> -- <u>Speciating Total Hydrocarbon Emissions Calculated with EPA Default Zero Factors, EPA Correlation Equations, and EPA Pegged Source Factors</u>

Table 5 is a speciation table for total hydrocarbon emissions calculated using EPA Default Zero Factors, EPA Correlation Equations and EPA Pegged Source Factors. The table shows speciation fractions for eight groups of hydrocarbons: methane only, non-methane, VOC (propane and heavier), C6+ (which can also be used as an upper limit of the n-hexane fraction), benzene, toluene, ethyl-benzene, and xylenes. Table 5 differs from the speciation fractions shown in Table 2 (p. 15) in that the fractions are divided primarily by facility types, not by streams. EPA Default Zero Factors, EPA Correlation Equations and EPA Pegged Source Factors do not differentiate between stream types, however, API has found that speciation is dependent on facility type.

Table 5. Speciation Fractions for Total Hydrocarbon Emissions Calculated Using EPA Default Zero Factors, EPA Correlation Equations and EPA Pegged Source Factors

	Onshore Light Oil	Onshore Heavy Oil	Onshore Gas Field	Onshore Gas Plant	Offshore Platform
Methane	0.613	0.942	0.920	0.564	0.791
Non-methane	0.387	0.058	0.080	0.436	0.210
VOC	0.292	0.030	0.035	0.253	0.110
C6+ *	0.02430	0.00752	0.00338	0.00923	0.00673
Benzene	0.00027	0.00935	0.00023	0.00123	0.00133
Toluene	0.00075	0.00344	0.00039	0.00032	0.00089
Ethyl-Benzene	0.00017	0.00051	0.00002	0.00001	0.00016
Xylenes	0.00036	0.00372	0.00010	0.00004	0.00027

* The C6+ fraction can be used to calculate an upper limit for n-hexane.

SOURCE: Star Environmental, 1993, p. ES-7

Example 7 shows how 71.1 lb/day of total hydrocarbon emissions calculated for the gas processing plant in Example 6 (Step 5) are speciated into the eight groups.

Column two of the following table shows the speciation fraction for each of the hydrocarbons in column one. Column three shows the calculated value of 71.1 lb./day total hydrocarbon (THC) emissions for the gas processing plant in Example 6 (Step 5). Column four shows the calculated speciated emissions found by multiplying columns two and three.

Example 7. Table of Calculated Values

	Speciation Fraction	THC Emissions (lb/day)	Speciated Emissions (lb/day)
Methane	0.564	71.1	40.1
Non-methane	0.436	71.1	31.0
VOC	0.253	71.1	18.0
C6+	0.00923	71.1	0.656
Benzene	0.00123	71.1	0.0875
Toluene	0.00032	71.1	0.0228
Ethyl-Benzene	0.00001	71.1	0.000711
Xylenes	0.00004	71.1	0.00284

Chapter 6

METHOD 4 -- USING LEAK QUANTIFICATIONS TO CALCULATE FUGITIVE HYDROCARBON EMISSIONS

The first step in using this method is to monitor all components using portable hydrocarbon monitoring instruments. The second step is to calculate emissions from components with screening values of less than 10,000 ppmv using the either EPA Screening Value Range Emission Factors (see Table 3 in Chapter 4) or EPA Default Zero Factors and Correlation Equations (see Table 4 in Chapter 5). The third step is to quantify at least twenty of the components with screening values of 10,000 ppmv or more using any of the quantification techniques described in Chapter 8 (EPA's "Protocol for Equipment Leak Emission Estimates" June 1993; EPA-453/R-93-026 contains additional details for component bagging). If more than 200 components with screening values of 10,000 ppmv or more are found, at least ten percent of them should be quantified. Quantify a representative selection of components; for example, if most of the components with screening values of 10,000 ppmv or more are valves, quantify more valve leaks than other component types. Use the average leak rate of quantified components as the average for all components with screening values of 10,000 ppmv or more.

Laboratory analyses can be used to speciate the total hydrocarbon emissions or the speciation factors in Table 2 or 5 of Chapter 3 or 5, respectively, can be used.

