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Emission Factors for Oil and Gas Production Operations

STEP
Strategies for Today's Environmental Partnership

American
Petroleum
Institute

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.

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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

API PUBLICATION NUMBER 4615

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American Petroleum Institute

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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 SOCMI 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

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	$THC = 7.97E\text{-}05(SV)^{0.735}$	1.497	1.570
Flange	0.000528	$THC = 2.34E\text{-}04(SV)^{0.703}$	4.490	4.456
Open End	0.000671	$THC = 1.14E\text{-}04(SV)^{0.704}$	1.600	4.177
Pump Seal	0.001621	$THC = 2.54E\text{-}03(SV)^{0.610}$	3.905	8.448
Valve	0.000644	$THC = 1.20E\text{-}04(SV)^{0.746}$	3.381	7.415
Other	0.000209	$THC = 6.97E\text{-}04(SV)^{0.589}$	3.846	5.808

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

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

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	$THC = 7.97E\text{-}05(SV)^{0.735}$	1.497	1.570
Flange	0.000528	$THC = 2.34E\text{-}04(SV)^{0.703}$	4.490	4.456
Open End	0.000671	$THC = 1.14E\text{-}04(SV)^{0.704}$	1.600	4.177
Pump Seal	0.001621	$THC = 2.54E\text{-}03(SV)^{0.610}$	3.905	8.448
Valve	0.000644	$THC = 1.20E\text{-}04(SV)^{0.746}$	3.381	7.415
Other	0.000209	$THC = 6.97E\text{-}04(SV)^{0.589}$	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.

Figure 1. Relationship of Default Zero, Correlation Equation, and Pegged Factor (Connection and Flange)

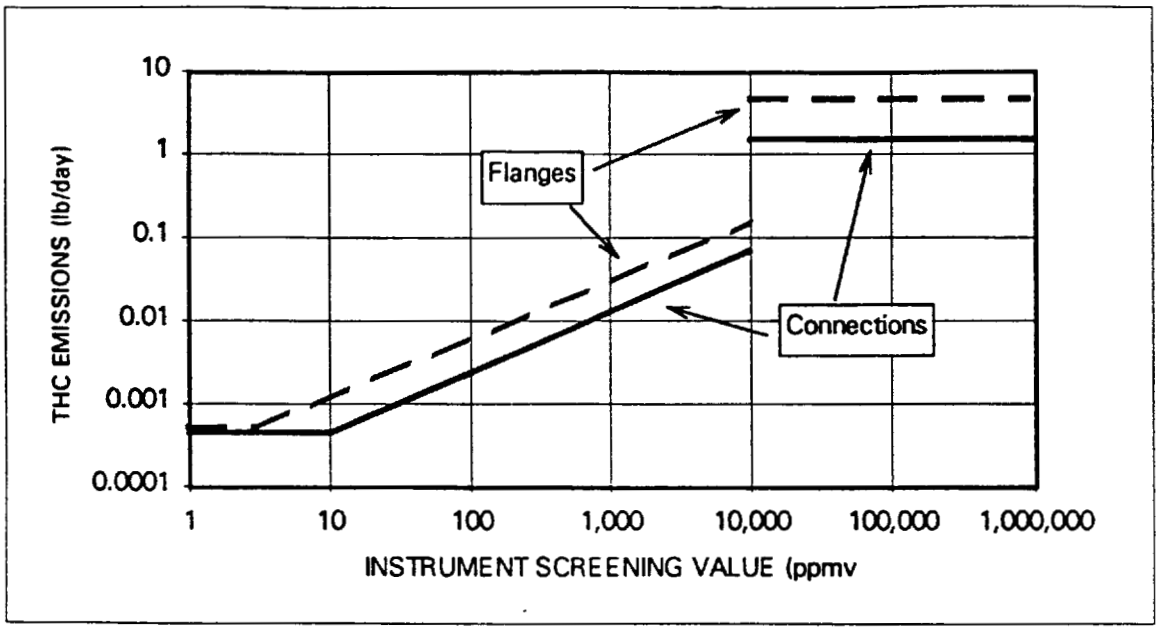


Figure 2. Relationship of Default Zero, Correlation Equation, and Pegged Factor (Valve and Open End Line)

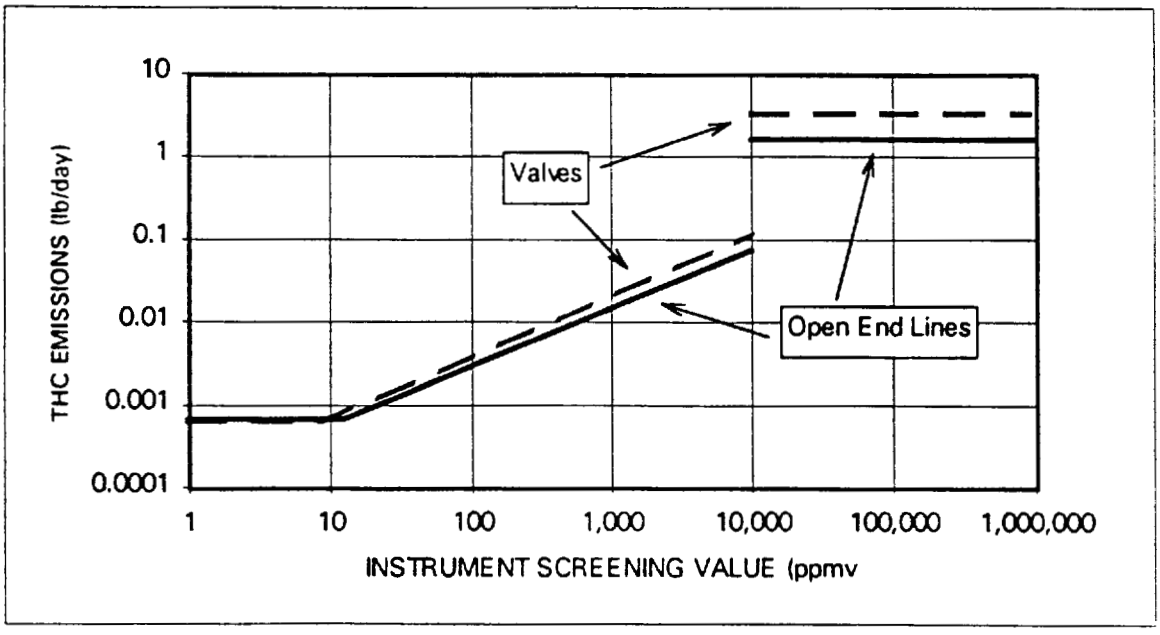


Figure 3. Relationship of Default Zero, Correlation Equation, and Pegged Factor (Pumps and Others)

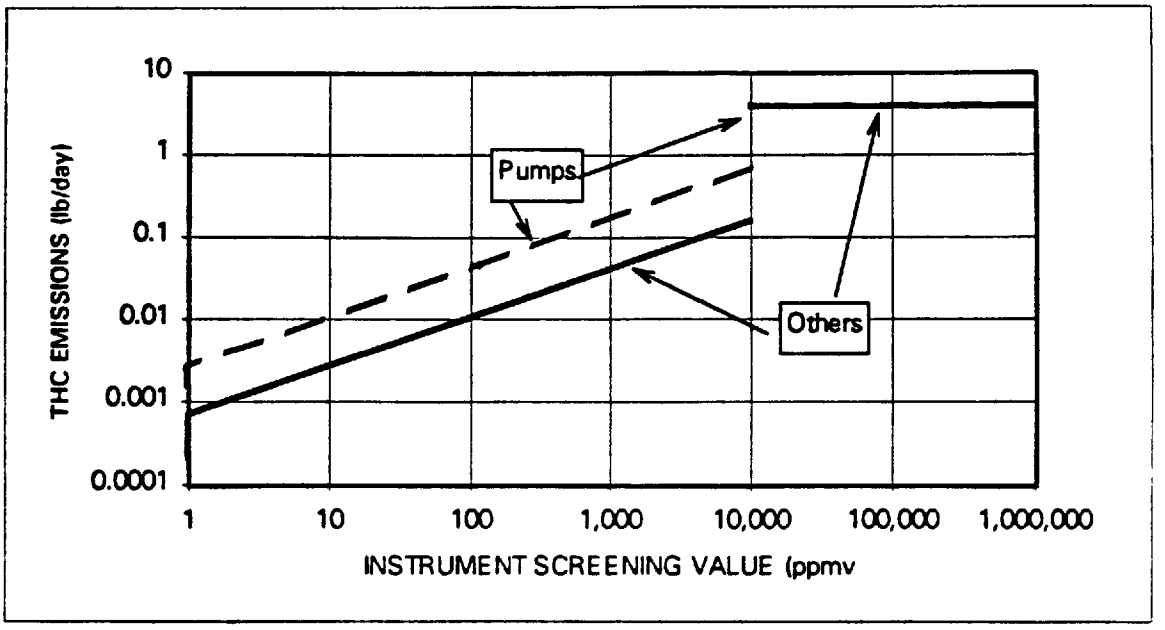


Table 3. Intersection of Default Zeros and Correlation Equations (lb/component-day)

	EPA Default Zero	Equivalent Equation (ppmv)
Connection	0.000441	10.25
Flange	0.000528	3.18
Open End	0.000671	12.40
Pump	0.001621	0.48
Valve	0.000644	9.50
Others	0.000209	0.13

CALCULATION OF EMISSION FACTORS

Emission factors were calculated by adding the contributions of three screening ranges to total emissions: non-emitters, emitters from 10 to 9,999 ppmv, and emitters pegged at 10,000 ppmv (see Table 4).

Contribution from Non-emitters

Adjustment for Minimum Instrument Screening Values. The API database contains 200,094 instrument screening values of less than 10 ppmv (uncorrected for background). It is not

possible in all cases to determine whether the corrected screening values were zero or some number between 1 and 9 ppmv. To be conservative, they were assumed to have screening values of 10 ppmv above background. Emissions from connections and open end lines in this group were calculated using the appropriate EPA default zeros; emission rates for flanges, pumps, valves, and other components in this category were calculated at a screening value of 10 ppmv. Table 4 shows the emission rates used to calculate the emissions of these components.

Table 4. Emission Rates Used for "Non-Emitters" (lb/component-day)

	EPA Default Zero	Equivalent Equation ppmv	Non-Emitter ppmv used	Non-Emitter Emission Rate used
Connection	0.000441	10.25	10.25	0.000441
Flange	0.000528	3.18	10.00	0.001183
Open End	0.000671	12.40	12.40	0.000671
Pump	0.001621	0.48	10.00	0.010348
Valve	0.000644	9.50	10.00	0.000671
Others	0.000209	0.13	10.00	0.002703

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

Adjustment for Flange and Other Connector Designations. The API 1993 database separates components as connection, valve, open-ended line, pump seal, compressor seal, pressure relief valve, instrument, hatch, polished rod stuffing box, dump lever arm, vent, meter, and drain. The database does not differentiate between non-emitting connections and non-emitting flanges; both types of components are included in a single category. Calculations in this report are based on a division of the connections into two categories: flange and other connections. Table 5 shows the assumptions used for assigning components to each category. These assumptions were based on component counts at sites 21 through 24 and additional inventory work at two light crude production sites. The sensitivity of the emission factors to these assumptions is discussed later in this report.

Table 5. Assumptions for Dividing API Connections by Type

Type of Site	Connection	Flange
Onshore Light Crude Production	71%	29%
Onshore Heavy Crude Production	71%	29%
Onshore Gas Production	86%	14%
Onshore Gas Plants	70%	30%
Offshore Oil and Gas Production	79%	21%

Contribution of Emitters from 10 to 9,999 ppmv

EPA correlation equations shown in Table 2 were used to calculate emission rates for components with screening values from 10 to 9,999 ppmv. The API 1993 database differentiates between emitting connections and emitting flanges, therefore no assumptions were necessary for this category of emitters.

