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ASSESSMENT OF FUGITIVE EMISSIONS OF PROC FROM PETROLEUM REFINING OPERATIONS

Final Report

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ABSTRACT

The primary objectives of this study were: (1) to evaluate fugitive emissions from various components (e.g., valves, flanges, pumps, etc.) at petroleum refineries, and (2) to evaluate factors which contribute to differences in these fugitive emissions between refineries and air pollution control districts. The technical approach for this study included: (1) collection of an extensive amount of data on the populations of these components by component type, process unit, and refinery, (2) collection of an extensive amount of hydrocarbon screening data that were obtained to comply with fugitive emission inspection/maintenance rules, (3) development of a database structure and extrapolation procedures and compilation of fugitive emissions data for all refineries in California, (4) a detailed evaluation of the effect on fugitive emissions of various provisions of air pollution control rules, and (5) a detailed evaluation of differences in fugitive emissions between refineries and air pollution control districts. The major conclusions of the study were: (1) significant uncertainty exists in estimating emissions from refinery fugitive emissions on the basis of hydrocarbon screening data obtained to comply with fugitive emission inspection/maintenance rules, (2) significant differences exist in the fraction of leaking components between individual refineries, (3) for components that are subject to the rule (nonexempt), there has been a reduction in emissions of between 56 and 91 percent as a result of fugitive emission control rules, and (4) between 44 and 78 percent of refinery fugitive emissions come from components which are exempt from the rules.

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1.0 INTRODUCTION

Fugitive emissions of photochemically reactive organic compounds (PROC) are emitted from a variety of equipment component types at petroleum refineries. These component types include valves, flanges, pumps, compressors, and pressure relief valves (PRVs). In order to promote attainment of federal and state ambient air quality standards for ozone (oxidant), these emissions have been reduced through the requirement of inspection/maintenance (I/M) programs. Suggested control measures (SCMs) for the control of PROC emissions from refinery valves, flanges, pumps, compressors, and PRVs were approved by the California Air Resources Board (ARB) in 1978, 1981, and 1982. Subsequently, air quality management and air pollution control districts adopted rules or rule elements partially based on the SCMs.

The typical air pollution control rule for refinery fugitive emissions in California has the following elements:

- Requirements for annual inspection of valves, flanges, and pumps. Requirements for quarterly inspection of compressors and PRVs.
- Use of a hydrocarbon detection instrument held at 1 cm from the source.
- Repair of any component screening greater than 10,000 parts per million by volume (ppmv).
- Reinspection of components after repair.
- Exemptions for component types with certain characteristics.

Radian Corporation conducted a study for the ARB to evaluate emissions of PROC from California petroleum refineries. There were several major objectives of the study: 1) to evaluate refinery fugitive emissions for each California refinery by process unit, component type, service type, and category of exemption, 2) to identify, and where possible quantify, those factors which contribute most significantly to differences in fugitive emission rates between refineries, 3) to compare post-rule vs pre-rule emissions, and 4) to evaluate the impact of rule exemptions on emissions.

In order to meet these objectives, an approach for estimating fugitive emissions was developed. This approach calculates fugitive emissions on the basis of four variables: 1) the number of components (component populations); 2) the fraction of components with screening values above 10,000 ppmv (fraction of components leaking); 3) the distribution of screening values for both leaking and nonleaking components (screening value distributions); and 4) the correlation between screening values and emission rates developed in previous fugitive emission studies. The first two variables are used in the process directly, the third and fourth variables are used to develop average emission rates (AERs) for leaking and nonleaking components.

Using this emission calculation approach as a cornerstone, an overall study approach was developed. This approach is summarized below.

- Questionnaires and data requests were sent to the refineries to obtain component population data and the I/M data that they have collected while complying with the rules.
- A consistent database was developed and all available data were entered.
- An extrapolation approach was developed and implemented to fill all gaps in the database.
- Average emission rates for leaking and nonleaking components were developed.

- Emissions were estimated from nonexempt and exempt components.

- A detailed evaluation of differences in component populations, fraction of components leaking, and emission estimates between refineries, and between air quality management and air pollution control districts was made.

As part of the work to improve the database, a small field sampling/data collection effort was conducted. This effort drew upon a small portion of the overall project budget and did not result in a significant amount of data being added to the database. Therefore, the study was almost solely based on data collected by refineries during implementation of I/M programs.

2.0 RESULTS AND CONCLUSIONS

2.1 General

The most significant result of this study was the creation of an extensive fugitive emission database for all refineries in California. This database was developed using LOTUS'123® software and can be used on any personal computer compatible with an IBM PC®. The database is very large; in hard copy format it consists of several thousand pages. Copies of the database in both magnetic and hard copy format have been made available to the ARB. The database contains component populations, fraction of components leaking, estimated average emission rates, and emission estimates by component type (e.g., valves, flanges, pumps, etc.) and by process unit for each refinery.

The database is made up of fugitive emission inspection/maintenance (I/M) data collected by California refineries. These data were collected by refineries solely for the purpose of complying with fugitive emission control rules. These data were submitted in response to requests for this study, and were provided with varying degrees of detail and documentation. The most recent year of usable data submitted by each refinery was included in the database.

Within the database, the source of each individual data point is documented. This allows future users to easily evaluate the source of the data and the level of confidence that can be placed on individual data points. It also facilitates updating the database. If actual data are obtained to replace extrapolated data, these data can easily be entered and the data source code changed.

There are three types of data or results that represent the most significant outcome of this study: component populations, fraction of components leaking, and emission estimates. The component populations represent a significant result of this study. These component populations are based on actual data submitted by the refineries for the majority of refineries. The fraction of components leaking is also a significant result. The amount of data collected on the fraction of components leaking in this study far exceeds the total amount of data on the fraction of components leaking in all previous studies. The final result of this study was emission estimates. While the development of detailed and accurate emission estimates was perhaps the most important objective of this study, it was not possible to develop one set of emission estimates for nonexempt valves and flanges that were certain enough to be presented as the sole results of this study. Therefore, two sets of valve and flange emission estimates were developed for nonexempt components. These two emission estimates differ by approximately an order of magnitude. Neither of these emission estimates can be stated with certainty to be accurate.

2.1.1 Component Populations

This study obtained the most comprehensive and detailed set of component populations ever developed for California refineries. Probably the most important information that these data provide is on the relative proportion of total components that are exempt from the rules. The percent of total components that are claimed as exempt for all refineries in California is presented below:

- Valves - gas service: 34.9 percent
- Valves - liquid service: 43.4 percent
- Flanges: 43.9 percent
- Pumps: 59.3 percent
- Compressors: 29.0 percent
- PRVs - gas service: 61.3 percent
- PRVs - liquid service: 61.8 percent

Another important conclusion about component populations relates to the consistency of component populations for a given process unit. A previous fugitive emission study entitled Assessment of Atmospheric Emissions from Petroleum Refining concluded that component populations were primarily a function of the type of process unit, not the size or capacity of that unit (Radian, 1980). This result was used in developing the component population extrapolation scheme that was used in this study. However, the data collected in this study show that there is a great deal of variability in component populations for a given process unit. For example, Table 2-1 presents information on the range of component populations by process unit for refineries in one example district, the South Coast Air Quality Management District (SCAQMD). Similar tables could be prepared for other air pollution control districts from the fugitive emission database.

Based on a more detailed review of component populations by process unit, there appear to be two primary reasons that variability in component populations exist: 1) it was not possible to define a discrete set of boundaries for a given process unit to ensure that these boundaries were consistently applied between refineries, 2) actual variability in component populations for a given process unit does exist due to process unit capacity, and 3) variability in the type and number of exemptions claimed by different refineries for similar process units.

Actual component population data provided by the refineries were grouped by process unit. As mentioned above, the boundaries of process units were not consistent in that each individual refinery providing data made the determination of which components belonged to particular units. The disparity in component populations is particularly evident in ancillary process units (those that serve in a supporting function) such as storage/blending/shipping and blowdown/flare/vapor recovery.

It was not possible within this study to perform a detailed evaluation of the relationship between process unit capacity and component populations. However, for many process units, there does appear to be a relationship between these two parameters.

TABLE 2-1. NONEXEMPT COMPONENT POPULATIONS - SOUTH COAST AIR QUALITY MANAGEMENT DISTRICT

	VALVES															PRESSURE RELIEF VALVES					
	GAS			LIQUID			FLANGES			PUMPS			COMPRESSORS			GAS			LIQUID		
PROCESS UNIT	MIN	MAX	AVG	MIN	MAX	AVG	MIN	MAX	AVG	MIN	MAX	AVG	MIN	MAX	AVG	MIN	MAX	AVG	MIN	MAX	AVG
Crude Distillation	33	357	110	30	1,113	362	14	2,237	895	0	20	10	0	8	1	0	13	2	0	18	3
Catalytic Cracking	258	1,096	594	693	2,330	1,561	2,031	7,764	5,189	5	47	31	0	9	4	0	30	9	0	30	10
Hydrocracking	53	67	60	480	604	542	338	1,960	1,299	3	11	6	0	2	1	0	13	3	0	5	1
Thermal Operations	215	507	352	188	1,218	685	979	4,299	2,356	4	21	13	0	5	1	1	7	5	0	26	9
Fluid Coking																					
Blowdown/VR/Flares	30	173	107	0	1,557	818	30	5,190	2,253	0	33	10	2	15	7	0	10	7	0	22	7
Wastewater Treating	0	0	0	175	280	228	372	840	605	4	8	6	0	0	0	0	0	0	0	4	2
Storage/Blend/Ship	0	376	131	95	6,560	1,966	0	20,598	7,288	8	118	49	0	8	2	0	82	28	0	520	87
Naphtha Hydrotreating	0	264	74	20	684	191	24	853	287	0	27	10	0	0	0	0	1	1	0	0	0
Catalytic Reforming	7	344	156	28	1,311	670	0	3,252	1,830	3	22	11	0	1	0	0	7	2	0	2	1
Aromatics Extraction																					
Fractionation	0	217	58	0	992	264	0	3,695	1,073	0	33	15	0	12	2	0	3	1	0	3	1
Alkylation	52	554	249	473	2,873	1,344	1,577	45,900	9,607	13	172	40	0	0	0	0	49	11	0	26	7
Polymerization	98	190	144	415	805	610	670	678	674	10	15	13	0	0	0	-	-	-	-	-	-
Isomerization																					
Gasoline Treating	0	21	14	40	191	144	50	635	344	0	27	7	0	2	0	0	0	0	0	7	3
Olefins Production																					
Boilers (Utilities)	40	902	401	0	176	78	20	3,763	1,438	0	45	10	0	2	1	0	5	1	0	0	0
Sulfur Plant	5	677	208	0	380	119	40	1,257	488	0	7	2	0	2	1	0	1	0	0	1	0
Mid Dist Hydrotreating	21	193	93	85	618	311	125	6,880	1,778	0	7	5	0	2	1	0	10	4	0	3	1
Lubes Process - Solvents																					
Hydrogen Production	335	853	554	0	316	152	97	1,005	584	0	6	3	0	0	0	0	15	5	0	0	0
Other Product Treating	0	0	0	140	164	152	207	220	214	0	2	1	0	0	0	0	0	0	0	0	0
Other Volatile Petro																					
Other Low Vol Petro	73	73	73	308	308	308	363	363	363	7	7	7	0	0	0	-	-	-	-	-	-
Vacuum Crude Dist	15	158	53	0	193	125	20	1,790	709	0	3	1	0	2	1	0	7	3	0	9	4
Gas Oil Hydrotreating	9	202	87	20	360	156	110	2,340	958	0	5	3	0	1	0	0	0	0	0	0	0
Vacuum Resid Hydro	215	297	256	129	239	184	200	6,180	3,190	3	8	6	0	1	1	0	0	0	0	0	0
Other Lube Oil Process																					
Asphalt Production																					