<u>Example 8</u> -- <u>Using Leak Quantifications and Screening Value Range Emission Factors to Calculate Total Hydrocarbon Emissions</u>

Step 1 -- Screen all of the Components

All of the components at an offshore gas production platform were screened with the following results:

SCREENING RESULTS
(Number of components in each screening range)

Component Type	Total	Screening Value <10,000 ppmv	Screening Value ≥10,000 ppmv
Connectors	2,520	2,498	22
Flanges	815	806	9
Open-Ended Lines	72	62	10
Others	39	27	12
Pumps	16	16	0
Valves	785	749	36
TOTAL	4,247	4,158	89

Step 2 -- Calculate Emissions from Components with Screening Values of or less than 10,000 ppmv

For this example, emissions from components with screening values of less than 10,000 ppmv were calculated using EPA Screening Value Range Emission Factors.

Column two of the following table shows the number of components found for each type of component. Column three of the table shows the EPA emission factors. Column four shows the calculated total hydrocarbon (THC) emissions found by multiplying columns two and three.

Screening Value <10,000 ppmv

Component	Number	Factor	lb/day
Connector	2,498	5.3E-04	1.32
Flange	806	3.0E-04	0.24
Open-Ended	62	7.9E-04	0.05
Other	27	6.3E-03	0.17
Pump	16	1.9E-02	0.30
Valve	749	1.3E-03	0.97
SUB-TOTAL	4,158		3.06

Step 3 -- Quantify at Least Twenty of the Components with Screening Values of 10,000 ppmv or more

Twenty leaks were bagged and quantified with the following results:

BAGGING RESULTS FOR AN OFFSHORE PLATFORM (lb/day)

Connector	5.32	Valve	8.85	Open-Ended	6.20
Connector	3.21	Valve	6.79	Open-Ended	4.24
Connector	0.96	Valve	3.82	Other	5.18
Connector	0.88	Valve	2.31	Other	2.95
Connector	0.04	Valve	1.05	Other	1.07
Flange	3.77	Valve	0.89		
Flange	0.12	Valve	0.37		
		Valve	0.11		

Total emissions from the 20 bagged components were 58.1 lb/day resulting in an average rate of 2.91 lb/leak-day. Emissions from all 89 leaks are therefore calculated to be:

89 leaks x 2.91 lb/leak-day = 259 lb/day

Step 4 -- Calculate Total Hydrocarbon Emissions

Total emissions from the platform are:

3.06 lb/day from SV <10,000 ppmv
+ 259 lb/day from SV $\geq$10,000 ppmv
= 262 lb/day

Chapter 7

COMPONENT SCREENING PROCEDURES

Any seam, packing, or connection to valves, pipes, rotating shafts, etc., can be a source of fugitive hydrocarbon emissions. The following instructions are based on monitoring guidelines published by the EPA in 40 CFR 60, Appendix A, Reference Method 21.

Place the inlet probe of the monitoring instrument as close as possible to the potential leak area without fouling of the probe tip or restricting sample flow into the instrument. Move the probe along the potential leak area while watching the instrument readout. This can be done fairly quickly. If there is an increase in the meter reading, slow down and go back to find the point that gives the highest reading. Stay at that point for approximately two times the instrument response time. Record the highest reading.

Check to see how the reading compares to ambient concentrations in the local area by moving the probe inlet upwind and downwind at a distance of one to six feet from the component. Be sure that there is not any contamination from a nearby leaking component. Record the background reading. It is important to minimize possible interference from high winds by shielding the probe tip with a hand or a piece of stiff cardboard.

Specific components are monitored as follows:

FLANGES AND OTHER CONNECTORS Measure the entire circumference of the flange-gasket interface. Measure the entire circumference of threaded connections, tubing fittings, and other types of non-permanent joints. Welded connections are not monitored. Connections into valves are counted as "flanges" or "connectors."

OPEN-ENDED LINES OR VALVES Place the probe inlet at the center of the opening to atmosphere.

PUMP SEALS Measure pump seals at the point where the shaft exits the seal. Make sure that the rapidly moving shaft, which may contain a protruding "key," can be monitored safely before beginning the measurement.

VALVES Measure all of the area where the stem comes out of the packing gland. Measure any body flanges, bonnet flanges, or plugs on the valve.