Contribution from Emitters That Pegged Instrument at 10,000 ppmv

EPA 10,000 ppmv pegged emission factors shown in Table 2 were used for components with screening values of 10,000 ppmv or more. The API 1993 database differentiates between pegged connections and pegged flanges, therefore no assumptions were necessary for this category of emitters.

Average Emission Factors for Each Site and Each Type of Component

Table 6 contains individual component emission factors (in lb/component-day) for each of the 24 sites except the heavy crude production sites which have been combined. These factors are average factors obtained by combining emissions for each type of component from all three screening ranges (non-emitters; emitters from 10 to 9,999 ppmv; and emitters pegged at 10,000 ppmv) and dividing by the total number of components of that type. Table 7 contains the same factors expressed in kg/component-hour.

Table 8 contains emission factors calculated after the data were grouped by type of site: onshore light crude production (Sites 1 through 4), onshore heavy crude production (Sites 5 through 8), onshore gas production (Sites 9 through 12), onshore gas plants (Sites 13 through 16 and Sites 21 through 24), and offshore oil and gas production (Sites 17 through 20). Table 9 contains the same data expressed in kg/component-hr. 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 6. Average Emission Factors by Site (lb/component-day)

	Connection	Flange	Open End	Pump	Valve	Others
Site 1	1.14E-02	3.48E-03	1.36E-01	1.03E-02	6.11E-02	5.58E-01
Site 2	5.23E-03	5.07E-03	3.93E-02	3.50E-02	1.04E-01	1.72E-01
Site 3	3.38E-03	6.28E-03	3.80E-02	1.03E-02	4.04E-02	4.01E-01
Site 4	9.29E-03	1.21E-03	7.71E-02	1.03E-02	9.21E-02	1.55E+00
Sites 5-8	4.22E-04	1.16E-03	8.18E-03	no data	6.86E-04	3.70E-03
Site 9	1.08E-02	1.20E-02	4.60E-02	1.03E-02	8.15E-02	3.09E-01
Site 10	7.13E-03	1.37E-03	1.97E-02	no data	1.01E-01	1.27E+00
Site 11	4.61E-02	5.60E-03	3.06E-02	1.03E-02	2.78E-01	3.01E-01
Site 12	5.76E-03	1.16E-03	5.92E-02	no data	1.37E-01	3.24E-01
Site 13	9.66E-03	1.72E-02	4.13E-02	2.17E-01	1.47E-01	7.71E-01
Site 14	2.18E-02	2.76E-02	5.12E-02	7.96E-01	2.68E-01	2.42E-01
Site 15	1.22E-02	4.69E-02	6.90E-02	1.22E+00	2.49E-01	4.92E-02
Site 16	2.20E-02	2.63E-02	1.32E-01	1.31E+00	2.84E-01	2.61E-01
Site 17	6.65E-03	9.66E-03	4.40E-02	1.03E-02	2.42E-02	2.10E-01
Site 18	1.90E-03	1.73E-02	7.31E-02	1.03E-02	3.46E-02	1.16E+00
Site 19	3.64E-03	4.22E-03	1.65E-02	1.03E-02	1.33E-02	2.69E-03
Site 20	1.05E-02	1.03E-02	6.41E-02	1.03E-02	4.69E-02	3.00E-01
Site 21	8.08E-03	2.09E-02	7.13E-03	1.03E-02	7.29E-02	4.37E-01
Site 22	8.98E-04	1.54E-02	5.32E-02	1.03E-02	9.03E-03	2.69E-03
Site 23	2.19E-02	1.16E-03	6.86E-04	1.03E-02	2.36E-01	2.69E-03
Site 24	8.18E-03	1.30E-02	6.86E-04	no data	3.84E-01	2.69E-03

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

Table 7. Average Emission Factors by Site (kg/component-hr)

	Connection	Flange	Open End	Pump	Valve	Others
Site 1	2.16E-04	6.60E-05	2.58E-03	1.96E-04	1.16E-03	1.06E-02
Site 2	9.90E-05	9.60E-05	7.44E-04	6.63E-04	1.97E-03	3.27E-03
Site 3	6.40E-05	1.19E-04	7.20E-04	1.96E-04	7.65E-04	7.60E-03
Site 4	1.76E-04	2.30E-05	1.46E-03	1.96E-04	1.75E-03	2.94E-02
Sites 5-8	8.00E-06	2.20E-05	1.55E-04	no data	1.30E-05	7.00E-05
Site 9	2.04E-04	2.28E-04	8.72E-04	1.96E-04	1.54E-03	5.84E-03
Site 10	1.35E-04	2.60E-05	3.73E-04	no data	1.92E-03	2.40E-02
Site 11	8.73E-04	1.06E-04	5.79E-04	1.96E-04	5.26E-03	5.69E-03
Site 12	1.09E-04	2.20E-05	1.12E-03	no data	2.60E-03	6.14E-03
Site 13	1.83E-04	3.25E-04	7.82E-04	4.12E-03	2.78E-03	1.46E-02
Site 14	4.12E-04	5.23E-04	9.69E-04	1.51E-02	5.08E-03	4.58E-03
Site 15	2.31E-04	8.88E-04	1.31E-03	2.31E-02	4.72E-03	9.31E-04
Site 16	4.16E-04	4.98E-04	2.50E-03	2.49E-02	5.38E-03	4.95E-03
Site 17	1.26E-04	1.83E-04	8.34E-04	1.96E-04	4.58E-04	3.97E-03
Site 18	3.60E-05	3.28E-04	1.39E-03	1.96E-04	6.56E-04	2.19E-02
Site 19	6.90E-05	8.00E-05	3.13E-04	1.96E-04	2.51E-04	5.10E-05
Site 20	1.99E-04	1.95E-04	1.21E-03	1.96E-04	8.89E-04	5.69E-03
Site 21	1.53E-04	3.95E-04	1.35E-04	1.96E-04	1.38E-03	8.28E-03
Site 22	1.70E-05	2.91E-04	1.01E-03	1.96E-04	1.71E-04	5.10E-05
Site 23	4.14E-04	2.20E-05	1.30E-05	1.96E-04	4.48E-03	5.10E-05
Site 24	1.55E-04	2.47E-04	1.30E-05	no data	7.27E-03	5.10E-05

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

Table 8. 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.

Table 9. Average Emission Factors by Facility Type (kg/component-hr)

	Connection	Flange	Open End	Pumps	Valve	Others
Light Crude	1.64E-04	7.70E-05	1.21E-03	3.18E-04	1.33E-03	7.53E-03
Heavy Crude	8.00E-06	2.20E-05	1.55E-04	no data	1.30E-05	7.00E-05
Gas Production	3.22E-04	1.18E-04	6.87E-04	1.96E-04	2.63E-03	9.20E-03
Gas Plants	2.74E-04	4.39E-04	1.04E-03	1.15E-02	3.87E-03	4.87E-03
Offshore	1.08E-04	1.97E-04	1.02E-03	1.96E-04	5.16E-04	6.95E-03

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

On the following pages, Figures 4-8 compare the individual and group emission factors. The group emission factors are shown as shaded columns behind the narrow columns representing individual emission factors.