2.1.2 Fraction of Components Leaking

Data on the fraction of components leaking at the time of inspection were submitted by 17 refineries. The average fraction of components leaking for all of these data represents an average of post-rule conditions. An average of pre-rule conditions for refineries nationwide was obtained from the reference cited as Radian, 1980. The Radian, 1980 data were all collected using a TLV calibrated with hexane at 0 cm from the source. The post-rule data were collected using a variety of different detection instruments, calibration gases, and screening distances. The most common of the combinations used to collect post-rule data was an OVA calibrated with methane at 1 cm from the source. In order to compare the two data sets, it was assumed that all of the post-rule data were collected using an OVA calibrated with methane at 1 cm from the source. The pre-rule data were then converted to this same basis using information from the source cited as Radian, 1980. Table 2-2 presents a comparison of the pre-rule and post-rule data.

2.1.3 Screening Values

Screening value data are the actual nonmethane hydrocarbon (NMHC) concentrations measured during the implementation of I/M programs. They are not actual measurements of emission rates but can be related to emission rates. Screening value data that were usable for this study were submitted by the following refineries:

- Coastal Petroleum, Bakersfield
- Edgington Oil, Wilmington
- Exxon, Benicia
- Shell Oil, Carson
- Texaco, Bakersfield
- Tosco, Martinez

TABLE 2-2. COMPARISON OF PERCENT OF COMPONENTS LEAKING FOR PRE-RULE AND POST-RULE CONDITIONS

Component Type	Percent of Components Leaking OVA (1 cm) Methane	
	Pre-Rule	Post-Rule
Valves		
Gas Service	8.0	1.58
Liquid Service	8.0	1.05
Flanges	0.0	0.13
Pumps	15.0	4.60
Compressors	29.0	8.65
PRVs		
Gas Service	4.5[a]	0.71
Liquid Service	4.5[a]	0.00

[a] A breakdown of the percent leaking for gas and liquid service was not available.

NOTES:

- The post-rule percent of components leaking (i.e., with screening values greater than 10,000 ppm) represents the maximum number of leaking components at the end of the inspection cycle. If you assume that almost all of these components are repaired promptly and leak occurs/recurs linearly over time, then the average percent of components leaking is slightly more than one-half of the percentage shown.

- The fraction of components leaking in the pre-rule case have been adjusted to be on the basis of an OVA calibrated with methane at 1 cm from the source. Post-rule data were collected using a variety of different detection instruments, calibration gases, and screening distances. The most common of the combinations used to collect post-rule data was an OVA calibrated with methane at 1 cm from the source.

As was the case for the fraction of components leaking, the screening value distributions were variable between refineries. This variability may be the result of the following possible factors:

- Real differences in the leak rates for components in different refineries. These differences could result from: 1) differences in district rules, 2) differences in enforcement practices between districts, or 3) differences in the practices followed by different operators in order to comply with the rules.

- Differences in the hydrocarbon detection instrument, calibration gas, and screening distance.

- Differences in the methods used to conduct component screening.

Because limited data were available and it was not clear that the variability in screening values represented real differences in leak rates, average emission rates (emission factors) were not developed for individual refineries. Instead, one set of average emission rates was developed for the South Coast Air Quality Management District (SCAQMD) and the Bay Area Air Quality Management District (BAAQMD), and one set was developed for the Kern County Air Pollution Control District (KCAPCD) and miscellaneous air pollution control districts.

2.1.4 Emission Estimates

In this study, average emission rates were estimated from screening values. Significant difficulties were encountered in the development of average emission rates from the screening value distributions for nonexempt valves and flanges obtained from the refineries. The difficulties arose in converting screening values between different detection instruments and correlating screening values to emission rates. As a result, two complete sets of nonexempt emission estimates were developed using two different sets of average emission rates for valves and flanges. These two emission estimates differ by approximately an order of magnitude. Neither of these sets of emission estimates can be stated with certainty to be accurate.

Table 2-3 presents a summary of controlled (i.e., post-rule) emissions from nonexempt and exempt components by district for the entire state. Tables 2-4, 2-5, 2-6, and 2-7 present this same information by refinery for SCAQMD, BAAQMD, KCAPCD, and other districts, respectively. Emissions from threaded connections were assumed to be negligible and were not included in this study.

2.1.4.1 Nonexempt Component Emission Estimates

As stated in the previous section, two different sets of post-rule nonexempt component emission estimates were developed. Both sets of average emission rates were developed through the following process of conversion and correlation.

- Screening values provided by refineries were obtained using a variety of different detection instruments, calibration gases, and distances from the source. These screening values were converted to a common basis (i.e., TLV®, calibrated with hexane, at the source).

- These TLV® screening values were then correlated to emission rates.

The two sets of average emission rates, referred to as Method 1 and Method 2, differ in the way that these conversions and correlations were made. This difference is described below.

TABLE 2-3. SUMMARY OF EMISSION ESTIMATES FOR REFINERIES IN CALIFORNIA (ton/yr)

	SCAQMD		BAAQMD		KCAPCD		Misc. Districts		Statewide	
	Total	% of Total	Total	% of Total	Total	% of Total	Total	% of Total	Total	% of Total
METHOD 1 –										
Nonexempt Components										
Valves	9600	34.3	6700	60.9	350	18.4	36	11.6	17,000	41.5
Flanges	3400	12.1	220	2.0	28	1.5	10	3.2	3700	9.0
Pumps	540	1.9	350	3.2	37	1.9	12	3.9	940	2.3
Compressors	130	0.5	110	1.0	2.9	0.2	5.8	1.9	250	0.6
PRVs	880	3.1	270	2.5	65	3.4	17	5.5	1200	2.9
Subtotal	15,000	53.6	7700	70.0	480	25.3	81	26.0	23,000	56.1
METHOD 2 –										
Nonexempt Components										
Valves	1000	6.3	660	12.9	40	2.5	5.1	1.9	1700	7.4
Flanges	470	2.9	26	0.5	12	0.8	4.2	1.6	500	2.2
Pumps	540	3.4	350	6.9	37	2.3	12	4.4	940	4.1
Compressors	130	0.8	110	2.2	2.9	0.2	5.8	2.2	250	1.1
PRVs	880	5.5	270	5.3	65	4.1	17	6.3	1200	5.2
Subtotal	3000	18.8	1400	27.5	160	10.0	44	16.3	4600	20.0
Exempt Components										
Low PROC	420	1.5/2.6	280	2.5/5.5	26	1.4/1.6	5.0	1.6/1.9	730	1.8/3.2
Low RVP	2600	9.3/16.3	1100	10.0/21.6	560	29.5/35.0	97	31.2/35.9	4400	10.7/19.1
Inaccess	9300	33.2/58.1	2300	20.9/45.1	810	42.6/50.6	130	41.8/48.1	13,000	31.7/56.5
High Temp	170	0.6/1.1	43	0.4/0.8	3.1	0.2/0.2	1.2	0.4/0.4	220	0.5/1.0
Subtotal	13,000	46.4/81.3	3700	33.6/72.5	1400	73.7/87.5	230	74.0/85.2	18,000	43.9/78.3
METHOD 1 – Total Exempt and Nonexempt	28,000	100	11,000	100	1900	100	300	100	41,000	100
METHOD 2 – Total Exempt and Nonexempt	16,000	100	5100	100	1600	100	270	100	23,000	100

Table 2-4. Summary of Emission Estimates (ton/yr) for Refineries in the SCAQMD

	ARCO, Carson	Champlin, Wilmington	Chevron, El Segundo	Edgington, Wilmington	Fletcher Oil, Wilmington	Golden West, Santa Fe Springs	Huntway, Wilmington	Macmillan, Signal Hill	Mobil Oil, Torrance	Newhall, Newhall	Paramount, Paramount	Shell Oil, Carson	Texaco, Wilmington	Union Oil, Los Angeles	Total SCAQMD
METHOD 1 -															
Nonexempt Components															
Valves	1100	960	4400	180	210	450	110	17	410	210	31	350	1100	120	9800
Flanges	740	420	320	5.1	190	150	68	1.5	410	14	20	610	430	48	3400
Pumps	75	59	90	4.6	28	39	13	4.4	46	8.9	12	77	52	35	540
Compressors	12	10	13	0.9	6.0	35	3.7	0.8	13	6.5	1.1	6.8	17	1.1	130
PRVs	210	84	44	19	41	39	37	38	60	0.0	29	160	94	23	880
Subtotal Nonexempt	2100	1500	4900	210	470	710	230	62	940	240	93	1200	1700	230	15000
METHOD 2 -															
Nonexempt Components															
Valves	140	100	420	17	23	54	16	1.7	50	20	7.5	47	110	28	1000
Flanges	100	58	44	0.7	26	21	9.0	0.2	56	1.9	2.6	83	59	5.8	470
Pumps	75	59	90	4.6	28	39	13	4.4	46	8.9	12	77	52	35	540
Compressors	12	10	13	0.9	6.0	35	3.7	0.8	13	6.5	1.1	6.8	17	1.1	130
PRVs	210	84	44	19	41	39	37	38	60	0.0	29	160	94	23	880
Subtotal Nonexempt	540	310	610	42	120	190	79	45	230	37	52	370	330	91	3000
Exempt Components															
Low PROC	40	17	61	5.5	6.4	25	6.4	0.2	11	30	13	18	24	160	420
Low RVP	740	270	300	97	110	120	19	1.0	56	9.4	130	390	280	110	2600
Inacess	2500	900	640	15	170	480	0.0	7.9	420	40	240	460	980	2500	9300
High Temp	16	13	48	22	4.3	5.0	0.0	7.7	4.2	0.0	21	0.0	12	20	170
Subtotal Exempt	3300	1200	1100	140	290	630	27	17	490	79	400	870	1300	2800	13000
METHOD 1 - Total Exempt and Nonexempt	5400	2700	6000	350	760	1300	260	79	1400	320	490	2100	3000	3000	28000
METHOD 2 - Total Exempt and Nonexempt	3800	1500	1710	180	410	820	110	62	720	120	450	1200	1800	2900	16000