OTHERS Measure the concentration of fugitive hydrocarbons (if any) at the center of a pressure relief valve (or device) exhaust horn. Measure other components such as compressors, diaphragms, drains, dump arms, hatches, instruments, meters, polished rods, and vents, etc., at all points of possible emissions.

Chapter 8
LEAK QUANTIFICATION PROCEDURES

EPA recognizes three techniques for quantifying a leak. Two techniques require construction of a tightly sealed plastic or metal foil bag around the leaking component and collection of the leak in a stream of nitrogen or air forced through the bag at a known rate. The "Vacuum Technique" uses a pump to draw ambient air through the bag at a known rate entraining the hydrocarbon with it. The "Blow-Through" technique uses a stream of nitrogen blowing into the bag at a known rate to mix with the leak. In either case, one or more samples of the hydrocarbon/carrier gas mixture is collected for analysis by gas chromatography or other laboratory procedure. The third technique of quantifying a leak, called the High Flow System or HFS, uses a high volume air pump to draw ambient air across the leaking component at a speed fast enough to entrain all of the leak without a fully constructed bag. The concentration of hydrocarbon in the air/hydrocarbon mixture is measured with a portable hydrocarbon analyzer calibrated to one or more methane-in-air standards.

THE VACUUM TECHNIQUE

Figure 1 is a vacuum technique sampling train adapted from the one given on page 4-5 of EPA's "Protocol for Equipment Leak Emission Estimates," June 1993; EPA-453/R-93-026.

Attach a 1/4 inch flexible plastic tube (sample tube) to the component with the open end of the tube within 1 centimeter of the exact point of highest emissions found during the monitoring procedure (this is considered the front of the leak). Attach a second flexible plastic tube (fresh air supply tube) at the "back" of the leak with the open end of the tube pointed toward the leak.

Enclose the leaking component and tubes in a polyethylene bag. Seal all the edges tightly using heavy tape or a heat-sealer to prevent uncontrolled entry of air. Connect the sample tube to a flow metering device (either a dry gas meter or a rotameter) and connect that to a control valve and then to the sampling pump. Start the pump and make sure that the bag collapses onto the component. A second flow measuring device can also be attached to the fresh air inlet tube to be sure that air is flowing in through the tube and across the leak rather than slipping in through an unintentional opening in the bag or sampling lines.

Measure the pump outlet with a portable monitoring instrument until a stable reading has been obtained and recorded for three consecutive 30 second periods. Then use the pump outlet to fill an inert sample collection bag. Measure the hydrocarbon concentration in the sample collection bag using a technique such as gas chromatography or mass spectroscopy.

Calculate the fugitive hydrocarbon emission rate (in liters per minute) by multiplying the pump flow rate (in liters per minute) by the laboratory chemical analysis (in parts-per-million by volume). The laboratory analysis can also be used to speciate the fugitive hydrocarbon emissions.