Figure 4

AVERAGE EMISSION FACTORS FOR LIGHT CRUDE PRODUCTION FACILITIES

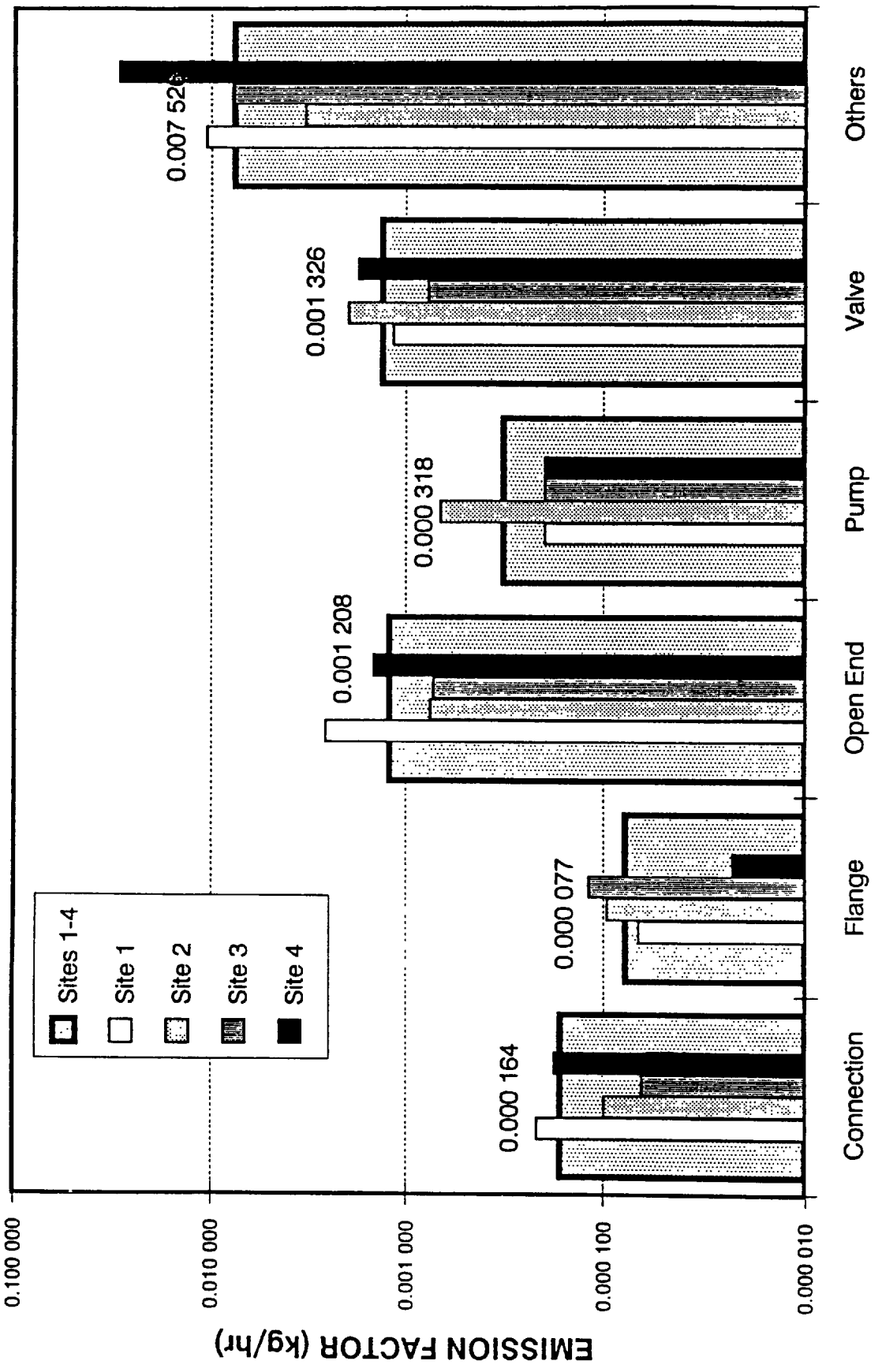


Figure 5

AVERAGE EMISSION FACTORS FOR HEAVY CRUDE PRODUCTION FACILITIES

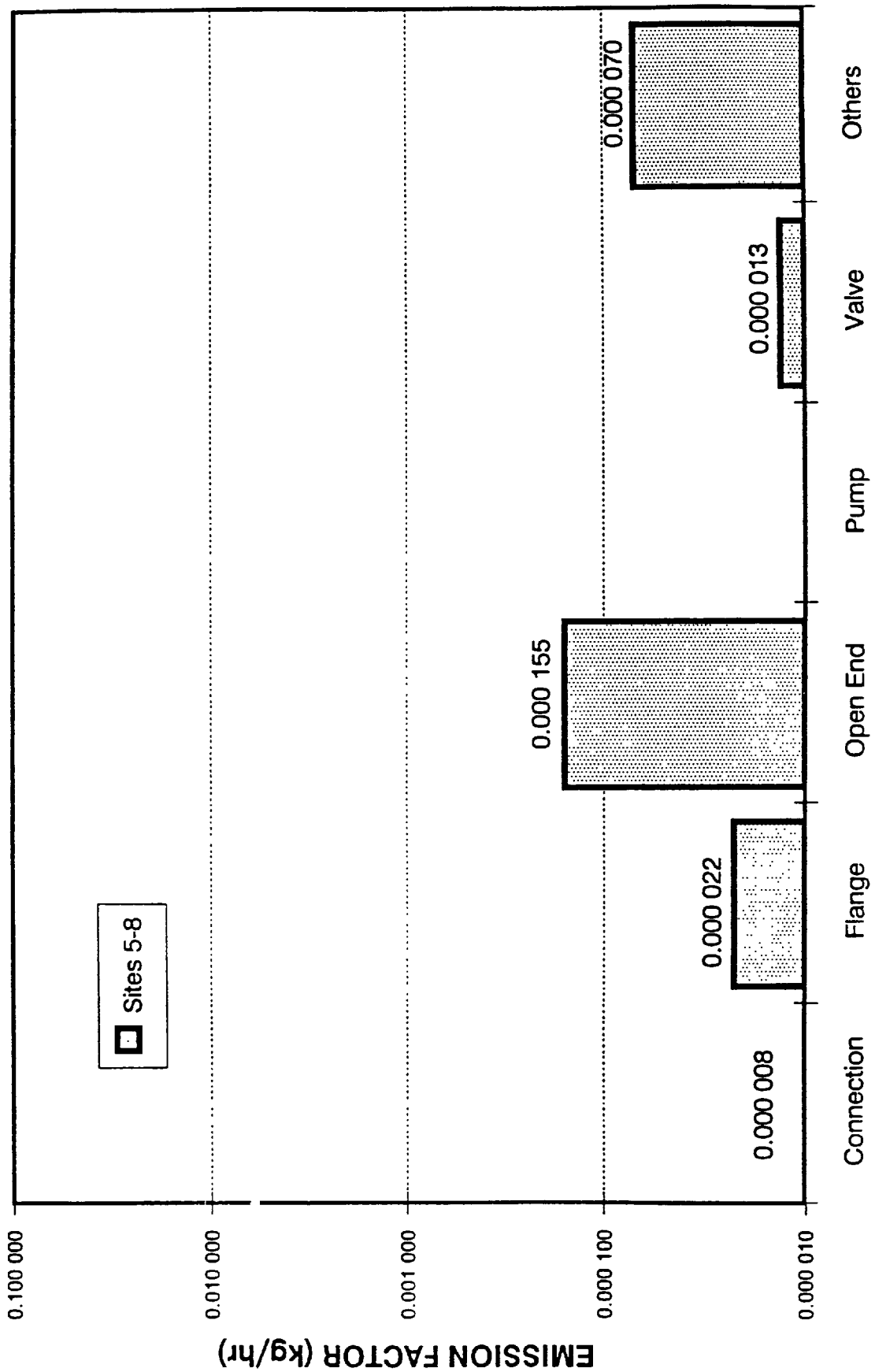


Figure 6

AVERAGE EMISSION FACTORS FOR GAS PRODUCTION FACILITIES

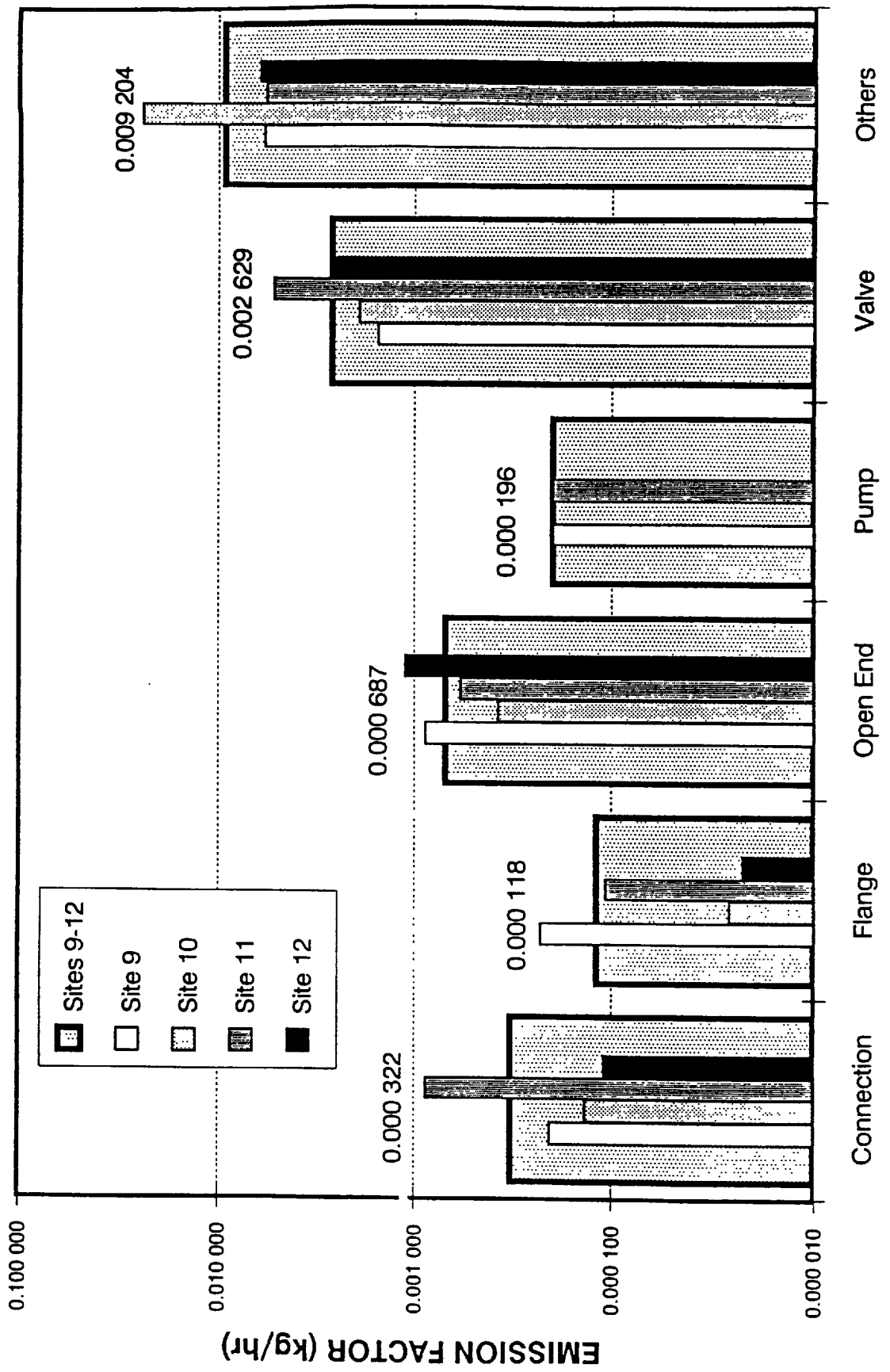


Figure 7

AVERAGE EMISSION FACTORS FOR GAS PLANTS

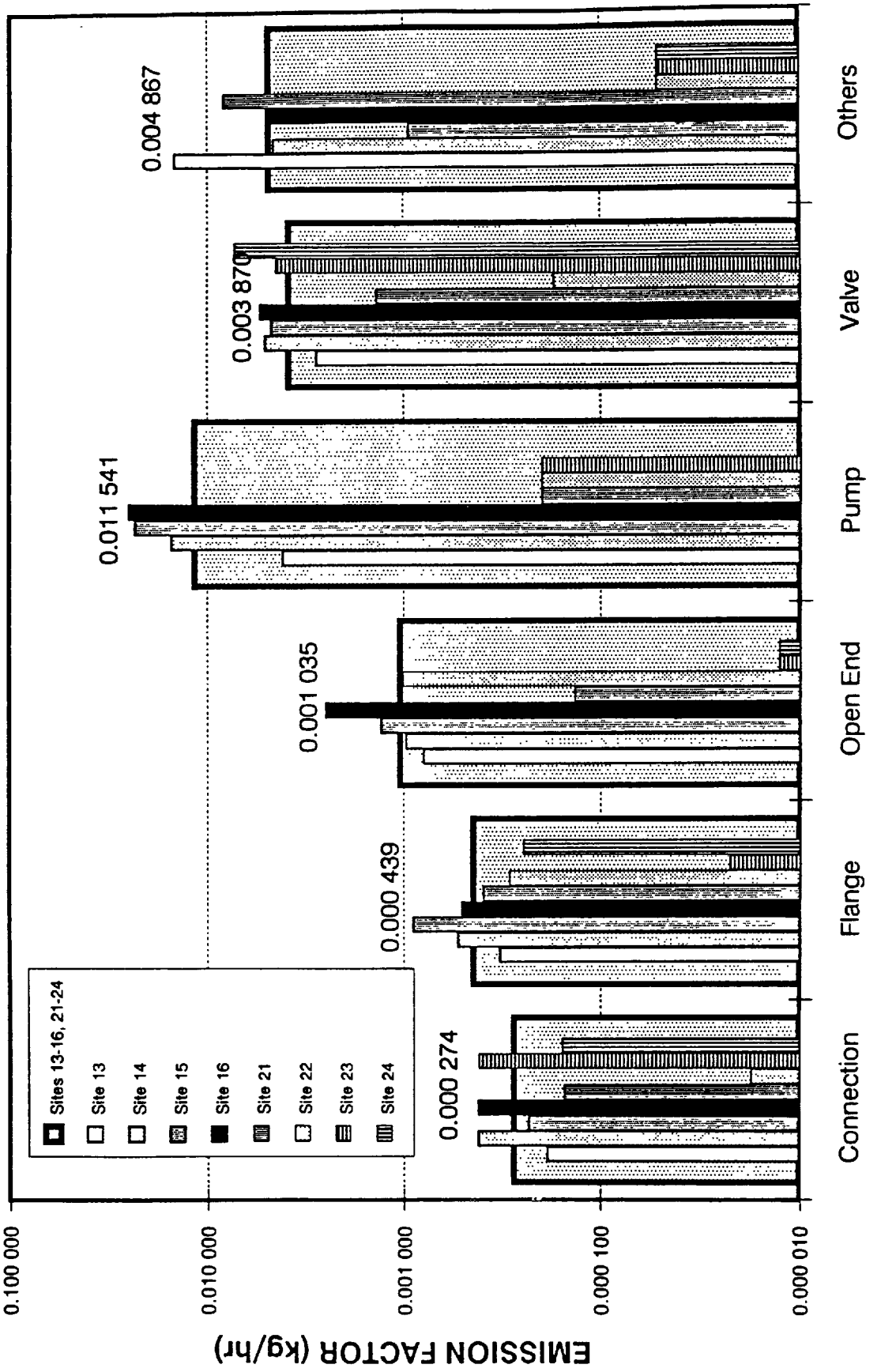
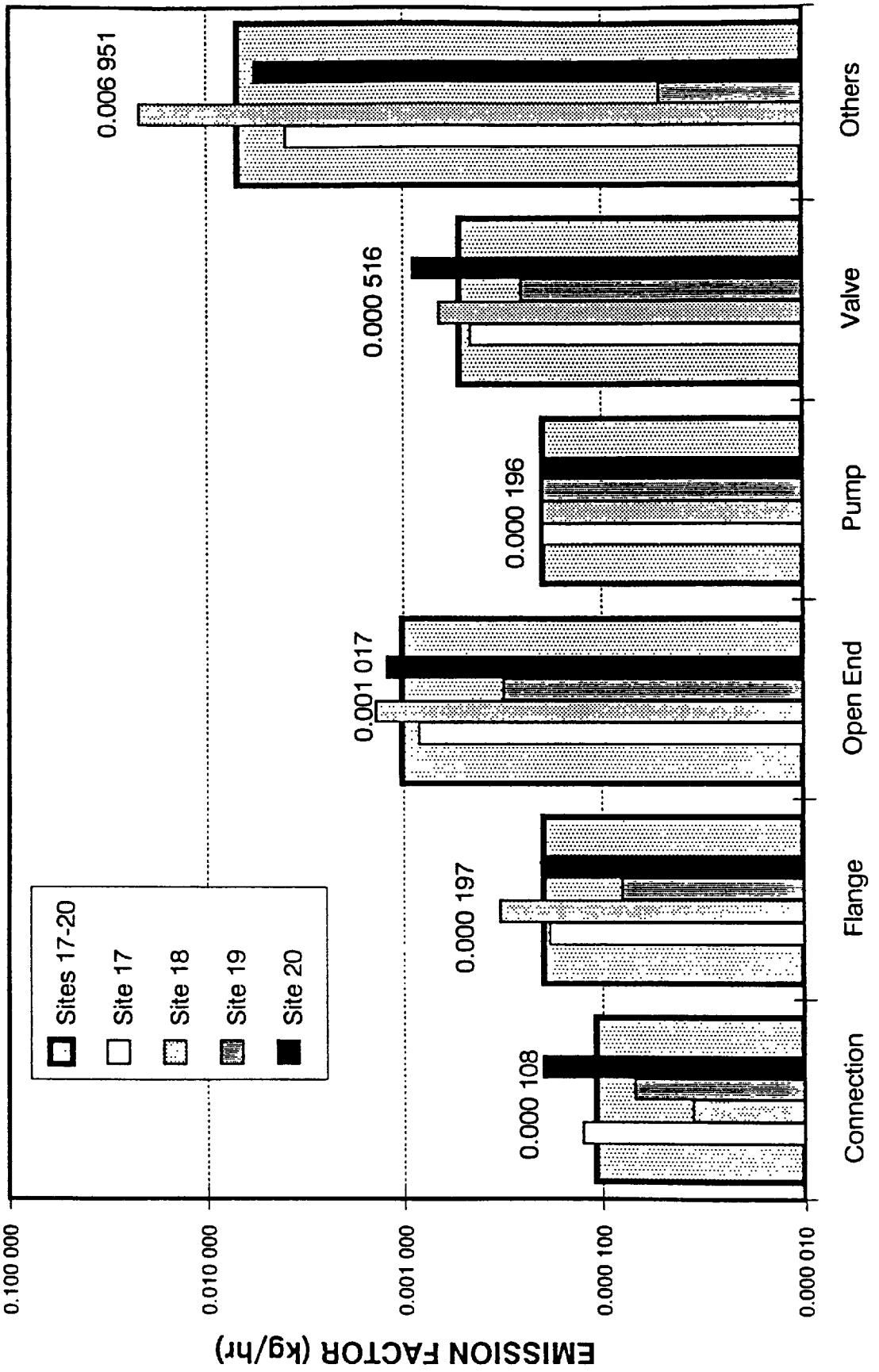


