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Emission Factors for Oil and Gas Production Operations





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- 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.

Emission Factors for Oil and Gas Operations

Health and Environmental Sciences Departments

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PREFACE

This report presents final results of an API study entitled, *Emission Factors for Oil and Gas Production Operations*. The report supplements API Publication Number 4589, published in December 1993, entitled, *Fugitive Hydrocarbon Emissions from Oil and Gas Production Operations*. Although API Publication Number 4589 contains correlation equations for several types of Exploration and Production (E&P) facilities and emission factors for those facilities, it does not contain emission factors for gas plants. This supplemental report contains emission factors for gas plants (as well as other E&P facilities) based upon the correlation equations recently published on the EPA electronic bulletin board. Emission factors for each component type were calculated by substituting screening values into the appropriate EPA correlation equation.



ABSTRACT

In 1980, the American Petroleum Institute (API) published emission factors for fugitive hydrocarbon emissions from onshore and offshore petroleum production sites. In 1993, API published the results of a joint study with the Gas Research Institute (GRI) at 20 oil and gas production sites, including light crude, heavy crude, gas production and offshore oil and gas facilities. The current report combines the 1993 API/GRI data with data from four additional gas processing plant sites. Emission factors contained in the current report replace the existing 1980 and 1993 API factors. More than 200,000 components were screened during the two recent studies using EPA Method 21 guidelines. Mass emission rates from nearly one thousand leaks were quantified. Approximately three-fourths of the quantified leaks were speciated to determine emission rates of total hydrocarbon, volatile organic compounds, and individual air toxics (i.e., benzene, toluene, ethyl benzene, and xylenes).

Recently published EPA correlation equations were used in combination with the 200,000 instrument screening values to produce new average and Leak/no-leak emission factors for oil and gas production operations. The new factors allow operators to more accurately quantify actual emissions from their sites. This greatly improves assessment of control technologies and selection of equipment to lower fugitive hydrocarbon emissions. As the new leak definition imposed by the Clean Air Act of 1990 becomes effective, results of this study will be indispensable to operators.



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EXECUTIVE SUMMARY

In December 1993, the American Petroleum Institute (API) published API Publication Number 4589, *Fugitive Hydrocarbon Emissions from Oil and Gas Production Operations* (Star Environmental, 1993) which contains correlation equations and emission factors developed from the screening of 184,035 components at 20 sites. In August 1994, the US EPA published new correlation equations for the petroleum industry (see Table ES-3), based in part on the data contained in the API report.

This report contains new emission factors developed from the 1993 API data using the new EPA correlation equations. The new emission factors are generally higher than the 1993 API factors, but they are lower than the SOCM factors, refinery factors, and gas plant factors published by the EPA in *Protocol for Equipment Leak Emission Estimate* (EPA, 1993). The new emission factors are highly dependent on the EPA pegged source emission factors. This report also contains emission factors for gas plants based on the data contained in the 1993 API report appendices and data collected at four additional gas plants as a part of this study.

Average emission factors, calculated for use with component inventories, are shown in Table ES-1. These factors can be used to predict total hydrocarbon emissions when screening data is not available and only the number of components installed at a site is known.

Table ES-1. Average Emission Factors by Facility Type (lb/component-day)

	Connection	Flange	Open End	Pump	Valve	Others
Light Crude	8.66E-03	4.07E-03	6.38E-02	1.68E-02	7.00E-02	3.97E-01
Heavy Crude	4.22E-04	1.16E-03	8.18E-03	no data	6.86E-04	3.70E-03
Gas Production	1.70E-02	6.23E-03	3.63E-02	1.03E-02	1.39E-01	4.86E-01
Gas Plants	1.45E-02	2.32E-02	5.46E-02	6.09E-01	2.04E-01	2.57E-01
Offshore	5.70E-03	1.04E-02	5.37E-02	1.03E-02	2.72E-02	3.67E-01

"Others" category includes instruments, loading arms, pressure relief valves, stuffing boxes, compressor seals, dump lever arms, and vents.

