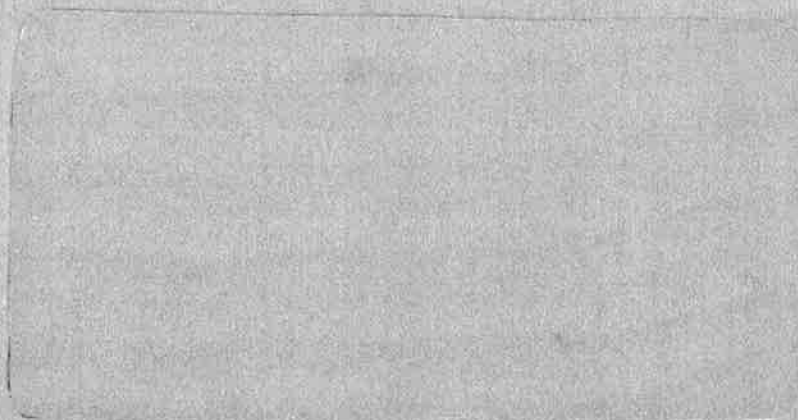


Development of Emission Factors for Leaks in Refinery Components in Heavy Liquid Service

Health and Environmental Affairs Department
Publication Number 337
August 1996





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API PUBLICATION NUMBER 337

PREPARED UNDER CONTRACT BY:

HAL TABACK COMPANY
378 PASEO SONRISA
WALNUT, CALIFORNIA, 91789

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API STAFF CONTACT

Karin Ritter, Health and Environmental Affairs Department

AIR TOXIC MULTI-YEAR STUDY WORKGROUP

HL EMISSION FACTORS OVERSIGHT COMMITTEE

Miriam Lev-On, Chairperson, ARCO

Robert D. Andrew, Mobil

Dan Isaacson, BP Oil

Dan VanDerZanden, Chevron

API FINANCE, ACCOUNTING, AND STATISTICS DEPARTMENT

Gina Papush

Paul Wakim

HAL TABACK COMPANY

Michael Godec, Data Analyst & Test Engineer

Steven A. Morrill, EIT, Test Director

H.J. Taback, PE, DEE, QEP, REA, Principal Investigator & Project Manager

ABSTRACT

The objective of this program was to develop a set of emission factors (expressed in lb/hr/component) applicable to refinery components (valves, flanged connectors, non-flanged connectors, pumps, open-ended lines, and others) in heavy liquid (HL) service. To accomplish this, more than 211,000 existing HL screening values from Southern California refineries were compiled and compared with 2,500 new HL screening measurements taken at two refineries in Washington State. Southern California is under stringent emission control regulations due to extreme non-attainment of the National Ambient Air Quality Standards (NAAQS); thus, its screening data may not be representative of refineries without stringent fugitive emission controls. However, the Southern California screening data were compared to screening measurements made at refineries in Washington State, which is an area in attainment of the NAAQS and therefore without fugitive emissions control. There was no significant statistical difference found in emission factors between the two areas; the results suggest there is no difference in emissions from heavy liquid components in areas with and without leak detection and repair (LDAR) programs. The new emission factors range from 65% to 86% less than the current EPA emission factors.

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EXECUTIVE SUMMARY

This report presents the results of a study to develop emission factors applicable to refinery components in heavy liquid (HL) service. It includes an analysis of whether the type of distillate or residual hydrocarbon in the stream would influence the emission factors. The objectives were accomplished using existing screening data for components in HL service and confirming those data with new screening data obtained from refineries without Leak Detection and Repair (LDAR) programs. These factors, expressed in pounds/hour/component, are such that they can be multiplied by the number of individual components in HL service in a refinery to calculate the volatile organic compound (VOC) emissions due to leaks from those components. Extensive statistical analysis of the screening data and related process parameters was performed.

TECHNICAL APPROACH

Refineries in Southern California (SoCal) were solicited for available HL screening data. Four refineries responded, providing 211,290 discrete screening values. Leak Detection and Repair has been practiced at these refineries for approximately ten years on components in gas (G) and light liquid (LL) service, but not for HL service. Nevertheless, because SoCal has tight emission controls, it was decided to conduct additional HL component screenings in an area without LDAR to determine whether or not the SoCal HL screening values were representative. The site chosen for the HL screenings was Washington State, which is in attainment for all of the National Ambient Air Quality Standards for VOCs and where LDAR programs are not required except for new or modified facilities under the New Source Performance Standards (NSPS). More than 2,500 discrete values were recorded from which the average emission factors for each component category were computed. A sampling matrix was used for the Washington test which would cover a representative range of middle distillate and residual process streams. These data were compared to values from SoCal to assess whether they were representative of all refineries.