Figure 8

AVERAGE EMISSION FACTORS FOR OFFSHORE PRODUCTION FACILITIES



Leak/No-leak Emission Factors for Each Type of Facility

Leak/no-leak emission factors were calculated for each type of facility (onshore light crude production; onshore heavy crude production; onshore gas production; onshore gas plants; and offshore production) using a leak definition of 10,000 ppmv. The Leak factors for all sites and component types are the EPA 10,000 ppmv pegged source values. The No-leak factors were calculated by adding the emissions from all components with screening values of 9,999 ppmv or less (including default zero components) and dividing by the total number of components. Table 10 gives the Leak/No-leak emission factors in lb/component-day; Table 11 gives the factors in kg/component-hr.

Table 10. Leak/no-leak Emission Factors by Facility Type (lb/component-day)

	Connection	Flange	Open End	Pump	Valve	Others
≥10,000 ppmv						
All Facilities	1.497	4.490	1.600	3.905	3.381	3.846
<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	1.03E02	8.50E-04	3.76E-03

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

Table 11. Leak/no-leak Emission Factors by Facility Type (kg/component-hr)

	Connection	Flange	Open End	Pump	Valve	Others
≥10,000 ppmv						
All Facilities	0.02836	0.08504	0.03031	0.07395	0.06403	0.07285
<10,000 ppmv						
Light Crude	9.94E-06	2.35E-05	2.85E-05	3.18E-04	2.10E-05	1.71E-04
Heavy Crude	8.35E-06	2.25E-05	1.68E-05	no data	1.32E-05	6.96E-05
Gas Production	1.20E-05	2.47E-05	2.39E-05	1.96E-04	3.08E-05	1.50E-04
Gas Plants	1.09E-05	2.73E-05	3.06E-05	8.14E-04	3.42E-05	1.72E-04
Offshore	9.67E-06	2.51E-05	1.78E-05	1.96E-04	1.61E-05	7.12E-05

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

ANALYSIS OF EMISSION FACTORS

Site to Site Comparison of Average Emission Factors

Individual emission factors for onshore light crude production sites vary slightly from one site to another. The variation is random; none of the sites has emissions factors that are consistently higher or lower than the average emission factors for the four sites. The same is generally true of emission factors for onshore gas production sites. Emission factors for Site 10 are lower than the average in most cases, but the difference is only slight for valves and open end lines.

Individual emission factors for onshore gas plants are fairly consistent for the three main categories: connection, flange, and valve. Individual emission factors for Sites 21 and 22 are lower than 5 of the 6 average factors. These sites processed natural gas with a hydrogen sulfide content of 2 percent and greater, consequently, equipment inspection and maintenance activities were at a relatively high level.

Individual emission factors for offshore oil and gas production platforms vary from site to site. Individual emission factors for Site 19 are slightly lower than the average emission factor for the four sites.

Comparison of Leak/no-leak Emission Factors

No-leak factors are all extremely small compared to Leak factors, the largest (for pumps) still being no more than 4% of the Leak factors.

Comparison to API 1993 E&P Emission Factors

Table 12 shows emission factors given in the 1993 API report; the units are pounds of hydrocarbon emissions per component-day. Table 13 shows the same emission factors converted to kilograms per component-hour. The API report did not contain emission factors for gas plants.

Table 12. Average API 1993 THC Emission Factors (lb/component-day)

	Connection	Valve	Open End	Others
Onshore Light Crude	4.10E-03	1.97E-02	3.51E-02	9.91E-02
Onshore Heavy Crude	1.00E-04	2.00E-04	1.00E-03	7.00E-04
Onshore Gas Production	3.80E-03	1.06E-01	1.07E-02	2.87E-01
Offshore Oil and Gas	6.00E-04	2.17E-02	9.90E-03	1.04E-01

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

Table 13. Average API 1993 THC Emission Factors (kg/component-hr)

	Connection	Valve	Open End	Others
Onshore Light Crude	7.77E-05	3.73E-04	6.65E-04	1.88E-03
Onshore Heavy Crude	1.89E-06	3.79E-06	1.89E-05	1.33E-05
Onshore Gas Production	7.20E-05	2.01E-03	2.03E-04	5.44E-03
Offshore Oil and Gas	1.14E-05	4.11E-04	1.88E-04	1.96E-03

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

Table 14 compares the emission factors developed in this report to the 1993 API factors. Figures 9 through 13 compare the factors graphically.

Table 14. Comparison of Average Emission Factors (kg/component-hr)

	Connection	Flange	Open End	Pump (Lt Liq)	Valve (Gas)	Others
Light Crude (New)	1.64E-04	7.70E-05	1.21E-03	3.18E-04	1.33E-03	7.53E-03
Light Crude (API 1993)	7.80E-05	7.80E-05	6.65E-04	1.88E-03	3.73E-04	1.88E-03
Heavy Crude (New)	8.00E-06	2.20E-05	1.55E-04	no data	1.30E-05	7.00E-05
Heavy Crude (API 1993)	2.00E-06	2.00E-06	1.90E-05	1.30E-05	4.00E-06	1.30E-05
Gas Production (New)	3.22E-04	1.18E-04	6.87E-04	1.96E-04	2.63E-03	9.20E-03
Gas Production (API 1993)	7.20E-05	7.20E-05	2.03E-04	5.44E-03	2.01E-03	5.44E-03
Offshore (New)	1.08E-04	1.97E-04	1.02E-03	1.96E-04	5.16E-04	6.95E-03
Offshore (API 1993)	1.10E-05	1.10E-05	1.88E-04	1.96E-03	4.11E-04	1.96E-03
Gas Plants (New)	2.74E-04	4.39E-04	1.04E-03	1.15E-02	3.87E-03	4.87E-03