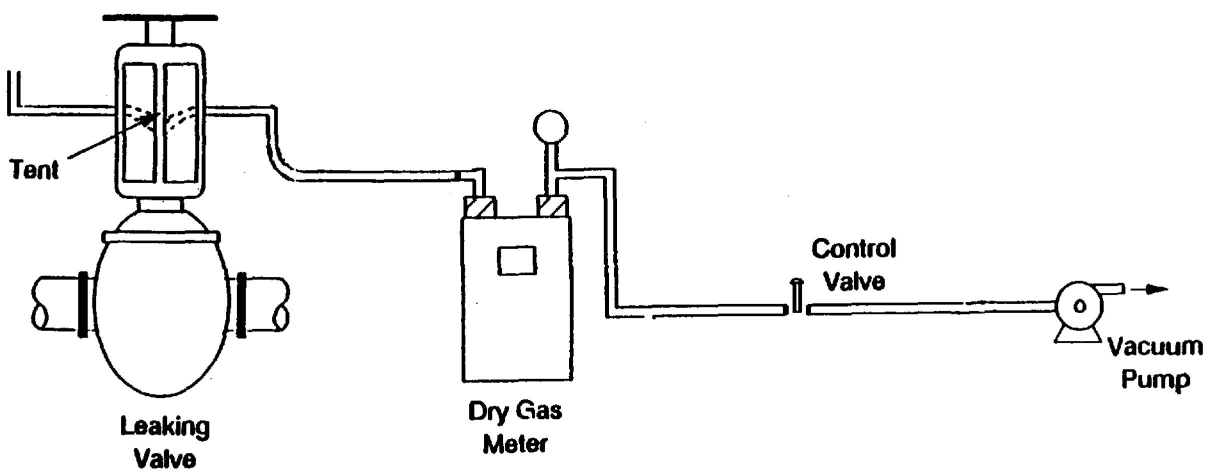

Figure 1 -- The Vacuum Technique

THE BLOW-THROUGH TECHNIQUE

The sampling train for the blow-through technique consists of a supply of compressed nitrogen, a flow meter for the nitrogen, and a Mylar or metal foil bag around the component being tested (see Figure 2).

First, construct a nearly air tight bag around the leaking component using Mylar or metal foil. Meter nitrogen into the bag through one or two tubes at a steady rate (monitored with a gas rotameter). The flow rate should be 60 liters per minute or less. Pressure inside the bag should never exceed 1 pound per square inch gauge (psig) to prevent ripping the bag. Monitor the temperature and oxygen concentrations inside the bag with a thermocouple or thermometer and an oxygen/combustible gas monitor.

Continue flowing nitrogen into the bag until the oxygen reading has reached equilibrium. In addition to the nitrogen flow into the bag, EPA has stated that some ambient air may also enter the bag. Oxygen measurements are used to determine the flow of ambient air through the bag. Once the oxygen concentration has become stable, use a portable hydrocarbon monitoring instrument to check concentration levels at several locations within the bag to ensure that the bag contents are at steady state. Collect two gas samples from the bag for laboratory analysis using a portable sampling pump.

Calculate the fugitive hydrocarbon emission rate from the component (in liters per minute) by multiplying the nitrogen flow rate (in liters per minute) by the chemical analyses (in part per million by volume) from the laboratory. The laboratory analyses can also be used to speciate the hydrocarbon emissions.