Table 2-5. Summary of Emission Estimates (ton/yr) for Refineries in the BAAQMD

	Chevron, Richmond	Exxon, Benicia	Huntway, Benicia	Pacific Refining, Hercules	Shell Oil, Martinez	Tosco, Martinez	Union Oil, Rodeo	Total BAAQMD
METHOD 1 –								
Nonexempt Components								
Valves	1800	680	260	420	790	2500	210	6700
Flanges	50	23	15	22	42	37	28	220
Pumps	81	30	21	26	48	120	19	350
Compressors	43	1.4	5.9	8.8	31	15	6.8	110
PRVs	79	31	19	25	45	48	21	270
Subtotal Nonexempt	2100	770	320	500	960	2700	290	7700
METHOD 2 –								
Nonexempt Components								
Valves	180	76	28	44	81	220	26	660
Flanges	6.0	2.8	1.8	2.6	5.1	4.5	3.3	26
Pumps	81	30	21	26	48	120	19	350
Compressors	43	1.4	5.9	8.8	31	15	6.8	110
PRVs	79	31	19	25	45	48	21	270
Subtotal Nonexempt	390	140	76	110	210	410	76	1400
Exempt Components								
Low PROC	68	84	3.9	11	83	5.6	24	280
Low RVP	330	130	61	73	280	160	38	1100
Inacess	570	220	100	180	610	500	130	2300
High Temp	42	0.0	0.0	0.0	1.4	0.0	0.0	43
Subtotal Exempt	1000	430	170	260	980	670	190	3700
METHOD 1 – Total Exempt and Nonexempt	3100	1200	490	760	1900	3400	480	11000
METHOD 2 – Total Exempt and Nonexempt	1400	570	250	370	1200	1100	270	5100

Table 2-6. Summary of Emission Estimates (ton/yr) for Refineries in the KCAPCD

	Chevron, Bakersfield	Coastal Petroleum, Bakersfield	Kern Oil and Refining, Bakersfield	Paramount, Bakersfield	San Joaquin Refining, Bakersfield	Texaco, Bakersfield	Witco Golden Bear, Bakersfield	Total KCAPCD
METHOD 1 -								
Nonexempt Components								
Valves	27	82	43	62	0.0	140	0.0	350
Flanges	0.4	3.3	1.8	6.6	0.0	16	0.0	28
Pumps	3.1	3.2	8.7	7.3	0.0	15	0.0	37
Compressors	0.2	0.2	0.7	0.3	0.0	1.5	0.0	2.9
PRVs	5.3	8.0	2.0	16	0.0	34	0.0	65
Subtotal Nonexempt	36	97	56	92	0.0	210	0.0	480
METHOD 2 -								
Nonexempt Components								
Valves	4.1	7.3	5.4	6.5	0.0	17	0.0	40
Flanges	0.2	1.4	0.6	2.7	0.0	6.6	0.0	12
Pumps	3.1	3.2	8.7	7.3	0.0	15	0.0	37
Compressors	0.2	0.2	0.7	0.3	0.0	1.5	0.0	2.9
PRVs	5.3	8.0	2.0	16	0.0	34	0.0	65
Subtotal Nonexempt	13	20	17	33	0.0	74	0.0	480
Exempt Components								
Low PROC	7.7	0.2	5.7	4.3	0.3	6.6	1.5	26
Low RVP	37	71	95	99	99	78	82	560
Inacess	56	7.1	180	140	28	260	140	810
High Temp	0.6	0.0	1.2	0.7	0.0	0.6	0.0	3.1
Subtotal Exempt	100	79	280	240	130	350	220	1400
METHOD 1 - Total Exempt and Nonexempt	140	175	340	270	130	560	220	1900
METHOD 2 - Total Exempt and Nonexempt	110	99	300	130	130	420	220	1600

Table 2-7. Summary of Emission Estimates (ton/yr) for Refineries in Kings County APCD, San Luis Obispo County APCD, and Ventura County APCD

	Beacon Oil, Hanford KCAPCD	Conoco, Santa Maria SLOCAPCD	Oxnard Refining, Oxnard VCAPCD	Total Miscellaneous Districts
METHOD 1 -				
Nonexempt Components				
Valves	32	1.8	2.1	38
Flanges	5.5	4.7	0.2	10
Pumps	9.5	0.0	2.6	12
Compressors	5.8	0.0	0.0	5.8
PRVs	16	0.1	0.7	17
Subtotal Nonexempt	69	6.6	5.6	81
METHOD 2 -				
Nonexempt Components				
Valves	4.2	0.4	0.5	5.1
Flanges	2.2	1.9	0.1	4.2
Pumps	9.5	0.0	2.6	12
Compressors	5.8	0.0	0.0	5.8
PRVs	16	0.1	0.7	17
Subtotal Nonexempt	38	2.4	3.9	44
Exempt Components				
Low PROC	2.2	0.0	2.8	5.0
Low RVP	26	0.3	71	97
Inacess	79	14	37	130
High Temp	0.6	0.0	0.6	1.2
Subtotal Exempt	110	14	110	233
METHOD 1 - Total Exempt and Nonexempt	180	21	120	310
METHOD 2 - Total Exempt and Nonexempt	150	16	110	280

- For Method 1, the conversions and correlations were made taking into account the uncertainty in these relationships. Therefore, a given value could be converted or correlated to a variety of possible values within the range of uncertainty for that conversion or correlation.

- For Method 2, the conversions and correlations were made on the basis of the mean values of these relationships.

There is one significant shortcoming for each of these methods.

- For Method 1, the resulting average emission rates are higher than appears reasonable when compared to actual data from the measurement of leak rates. For example, for leaking gas service values, the Method 1 average emission rate for BAAQMD/SCAQMD is 6.6 lb/hr-source. However, in the report cited as Radian, 1980, the highest measured leak rate for a gas service valve was 2.5 lb/hr. This was the highest measured value from over 100 data points on leaking gas service valves.

- The shortcoming of Method 2 is that it does not account for the uncertainty that exists in converting screening values for different detection instrument, calibration gas, and screening distance combinations or the uncertainty that exists in correlating screening values to emission rates. For example, when a mean screening value is obtained through the conversion process, the actual screening value that would have been measured with a TLV, calibrated with hexane, at the source might be significantly higher or lower. Because the screening values are approximately lognormally distributed, the exclusion of these uncertainties results in lower average emission rates.

2.1.4.2 Exempt Component Emission Estimates

One set of exempt component emission factors was developed for use in estimating exempt component emissions. These emission factors were developed using uncontrolled AP-42 emission factors (EPA, 1985) in conjunction with engineering judgement. The basis for these exempt component emission factors is described in Section 4.4.2. The use of these emission factors may lead to the overestimation or underestimation of emissions for different exemption types. Table 2-8 presents exempt component emissions as a percent of total emissions. Although there are only one set of exempt component emission estimates, the percent of total emissions varies depending on whether nonexempt component emissions were estimated using Method 1 or Method 2.

In either case, emissions from inaccessible components are significant, over 30 percent of the total emissions. Low RVP component emissions are also significant, over 10 percent of total emissions. Emissions from low PROC components and high temperature components appear to be less significant, with less than 5 percent of total emissions in both cases.

2.1.4.3 Pre-Rule Emission Estimates

Pre-rule emission estimates are presented in Table 2-9. The emission estimates are presented on a statewide basis for nonexempt components only. Pre-rule emission estimates for nonexempt components were developed using uncontrolled AP-42 emissions factors (EPA, 1985) in conjunction with component population data provided by refineries in response to survey questionnaires.

Comparison of pre-rule emissions to post-rule emissions for both Method 1 and Method 2 indicate a decrease in emissions for nearly all component types. The total emission reductions due to implementation of fugitive emission control rules was estimated to be 56 percent for Method 1 and 91 percent for Method 2.

TABLE 2-8. EXEMPT EMISSIONS AS A PERCENT OF TOTAL EMISSIONS ON A STATEWIDE BASIS

COMPONENT EXEMPTION TYPE	PERCENT OF TOTAL EMISSIONS METHOD 1 (ton/yr)	PERCENT OF TOTAL EMISSIONS METHOD 2 (ton/yr)
Nonexempt Components	56.1	20.0
Exempt Components	43.9	78.3
Exemption Type		
Low PROC	1.8	3.2
Low RVP	10.7	19.1
Inaccessible	31.7	56.5
High Temperature	0.5	1.0

TABLE 2-9. COMPARISON OF PRE-RULE VS POST-RULE EMISSIONS FOR NONEXEMPT COMPONENTS ON A STATEWIDE BASIS

	Post-Rule Emissions (ton/yr)		Pre-Rule Emissions (ton/yr)	Estimated Emission Reduction (%)	
	Method 1	Method 2		Method 1	Method 2
Nonexempt Components					
Valves	17,000	1,700	37,000	54	95
Flanges	3,700	500	1,400	—[a]	64
Pumps	940	940	5,100	82	82
Compressors	250	250	2,700	91	91
PRVs	1,200	1,200	4,600	74	74
Subtotal Nonexempt Components	**23,000**	**46,000**	**52,000**	**56**	**91**
Exempt Components	**18,000**	**18,000**	**18,000**	**0**	**0**
TOTAL All Components	**41,000**	**22,600**	**70,000**	**41**	**68**

[a] The post-rule emissions for flanges calculated using Method 1 are greater than the pre-rule emissions for flanges.

2.2 Differences in Fugitive Emissions and Inspection/Maintenance Programs Between Districts

2.2.1 Component Populations

Table 2-10 presents the percentage of components that are exempt in each district by type of exemption. The following observations can be made from reviewing this information.

- While the percentage of components that are claimed as exempt varies by district, there are no trends to indicate that significantly more components are being claimed as exempt in one district relative to another.

- It was expected that refineries in KCAPCD would have a significantly greater percentage of components that are exempt as low RVP because these refineries primarily process heavy crudes. However, this was not the case.

2.2.2 Fraction of Components Leaking

Table 2-11 summarizes the percent of components leaking at time of inspection for each district. These results were compared to determine whether, for a given component type, a statistically significant difference exists for the percent of leaking components between districts. This comparison takes into account both the number of data points and the magnitude of the differences between results. The comparison assumes a binomial distribution and is made with 95 percent confidence. For each component type, the only differences between districts that were determined to be statistically significant are indicated below.