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

Figure 9
Connection Emission Factors

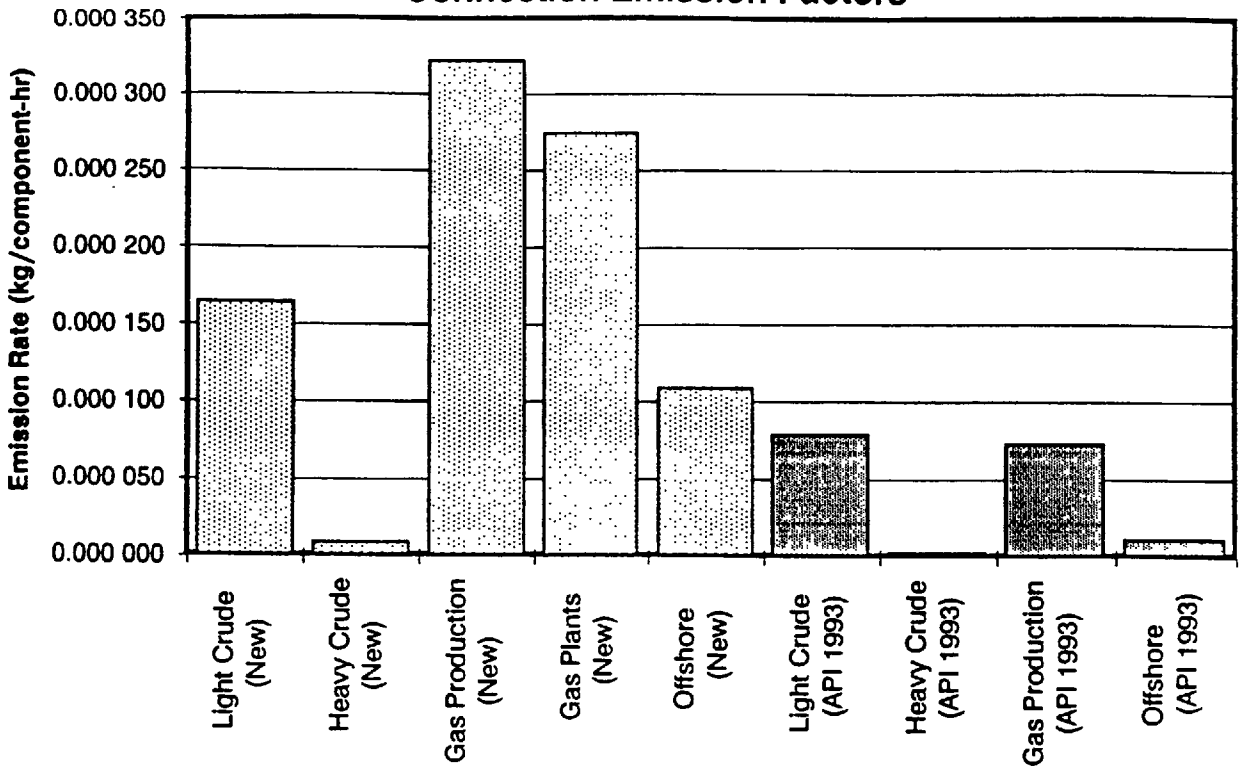


Figure 10
Flange Emission Factors

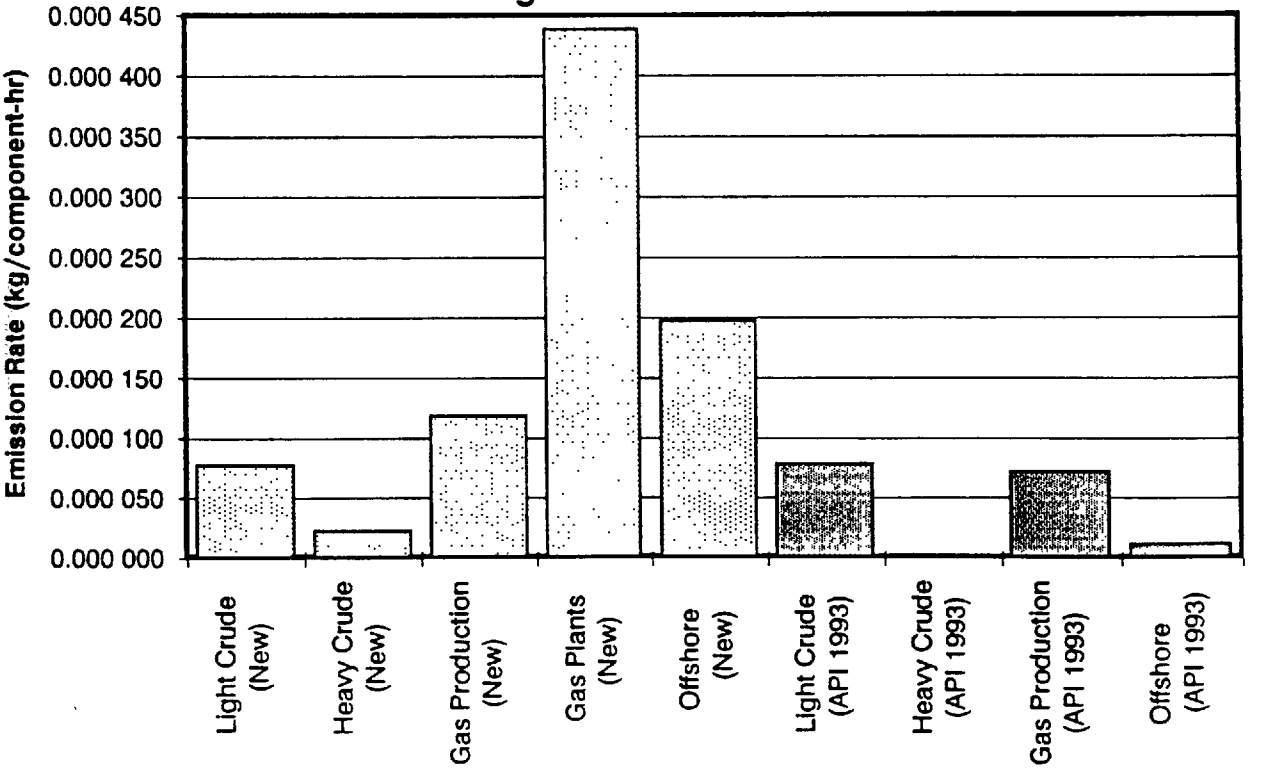


Figure 11

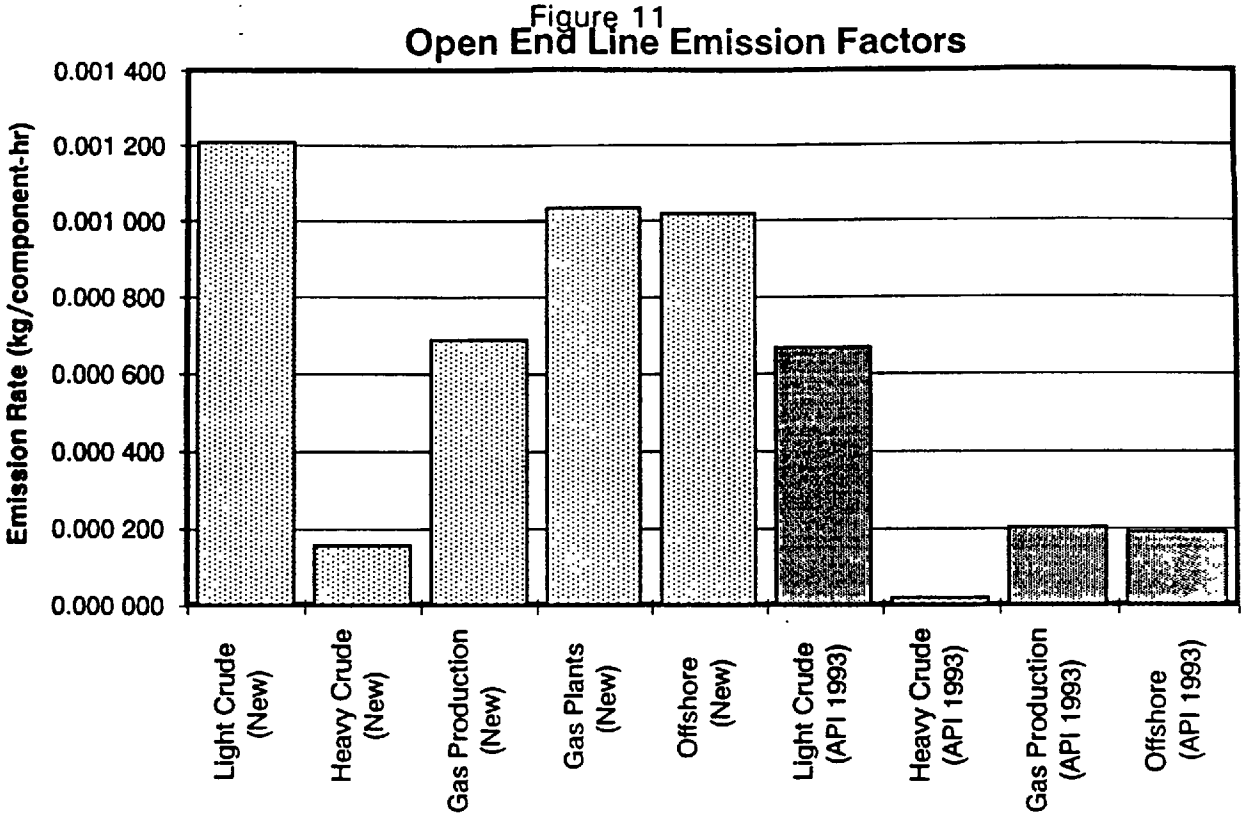


Figure 12

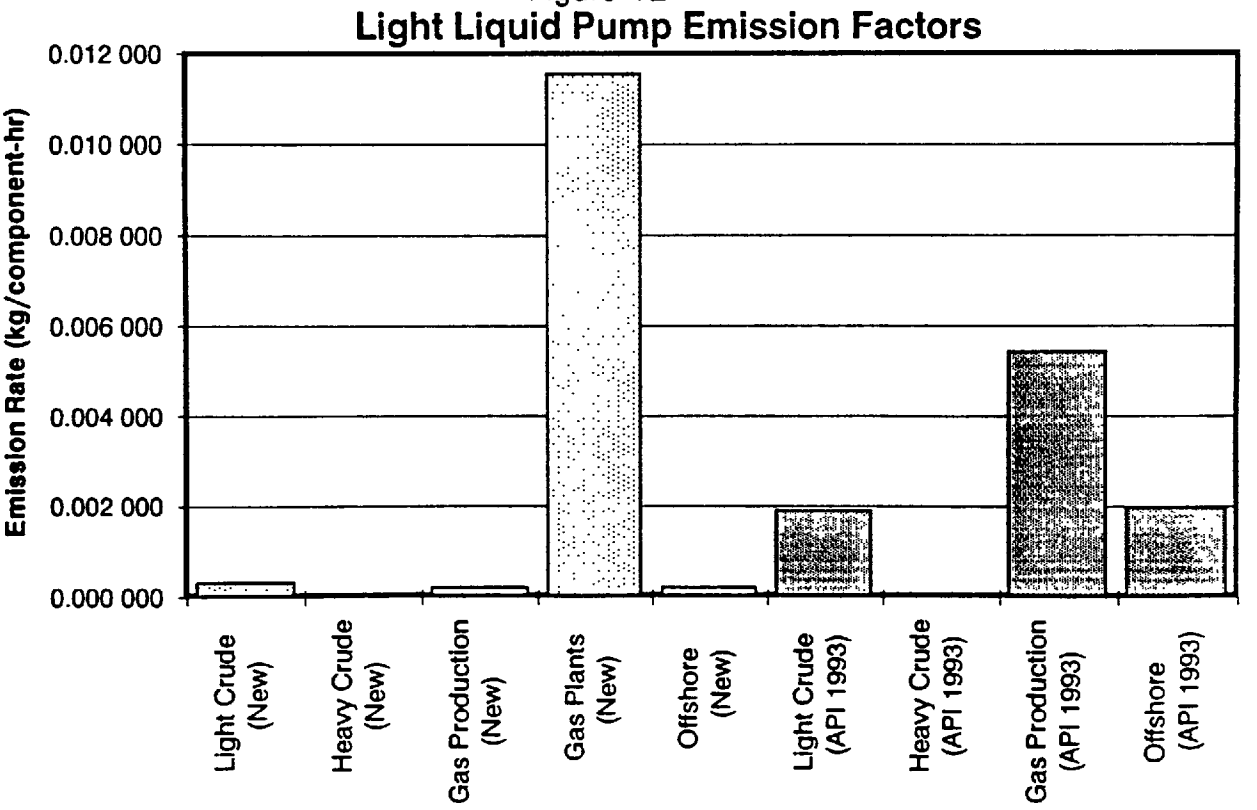
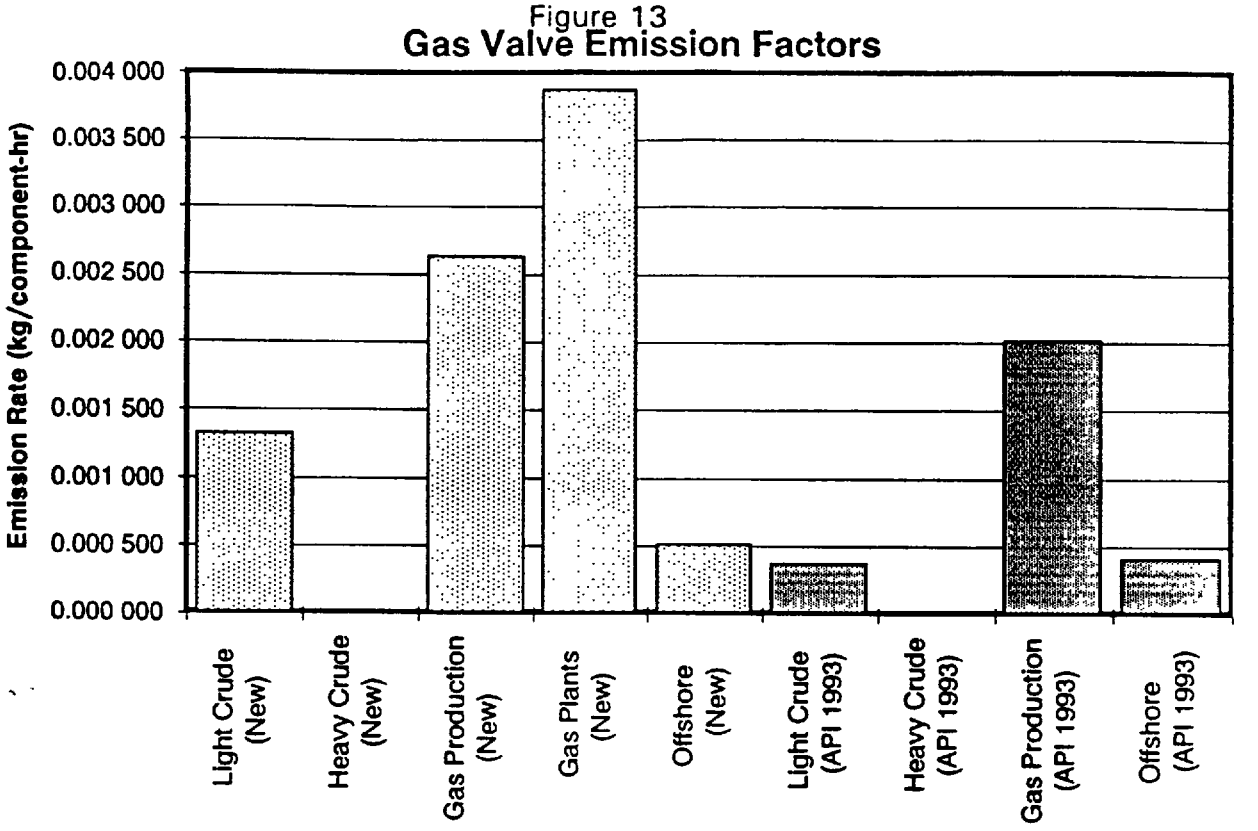