CONCLUSIONS

The screening tests performed as part of the program showed that the emission factors for the refineries in Southern California, for which HL screening data were available, were similar to

emission factors determined based on measurements at the Washington State refineries. Both sets of emission factors are lower than those published in EPA's "Protocol for Equipment Leak Estimates," Contract 68-d1-0117, for EPA by Radian Corp., June 1993 (EPA 1993). The Washington State factors are lower than those from Southern California for all components with the exception of pumps. The higher pump value in Washington State was influenced by one pump leaking at a high rate.

The screening values for components in HL service were found to be independent of stream temperature and hydrocarbon composition (as defined by the 10% Distillation Temperature, ASTM Method D86). At first this may seem odd. The heavy liquid streams range from kerosene to asphalt. Intuitively, kerosene should leak more than asphalt. However, a reasonable explanation of this observed phenomenon is that the heavier hydrocarbons, which are more viscous and less volatile at ambient temperatures, inherently circulate in higher temperature process streams. Therefore, for the medium-weight middle distillate, the heavy-weight middle distillate, and the heavy residual streams, it appears that the viscosity and vapor pressure (properties that affect leakage) have a similar effect on the screening values.

In this report, the SoCal data are presented and discussed along with the details of the Washington State tests. An extensive statistical analysis of the various data sets is presented in Appendix A discussing various methods of combining the data to derive emission factors. The conclusions reached as a result of the statistical analysis follow:

- The SoCal data have a similar distribution of emission rates from quarter to quarter. Therefore, in aggregating screening data from different refineries, where individual refineries have different amounts of data (i.e., 2 quarters, 6 quarters and 7 quarters), the individual refinery data sets were reduced by averaging repeated measurements for each component.
- The analysis of the Washington State screening data indicates that there is a significant difference in emission factors among component types (e.g., valve, pump). However, the differences in emission factors among the various HL stream types (i.e., medium middle distillate, heavy middle distillate and heavy residual) are not considered to be statistically significant.

- The emission factors for the SoCal refineries and the Washington refineries are statistically similar. (For all components except pump seals, the respective emission factors for the Washington refineries are slightly lower than those for the SoCal refineries.) This serves to demonstrate that there should be no significant differences in HL emission factors between areas with and without LDAR programs, indicating that the HL emission factors generated by these screening data should be universally applicable to refineries in the U.S.

Table ES-1 presents two sets of factors derived using a two-step averaging method, as discussed in Appendix A, one based exclusively on SoCal data (where the quantity of data is large) and one based on a combination of SoCal and Washington data. These are compared to the factors currently published in EPA's Protocol document. API recommends the use of the combined emission factors. This data set is representative of refineries both with and without LDAR programs. The statistical analysis shows no significant difference between the data sets.

Table ES-1. Emission Factors for Components in HL Service

Component Type	Emission Factor SoCal Data, lb/hr/component	Emission Factor Combined SoCal & Washington Data, lb/hr/component	Emission Factor EPA Protocol (1980 Ref. Study), lb/hr/component
Valve	2.13E-04	1.76E-04	5.07E-04
Fitting	9.49E-05	7.93E-05	5.51E-04
Flange	9.66E-05	7.00E-05	5.51E-04
Pump	7.63E-03	8.25E-03	4.63E-02
Open-Ended Line	--	1.86E-05	--
Other	1.14E-04	6.21E-05	--

Section 1

INTRODUCTION

BACKGROUND

Estimating air pollutants from stationary sources is necessary for compiling emission inventories, determining emission fees, and meeting the conditions of various permits and compliances.

Extensive field measurements have been made over the last four years to develop more accurate emission correlation and emission factor data for estimating emissions from leaking pipeline components. For any petroleum industry facility employing leak detection and repair (LDAR) procedures, the component-leak emissions can be estimated using the recorded screening values expressed in parts per million (ppmv) along with component-specific correlation equations approved by EPA and found on its Technology Transfer Network (TTN) bulletin board (EPA TTN, 1995). For certain types of facilities where LDAR is not practiced, such as oil production fields and bulk terminals, EPA emission factors are readily available for use in estimating emissions.