Emission factors for connections and flanges are typically an order of magnitude lower than valve emission factors. Emission factors for onshore light crude production and onshore gas

ES-1

production are similar and lower than emission factors for onshore gas plants. Emission factors for onshore heavy crude production are significantly lower than the other onshore emission factors. Offshore emission factors are lower than those for onshore light crude production or onshore gas production.

Leak/no-leak factors, calculated with a leak definition of 10,000 ppmv, are shown in Table ES-2. These factors can be used with leak/no-leak screening data to predict total hydrocarbon emissions.

Table ES-2. Leak/no-leak Emission Factors by Facility Type (lb/component-day)

	Connection	Flange	Open End	Pump	Valve	Others
LEAK (>10,000 ppmv)						
All Facilities	1.497	4.490	1.600	3.905	3.381	3.846
NO-LEAK (<10,000 ppmv)						
Light Crude	5.25E-04	1.24E-03	1.50E-03	1.68E-02	1.11E-03	9.01E-03
Heavy Crude	4.41E-04	1.19E-03	8.86E-04	no data	6.95E-04	3.67E-03
Gas Production	6.33E-04	1.30E-03	1.26E-03	1.03E-02	1.63E-03	7.92E-03
Gas Plants	5.76E-04	1.44E-03	1.62E-03	4.30E-02	1.81E-03	9.09E-03
Offshore	5.11E-04	1.33E-03	9.40E-04	1.03E-02	8.50E-04	3.76E-03

"Others" category includes instruments, loading arms, pressure relief valves, stuffing boxes, compressor seals, dump lever arms, and vents.

Total hydrocarbon emissions can also be calculated using component screening data and the new EPA correlation equations and factors shown in Table ES-3.

Table ES-3. August 1994 EPA Correlation Equations and Factors (lb/component-day)

Component	Default Zero	Correlation Equation	Pegged at 10,000 ppmv	Pegged at 100,000 ppmv
Connection	0.000441	$\text{THC} = 7.97\text{E-}05(\text{SV})^{0.735}$	1.497	1.570
Flange	0.000528	$\text{THC} = 2.34\text{E-}04(\text{SV})^{0.703}$	4.490	4.456
Open End	0.000671	$\text{THC} = 1.14\text{E-}04(\text{SV})^{0.704}$	1.600	4.177
Pump Seal	0.001621	$\text{THC} = 2.54\text{E-}03(\text{SV})^{0.610}$	3.905	8.448
Valve	0.000644	$\text{THC} = 1.20\text{E-}04(\text{SV})^{0.746}$	3.381	7.415
Other	0.000209	$\text{THC} = 6.97\text{E-}04(\text{SV})^{0.589}$	3.846	5.808

EPA's "other" category includes instruments, loading arms, pressure relief valves, stuffing boxes, and vents.

ES-2

Speciated hydrocarbon emission rates can be calculated using total hydrocarbon emission rates obtained from either Table ES-1, ES-2, or ES-3 and the speciation factors contained in Table ES-4.

Table ES-4. Speciated Fugitive Emission Factors
(Weight Fraction of THC emissions in each category)

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

- NOTES: 1. Emission factor = Speciated Emissions/Total Emissions
 2. NMHC = Non-methane hydrocarbon
 3. VOC = Propane and heavier hydrocarbon

ES-3

INTRODUCTION

API Report No. 4589

The American Petroleum Institute (API) and the Gas Research Institute (GRI) conducted a field study of fugitive hydrocarbon emissions from 184,035 equipment components at 20 petroleum production facilities. A total of 4,796 components were found to be emitting hydrocarbons. Seven hundred and five (705) of the emitters were quantified and speciated into C1 through C6+ fractions. Approximately 25 percent of the samples were also analyzed for air toxics. Results of the study were published in *Fugitive Hydrocarbon Emissions for Oil and Gas Production Operations*, API Publication No. 4589 (Star Environmental, 1993).