Figure 13



Sensitivity of Average Emission Factors to Screening Values

Table 15 shows the contribution of each screening range to the average emission factors.

Table 15. Contribution of Each Screening Range to Average Emission Factors

	Emission Factor (lb/day)	Emission Factor (kg/hr)	Contribution by Screening Range		
			Non-emitter	10 to 9,999 ppmv	≥ 10,000 ppmv
Light Crude					
Connection	8.66E-03	1.64E-04	5%	1%	94%
Flange	4.07E-03	7.70E-05	29%	1%	70%
Open End	6.38E-02	1.21E-03	1%	1%	98%
Pump	1.68E-02	3.18E-04	59%	41%	0%
Valve	7.00E-02	1.33E-03	1%	1%	98%
Others	3.97E-01	7.53E-03	0%	2%	98%
Heavy Crude					
Connection	4.22E-04	8.00E-06	100%	0%	0%
Flange	1.16E-03	2.20E-05	100%	0%	0%
Open End	8.18E-03	1.55E-04	8%	3%	89%
Pump	no data	no data	no data	no data	no data
Valve	6.86E-04	1.30E-05	96%	4%	0%
Others	3.70E-03	7.00E-05	63%	37%	0%
Gas Prod.					
Connection	1.70E-02	3.22E-04	3%	1%	96%
Flange	6.23E-03	1.18E-04	19%	2%	79%
Open End	3.63E-02	6.87E-04	2%	2%	97%
Pump	1.03E-02	1.96E-04	100%	0%	0%
Valve	1.39E-01	2.63E-03	0%	1%	99%
Others	4.86E-01	9.20E-03	0%	1%	99%
Gas Plant					
Connection	1.45E-02	2.74E-04	3%	1%	96%
Flange	2.32E-02	4.39E-04	5%	1%	94%
Open End	5.46E-02	1.04E-03	1%	2%	97%
Pump	6.09E-01	1.15E-02	1%	5%	94%
Valve	2.04E-01	3.87E-03	0%	1%	99%
Others	2.57E-01	4.87E-03	1%	2%	97%
Offshore					
Connection	5.70E-03	1.08E-04	8%	1%	91%
Flange	1.04E-02	1.97E-04	11%	2%	87%
Open End	5.37E-02	1.02E-03	1%	1%	98%
Pump	1.03E-02	1.96E-04	100%	0%	0%
Valve	2.72E-02	5.16E-04	2%	1%	97%
Others	3.67E-01	6.95E-03	1%	0%	99%

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

In most cases, over 90% of the average emission factor comes from pegged sources. The exceptions are heavy crude emission factors, some pump emission factors, and some flange emission factors. The contribution of components with screening values between 10 and 9,999 ppmv seldom exceeds 2%. The contribution of non-emitters is generally less than 10%.

SPECIATION OF EMISSIONS

Recalculation of the emission factors did not change the speciation factors presented in API Publication No. 4589. The factors are shown in Table 16. Emission rates for individual hydrocarbon species can be calculated by multiplying total hydrocarbon emissions obtained using emission factors by the weight fractions given in Table 16.

Table 16. Speciated Fugitive Emission Factors
(Weight Fraction of THC emissions in each category)

	Methane	NMHC	VOC	C6+	Benzene	Toluene	E-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

SUMMARY AND CONCLUSIONS

Emission factors were developed from instrument screening data gathered at 24 sites and the August 1994 EPA correlation equations. 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 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.

REFERENCES

EPA Bulletin Board Announcement, August 4, 1994, Emission Correlation Equations

Environmental Protection Agency, 1993. *Protocol for Equipment Leak Emission Estimates.* U.S. EPA Office of Air Quality Planning and Standards. Research Triangle Park, NC.

Radian Corporation, 1993. *Development of Fugitive Emission Factors and Emission Profiles for Petroleum Marketing Terminals.* Volume I: Text. API Publication No. 4588. American Petroleum Institute. Washington, D.C.

Radian Corporation, 1993. *Development of Fugitive Emission Factors and Emission Profiles for Petroleum Marketing Terminals.* Volume II: Appendices. API Publication No. 45881. American Petroleum Institute. Washington, D.C.

Radian Corporation, 1994. *Study of Refinery Fugitive Emissions from Equipment Leaks.* API Publication No. 4612. American Petroleum Institute. Washington, D.C.

Radian Corporation, 1994. *Study of Refinery Fugitive Emissions from Equipment Leaks: Appendices.* API Publication No. 4613. American Petroleum Institute. Washington, D.C.

Star Environmental, 1993. *Fugitive Hydrocarbon Emissions from Oil and Gas Production Operations.* API Publication No. 4589. American Petroleum Institute. Washington, D.C.

APPENDIX A
FIELD INVENTORY SHEET DATA

SITE	AREA	Flange	Connection	Valve	Open End	Comp. Seal	Pump Seal	Pressure Relief Valve	Other	ALL	EMITTERS BY SCREENING RANGE (ppmv)				
											10 to 99	100 to 999	1000 to 9,999	10,000+	ALL
21	1	126	82	63	0	0	0	0	0	271	0	1	0	0	1
21	2	142	8	65	0	0	0	0	0	215	1	0	0	0	1
21	3	245	66	126	0	0	0	0	0	437	0	1	2	1	4
21	4	251	4	102	1	0	0	0	0	358	0	1	1	1	3
21	5	43	0	20	0	0	0	0	0	63	0	1	1	0	2
21	6	203	231	119	2	0	2	0	0	557	0	1	0	1	2
21	7	157	31	82	4	0	2	0	0	276	3	0	1	0	4
21	8	87	0	49	0	0	0	0	0	136	0	2	1	0	3
21	9	37	28	22	0	0	0	3	0	90	1	3	0	4	8
21	10	31	0	24	0	0	0	10	0	65	0	2	1	1	4
21	11	18	13	72	1	0	0	0	0	104	0	0	0	0	0
21	12	130	39	60	0	2	0	0	0	231	1	0	2	0	3
21	13	146	14	83	1	0	0	0	0	244	0	0	1	1	2
21	14	77	0	42	0	0	0	0	0	119	0	1	0	0	1
21	15	125	315	28	0	0	0	0	0	468	0	4	4	3	11
21	16	126	294	28	0	0	0	0	0	448	0	0	3	0	3
21	17	104	283	54	0	0	0	0	8	449	1	9	1	5	16
21	18	131	53	79	0	0	0	0	0	263	0	2	2	5	9
21	19	47	16	33	0	0	0	0	0	96	0	1	1	1	3
21	20	117	112	61	0	0	0	1	0	291	0	7	7	1	15
21	21	94	102	63	7	0	11	0	0	277	0	3	3	2	8
21	22	147	54	79	0	0	0	0	0	280	0	11	9	18	38
21	23	184	58	114	0	0	0	12	0	368	0	4	8	12	24
		824	1,803	483	7	0	11	13	8	2,024	7	54	48	56	165

SITE	AREA	Flange	Connection	Valve	Open End	Comp. Seal	Pump Seal	Pressure Relief Valve	Other	ALL	EMITTERS BY SCREENING RANGE (ppmv)				
											10 to 99	100 to 999	1000 to 9,999	10,000+	ALL
22	1	7	118	27	0	0	0	0	0	152	0	0	0	0	0
22	2	7	31	18	0	0	0	0	0	56	0	0	0	0	0
22	3	14	139	43	2	0	0	0	0	198	0	1	1	0	2
22	4	20	194	49	3	0	0	0	0	266	0	0	0	0	0
22	5	4	100	23	2	0	0	0	0	129	0	0	0	0	0
22	6	15	146	48	3	0	0	0	0	212	0	0	0	0	0
22	7	13	135	43	4	0	0	0	0	195	1	0	0	1	2
22	8	26	201	79	4	0	0	1	0	311	0	0	0	0	0
22	9	11	270	74	6	0	0	0	0	361	0	0	0	0	0
22	10	8	54	26	0	0	0	0	0	88	0	0	0	0	0
22	11	5	25	11	0	0	0	0	0	41	0	1	1	1	3
22	12	15	155	42	4	0	0	1	0	217	0	0	0	0	0
22	13	4	6	3	0	0	0	0	0	13	0	0	0	0	0
22	14		46	4						50	0	0	0	1	1
22	15	3	48	10	0	0	0	1	0	62	0	0	0	0	0
22	16	37	278	70	13	0	6	7	0	411	0	0	0	0	0
22	17	11	84	27	4	0	0	0	0	126	0	0	0	0	0
22	18	35	264	59	5	0	0	0	0	363	0	0	0	0	0
22	19	46	305	82	4	0	C	0	0	437	0	3	1	3	7
22	20	36	606	75	7	0	0	0	0	724	0	1	0	0	1
		128	3,205	243	20	0	0	0	0	1,650	1	6	3	6	16