- Valves-gas service: SCAQMD vs BAAQMD
- Valves-liquid service: SCAQMD vs KCAPCD vs BAAQMD

TABLE 2-10. PERCENT OF TOTAL COMPONENT POPULATIONS THAT ARE EXEMPT BY DISTRICT

	VALVES					PRVS	
DISTRICT	GAS	LIQUID	FLANGES	PUMPS	COMPRESSORS	GAS	LIQUID
SCAQMD							
Percent Nonexempt	57.7	58.8	57.0	42.6	69.4	37.4	42.8
Percent Exempt							
Low PROC	20.3	4.3	6.9	15.3	30.3	13.9	0.9
Low RVP	0.0	29.9	22.5	41.0	0.0	0.0	24.3
Inaccessible	22.0	6.9	10.0	0.0	0.0	48.4	31.9
High Temperature	0.0	0.1	3.6	1.1	0.3	0.3	0.0
BAAQMD							
Percent Nonexempt	73.2	53.6	52.0	38.0	77.2	28.0	17.9
Percent Exempt							
Low PROC	17.6	1.4	9.0	10.9	22.8	38.0	1.6
Low RVP	0.0	40.3	28.4	51.0	0.0	0.0	63.6
Inaccessible	9.2	4.7	10.3	0.0	0.0	33.9	16.9
High Temperature	0.0	0.0	0.3	0.0	0.0	0.0	0.0
KCAPCD							
Percent Nonexempt	69.0	48.4	67.5	37.5	57.1	84.6	23.3
Percent Exempt							
Low PROC	4.7	3.1	2.2	3.1	42.9	5.1	0.7
Low RVP	0.0	35.9	24.2	54.0	0.0	4.3	65.7
Inaccessible	26.2	12.6	6.0	5.4	0.0	6.0	10.2
High Temperature	0.0	0.1	0.1	0.0	0.0	0.0	0.0
ALL DISTRICTS							
Percent Nonexempt	65.1	56.6	56.1	40.7	71.0	38.7	38.2
Percent Exempt							
Low PROC	18.1	3.3	7.3	13.0	28.8	18.6	1.0
Low RVP	0.0	33.5	24.2	45.2	0.0	0.0	32.5
Inaccessible	16.7	6.5	9.9	0.4	0.0	42.5	28.3
High Temperature	0.0	0.1	2.6	0.6	0.2	0.2	0.0

NOTE: The numbers in these tables were compiled for refineries that provided relatively complete sets of component populations for both nonexempt and exempt components. These refineries are listed below by district.

SCAQMD – ARCO, Chevron, Edgington, Huntway, MacMillan, Newhall, Shell, and Union.

BAAQMD – Exxon, Shell, Tosco, and Union.

KCAPCD – Coastal, Paramount, Texaco, and Witco Golden Bear.

Misc. Districts – No complete data sets were available.

TABLE 2-11. SUMMARY OF ACTUAL DATA BY DISTRICT - FRACTION AND PERCENT OF COMPONENTS LEAKING AT TIME OF INSPECTION

	SCAQMD		BAAQMD		KCAPCD		Misc. Districts[a]	
Component	Fraction	Percent	Fraction	Percent	Fraction	Percent	Fraction	Percent
Valves								
Gas	316/14417	2.19	162/19750	0.82	43/2741	1.57	3/1178	0.25
Liquid	543/37181	1.46	97/27970	0.35	34/5427	0.63	9/2412	0.36
Flanges	11/2979	0.37	0/0	ND[b]	17/15299	0.11	4/6278	0.06
Pumps	62/1233	5.03	67/1260	5.32	1/212	0.47	0/113	0.00
Compressors	7/46	15.2	34/393	8.65	0/12	0.0	0/7	0.0
PRVs								
Gas	1/41	2.44	0/0	ND	0/72	0.0	0/29	0.0
Liquid	0/1	0.0	0/0	ND	0/46	0.0	0/7	0.0

[a] Miscellaneous districts are Kings County Air Pollution Control District, San Luis Obispo County Air Pollution Control District, and Ventura County Air Pollution Control District. There is one petroleum refinery in each of these districts.

[b] ND = No data available.

- Flanges: SCAQMD vs KCAPCD
- Pumps: SCAQMD and BAAQMD vs KCAPCD

In all cases where there is a statistically significant difference between the SCAQMD and another district, the data indicate that the SCAQMD has the higher percent of leaking components.

Table 2-12 summarizes the fraction and the percent of components leaking 15 days after inspection for each district. These results were also compared to determine whether statistically significant differences exist between districts. Partly because there are fewer data points 15 days after inspection, there were fewer differences that were determined to be statistically significant. The differences between districts that were determined to be statistically significant are indicated below.

- Valves-gas service: BAAQMD vs SCAQMD and KCAPCD
- Valves-liquid service: BAAQMD vs KCAPCD

2.2.3 Differences in District Rules

A detailed comparison of the district rules is presented in Section 5. This comparison demonstrates that there are few significant differences in the refinery fugitive I/M rules between districts. An example of the difference between district rules are the requirements to calibrate hydrocarbon detection instruments with hexane in the SCAQMD and methane in the BAAQMD.

While there are few significant differences between the rules themselves, there are differences in how the rules are implemented. For example, the BAAQMD must be more rigorous than the SCAQMD in promoting that complete usable I/M records be kept. This is seen in the fact that BAAQMD refineries were able to provide more than five times the actual I/M screening measurements than SCAQMD refineries.

TABLE 2-12. SUMMARY OF ACTUAL DATA BY DISTRICT - FRACTION AND PERCENT OF COMPONENTS LEAKING 15 DAYS AFTER INSPECTION

	SCAQMD		BAAQMD		KCAPCD		Misc. Districts[a]	
Component	Fraction	Percent	Fraction	Percent	Fraction	Percent	Fraction	Percent
Valves								
Gas	2/3905	0.05	60/17493	0.34	0/2299	0.0	0/1131	0.0
Liquid	12/8342	0.14	31/22822	0.14	0/3501	0.0	0/1773	0.0
Flanges	0/1418	0.0	0/0	ND[b]	1/11834	0.01	0/5808	0.0
Pumps	7/553	1.27	50/1260	3.97	1/140	0.71	0/90	0.0
Compressors	5/40	12.5	20/393	5.09	0/10	0.0	0/70	0.0
PRVs								
Gas	0/9	0.0	0/0	ND[2]	0/72	0.0	0/28	0.0[2]
Liquid	0/1	0.0	0/0	ND[2]	0/13	0.0	0/0	ND[2]

[a] Miscellaneous districts are Kings County Air Pollution Control District, San Luis Obispo County Air Pollution Control District, and Ventura County Air Pollution Control District. There is one petroleum refinery in each of these districts.

[b] ND = No data available.

2.3 Differences in Fugitive Emissions and Inspection/Maintenance Programs Between Refineries

2.3.1 Component Populations

Table 2-1, presented earlier in this section, shows the variability that exists in nonexempt component populations by process unit. In many cases the difference between the nonexempt component populations for the same process unit between two different refineries is an order of magnitude. In some cases, this difference is more than two orders of magnitude. As discussed earlier, this suggests that component populations for a given process unit are a function of both the type of process unit and the size of the unit.

There is even greater variability in exempt components populations by process unit. This variability is increased because of the flexibility that exists in interpreting the exemptions. For example, for a given process unit, one refinery might claim a large percentage of the components exempt due to low RVP, whereas another refinery in the same district might not claim any components exempt due to low RVP. There are numerous examples of this type of situation that can be identified by reviewing the database.

2.3.2 Fraction of Components Leaking

Table 2-13 presents the percent of components leaking at the time of inspection by component type for all refineries that submitted actual I/M data.

The differences that exists in the percent of components leaking is surprisingly large. The most significant example of these differences is the percent of gas service valves leaking for Shell Oil, Carson versus Chevron, El Segundo. Both refineries submitted over 5,000 data points for gas service values. The percent leaking was 0.08 percent for Shell and 3.91 percent for Chevron. This difference is statistically significant. It is not completely

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TABLE 2-12. SUMMARY OF ACTUAL DATA SUBMITTED FOR FRACTION OF COMPONENTS LEAKING AT TIME OF INSPECTION

District/Refinery	Valves Gas Fraction	Valves Gas %	Valves Liquid Fraction	Valves Liquid %	Flanges Fraction	Flanges %	Pumps Fraction	Pumps %	Compressors Fraction	Compressors %	PRV Gas Fraction	PRV Gas %	PRV Liquid Fraction	PRV Liquid %
SCAQMD[a]														
ARCO, Carson							12/309	3.88						
Chevron, El Segundo	271/6,937	3.91	456/20,602	2.1			10/488	2.05	1/21	4.76	0/5	0.00		
Edgington, Wilmington	11/151	7.28	3/558	0.54	2/1,418	0.14	0/15	0.00	0/2	0.00	1/36	2.78	0/1	0.00
Golden West	16/1,485	1.08	44/3,205	1.37			18/56	32.1	5/17	29.4				
MacMillan, Signal Hill	1/127	0.79	0/232	0.00	1/91	1.10	0/29	0.00						
Newhall, Newhall	13/470	2.77	29/650	4.46	8/1,470	0.54	0/47	0.00	1/6	16.7				
Shell Oil, Carson	4/5,247	0.08	11/11,934	0.09			22/293	7.51						
SCAQMD Subtotal	316/14,417	2.19	543/37,181	1.46	11/2,979	0.37	62/1,237	5.01	7/46	15.2	1/41	2.44	0/1	0.00
BAAQMD[b]														
Chevron, Richmond							7/428	1.64	4/134	2.99				
Exxon, Benicia	27/5,191	0.52	58/9,709	0.60			5/188		0/14	0.00				
Shell, Martinez	14/2,250	0.62	18/5,148	0.35			11/187	5.82	13/41	31.7				
Tosco, Martinez	112/9,600	1.17	10/6,338	0.16			41/311	13.1	10/168	5.99				
Union Oil, Rodeo	9/2,709	0.33	11/6,775	0.16			3/146	1.15	7/36	19.4				
BAAQMD Subtotal	162/19,750	0.82	97/27,970	0.35			67/1,260	5.32	34/393	8.65				
KCAPCD[c]														
Coastal, Bakersfield	16/555	2.88	0/533	0.00	3/2,208	0.09	0/30	0.00	0/1	0.00	0/14	0.00	0/2	0.00
Kern Oil and Refining	5/390	1.03	5/1,738	0.29	0/2,981	0.00	0/66	0.00	0/3	0.00				
Texaco, Bakersfield	22/1,796	1.22	29/3,156	0.92	14/10,110	0.14	1/116	0.86	0/9	0.00	0/58	0.00	0/44	0.00
KCAPCD Subtotal	43/2,741	1.57	34/5,427	0.63	17/15,299	0.11	1/212	0.47	0/13	0.00	0/72	0.00	0/46	0.00
Misc. Districts[d]														
Beacon Oil, Hanford	3/1,131	0.27	8/1,773	0.45	4/5,808	0.07	0/90	0.00	0/7	0.00	0/28	0.00		
Conoco, Santa Maria	0/10	0.00	0/174	0.00									0/3	0.00
Oxnard, Oxnard	0/37	0.00	1/465	0.22	0/470	0.00	0/23	0.00			0/1	0.00	0/4	0.00
Misc. District Subtotal	3/1,178	0.25	9/2,412	0.36	4/6,278	0.06	0/113	0.00	0/7	0.00	0/29	0.00	0/7	0.00
TOTAL ALL DISTRICTS	524/38,086	1.38	683/72,990	0.94	32/24,556	0.13	130/2,822	4.61	41/459	8.93	1/142	0.70	0/54	0.00

Notes: Footnotes are defined on the continuation of this table on the following page.