The report contains emission correlation equations that relate instrument screening values to mass emission rates for four component types (connection, valve, open end line, others) at five types of production operations: 1) light crude production, 2) heavy crude production, 3) gas production, 4) gas processing, and 5) Gulf of Mexico (Gulf) offshore production. "Default zero" emission rates were defined for components with instrument screening values below 10 ppmv. Emission factors were derived for four of the five types of facilities using the emissions correlation equations and component screening values. Emission factors included average facility factors, component specific factors, "Leak/No-leak" factors, and stratified factors.

The study also developed profiles of speciated hydrocarbon emissions including air toxics, assessed regional differences in fugitive emissions, and assessed control of efficiency of Inspection and Maintenance programs.

The report contains a workbook with instructions on using emission factors and correlation equations. Inventory data, screening data, and leak quantification data for all 20 sites are contained in appendices published with the report.

EPA August 1994 Correlation Equations

In August 1994, the U.S. EPA published a single set of emissions correlation equations for the entire petroleum industry. The EPA equations were calculated by combining data from three reports: API Publication No. 4589 on exploration and production operations (Star Environmental, 1993), API Publication Nos. 4612 and 4613 on refineries (Radian, 1994), and

API Publication Nos. 4588 and 48881 on marketing terminals (Radian, 1993). The EPA equations, which yield higher emission rates than the equations used by API in Publication No. 4589, divide the components into six types (flange, other connection, valve, open end line, pump seal, other components) but combine all facility types including production facilities, refineries, and marketing facilities. The publication of these new EPA correlation equations created the need to revise the API emission factors given in API Publication No. 4589.

Current Study

This report contains a recalculation of API emission factors based on the new EPA correlation equations. The factors were developed using the component counts and screening data contained in API Publication No. 4589 and additional data collected at four gas plants. This report also contains emission factors for gas plants which were developed from data collected at the four gas plants monitored as a part of API's 1993 study and four additional gas plants monitored as part of this study. The new emission factors are slightly higher than the previous ones published by API, but are lower than the Synthetic Organic Chemical Manufacturing Industry (SOCMI) factors, refinery factors, and gas plant factors published by the EPA in *Protocol for Equipment Leak Emission Estimates* (EPA, 1993). Many of the EPA factors were based on 1970-1980 data and are not representative of current petroleum industry practices.

COMBINED DATABASE

Table 1 shows general screening data for 20 sites included in Publication No. 4589 (Sites 1 through 20) and four additional sites monitored as a part of the current effort (Sites 21 through 24). The table lists the sites by type and identification number, and includes: the number of components screened; the number components classified as non-emitters (instrument screening values less than 10 parts-per-million, by volume, methane equivalence [ppmv]); the number of components with screening values from 10 through 9,999 ppmv, and the number with screening values of 10,000 ppmv or more. Detailed screening data for Sites 1 through 20 are included in Publication No. 4589; detailed screening data for Sites 21 through 24 are contained in Appendix A of this report.

Information recorded for each emitter includes component type (flange, other connector, open end line, pump seal, valve, others), component size in inches, and instrument screening

value. Emitter data for Sites 1 through 20 are appended to Publication No. 4589; emitter data for Sites 21 through 24 are contained in Appendix B of this report. Mass emission rates from a total of 945 leaks were quantified. Emission rates for 705 leaks quantified at sites 1 through 20 are appended to Publication No. 4589; emission rates for 240 leaks quantified at sites 21 through 24 are included in Appendix C of this report.