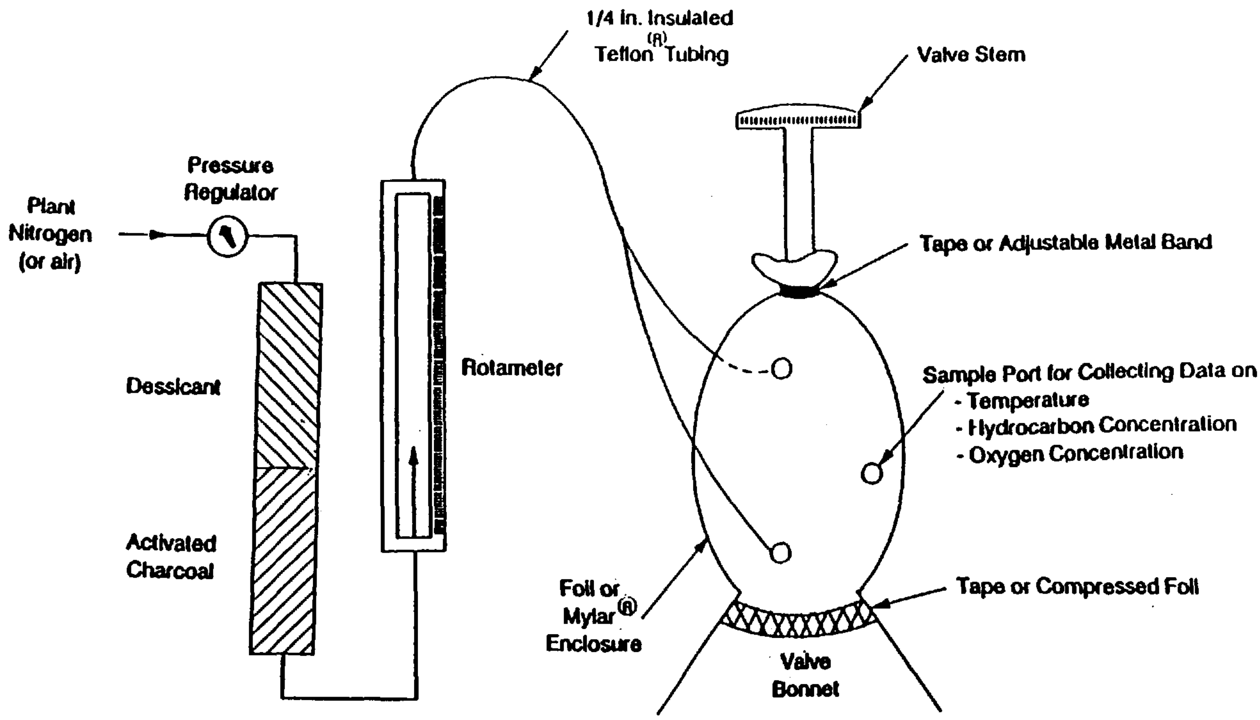

Figure 2 -- The Blow-Through Technique

THE HIGH FLOW SYSTEM

EPA recently tested a new technique for quantifying fugitive hydrocarbon emissions in the field. The technique is called the High Flow System (HFS). The technique was found to give the same results as the Vacuum Technique.

The HFS consists of a high volume pump (200 liter per minute or more), a control valve that can regulate the pump flow, a series of flow meters for measuring flows between 1 and 200 l/min, and a portable hydrocarbon monitoring instrument.

Use the monitoring instrument to locate the exact point of emission from the component. Secure the HFS sample line inlet at the point of the highest screening. Apply thin plastic film (such as food wrapping plastic) or duct tape to the area around the leak to channel all hydrocarbon emissions to the HFS sample line and to deflect any crosswind. Be careful not to over-seal the area as this might prevent flow of ambient air across the leak.

Start the HFS at a high sampling rate. Measure the hydrocarbon content of the HFS pump outlet with the monitoring instrument. Allow the instrument reading of the HFS pump outlet to stabilize and then record it. Decrease the HFS flow rate in a number of steps and record both the decreased flow rates and the corresponding increased instrument readings. Continue this until the minimum flow of the HFS is reached (approximately 1 l/min) or the hydrocarbon concentration becomes too high for the monitoring instrument

Use a minimum of three different flow rates for each component. If the monitoring instrument has been calibrated with one or more calibration gases, try to adjust the HFS flow rate to give concentrations in the pump outlet that are the same as the calibration gases. This will maximize the accuracy of the HFS technique.

Calculate the fugitive emission leak rate (in liters per minute) by multiplying the HFS sampling rates (in liters per minute) with the corresponding instrument readings (parts-per-million by volume). Calculate the average emission rate for the three or more HFS flow rates that were recorded. Calculate the standard deviation of the measurements to determine the precision of the measurements. Table 2 or 5 in Chapter 3 or 5, respectively, can be used to speciate the hydrocarbon emissions.