TABLE 2-13. (Continued)

FOOTNOTES:

[a] The SCAQMD defines a leaking component as one that leaks greater than 10,000 ppm, measured in hexane at the source.

[b] The BAAQMD defines a leaking component as one that leaks greater than 10,000 ppm, measured in methane 1 cm from the source.

[c] The KCAPCD defines a leaking liquid component as one that leaks at a rate of more than 3 drops per minute. A leaking gas component is defined as one that leaks greater than 10,000 ppm, measured in methane 1 cm from the source.

[d] The Kings County APCD defines: 1) leaking valves and flanges as those that leak greater than 1,000 ppm, measured as hexane at the source; 2) leaking PRVs as those that leak greater than 10,000 ppm, measured as hexane at the source; and 3) leaking pumps and compressors as those that leak greater than 10,000 ppm, measured as methane 1 cm from the source. The Santa Barbara County APCD defines leaking valves and flanges as those that leak greater than 10,000 ppm, measured as methane 1 cm from the source. The Ventura County APCD defines a leaking liquid component as one that leaks at a rate of more than 3 drops per minute. A leaking gas component is defined as one that leaks greater than 10,000 ppm, measured as methane 1 cm from the source.

clear what could cause such significant differences in the percent of components leaking. However, differences in the I/M approach used may play a role here.

2.3.3 Difference in Inspection/Maintenance Approach

The three primary approaches to I/M program implementation are as follows:

- The program is conducted by each individual process unit operator.
- The program is conducted by a group of refinery personnel who perform the I/M activities for the entire refinery.
- The program is conducted by an outside contractor.

The most significant difference in these approaches is applicable to the use of process unit operators to conduct the I/M program. There are two views regarding use of process unit operators to conduct I/M programs. The fact that the process unit operator is involved in the I/M program may significantly improve their desire and ability to recognize leaks. However, the fact that a variety of process unit operators are conducting the component screening may result in the use of inconsistent procedures and a decrease in quality assurance/quality control. These inconsistencies may carry over to the recordkeeping associated with the I/M program.

3.0 RECOMMENDATIONS

There are a number of recommendations that are prompted by the results and conclusions of this study. These recommendations are presented in this section along with the primary result or conclusion that prompted the recommendation. The intent of these recommendations is to suggest actions that would improve consistency in the implementation of fugitive I/M programs and lead to a better understanding of the magnitude of refinery fugitive emissions. It is recognized that some of these recommendations would have a significant effect on industry and agency resources.

3.1 Possible Improvement to Inspection/Maintenance Procedures and Methods

This study found that inspection/maintenance procedures and methods are being applied inconsistently. As a result, the levels of emission control that are being achieved in the various districts and refineries are both variable and difficult to quantify. The following recommendations address this and other related issues.

- Emissions from inaccessible components were estimated to be greater than 30 percent of total emissions. The number of inaccessible components claimed as exempt varied significantly between refineries. It is recommended that distinct criteria be developed to define an inaccessible component. Consideration could also be given to requiring refineries to submit a detailed plan justifying exemption claims.

- The use of different combinations of detection instruments, calibration gas, and screening distance results in inconsistent levels of emission control. It also leads to significant difficulty in evaluating the relative effectiveness of a given

I/M program. It is recommended that a standard detection instrument, calibration gas, and screening distance be adopted statewide.

- The content and format of I/M records that are currently maintained are extremely inconsistent. Recordkeeping requirements are an important tool in assuring and monitoring compliance with rules. It is recommended that I/M records be submitted annually to the districts in a standard statewide format. These records should, at a minimum, include: the process unit, component/stream type, component ID number, inspection date, and screening value for all components inspected. For leaking components, these records should include: the repair date, repair method, reinspection date, and reinspection screening values.

3.2 Additional Studies and Analyses for Consideration

Several of the important results of this study lead to recommendations for further studies and analyses. These results and the related studies or analyses are described below.

- Statistically significant differences exist in the fraction of components leaking between refineries and districts. It would be valuable to further investigate these differences. Are they real differences in leak rates or a result of inconsistent measurement techniques? How much of the variability in the fraction of components leaking can be attributed to different I/M approaches?

- Emissions from exempt components were shown to be a significant percentage of total emissions. It is recommended that a review of the exemptions claimed by refineries be conducted to evaluate their appropriateness. It would also be valuable to conduct a field study of exempt components with particular emphasis on inaccessible and low RVP components. This field study should define leak frequencies, degrees of inaccessibility, and ranges of RVPs.

- The average emission rates developed in this study are uncertain because the only correlations that exist between screening values and leak rates are for a TLV, calibrated with hexane, at the source. In order to develop average emission rates with greater certainty, it will be necessary to conduct a field study to measure screening values and leak rates for different (or a future standard) instruments, calibration gases, and screening distances.

- The database that was developed in this study will be very useful and valuable in performing detailed evaluations of fugitive emissions. One possibility for improving the database would be to require each refinery to perform a complete component inventory for its refinery. This information could then be used for many years and would only need to be updated as refinery modifications occurred.

4.0 EMISSION ESTIMATION METHODOLOGY

4.1 Data Requirements

There are several key types of data necessary to achieve the objectives of this study. These data requirements are as follows:

- Component Populations
  - Nonexempt components
  - Exempt components

- Inspection/Maintenance Data
  - Fraction of components leaking at the time of inspection
  - Fraction of components leaking 15 days following inspection
  - Screening values

Component populations are the number of the various types of fugitive emission sources (i.e., valves, flanges, pumps, compressors, and pressure relief valves) found in each refinery process unit. In order to be readily usable for the purposes of this study, valve and pressure relief valve component populations required a distinction as to the type of stream (i.e., gas or liquid service) each component services.

It was also necessary for the component populations to be grouped into nonexempt and exempt categories. Nonexempt components are those that are subject to fugitive emission control rules. Exempt components are those not subject to the rules for various reasons. Some of the reasons that components are considered exempt include components that handle low Reid Vapor Pressure (RVP) or low PROC content streams, high temperature components, and inaccessible components.

Inspection/maintenance (I/M) data are the data collected by refinery personnel during the regularly scheduled inspections for fugitive emission leak detection and repair programs. The three types of I/M data that can be collected are the fraction of components leaking at the time of inspection, the fraction of components leaking 15 days following inspection, and screening values.

A leaking component is a component with a screening value exceeding the threshold that is defined as a leak (normally 10,000 ppm). The fraction of components leaking at the time of inspection refers to leaking components detected when the normally scheduled inspection occurs. The fraction leaking 15 days after inspection refers to components that are still leaking following the allowable repair period.

Screening value data are the actual nonmethane hydrocarbon (NMHC) concentrations obtained by the detection instrument during regularly scheduled inspections. Screening values are presented as the concentration in parts per million by volume (ppmv) of NMHC.

4.2 Data Collection

To the maximum extent possible, the emission estimates and all analyses performed for this study are based on recently collected inspection/maintenance data for refineries in the same district. These data include component populations, fraction of components leaking at the time of inspection, fraction of components leaking 15 days following inspection, and screening values.

4.2.1 Questionnaires

4.2.1.1 September 10, 1985 Questionnaire

The first step in collecting data was to send out a questionnaire requesting component population data and inspection/maintenance (I/M) data.

Also requested was information regarding the current inspection/maintenance program including: frequency of inspection, detection instrument used; type of calibration; distance from source at which measurements are taken; and process unit turnaround frequency. The September 10, 1985 questionnaire presented in Appendix A was developed and sent to all California petroleum refineries. Numerous telephone contacts were required to clarify information contained in the questionnaire. As the data that were obtained from this first questionnaire were reviewed, it became clear that the majority of data collected did not contain certain important information. The important information that was omitted included component identification numbers, specification of the process unit that a component is part of, specific component type (e.g., valve, flange, pump, etc), and the stream service type for each component (i.e., gas or liquid service).

4.2.1.2 March 26, 1986 Questionnaire

In response to the need for additional information, a second questionnaire was developed and sent to selected refineries. This questionnaire, dated March 26, 1986, is presented in Appendix B. This questionnaire was tailored for refinery specific requests using optional bulletized paragraphs in a cover letter and optional component population tables. Again, a significant amount of telephone contacts were required to follow-up the questionnaire.

4.2.1.3 Summary of Data Received in Response to Questionnaires

A summary of the final status of data acquisition is presented in Table 4-1. This table presents the key types of data, by component type, provided by each refinery. The information presented is limited to data considered to be usable for the purpose of fulfilling the objectives of the study. One of the primary reasons data would be considered not usable, thus not included in this summary, is the absence of component stream service type distinctions (i.e., gas or liquid service).

RADIAN
CORPORATION

TABLE 4-1. SUMMARY OF USABLE DATA RECEIVED IN RESPONSE TO QUESTIONNAIRES

	Component Populations				Fraction of Components Leaking at Time of Inspection		Fraction of Components Leaking 15 Days After Inspection		Screening Values	
	Exempt	Counts(C) or Estimates(E)[1]	Nonexempt	Counts(C) or Estimates(E)[1]	Exempt	Nonexempt	Exempt	Nonexempt	Exempt	Nonexempt
<u>SCAQMD</u>										
ARCO, Carson	V,F,P,C,PRV	C	V,F,P,C,PRV	C		P				
Champlin, Wilmington										
Chevron, El Segundo	F,P,C,PRV	C	V,P,C,PRV	C		V, P,C,PRV		V, P,C		P,C,PRV
Edgington Oil, Wilmington	V,F,P,C,PRV	C	V,F,P,C,PRV	C		V,F,P,C,PRV		V,F,P,C,PRV		V,F,P,C,PRV
Fletcher Oil, Wilmington	V	E	V	E						
Golden West, Sante Fe Springs	P,C,PRV	E	P,C,PRV	E		V,P,C		P,C		
Huntway, Wilmington	V,F,P,C,PRV	E	V,P,C,PRV	E						
Macmillan Ring Free Oil, Signal Hill	V,F,P,C,PRV	C	V,F,P,C,PRV	C		V,F,P				
Mobil Oil, Torrance	V,P,C,PRV	E	P,C,PRV	E						
Newhall Refinery, Newhall	V,F,P,C,PRV	E	V,F,P,C,PRV	E		V,F,P,C,PRV				P,C
Paramount, Paramount										
Shell Oil, Carson	V,F,P,C,PRV	E	F,P,C,PRV	E		V,P				V
Texaco, Wilmington										
Union Oil, Los Angeles	F,P,C,PRV	E	F,P,C,PRV	E						
<u>BAAQMD</u>										
Chevron, Richmond			P,C,PRV	C		P,C		P,C		P,C
Exxon, Benicia	V,P,C	E	V,P,C	E		V,P,C		V,P,C		V
Huntway, Benicia										
Pacific Refinery, Hercules										
Shell Oil, Martinez	V,P,C,PRV	E	V,,C,PRV	E		V,P,C		P,C		P,C
Tosco Corp., Martinez	V,F,P,C	C	V,F,P,C	C	V,P,C	V,P,C	V,P,C	V,P,C	V,P,C	V,P,C
Union Oil, Rodeo	V,F,P,C,PRV	E	V,F,P,C,PRV	E		V,P,C		V,P,C		P,C
<u>KCAPCD</u>										
Chevron, Bakersfield	P,C,PRV	C	P,C,PRV	C						
Coastal, Bakersfield	V,F,P,C,PRV	E	V,F,P,C,PRV	C		V,F,P,C,PRV		V,F,P,C,PRV		V,F,P,C,PRV
Kern Oil and Refining, Bakersfield			V,F,P,C,PRV	C		V,F,P,C				
Paramount, Bakersfield	V,F,P,C,PRV	E	V,F,P,C,PRV	E						
San Joaquin Refining, Bakersfield	V,F,P,C	C								
Texaco, Bakersfield	V,F,P,C,PRV	E	V,F,P,C,PRV	C		V,F,P,C,PRV		V,F,P,C,PRV		V,F,P,C,PRV
Witco Golden Bear, Bakersfield	V,F,P,C,PRV	E			V,F,P,C,PRV		V,F,P,C,PRV	V,F,P,C,PRV		
<u>Misc. Districts</u>										
Beacon Oil, Hanford			V,P,C,PRV	C		V,F,P,C,PRV		V,F,P,C,PRV		
Conoco, Santa Maria	V,P,C,PRV	E	V,P,C,PRV	E		V,PRV		V,PRV		
Oxnard Refining, Oxnard			V,F,P,C,PRV	C		V,F,P,C,PRV				