Pipeline components in heavy liquid (HL) service are generally not included in LDAR programs regardless of the facility. Since HL screening values are generally not available, it is necessary to use EPA's emissions factors. The HL emission factors published in EPA's 1993 *Protocol for Equipment Leak Estimates* (EPA, 1993) were believed to be high, based on available information. Therefore, API conducted a study to develop more accurate HL emission factors.

OBJECTIVE

The objective of the program was to develop the emission factors and to determine whether or not the type of distillate or residual hydrocarbon in the HL stream would influence the emission factors. Emission factor data were obtained and extensive statistical analysis of the screening data and related process parameters was performed and discussed.

APPROACH

Refineries in Southern California (SoCal) were solicited for available HL screening data. Four refineries responded, providing 211,000 discrete HL screening values. At those refineries, LDAR has been practiced for approximately ten years on components in gas (G) and light liquid (LL) service, but not generally for HL service. Nevertheless, because SoCal has tight emission controls, additional HL component screenings were conducted in an area without LDAR to determine whether or not the SoCal HL screening values were representative. Two refineries in Washington State were chosen for the HL screenings. Washington is in attainment of the National Ambient Air Quality Standards and LDAR programs are not required except for new or modified facilities under the New Source Performance Standards (NSPS). More than 2,500 discrete values were recorded from which the average emission factors for each component category were computed. The Washington test used a sampling matrix which covered a representative range of middle distillate and residual process streams.

REPORT ORGANIZATION

Section 2 presents the SoCal data from four refineries showing leak rate distribution and average emission rates for various components. Section 3 presents the Washington State refinery data including the screening values, leak rate distribution, average emissions and the effects of stream composition and temperature on leak rate. Section 4 presents the conclusions. The statistical treatment of the SoCal, Washington and aggregated data is presented in Appendix A and the discrete screening and associated measurements, taken at the Washington refineries, are tabulated in Appendix B.

Section 2

DATA FROM SOUTHERN CALIFORNIA REFINERIES

Four sets of existing screening data, received from SoCal refineries, were used to derive the refinery HL component emission factors. The refineries are designated C1, C2, C3, and C4, respectively. Refinery C1 provided 165,852 values of HL screening data in electronic format. The data were taken over seven quarters, from 1992 to 1994. Refinery C1 has a full LDAR program and had screened the HL components along with G & LL service components in accordance with South Coast Air Quality Management District's (SCAQMD) Rule 1173 even though the screening of HL components has never been required by the SCAQMD. The data were taken with a Foxboro Model 108 Organic Vapor Analyzer (OVA) with strict Quality Control (QC) procedures in accordance with EPA Method 21, which stipulates that the OVA probe is maintained at the surface of the component being screened.

Refinery C2 provided 21,410 HL screening values for six quarters also over 1992 to 1994. This refinery had been screening HL components in addition to conducting its SCAQMD Rule 1173 program. Data from Refinery C3 and C4 were originally obtained in electronic format during a WSPA/API study in 1992 as part of the planning effort for the 1993 refinery screening and bagging study (Radian Corp., 1992). These screening values, which included various component types and services, were measured in the initial two quarters of the Rule 1173 program in 1991. In reviewing the data, it was found that two of the refineries had included HL screening data. The C3 and C4 data set, when merged, comprised a total of 24,028 screening values.

The screening values in the three data sets were converted to emission rates using the latest set of correlation equations and zero and pegged source emission factors accepted by EPA and posted on EPA's TTN (EPA TTN, 1995), which are presented in Table 2-1.