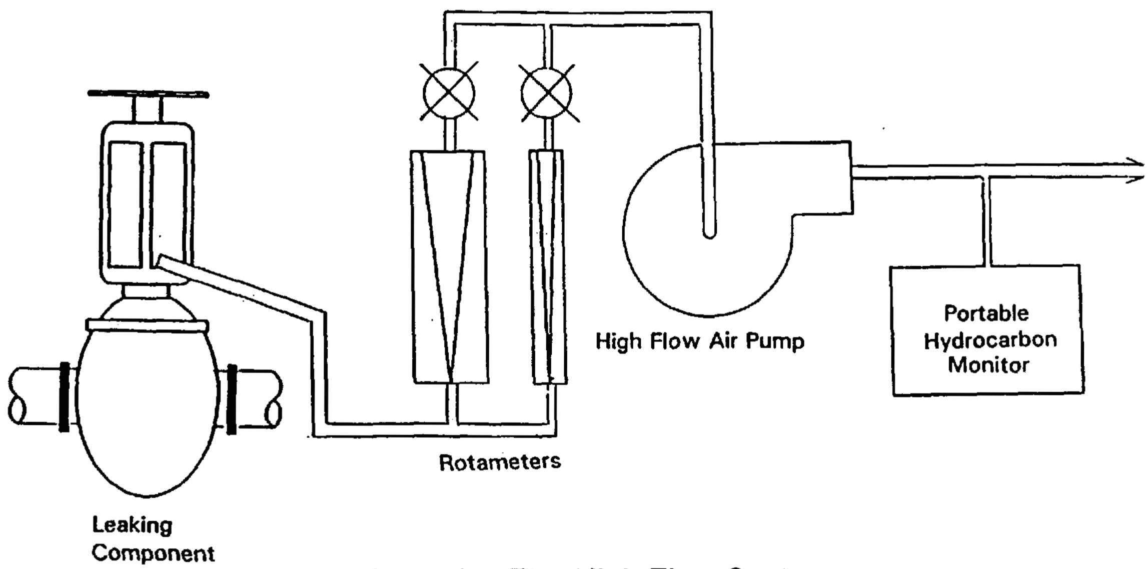

Figure 3 -- The High Flow System

Chapter 9
DEFINITIONS

API GRAVITY

The density of the liquid expressed in degrees and defined by the following equation:

$$\text{API Gravity} = (141.5/ \text{Sp. Gr.}) - 131.5$$

Where Sp. Gr. is the specific gravity of the liquid at $60^{o}F$.

AVERAGE EMISSION FACTOR

The average mass emission rate for the total population (including leakers and non-leakers) of a component type.

BAGGING

Enclosing a leaking component in plastic film or a metal foil enclosure is referred to as bagging. Bagging is used to gather a sample of leaking hydrocarbon. Typically ambient air is drawn through the bag to catch the hydrocarbon (vacuum technique) or nitrogen is blown into the bag to mix with the hydrocarbon. Either way, one or more samples of the hydrocarbon/carrier gas mixture is collected for laboratory analysis.

BLOW-THROUGH BAGGING TECHNIQUE

A leak quantification technique that uses compressed gas (usually nitrogen) to sweep fugitive hydrocarbons through a plastic or metal foil bag fastened tightly around the leaking component. The hydrocarbon fraction in the nitrogen/hydrocarbon mixture is determined by gas chromatography or other laboratory techniques.

CALIBRATION GAS

EPA has specified that monitoring instruments are to be calibrated with mixtures of methane-in-air. A commonly used calibration gas for the high range of the monitoring instrument is 10,000 parts-per-million by volume, methane-in-air.

CONNECTORS (See **COMPONENT**).

COMPONENT

Connector Threaded connectors and tubing fittings, generally having an outside diameter 3 inches or less. Each threaded connection of processing lines to a valve is considered a connector and should be included in the group. However, the body connection and bonnet of a valve, and plugs threaded directly into the valve body are considered part of the valve and should not be included in this group. A piece of pipe with one end connected to a valve and the second end open to atmosphere is considered an "open-ended line," not a connector.

Flange Bolted connections generally having an outside diameter greater than 3 inches. Each bolted connection of processing lines to a valve is considered a flange and should be included in this group. However, the body connection and bonnet of a valve, and plugs threaded directly into the valve body are considered part of the valve and should not be included in this group. A piece of pipe with one end connected to a valve and the second end open to atmosphere is considered an "open-ended line" not a flange. Body flanges on meters and filters, and hatches on tanks and vessels are not counted in this category. They are included in the "Other" category.

Open-Ended Lines (Also called "open-ended valves") The end of any valve that can be opened to the atmosphere (sample connections, drains, bleed valves, etc.) is an open-ended line. The open end of a pressure relief valve is not included in this category. If a short piece of pipe is attached to the end of a valve, but no pressure build-up can occur in the pipe, the system is included as an open-ended line and not a connector or flange. When two valves are installed in series and both are closed (creating a double seal to prevent loss to atmosphere) the open end of the second valve is not counted as an "open-ended line." If the line is sealed with a plug or cap, it is not considered an open-ended line.

Pump Seal This category refers to pump seals located at the interface of the pump shaft and housing and other joints of the pump. A pump is defined as a device that raises, transfers or compresses fluids by suction or pressure or both.

Valve Valves that have visible actuators are included in this category. Check valves and pressure relief valves are not included in this category.

Each valve is counted once regardless of the number of body flanges, bonnet flanges or plugs that are a part of the valve. Each connector or flange of a valve to a processing line is considered a connector or flange and is not included in this group. Small drain valves or vent valves attached to large valves are counted as separate valves.

Others The "Other" component category includes: compressors, diaphragms, drains, dump arms, hatches, instruments, meters, pressure relief valves, polished rods, and vents.