V = Values F = Flanges P = Pumps
C = Compressors PRV = Pressure Relief Values

[1] This column provides a generalization of whether component population counts or estimates were provided. In some cases, counts and/or estimates may have been provided for one or more different exemption types.

Review of Table 4-1 indicates the relatively minimal coverage for certain data types. Significant data gaps existing after data acquisition efforts included:

- Exempt component data for all districts.

- Screening value data for all districts.

- Component populations and fraction of components leaking both at the time of inspection and 15 days following inspection for nonexempt valves for integrated refineries in the SCAQMD.

- Fraction of components leaking both at the time of inspection and 15 days following inspection for nonexempt pressure relief valves for refineries in the BAAQMD.

Table 4-2 presents the year of data provided by each refinery for data that were included in the fugitive emission database. The information is presented for each type of data (e.g., fraction of components leaking at the time of inspection, screening values, etc.). This table also indicates where extrapolations of data were used when actual data were not available.

In addition, Table 4-2 indicates the primary source of data on which component populations were based. The potential sources include Table 1, Table A, Oil and gas Journal Information, and Extrapolations. Table 1 was provided by refineries in response to the September 10, 1986 questionnaire. Table A was provided by refineries in response to the March 26, 1986 questionnaire.

The Oil and Gas Journal annual refinery report (OGJ, 1986) provides information regarding the types of process units found at each refinery in the nation. This information was used to determine the process units found at refineries that did not provide questionnaire responses. Component populations were then developed for each process unit following the extrapolation procedures outlined in Section 4.3.3.

TABLE 4-2. SOURCES AND DATES OF DATA USED IN THE FUGITIVE EMISSIONS DATA BASE

Component Populations	Fraction of Nonexempt Components Leaking at Time of Inspection	Fraction of Nonexempt Components Leaking 15 Days After Inspection	Screening Values	Component Populations Exempt	Component Populations Nonexempt
SCAQMD					
ARCO, Carson	P-1984/V,F,C,PRVs-EXTRAP	EXTRAP	NA	Table A	Table A
Champlin, Wilmington	EXTRAP	EXTRAP	NA	OGJ/EXTRAP	OGJ/EXTRAP
Chevron, El Segundo	V,P,C,PRVs-1985/F-EXTRAP	V,P,C,PRVs-1985/F-EXTRAP	NA	Table 1 & A	Table 1 &A
Edgington Oil, Wilmington	V,F,P,C,PRVs-1983	V,F,P,C,PRVs-1983	V,F,PRVs-1983	Table A	Table A
Fletcher Oil, Wilmington	EXTRAP	EXTRAP	NA	EXTRAP	EXTRAP
Golden West, Sante Fe Springs	V,P,C-1984/F,PRVs-EXTRAP	P,C-1984/V,F,PRVs-EXTRAP	NA	Table 1	Table 1
Huntway, Wilmington	EXTRAP	EXTRAP	NA	Table 1 & A	Table 1 & A
Macmillan Ring Free Oil, Signal Hill	V,F,P-1985/C,PRVs-EXTRAP	EXTRAP	NA	Table 1	Table A
Mobil Oil, Torrance	EXTRAP	EXTRAP	NA	Table 1 & A	Table 1 & A
Newhall Refinery, Newhall	V,F,P,C,PRVs-1983	EXTRAP	NA	Table A	Table A
Paramount, Paramount	EXTRAP	EXTRAP	NA	EXTRAP	EXTRAP
Shell Oil, Carson	V,P-1984/F,C,PRVs-EXTRAP	V-1984/F,P,C,PRVs-EXTRAP	1984	Table 1	Table 1
Texaco, Wilmington	EXTRAP	EXTRAP	NA	OGJ/EXTRAP	OGJ/EXTRAP
Union Oil, Los Angeles	EXTRAP	EXTRAP	NA	Table 1 & A	Table 1 & A
BAAQMD					
Chevron, Richmond	P,C-1985/V,F,PRVs-EXTRAP	P,C-1985/V,F,PRVs-EXTRAP	NA	Table 1	EXTRAP
Exxon, Benicia	V,P,C-1985/F,PRVs-EXTRAP	V,P,C-1985/F,PRVs-EXTRAP	1985	Table 1	Table A
Huntway, Benicia	EXTRAP	EXTRAP	NA	EXTRAP	EXTRAP
Pacific Refinery, Hercules	EXTRAP	EXTRAP	NA	OGJ/EXTRAP	OGJ/EXTRAP
Shell Oil, Martinez	V,P,C-1984/F,PRVs-EXTRAP	P,C-1984/V,F/PRVs-EXTRAP	NA	Table 1	Table A
Tosco Corp., Martinez	V,P,C-1985/F,PRVs-EXTRAP	V,P,C-1985/F,PRVs-EXTRAP	1985	Table 1	Table A
Union Oil, Rodeo	V,P,C-1985/F,PRVs-EXTRAP	V,P,C-1983/F,PRVs-EXTRAP	NA	Table 1	Table A
KCAPCD					
Chevron, Bakersfield	EXTRAP	EXTRAP	NA	Table 1	Table 1
Coastal, Bakersfield	V,F,P,C,PRVs-1985	V,F,P,C,PRVs-1985	1985	Table 1	Table A
Kern Oil and Refining, Bakersfield	V,F,PC,-1983/PRVs-EXTRAP	EXTRAP	NA	Table 1	Table 1
Paramount, Bakersfield	EXTRAP	EXTRAP	NA	Table 1	Table 1
San Joaquin Refining, Bakersfield	EXTRAP	EXTRAP	NA	Table 1	Table 1
Texaco, Bakersfield	V,F,P,C,PRVs-1985	V,F,P,C,PRVs-1985	1985	Table 1	Table 1
Witco Golden Bear, Bakersfield	EXTRAP	EXTRAP	NA	--	Table 1
Misc. Districts					
Beacon Oil, Hanford	V,F,P,C,PRVs-1986	V,F,P,C,PRVs-1986	NA	OGJ/Table 1	OGJ/Table 1
Conoco, Santa Maria	V,PRVs-1982/F,P,C-EXTRAP	EXTRAP	NA	OGJ/Table 1	OGJ/Table 1
Oxnard Refining, Oxnard	V,F,P,C,PRVs-1986	EXTRAP	NA	OGJ/Table 1	OGJ/Table 1

V = Values F = Flanges P = Pumps
C = Compressors PRVs = Pressure Relief Values

EXTRAP = These data were based on extrapolations of data provided by other refineries.

OGJ = The basis for component populations was information regarding the type of process units found at each refinery. This information was obtained from the 1986 "Annual Refinery Report" of the Oil and Gas Journal (OGJ, 1986).

One of the objectives of the data collection efforts was to obtain information to determine the effect on emissions of allowing repairs to be delayed until the next process unit turnaround. Sufficient information was not obtained on the frequency and scheduling of process unit turnarounds to perform this evaluation. However, the emission calculation methodology did account for repairs that had not been performed within 15 days of inspection.

4.2.1.4 Improvement of Data Collected in Response to Questionnaires

Numerous data sets received in response to the questionnaires were considered to be unusable for the purpose of this study. The primary reasons data were considered to be unusable included the lack of segregation by process units, the apparent incompleteness of certain data sets, and the absence of stream service type distinctions. Due to significant gaps in data coverage for specific types of data requirements (i.e., fraction of components leaking and screening values) several data sets were improved. These data sets and the type of improvement performed are discussed in the following paragraphs.

As discussed in Section 4.2.1.3, significant data gaps existed in nonexempt valve component populations, fraction of components leaking both at the time of inspection and 15 days following inspection, and screening values. In response to the questionnaires, several complex refineries provided large data sets for nonexempt valves that were considered unusable due to the absence of stream service type distinctions. These data sets were improved by determining stream service for each nonexempt valve by reviewing process and instrumentation diagrams (P&IDs) and descriptions of valve locations. Listed below are the three data sets which were improved, including for each a description of the type of data resulting from improvement:

- Chevron, El Segundo - Fraction of components leaking both at the time of inspection and 15 days following inspection.

- Shell Oil, Carson - Component populations, fraction of components leaking at the time inspection, and screening values.

- Shell Oil, Martinez - Fraction of components leaking at the time of inspection.

4.2.2 Data Collection Through Field Sampling

As part of the work to improve the database, a small field sampling/ data collection effort was conducted. This effort drew upon a small portion of the overall project budget. Field sampling/data collection was performed at two process units at the Chevron, El Segundo refinery. Data on component populations, fraction of components leaking, and screening values were collected. Component populations were the only field collected data used in this study. These component populations were entered into the database for the applicable process units. The data on fraction of components leaking and screening values are not included in this report but have been provided to the ARB.

4.3 Development of the Database

4.3.1 Structure of the Database

The data obtained from the refineries were computerized in a consistent format. Separate databases were created to archive data and estimate emissions from nonexempt and exempt components. An example of the database for nonexempt components for one process unit is presented in Table 4-3. An example of the database output for an entire refinery for nonexempt components for a generic refinery is provided in Appendix D. Table 4-3 and the output in Appendix D include the following information.

- The component populations provided by the refinery in Table 1 or Table A of Radian's questionnaires.