Table 2-1. Correlation Equations, Default Zero Emission Rates, and Pegged Emission Rates Used For Emissions Calculations (EPA TTN Bulletin Board, 1995)

Equipment Type/Service	Default Zero Emission Rate (lb/hr/comp)	Pegged Emission Rates (lb/hr/comp)		Correlation Equation ^a
		10,000 ppmv	100,000 ppmv	
Connector/All	1.65E-05	0.062	0.066	$E = 3.33E-06 \times (SV)^{0.735}$
Flange/All	6.84E-07	0.19	0.19	$E = 9.79E-06 \times (SV)^{0.703}$
Open-Ended Line/All	4.41E-06	0.66	0.17	$E = 4.76E-06 \times (SV)^{0.704}$
Pump/All	5.29E-05	0.16	0.35 ^b	$E = 1.06E-04 \times (SV)^{0.610}$
Valve/All	1.72E-05	0.14	0.31	$E = 5.03E-06 \times (SV)^{0.746}$
Other ^c /All	8.80E-06	0.16	0.24	$E = 2.91E-06 \times (SV)^{0.589}$

^a E is the predicted mass emission rate (lb/hr) and SV is the screening value (ppmv) measured by the monitoring device.

^b Only 2 data values were available for the pump over-100,000 emission factor. Therefore, the pump over-100,000 ppmv emission factor was obtained by multiplying by the over-100,000 ppmv emission factor for "other" by the ratio, pump/other at the over-100,000 ppmv level.

^c The "other" equipment type includes instrument, loading arms, pressure relief valves, stuffing boxes, vents, compressors, and dump lever arms.

Table 2-2 summarizes the SoCal component-leak emission data, showing the total number of components of each type screened, the total estimated emissions using the Table 2-1 conversion, and the average emission factor obtained by dividing the total emissions by the number of components. Values are presented for each of the three data sets. In each case the average emission factors computed are compared to the 1980 refinery HL emission factors as presented in EPA's June 1993 Protocol document.

Table 2-2. Average Emission Factors for Components in Heavy Liquid Service
(7 Qtrs. of Refinery C1 Data, 6 Qtrs. of Refinery C2 data, and 2 Qtrs. of Refineries C3 & C4 data)

Refinery C1 data					
Component	Service	Count	Total Emissions (EPA August 1995) (lb/hr)	Average Emission Factor (lb/hr/comp)	1980 Refinery (lb/hr/comp)
Valve	HL	28,265	0.8782	3.11E-05	5.07E-04
Fitting	HL	100,482	1.8313	1.82E-05	5.51E-04
Flange	HL	23,370	1.1716	5.01E-05	5.51E-04
Pump	HL	787	0.4364	5.54E-04	4.63E-02
Other	HL	12,077	1.3669	1.13E-04	--
PRD	HL	871	0.0984	1.13E-04	--
Total = 165,852					
Refinery C2 data					
Component	Service	Count	Total Emissions (EPA August 1995) (lb/hr)	Average Emission Factor (lb/hr/comp)	1980 Refinery (lb/hr/comp)
Valve	HL	5,468	0.8456	1.55E-04	5.07E-04
Fitting	HL	14,268	0.2626	1.84E-05	5.51E-04
Flange	HL	1,536	0.2192	1.43E-04	5.51E-04
Pump	HL	72	0.1070	1.49E-03	4.63E-02
PRD	HL	66	0.0006	8.71E-06	--
Total = 21,410					
Refinery C3 & C4 data					
Component	Service	Count	Total Emissions (EPA August 1995) (lb/hr)	Average Emission Factor (lb/hr/comp)	1980 Refinery (lb/hr/comp)
Valve	HL	10,137	3.5001	3.45E-04	5.07E-04
Fitting	HL	13,312	2.1927	1.65E-04	5.51E-04
Pump	HL	116	1.6503	1.42E-02	4.63E-02
PRD	HL	463	0.0499	1.08E-04	--
Total = 24,028					

Figures 2-1, 2-2, 2-3, and 2-4 show the distribution of the screening values for the aggregate of all components, for the four refineries, in screening ranges of less than 10 ppmv, 10 to 99 ppmv, 100 to 999 ppmv, etc. As can be seen, the percentage of components screening greater than 1,000 ppmv ranges from 0.02 to 0.7 percent.

Refer to Appendix A for further analysis of these data.