Table 1. Sites Used to Develop New E&P Emission Factors

Facility Type	Site No.	Components Screened	Non-Emitters	Emitters 10 to 9,999 ppmv	Emitters >10,000 ppmv
Light Crude	1	27,155	26,633	275	247
Light Crude	2	14,620	14,330	182	108
Light Crude	3	4,095	4,011	57	27
Light Crude	4	2,782	2,687	60	35
Heavy Crude	5	6,362	6,343	19	0
Heavy Crude	6	2,799	2,778	19	2
Heavy Crude	7	2,696	2,688	8	0
Heavy Crude	8	1,899	1,885	14	0
Gas Production	9	14,066	13,742	198	126
Gas Production	10	9,374	9,058	200	116
Gas Production	11	9,094	8,466	310	318
Gas Production	12	7,644	7,399	157	88
Gas Plant	13	11,235	10,819	250	166
Gas Plant	14	10,673	10,057	330	286
Gas Plant	15	7,786	7,483	143	160
Gas Plant	16	6,070	5,790	114	166
Offshore Platform	17	15,734	15,516	141	77
Offshore Platform	18	10,967	10,822	75	70
Offshore Platform	19	10,271	10,178	68	25
Offshore Platform	20	8,713	8,554	88	71
Gas Plant	21	6,106	5,941	109	56
Gas Plant	22	4,412	4,396	10	6
Gas Plant	23	8,047	7,832	30	185
Gas Plant	24	2,797	2,686	5	106
Totals		205,397	200,094	2,862	2,441

EPA CORRELATION EQUATIONS, DEFAULT ZERO FACTORS, AND PEGGED SOURCE FACTORS

Table 2 gives the August 1994 EPA correlation equations, default zero factors, factors for sources pegged at 10,000 ppmv, and factors for sources pegged at 100,000 ppmv as published on EPA's electronic bulletin board. Default zero factors are used for components that do not give significant instrument screening values (zero instrument reading). Pegged

factors are used for components that give instrument screening values equal to or greater than 10,000 ppmv or 100,000 ppmv, respectively. Correlation equations are used to calculate emissions for components with instrument screening values between the default zero levels and pegged values. Compressor seals and dump lever arms were inadvertently left out of the "others" category when the factors and equations were published on EPA's electronic bulletin board.

Table 2. August 1994 EPA Correlation Equations and Factors (lb/component-day)

Component	Default Zero	Correlation Equation	Pegged at 10,000 ppmv	Pegged at 100,000 ppmv
Connection	0.000441	$\text{THC} = 7.97\text{E-}05(\text{SV})^{0.735}$	1.497	1.570
Flange	0.000528	$\text{THC} = 2.34\text{E-}04(\text{SV})^{0.703}$	4.490	4.456
Open End	0.000671	$\text{THC} = 1.14\text{E-}04(\text{SV})^{0.704}$	1.600	4.177
Pump Seal	0.001621	$\text{THC} = 2.54\text{E-}03(\text{SV})^{0.610}$	3.905	8.448
Valve	0.000644	$\text{THC} = 1.20\text{E-}04(\text{SV})^{0.746}$	3.381	7.415
Other	0.000209	$\text{THC} = 6.97\text{E-}04(\text{SV})^{0.589}$	3.846	5.808

EPA's "other" category includes instruments, loading arms, pressure relief valves, stuffing boxes, and vents.

For this report, average emission factors were calculated using pegged source values of 10,000 ppmv rather than 100,000 ppmv for the following reasons:

Some monitoring instruments do not give direct measurements above 10,000 ppmv;

Some agency regulations contain 10,000 ppmv as the definition of a leak; and,

"Leak/No-leak" emission factors published by EPA for other industries have 10,000 ppmv as the division point between "leaking" and "non-leaking" components.

Total emissions calculated using 10,000 ppmv pegged factors are generally more conservative (higher) than those calculated using 100,000 ppmv pegged factors

Figures 1 through 3 show relationships between the EPA default zeros, correlation equations, and 10,000 ppmv pegged factors. The intersection of the default zero factor and the correlation equation is different for each type of component. Table 3 lists the intersections of the default zeros and the correlation equations.