Table 4-3. Example of Data Base Used to Calculate Emissions from Nonexempt Components

Refinery:Macmillan Ring Free Oil Signal Hill
Leak Frequencies for
Nonexempt Components
Date of Inspection:1985 Annual

Process Unit:
Blowdown/Flare/Vapor Recovery

						A (Inspection)		B (15 days)	
Comp. Type	Service	Table 1 or A	Number Insp.	Comp. Pop.	Source of Data	Number Leak	Fraction Leak	Number Leak	Fraction Leak
Valves	G	31	30	30	C,K,N	1	0.0333		0.0000
	L		0	0	C		0.0000		0.0000
	NS								
Flanges	NS	10	30	30	C,K,P	1	0.0333		0.0000
Thread Conn.	NS	0							
Pumps	L	0	0	0	C		0.0000		0.0000
Compressors	G	2		2	A,M,N		0.0667		0.0000
PRVs	G	0		10	A,O,P		0.0278		0.0000
	L	0		0	A		0.0000		0.0000
	Other	10		0	A		0.0000		0.0000
	NS								

Note - See text in Section 4.3 for an explanation of each data field.

- The number of components that were inspected by the refinery if inspection/maintenance data were provided.

- The component populations used to estimate emissions. Where both data from Table 1 or A and data on the number of components inspected were available, the number of components inspected were used to estimate emissions.

- The sources of data for component populations and fraction of components leaking.

- The number and/or fraction of components leaking at the time of inspection.

- The number and/or fraction of components leaking 15 days after inspection.

- Average emission rates (AERs) for leaking and nonleaking components (two different sets of AERs exist in the database, as discussed in Section 4.4).

- Average post-rule emissions.

- Pre-rule emission factors (these are AP-42 emission factors (EPA, 1985)).

- Pre-rule emissions.

An example process unit table indicating the format of the database for exempt components is presented in Table 4-4. An example of the database output for an entire refinery for exempt components is presented in Appendix D for a generic refinery. For both the nonexempt and exempt databases, one data file was created for each process unit in each refinery in the state.

Table 4-4. Example of Data Base Used to Calculate Emissions from Exempt Components

Refinery: Union Oil, Rodeo
Leak Frequencies for
Exempt Components

Entered by: LEM 1/2
Checked by:

Process Unit:
Vacuum Crude
Distillation No. 1

Component	Service	Reason for Exemption	Component Pop.	Source of Component Pop.	Average Emission Factor (lb/hr-source)	95% Confidence Interval (lb/hr-source)	Average Emissions (ton/yr)	95% Confidence Interval (ton/yr)
Valves	G	Low PROC	0	G	0.0059	0.003 - 0.011	0.00	0 - 0
	L	Low PROC	0	G	0.0024	0.0017 - 0.0036	0.00	0 - 0
	L	Low RVP (1.55-0.1)	0	A	0.0005	0.0002 - 0.0015	0.00	0 - 0
	L	Low RVP (=<0.1)	88	A	0.0005	0.0002 - 0.0015	0.19	0.07708 - 0.57816
	G	Inaccessible	0	A	0.059	0.03 - 0.11	0.00	0 - 0
	L	Inaccessible	0	A	0.024	0.017 - 0.036	0.00	0 - 0
	G	High Temp	0	G	0.059	0.03 - 0.11	0.00	0 - 0
	L	High Temp	0	G	0.024	0.017 - 0.036	0.00	0 - 0
	G	CPU	4	A	0	0 - 0	0.00	0 - 0
	L	CPU	16	A	0	0 - 0	0.00	0 - 0
	G	Other	0	A	0	0 - 0	0.00	0 - 0
	L	Other	0	A	0	0 - 0	0.00	0 - 0
Flanges	NS	Low PROC	0	G	0.000056	0.00002 - 0.00025	0.00	0 - 0
	NS	Low RVP (1.55-0.1)	0	A	0.00056	0.0002 - 0.0025	0.00	0 - 0
	NS	Low RVP (=<0.1)	259	A	0.00056	0.0002 - 0.0025	0.64	0.22688 - 2.83605
	NS	Inaccessible	0	A	0.00056	0.0002 - 0.0025	0.00	0 - 0
	NS	High Temp	0	G	0.00056	0.0002 - 0.0025	0.00	0 - 0
	NS	CPU	57	A	0	0 - 0	0.00	0 - 0
	NS	Other	0	A	0	0 - 0	0.00	0 - 0
Pumps	L	Low PROC	6	G	0.0104	0.005 - 0.021	0.27	0.1314 - 0.55188
	L	Low RVP (1.55-0.1)	0	A	0.005	0.002 - 0.011	0.00	0 - 0
	L	Low RVP (=<0.1)	12	A	0.005	0.002 - 0.011	0.26	0.10512 - 0.57816
	L	Inaccessible	0	A	0.25	0.16 - 0.37	0.00	0 - 0
	L	High Temp	0	G	0.25	0.16 - 0.37	0.00	0 - 0
	L	CPU	0	C	0	0 - 0	0.00	0 - 0
	L	Other	0	A	0	0 - 0	0.00	0 - 0
Compressors	G	Low PROC	0	G	0.035	0.012 - 0.095	0.00	0 - 0
	G	High Temp	0	G	1.4	0.66 - 2.9	0.00	0 - 0
	G	CPU	0	A	0	0 - 0	0.00	0 - 0
	G	Other	0	A	0	0 - 0	0.00	0 - 0
PRVs	G	Low PROC	0	G	0.036	0.01 - 0.13	0.00	0 - 0
	L	Low PROC	0	G	0.036	0.01 - 0.13	0.00	0 - 0
	Other	Low PROC	0	G	0.036	0.01 - 0.13	0.00	0 - 0
	G	Low RVP (1.55-0.1)	0	A	0.36	0.1 - 1.3	0.00	0 - 0
	L	Low RVP (1.55-0.1)	0	A	0.36	0.1 - 1.3	0.00	0 - 0
	Other	Low RVP (1.55-0.1)	0	A	0.36	0.1 - 1.3	0.00	0 - 0
	G	Low RVP (=<0.1)	0	A	0.36	0.1 - 1.3	0.00	0 - 0
	L	Low RVP (=<0.1)	0	A	0.36	0.1 - 1.3	0.00	0 - 0
	Other	Low RVP (=<0.1)	0	A	0.36	0.1 - 1.3	0.00	0 - 0
	G	Inaccessible	0	A	0.36	0.1 - 1.3	0.00	0 - 0
	L	Inaccessible	0	A	0.36	0.1 - 1.3	0.00	0 - 0
	Other	Inaccessible	0	A	0.36	0.1 - 1.3	0.00	0 - 0
	G	Vent to VR	0	A	0	0 - 0	0.00	0 - 0
	L	Vent to VR	0	A	0	0 - 0	0.00	0 - 0
	Other	Vent to VR	0	A	0	0 - 0	0.00	0 - 0
	G	High Temp	0	G	0.36	0.1 - 1.3	0.00	0 - 0
	L	High Temp	0	G	0.36	0.1 - 1.3	0.00	0 - 0
	Other	High Temp	0	G	0.36	0.1 - 1.3	0.00	0 - 0
	G	CPU	1	A	0	0 - 0	0.00	0 - 0
	L	CPU	0	G	0	0 - 0	0.00	0 - 0
	Other	CPU	1	A	0	0 - 0	0.00	0 - 0
	G	Other	0	A	0	0 - 0	0.00	0 - 0
	L	Other	10	A	0	0 - 0	0.00	0 - 0
	Other	Other	0	A	0	0 - 0	0.00	0 - 0
Total for Process Unit							1.36	0.54 - 4.54

4.3.2 Summary of Actual Data

Table 4-1 in Section 4.2.1.3 summarizes the extent to which actual component population and fraction of components leaking data were provided by the refineries. For component populations, almost every refinery in the state provided some information. The five refineries in the state that did not provide any information in response to our questionnaires are listed below.

- Champlin, Wilmington.
- Paramount Refining, Paramount.
- Texaco, Wilmington.
- Huntway, Benicia.
- Pacific Refining, Hercules.

For the fraction of components leaking, data were available for a much smaller set of refineries. Table 2-12 in Section 2.2.2 presents a summary of the actual data that exists for fraction of components leaking at the time of inspection. For refineries that are not listed in Table 2-12, all of the data for fraction of leaking components were developed using the extrapolation procedures described in the following section.

4.3.3 Extrapolation Procedures

The first step in developing a complete component population data set for each process unit in each refinery was to enter all available data into the database. For nonexempt components, if both component population data submitted by the refineries and data on the number of components inspected were available, the number of components inspected was used to estimate emissions.

For the data that were provided by the refineries, it was necessary to characterize the process units in a consistent manner. Each process unit was categorized as one of the 30 process units that were used as the basis of this study. These 30 process units are listed in a variety of tables toward the end of this section of the report. For refineries that did not provide any data, it was necessary to determine what process units existed at the refinery. Information indicating the type and size of primary process units found at each refinery in the nationl obtained from the 1986 Annual Refining Report of the Oil and Gas Journal (OGJ, 1986) was used to make this determination. Wherever possible, the refineries were contacted to verify that correct process units had been selected. In numerous cases secondary process units, such as blending/shipping/storage, wastewater treatment, and blowdown/ flave/vapor recovery, were identified during these phone contacts.

After all of the available data were input to the database, there were numerous data gaps. In order to fill these gaps, average component populations by process unit by district were developed. These average component populations, the basis for extrapolation, are presented in the next subsection. The gaps were then filled according to the hierarchy of options listed below.

- First Choice: Where component populations were available without service type breakdowns, the service type breakdown (i.e., gas or liquid) was extrapolated from an average for the same process unit within the same district.

- Second Choice: Component populations were extrapolated from the same process unit within the same district.

- Third Choice: Component populations were extrapolated from the same process unit within a different district.

- Fourth Choice: Component populations were extrapolated for the same process unit from default component populations presented in a previous fugitive emission study titled A Model for Evaluation of Refinery and Synfuels Hydrocarbon VOC Emission Data (Radian, 1983).

- Fifth Choice: In limited cases, component populations were extrapolated from a similar process unit within the same district. A cross-reference of similar process units is presented in Appendix E.

The logic behind this extrapolation hierarchy is as follows. Previous studies of fugitive emissions from refineries have shown component populations to most closely correlate with the type of process units. Therefore, all extrapolation options use data for the same process unit. It was preferred that the data be obtained from the same district for two reasons. First, different districts have different types of refineries in terms of the crude oil they process, their age, etc. Second, the types and interpretation of exemptions vary from district to district which affects the ratio of components that are exempt vs. nonexempt.

The use of data on the fraction of components leaking only applies to nonexempt components. In order to fill the gaps for these data, the average fraction of components leaking by process unit for each district was developed. In addition, the average fraction of components leaking was developed by process unit category averages by stream types for each district. The four process unit category averages by stream type and the process units that were included in these categories are presented in Table 4-5. Finally, the average fraction of components leaking was developed for all process units combined for each district. Each of these average fractions of components leaking provide the basis for extrapolation and are presented in the next subsection. The gaps were then filled according to the hierarchy of options listed below.