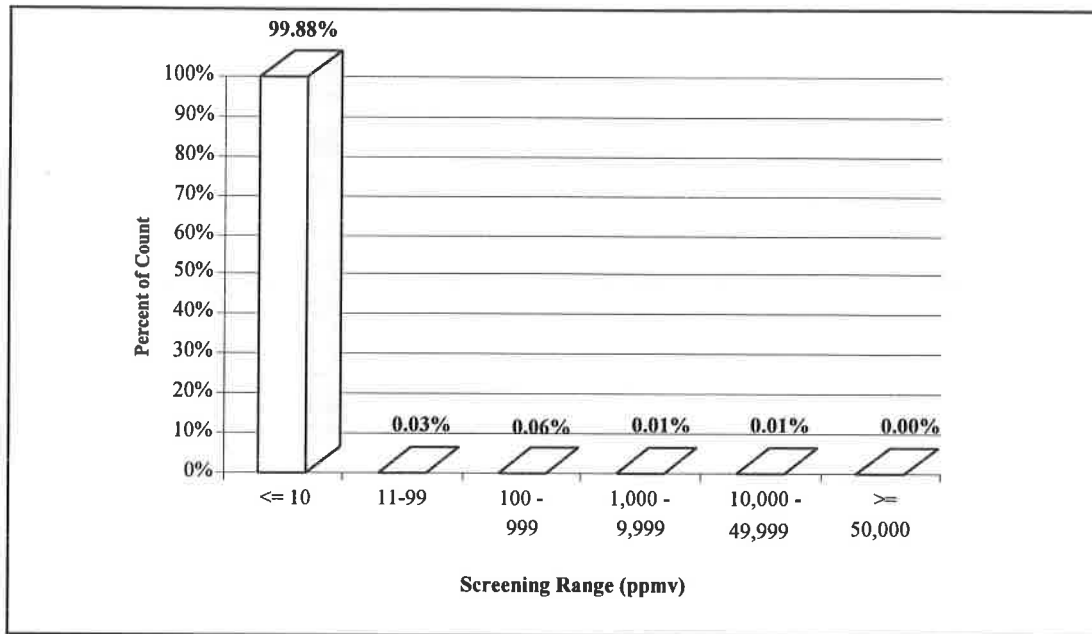


Figure 2-1. HL Component Leak Rate Distribution - Refinery C1 (165,852 values)

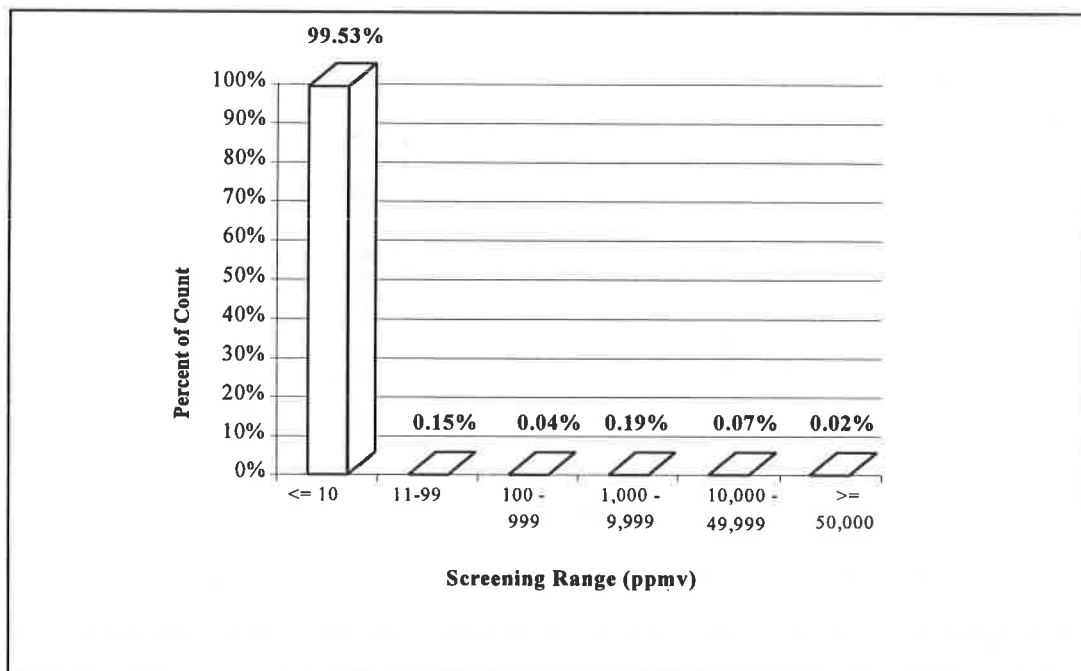


Figure 2-2. HL Component Leak Rate Distribution - Refinery C2 (21,410 values)