CORRELATION EQUATION

An equation that relates fugitive hydrocarbon mass emission rates in kilograms/hour, pounds/day, or pounds/year to instrument screening values in parts per million by volume. Correlation equations are used to calculate emissions from individual instrument screening values.

DEFAULT ZERO

An average emission rate to be used for components that do not give instrument screening values higher than the background reading.

EMISSION FACTOR

The average mass fugitive emission rate for components in a specific screening value range. The factor is multiplied by the number of components to calculate fugitive emissions.

FLANGE (See **COMPONENT**).

FUGITIVE HYDROCARBON EMISSIONS

The term "fugitive" refers to unintentional emissions of hydrocarbon gases or liquid from valve stems, connections, shaft seals, etc. Occasional or continuous release of emissions through stacks or vents, whether intentional, accidental, or the results of a shut-down, start-up or emergency procedure are not considered fugitive emissions.

GAS (See **STREAM**).

HEAVY OIL (See **STREAM**).

HIGH FLOW SYSTEM

A leak quantification technique that uses a high flow of air to capture fugitive hydrocarbon leaks. The hydrocarbon fraction in the air/hydrocarbon mixture is determined using a portable hydrocarbon monitor.

LEAK FREQUENCY

The number of leaks per 100 components.

LIGHT OIL (See **STREAM**).

MONITORING INSTRUMENT

Portable monitoring instruments with internal pumps and hydrocarbon detectors. They are used to locate and/or quantify fugitive hydrocarbon emissions from equipment components.

OPEN-ENDED LINES (See **COMPONENT**).

OTHER COMPONENT (See **COMPONENT**).

PARTS-PER-MILLION (PPMV)

Most hydrocarbon monitoring instruments have displays that show the response of the instrument to known concentrations of methane-in-air measured in parts of methane per million parts of air by volume.

PEGGED SOURCE

An equipment component with fugitive hydrocarbon emissions that cause the monitoring instrument to exceed its maximum useful range. Because of this, no precise instrument screening value can be obtained for the component and it is referred to as a "pegged source."

PRODUCTION OPERATIONS

All operations and equipment that produce petroleum including wells, headers, separators, gathering lines, oil treatment facilities, gas treatment facilities, and transmission lines.

PUMP SEALS (See **COMPONENT**).

SCREENING

Monitoring an equipment component for fugitive hydrocarbon emissions usually through the use of a portable instrument.

SCREENING INSTRUMENT (See **MONITORING INSTRUMENT**).

SCREENING VALUE RANGE EMISSION FACTOR

The average mass emission rates for components with instrument screening values above an arbitrary leak definition (such as 10,000 ppmv) and below that definition.

STREAM

Gas Material in a gaseous state at operating conditions. Liquefied gases are considered light oil.

Light Oil Oil produced at production sites having an API Gravity of 20 or more. Bearing seal oils and hydrocarbon-based heat transfer fluids are also included in this category. Light hydrocarbons (such as propane and butane) that are in a liquid state inside of the components due to high pressure and/or low temperature are also included in this category. This category includes both pure liquid streams and streams that are mixtures of light liquids and gases.

Heavy Oil Oil produced at production sites having an API Gravity of less than 20. Pure liquid streams and streams containing mixtures of heavy oil and gases are included in this category.

Water/Oil Water streams in oil service with a water content greater than 50%, from the point of origin to the point where the water content reaches

99%. For water streams with a water content greater than 99%, the emission rate is considered negligible. Emission factors for water/oil service should be used for components on oil-water separators, components on produced water tanks and components on piping and other equipment used for handling produced water prior to its injection underground.

THC and VOC

Total hydrocarbons (THC) include methane, ethane, propane, and any other organic molecule containing carbon. Volatile Organic Compounds (VOC) are defined differently by agencies but typically methane and sometimes ethane are not counted as VOCs.

VACUUM BAGGING TECHNIQUE

A leak quantification technique that uses a vacuum pump to pull ambient air through a plastic bag fastened tightly around a leaking component. The hydrocarbon fraction in the resulting air/hydrocarbon mixture is determined by gas chromatography or other laboratory technique.

VALVES (See **COMPONENT**).

WATER/OIL (See **STREAM**).

Chapter 10

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