SITE	AREA	Flange	Connection	Valve	Open End	Comp. Seal	Pump Seal	Pressure Relief Valve	Other	ALL	EMITTERS BY SCREENING RANGE (ppmv)				
											10 to 99	100 to 999	1000 to 9,999	10,000+	ALL
23	1	86	65	52	0	0	0	0	0	203	0	0	1	3	4
23	2	112	135	119	8	0	0	4	0	378	0	0	1	0	1
23	3	63	300	155	0	0	4	0	0	522	0	5	3	10	18
23	4	32	14	34	3	0	0	1	0	84	0	0	0	0	0
23	5	97	192	111	2	0	2	1	0	405	0	0	0	0	0
23	6	81	167	104	3	0	3	2	0	360	0	0	0	0	0
23	7	23	82	48	0	0	0	0	0	153	0	1	0	2	3
23	8	12	66	39	1	0	0	1	0	119	1	0	0	3	4
23	9	20	53	34	1	0	0	1	0	109	0	0	0	2	2
23	10	4	94	63	0	0	2	0	0	163	1	0	0	1	2
23	11	46	69	44	0	0	0	0	0	159	0	0	2	11	13
23	12	115	163	95	0	0	0	2	0	375	0	1	1	1	3
23	13	34	113	57	3	0	2	0	0	209	0	0	0	1	1
23	14	21	167	107	0	0	6	2	0	303	0	0	0	0	0
23	15	54	114	79	1	0	4	0	0	252	0	1	1	4	6
23	16	71	146	93	3	0	0	0	0	313	0	1	2	15	18
23	17	18	78	36	1	0	0	0	0	133	0	0	0	3	3
23	18	72	97	84	4	0	0	2	0	259	0	0	8	23	31
23	19	92	272	72	0	0	0	1	0	437	0	0	0	0	0
23	20	187	1,606	0	0	0	0	0	0	1,793	0	0	0	99	99
23	21	55	144	52	0	0	0	0	0	251	0	0	0	7	7
23	22	55	36	37	0	0	0	0	0	128	0	0	0	0	0
23	23	106	670	151	0	0	0	12	0	939	0	0	0	0	0
		567	4,843	396	4	0	0	15	0	3,807	2	9	19	185	215

SITE	AREA	Flange	Connection	Valve	Open End	Comp. Seal	Pump Seal	Pressure Relief Valve	Other	ALL	EMITTERS BY SCREENING RANGE (ppmv)				
											10 to 99	100 to 999	1000 to 9,999	10,000+	ALL
24	1	22	42	24	0	0	0	0	0	88	0	0	0	3	3
24	2	24	38	39	0	0	0	0	0	101	0	0	0	11	11
24	3	30	105	52	1	0	0	0	0	188	0	0	0	3	3
24	4	38	73	56	3	0	0	0	0	170	0	0	0	19	19
24	5	34	92	93	3	0	0	1	0	223	0	0	1	11	12
24	6	24	205	112	2	0	0	0	0	343	0	0	0	4	4
24	7	10	66	0	0	0	0	0	0	76	0	0	0	2	2
24	8	5	10	15	0	0	0	0	0	30	0	0	0	0	0
24	9	48	210	175	3	0	0	2	0	438	0	0	1	20	21
24	10	56	178	55	0	0	0	0	0	289	0	0	0	19	19
24	11	28	153	70	1	0	0	1	0	253	0	0	0	9	9
24	12	26	232	87	0	0	0	0	0	345	0	0	3	5	8
24	13	34	141	78	0	0	0	0	0	253	0	0	0	0	0
		192	1,545	465	4	0	0	3	0	1,578	0	0	0	0	0
											0	0	5	106	111

APPENDIX B
EMITTER DATA

SITE	TYPE	PPMV
21	Threaded	FlameOut
21	Threaded	10,000
21	Threaded	10,000
21	Threaded	10,000
21	Threaded	5,000
21	Threaded	4,000
21	Threaded	3,000
21	Threaded	1,600
21	Threaded	1,000
21	Threaded	1,000
21	Threaded	1,000
21	Threaded	1,000
21	Threaded	500
21	Threaded	500
21	Threaded	400
21	Threaded	300
21	Threaded	300
21	Threaded	300
21	Threaded	300
21	Threaded	200
21	Threaded	150
21	Threaded	150
21	Threaded	50
21	Tubing	FlameOut
21	Tubing	FlameOut
21	Tubing	10,000
21	Tubing	10,000
21	Tubing	10,000
21	Tubing	3,000
21	Tubing	250
21	Tubing	100
21	Flange	FlameOut
21	Flange	10,000
21	Flange	10,000
21	Flange	10,000

SITE	TYPE	PPMV
21	Flange	10,000
21	Flange	10,000
21	Flange	10,000
21	Flange	10,000
21	Flange	10,000
21	Flange	10,000
21	Flange	10,000
21	Flange	5,000
21	Flange	2,000
21	Flange	1,500
21	Flange	1,500
21	Flange	1,000
21	Flange	1,000
21	Flange	1,000
21	Flange	500
21	Flange	500
21	Flange	400
21	Flange	400
21	Flange	300
21	Flange	300
21	Flange	250
21	Flange	200
21	Flange	200
21	Flange	200
21	Flange	200
21	Flange	200
21	Flange	100
21	Flange	100
21	Flange	100
21	Flange	50

SITE	TYPE	PPMV
21	Flange	50
21	Flange	50
21	Valve	FlameOut
21	Valve	FlameOut
21	Valve	FlameOut
21	Valve	FlameOut
21	Valve	FlameOut
21	Valve	FlameOut
21	Valve	FlameOut
21	Valve	FlameOut
21	Valve	FlameOut
21	Valve	FlameOut
21	Valve	FlameOut
21	Valve	10,000
21	Valve	10,000
21	Valve	10,000
21	Valve	10,000
21	Valve	10,000
21	Valve	10,000
21	Valve	10,000
21	Valve	10,000
21	Valve	10,000
21	Valve	10,000
21	Valve	10,000
21	Valve	10,000
21	Valve	10,000
21	Valve	10,000
21	Valve	10,000
21	Valve	10,000
21	Valve	9,000
21	Valve	9,000

SITE	TYPE	PPMV
21	Valve	8,000
21	Valve	4,000
21	Valve	4,000
21	Valve	3,000
21	Valve	3,000
21	Valve	2,000
21	Valve	2,000
21	Valve	2,000
21	Valve	2,000
21	Valve	2,000
21	Valve	2,000
21	Valve	2,000
21	Valve	2,000
21	Valve	1,800
21	Valve	1,800
21	Valve	1,500
21	Valve	1,500
21	Valve	1,500
21	Valve	1,400
21	Valve	1,250
21	Valve	1,200
21	Valve	1,200
21	Valve	1,000
21	Valve	1,000
21	Valve	900
21	Valve	900
21	Valve	700
21	Valve	700
21	Valve	700
21	Valve	700
21	Valve	600
21	Valve	600
21	Valve	600
21	Valve	500
21	Valve	500

SITE	TYPE	PPMV
21	Valve	500
21	Valve	350
21	Valve	300
21	Valve	300
21	Valve	200
21	Valve	200
21	Valve	150
21	Valve	100
21	Valve	100
21	Valve	100
21	Valve	100
21	Valve	50
21	Valve	50
21	Valve	50
21	OpenEnd	6,000
21	OpenEnd	5,000
21	OpenEnd	300
21	OpenEnd	200
21	PressureRelief	FlameOut
21	PressureRelief	5,000
21	Vent	FlameOut
21	Vent	FlameOut
21	Vent	FlameOut
21	Vent	5,000
21	Vent	1,200

SITE	TYPE	PPMV

SITE	TYPE	PPMV

SITE	TYPE	PPMV

SITE	TYPE	PPMV
22	Threaded	FlameOut
22	Threaded	4,000
22	Threaded	1,000
22	Threaded	200
22	Threaded	200
22	Tubing	500
22	Tubing	100
22	Flange	10,000
22	Flange	50
22	Valve	10,000
22	Valve	10,000
22	Valve	4,000
22	Valve	900
22	OpenEnd	FlameOut
22	OpenEnd	10,000
22	OpenEnd	200

SITE	TYPE	PPMV

SITE	TYPE	PPMV

SITE	TYPE	PPMV

SITE	TYPE	PPMV	SITE	TYPE	PPMV	SITE	TYPE	PPMV	SITE	TYPE	PPMV
23	Threaded	FlameOut	23	Threaded	10,000	23	Tubing	10,000	23	Valve	FlameOut
23	Threaded	FlameOut	23	Threaded	10,000	23	Tubing	10,000	23	Valve	FlameOut
23	Threaded	FlameOut	23	Threaded	10,000	23	Tubing	10,000	23	Valve	FlameOut
23	Threaded	FlameOut	23	Threaded	10,000	23	Tubing	10,000	23	Valve	FlameOut
23	Threaded	FlameOut	23	Threaded	10,000	23	Tubing	10,000	23	Valve	FlameOut
23	Threaded	FlameOut	23	Threaded	10,000	23	Tubing	10,000	23	Valve	FlameOut
23	Threaded	FlameOut	23	Threaded	10,000	23	Tubing	10,000	23	Valve	FlameOut
23	Threaded	FlameOut	23	Threaded	10,000	23	Tubing	10,000	23	Valve	FlameOut
23	Threaded	FlameOut	23	Threaded	10,000	23	Tubing	10,000	23	Valve	FlameOut
23	Threaded	FlameOut	23	Threaded	10,000	23	Tubing	1,200	23	Valve	FlameOut
23	Threaded	FlameOut	23	Threaded	10,000	23	Tubing	800	23	Valve	FlameOut
23	Threaded	FlameOut	23	Threaded	10,000	23	Tubing	700	23	Valve	FlameOut
23	Threaded	FlameOut	23	Threaded	10,000	23	Tubing	500	23	Valve	FlameOut
23	Threaded	FlameOut	23	Threaded	10,000	23	Tubing	200	23	Valve	FlameOut
23	Threaded	10,000	23	Threaded	10,000	23	Tubing	200	23	Valve	FlameOut
23	Threaded	10,000	23	Threaded	10,000	23	Tubing	200	23	Valve	FlameOut
23	Threaded	10,000	23	Threaded	10,000	23	Valve	FlameOut	23	Valve	FlameOut
23	Threaded	10,000	23	Threaded	10,000	23	Valve	FlameOut	23	Valve	FlameOut
23	Threaded	10,000	23	Threaded	10,000	23	Valve	FlameOut	23	Valve	FlameOut
23	Threaded	10,000	23	Threaded	10,000	23	Valve	FlameOut	23	Valve	10,000
23	Threaded	10,000	23	Threaded	10,000	23	Valve	FlameOut	23	Valve	10,000
23	Threaded	10,000	23	Threaded	10,000	23	Valve	FlameOut	23	Valve	10,000
23	Threaded	10,000	23	Threaded	8,000	23	Valve	FlameOut	23	Valve	10,000
23	Threaded	10,000	23	Threaded	8,000	23	Valve	FlameOut	23	Valve	10,000
23	Threaded	10,000	23	Threaded	7,000	23	Valve	FlameOut	23	Valve	10,000
23	Threaded	10,000	23	Threaded	6,000	23	Valve	FlameOut	23	Valve	10,000
23	Threaded	10,000	23	Threaded	5,000	23	Valve	FlameOut	23	Valve	10,000
23	Threaded	10,000	23	Threaded	2,500	23	Valve	FlameOut	23	Valve	10,000
23	Threaded	10,000	23	Threaded	1,500	23	Valve	FlameOut	23	Valve	10,000
23	Threaded	10,000	23	Threaded	1,300	23	Valve	FlameOut	23	Valve	10,000
23	Threaded	10,000	23	Threaded	1,000	23	Valve	FlameOut	23	Valve	10,000
23	Threaded	10,000	23	Threaded	800	23	Valve	FlameOut	23	Valve	10,000
23	Threaded	10,000	23	Tubing	FlameOut	23	Valve	FlameOut	23	Valve	10,000
23	Threaded	10,000	23	Tubing	10,000	23	Valve	FlameOut	23	Valve	10,000
23	Threaded	10,000	23	Tubing	10,000	23	Valve	FlameOut	23	Valve	10,000

SITE	TYPE	PPMV
23	Valve	10,000
23	Valve	10,000
23	Valve	10,000
23	Valve	10,000
23	Valve	10,000
23	Valve	10,000
23	Valve	10,000
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23	Valve	10,000
23	Valve	10,000
23	Valve	10,000
23	Valve	10,000
23	Valve	10,000

SITE	TYPE	PPMV
23	Valve	10,000
23	Valve	10,000
23	Valve	10,000
23	Valve	10,000
23	Valve	10,000
23	Valve	10,000
23	Valve	10,000
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23	Valve	10,000
23	Valve	10,000
23	Valve	10,000
23	Valve	10,000
23	Valve	10,000
23	Valve	10,000
23	Valve	8,000
23	Valve	5,000
23	Valve	3,000
23	Valve	2,800
23	Valve	2,500
23	Valve	2,000
23	Valve	1,700
23	Valve	1,000

SITE	TYPE	PPMV
23	Valve	1,000
23	Valve	800
23	Valve	800
23	Valve	80
23	Valve	50

SITE	TYPE	PPMV

SITE	TYPE	PPMV
24	Threaded	FlameOut
24	Threaded	FlameOut
24	Threaded	FlameOut
24	Threaded	FlameOut
24	Threaded	FlameOut
24	Threaded	FlameOut
24	Threaded	10,000
24	Threaded	10,000
24	Flange	FlameOut
24	Valve	FlameOut
24	Valve	FlameOut
24	Valve	FlameOut
24	Valve	FlameOut
24	Valve	FlameOut
24	Valve	FlameOut
24	Valve	FlameOut
24	Valve	FlameOut
24	Valve	FlameOut
24	Valve	FlameOut
24	Valve	FlameOut
24	Valve	FlameOut
24	Valve	FlameOut
24	Valve	FlameOut
24	Valve	FlameOut
24	Valve	FlameOut
24	Valve	FlameOut
24	Valve	FlameOut
24	Valve	FlameOut
24	Valve	FlameOut
24	Valve	FlameOut
24	Valve	FlameOut
24	Valve	FlameOut
24	Valve	FlameOut
24	Valve	FlameOut
24	Valve	FlameOut

SITE	TYPE	PPMV
24	Valve	FlameOut
24	Valve	FlameOut
24	Valve	FlameOut
24	Valve	FlameOut
24	Valve	FlameOut
24	Valve	FlameOut
24	Valve	FlameOut
24	Valve	FlameOut
24	Valve	FlameOut
24	Valve	FlameOut
24	Valve	FlameOut
24	Valve	FlameOut
24	Valve	FlameOut
24	Valve	FlameOut
24	Valve	FlameOut
24	Valve	FlameOut
24	Valve	FlameOut
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24	Valve	FlameOut
24	Valve	FlameOut

SITE	TYPE	PPMV
24	Valve	FlameOut
24	Valve	FlameOut
24	Valve	FlameOut
24	Valve	FlameOut
24	Valve	FlameOut
24	Valve	FlameOut
24	Valve	FlameOut
24	Valve	FlameOut
24	Valve	FlameOut
24	Valve	FlameOut
24	Valve	FlameOut
24	Valve	FlameOut
24	Valve	FlameOut
24	Valve	FlameOut
24	Valve	FlameOut
24	Valve	FlameOut
24	Valve	FlameOut
24	Valve	FlameOut
24	Valve	FlameOut
24	Valve	FlameOut
24	Valve	FlameOut
24	Valve	10,000
24	Valve	10,000
24	Valve	10,000
24	Valve	10,000
24	Valve	10,000
24	Valve	10,000
24	Valve	10,000
24	Valve	10,000
24	Valve	10,000
24	Valve	10,000
24	Valve	10,000
24	Valve	10,000
24	Valve	10,000
24	Valve	10,000

SITE	TYPE	PPMV
24	Valve	10,000
24	Valve	6,000
24	Valve	5,000
24	Valve	5,000
24	Valve	4,000
24	Valve	2,000

APPENDIX C
LEAK RATES

SITE	TYPE	PPMV	CC/MIN
21	Valve	Flame	706
21	Valve	10,000	17
21	Valve	Flame	713
21	Valve	9,000	58
21	Open End	5,000	1
21	Valve	10,000	14
21	FL	Flame	1,553
21	Valve	Flame	56
21	Valve	Flame	69
21	Valve	10,000	16
21	Valve	10,000	5
21	Valve	Flame	29
21	Valve	10,000	45
21	Valve	10,000	52
21	Vent	Flame	8,075
21	Vent	Flame	8,713
21	Flange	10,000	6
21	Flange	10,000	18
21	Thread	10,000	42
21	Valve	Flame	227
21	Flange	10,000	15
21	Valve	10,000	10
21	Thread	10,000	65
21	Valve	Flame	106
21	Valve	10,000	57
21	PRV	Flame	3,229
21	Valve	Flame	2,644
21	Valve	Flame	751
21	Valve	10,000	8
21	Valve	Flame	149
21	Valve	10,000	31
21	Flange	10,000	10
21	Valve	10,000	27
21	Tube	10,000	10
21	Valve	10,000	24
21	Valve	Flame	333
21	Flange	10,000	8
21	Tube	10,000	217
21	Valve	10,000	38
21	Flange	10,000	192
21	Tube	10,000	23
21	Valve	10,000	7
21	Valve	10,000	21
21	Valve	10,000	32
21	Flange	10,000	157
21	Thread	10,000	153

SITE	TYPE	PPMV	CC/MIN
22	Open End	Flame	34
22	Open End	10,000	10
22	Valve	10,000	44
22	Thread	10,000	265
22	Flange	10,000	39

SITE	TYPE	PPMV	CC/MIN
23	Thread	10,000	40
23	Valve	Flame	360
23	Thread	8,000	259
23	Thread	10,000	342
23	Thread	10,000	11
23	Valve	Flame	1,424
23	Valve	Flame	20,895
23	Thread	10,000	55
23	Valve	10,000	29
23	Valve	10,000	66
23	Valve	Flame	252
23	Valve	10,000	22
23	Valve	10,000	169
23	Valve	10,000	72
23	Valve	Flame	715
23	Valve	Flame	2,306
23	Valve	Flame	790
23	Valve	Flame	49
23	Valve	Flame	56
23	Valve	Flame	341
23	Valve	Flame	1,128
23	Valve	Flame	72
23	Valve	10,000	3
23	Thread	Flame	1,747
23	Valve	10,000	43
23	Valve	Flame	59
23	Valve	Flame	364
23	Valve	10,000	38
23	Thread	10,000	244
23	Thread	Flame	3,224
23	Valve	10,000	3
23	Thread	Flame	68
23	Valve	10,000	16
23	Thread	Flame	113
23	Thread	10,000	11
23	Valve	Flame	127
23	Thread	10,000	447
23	Thread	10,000	2,010
23	Valve	Flame	763
23	Thread	10,000	110
23	Thread	Flame	16,038
23	Valve	Flame	2,821
23	Valve	10,000	42
23	Thread	10,000	12
23	Thread	10,000	70
23	Thread	10,000	220

SITE	TYPE	PPMV	CC/MIN
23	Valve	Flame	1,361
23	Valve	10,000	72
23	Tube	10,000	156
23	Thread	10,000	55
23	Valve	Flame	281
23	Valve	Flame	7,076
23	Valve	10,000	197
23	Thread	10,000	13
23	Valve	10,000	41
23	Thread	Flame	24
23	Valve	Flame	225
23	Valve	Flame	1,039
23	Valve	Flame	146
23	Valve	Flame	320
23	Valve	Flame	35
23	Valve	Flame	12
23	Thread	Flame	51
23	Valve	10,000	46
23	Valve	Flame	1,595
23	Valve	Flame	6,604
23	Valve	Flame	1,020
23	Valve	Flame	539
23	Valve	Flame	780
23	Valve	Flame	139
23	Valve	Flame	351
23	Valve	10,000	132
23	Valve	10,000	31
23	Valve	10,000	16

SITE	TYPE	PPMV	CC/MIN
24	Valve	Flame	3,420
24	Valve	Flame	814
24	Valve	6,000	12
24	Thread	10,000	21
24	Valve	10,000	78
24	Tube	Flame	551
24	Tube	Flame	306
24	Valve	Flame	328
24	Valve	Flame	1,518
24	Valve	Flame	1,198
24	Valve	Flame	1,714
24	Valve	10,000	60
24	Valve	10,000	17
24	Valve	Flame	117
24	Valve	Flame	18,454
24	Valve	Flame	2,722
24	Valve	Flame	1,791
24	Valve	Flame	3,250
24	Valve	Flame	57,574
24	Valve	Flame	1,026
24	Valve	Flame	1,087
24	Valve	Flame	20,914
24	Valve	Flame	6,341
24	Valve	Flame	2,212
24	Valve	Flame	784
24	Valve	Flame	85
24	Dia	1,000	0
24	Dia	Flame	52,825
24	Valve	10,000	9
24	Dia	Flame	1,099
24	Thread	10,000	66
24	Valve	Flame	398
24	Valve	Flame	2,066
24	Valve	2,000	2
24	Valve	Flame	176
24	Valve	5,000	4
24	Valve	10,000	5
24	Valve	10,000	19
24	Valve	10,000	18
24	Valve	Flame	1,665
24	Valve	Flame	3,407
24	Valve	Flame	220
24	Valve	Flame	92
24	Valve	Flame	101
24	Valve	Flame	805
24	Valve	10,000	26
24	Valve	10,000	30

SITE	TYPE	PPMV	CC/MIN
24	Valve	10,000	11
24	Valve	Flame	112
24	Thread	Flame	192
24	Valve	Flame	1,648
24	Valve	Flame	1,322
24	Valve	Flame	677
24	Valve	Flame	2,203
24	Valve	Flame	4,993
24	Valve	Flame	1,122
24	Valve	Flame	1,823
24	Valve	Flame	2,213
24	Valve	Flame	6,469
24	Valve	Flame	140
24	Thread	Flame	780
24	Valve	Flame	75
24	PRV	2,000	7
24	Thread	Flame	155
24	Dia	Flame	1,015
24	Dia	Flame	16,625
24	Flange	Flame	500
24	Valve	Flame	5,745
24	Valve	Flame	393
24	Valve	Flame	517
24	Flange	Flame	459
24	Valve	10,000	321
24	Valve	Flame	406
24	Valve	Flame	627
24	Valve	10,000	26
24	Valve	Flame	452
24	Valve	10,000	11
24	Valve	Flame	1,113
24	Valve	Flame	1,289
24	Compress	Flame	4,102
24	Valve	1,000	1
24	Valve	Flame	119
24	Valve	10,000	14
24	Thread	10,000	31
24	Valve	10,000	21
24	Valve	Flame	1,254
24	Valve	10,000	39
24	Valve	10,000	38
24	Valve	10,000	52
24	Valve	Flame	482
24	Valve	10,000	16
24	Valve	6,000	5
24	Valve	10,000	8
24	Thread	Flame	99

SITE	TYPE	PPMV	CC/MIN
24	Valve	10,000	51
24	Valve	Flame	443
24	Valve	10,000	43
24	Valve	Flame	162
24	Valve	Flame	146
24	Valve	Flame	394
24	Valve	Flame	750
24	Valve	Flame	393
24	Thread	Flame	293
24	Valve	Flame	294
24	Valve	10,000	16
24	Valve	Flame	111
24	Valve	Flame	252
24	Valve	Flame	7,740
24	Valve	Flame	204
24	Valve	Flame	221
24	Valve	Flame	199
24	Valve	Flame	987
24	Valve	Flame	590
24	Valve	Flame	3,776
24	Valve	Flame	5,620

SITE	TYPE	PPMV	CC/MIN

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