TABLE 4-5. DEFINITION OF PROCESS UNIT CATEGORIES BY STREAM TYPE

Broad Range of Streams

- Crude Distillation
- Catalytic Cracking
- Hydrocracking
- Thermal Operations
- Fluid Coking
- Blowdown/Vapor Recovery/Flares
- Wastewater Treating
- Storage/Blending/Shipping

Heavy Streams

- Vacuum Crude Distillation
- Gas Oil Hydrotreating
- Vacuum Resid Hydrodesulfurization
- Other Lube Oil Processing
- Asphalt Production

Medium Streams

- Middle Distillate Hydrotreating
- Lubes Processing - Volatile Organic Solvent
- Hydrogen Production
- Other Product Treating
- Other Volatile Petrochemicals
- Other Low Volatility Petrochemicals

Light Streams

- Naptha Hydrotreating
- Catalytic Reforming
- Aromatics Extraction
- Fractionation
- Alkylation
- Polymerization
- Isomerization
- Gasoline Treating
- Olefins Production
- Boilers (Utilities)
- Sulfur Plant

- First Choice: The fraction of components leaking were extrapolated from the same process unit within the same district.

- Second Choice: The fraction of components leaking were extrapolated from the process unit category averages by stream type within the same district.

- Third Choice: The fraction of components leaking were extrapolated from an average of all process units combined within the same district.

The logic behind this extrapolation hierarchy is as follows. The fraction of components leaking are most directly a function of the process unit they are in which affects the volatility of streams, and pressures, temperatures, and other environmental factors. However, if the fraction of components leaking was not available for a given process unit, the next preference was to use a fraction of components leaking that was derived from process units that handle streams with similar volatility. Finally, if no other detailed data were available, the use of an average fraction of components leaking for all process units combined was used. In all cases, data for the same district were used. This insured that differences in the fraction of components leaking between districts (which could occur for a wide variety of reasons) were not obscured by the extrapolation process.

As actual or extrapolated data were entered into the database, codes that indicate the source of the data were also entered. These codes are presented in Table 4-6 for nonexempt components and Table 4-7 for exempt components. These codes were developed in the order of preference for the various extrapolation options.

TABLE 4-6. SOURCE OF COMPONENT POPULATIONS AND FRACTIONS OF LEAKING COMPONENTS FOR NONEXEMPT COMPONENTS

A. Component population from Table 1 of the 10 September 1985 questionnaire.

B. Component population from Table A of the 26 March 1986 questionnaire.

C. Component population from the actual number of components inspected.

D. Component population from Table 1 of the 10 September 1985 questionnaire multiplied by service type breakdown extrapolated from an average for the same process unit within the same district.

E. Component population from the actual number of components inspected multiplied by service type breakdowns extrapolated from an average for the same process unit within the same district.

F. Component population extrapolated from an average for the same process unit within the same district.

G. Component population extrapolated from an average for the same process unit within SCAQMD.

H. Component population extrapolated from an average for the same process unit within BAAQMD.

I. Component population extrapolated from an average for the same process unit within KCAPCD.

J. Component population extrapolated from the same process unit from default values presented in the Radian/EPA 1983 Refinery Model document (Radian, 1983).

K. Fraction of components leaking at time of inspection from data submitted by refinery.

L. Fraction of components leaking 15 days after inspection from data submitted by refinery.

M. Fraction of components leaking at time of inspection from an average for the same process unit within the same district.

N. Fraction of components leaking 15 days after inspection from an average for the same process unit within the same district.

(Continued)

TABLE 4-6. (Continued)

O.	Fraction of components leaking at time of inspection from process unit category averages by stream type within the same district.
P.	Fraction of components leaking 15 days after inspection from process unit category averages by stream type within the same district.
Q.	Fraction of components leaking at time of inspection from average of all process units within the same district.
R.	Fraction of components leaking 15 days after inspection from average of all process units within the same district.
S.	Fraction of components leaking at time of inspection from an average for the same process unit within KCAPCD.
T.	Fraction of components leaking 15 days after inspection from an average for the same process unit within KCAPCD.

TABLE 4-7. SOURCE OF COMPONENT POPULATIONS FOR EXEMPT COMPONENTS

A.	Component population from Table 1 of the 10 September 1985 questionnaire or Table A of the 26 March 1986 questionnaire.
B.	Component population from Table 1 or Table A multiplied by service type breakdowns extrapolated from an average for the same process unit within the same district.
C.	Component population from Table 1 or Table A multiplied by service type breakdowns extrapolated from an average for the same process unit within the SCAQMD.
D.	Component population from Table 1 or Table A multiplied by service type breakdowns extrapolated from an average for the same process unit within the BAAQMD.
E.	Component population from Table 1 or Table A multiplied by service type breakdowns extrapolated from an average for the same process unit within the KCAPCD.
F.	Component population from Table 1 or Table A multiplied by service type breakdowns extrapolated from default values for the same process unit in the Radian/EPA 1983 Refinery Model document (Radian, 1983).
G.	Component population extrapolated from an average for the same process unit within the same district.
H.	Component population extrapolated from an average for the same process unit within the SCAQMD.
I.	Component population extrapolated from an average for the same process unit within the BAAQMD.
J.	Component population extrapolated from an average for the same process unit within the KCAPCD.
K.	Component population extrapolated from default values for the same Pocess unit in the Radian/EPA 1983 Refinery Model document (Radian, 1983).
L.	Component population extrapolated from an average for a similar process unit within the SCAQMD.
M.	Component population extrapolated from an average for a similar process unit within the BAAQMD.
N.	Component population extrapolated from an average for a similar process unit within the KCAPCD.

4.3.4 Basis for Extrapolation

The basis for extrapolation for component populations is presented in tables in Appendices F and G, for nonexempt and exempt components, respectively. These tables show the average number of components by process unit for nonexempt and exempt components.

Tables 4-8 through 4-10 present the fraction of components leaking for the process unit category averages by stream type. In these tables, both the actual fraction of components leaking (the number of component leaking over the number of components inspected) and the percent of components leaking are presented. This allows the reader to determine how many data points an individual result is based on. In general, these results are based on a significantly greater amount of data than any previous refinery fugitive emissions study. In summary, the following numbers of actual inspected sources screened at the time of inspection for all of the component types combined exist in the database.

- SCAQMD - Over 10,000 inspected sources.
- BAAQMD - Over 50,000 inspected sources.
- KCAPCD - Over 15,000 inspected sources.

Tables 4-11 through 4-13 present the fraction of components leaking for all process units. These tables do not provide information on the number of data points that each result is based on. However, these tables do provide information on the variability of the basis for extrapolation between different process units.

4.4 Development/Selection of Average Emission Rates and Emission Factors

In this study, the term "average emission rate" is used to describe average emission rates that have been developed for leaking components (i.e., components with screening values greater than 10,000 ppmv) and nonleaking components. In this study, the term "emission factor" is used to describe average emission rates for all components regardless of their screening value.

TABLE 4-8. LEAK FREQUENCIES FOR PROCESS UNIT CATEGORY AVERAGES BY STREAM TYPE FOR THE SCAQMD

Component Type	Units	Broad Range of Streams: At Inspect.	Broad Range of Streams: 15 Days After Inspect.	Light Streams: At Inspect.	Light Streams: 15 Days After Inspect.	Medium Streams: At Inspect.	Medium Streams: 15 Days After Inspect.	Heavy Streams: At Inspect.	Heavy Streams: 15 Days After Inspect.	All Process Units: At Inspect.	All Process Units: 15 Days After Inspect.
Valves											
Gas	Fraction	94/5419	0/1021	117/5651	2/2653	101/2837	0/73	4/510	0/158	316/14417	2/3905
	Percent	1.73	0.00	2.07	0.01	3.56	0.0	0.78	0.0	2.19	0.05
Liquid	Fraction	209/21813	3/2103	305/13327	9/5738	26/1445	0/308	3/596	0/193	543/37181	12/8342
	Percent	0.96	0.14	2.29	0.16	1.80	0.0	0.50	0.0	1.46	0.14
Flanges	Fraction	8/2112	0/1418	3/757	0/0	0/0	0/0	0/110	0/0	11/2979	0/1418
	Percent	0.38	0.00	0.40	ND	ND	ND	0.00	ND	0.37	0.00
Pumps	Fraction	25/694	3/247	37/494	4/275	0/35	0/23	0/14	0/12	62/1237	7/55
	Percent	3.60	1.21	7.49	1.45	0.00	0.00	0.00	0.00	5.01	1.27
Compressors	Fraction	2/20	1/16	4/22	4/20	0/2	0/2	1/2	0/2	7/46	5/40
	Percent	10.00	6.25	18.20	20.00	0.00	0.00	50.00	0.00	15.2[a]	12.5[a]
PRVs											
Gas	Fraction	1/36	0/9	0/0	0/0	0/0	0/0	0/5	0/0	1/41	0/9
	Percent	2.78	0.00	ND	ND	ND	ND	0.00	ND	2.44	0.00
Liquid	Fraction	0/1	0/1	0/0	0/0	0/0	0/0	0/0	0/0	0/1	0/1
	Percent	0.0	0.0	ND	ND	ND	ND	ND	ND	0.0	0.0

ND = No data

[a] The fraction of compressors leaking at the time of inspection and 15 days after inspection for all process units (as opposed to process unit category averages by stream type) was used as the basis of extrapolation in all cases.

TABLE 4-9. LEAK FREQUENCIES FOR PROCESS UNIT CATEGORY AVERAGES BY STREAM TYPE FOR THE BAAQMD

Component Type	Units	Broad Range of Streams		Light Streams		Medium Streams		Heavy Streams		All Process Units	
		At Inspect.	15 Days After Inspect.	At Inspect.	15 Days After Inspect.	At Inspect.	15 Days After Inspect.	At Inspect.	15 Days After Inspect.	At Inspect.	15 Days After Inspect.
Valves											
Gas	Fraction	43/7458	21/6450	103/8477	34/8034	11/3163	3/2392	5/652	2/619	162/19750	60/17495
	Percent	0.58	0.33	1.22	0.42	0.35	0.13	0.77	0.32	0.82	0.34
Liquid	Fraction	42/17043	13/15373	42/8499	13/5287	2/1540	0/1473	7/888	5/689	97/27970	31/22822
	Percent	0.25	0.08	0.54	0.25	0.13	0.00	0.79	0.73	0.35	0.14
Flanges	Fraction	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0
	Percent	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Pumps	Fraction	26/660	20/660	39/415	28/415	0/57	0/57	2/128	2/128	67/1260	50/1260
	Percent	3.94	3.03	9.40	6.75	0.00	0.00	1.56	1.56	5.32	3.97
Compressors	Fraction	11/121	9/121	6/154	1/154	16/59	9/59	1/59	1/59	34/393	20/393
	Percent	9.09	7.44	3.90	0.65	27.1	15.3	1.69	1.69	8.65[a]	5.09[a]
PRVs											
Gas	Fraction	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0
	Percent	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Liquid	Fraction	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0
	Percent	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND

ND = No data

[a] The fraction of compressors leaking at the time of inspection and 15 days after inspection for all process units (as opposed to process unit category averages by stream type) was used as the basis of extrapolation in all cases.

TABLE 4-10. LEAK FREQUENCIES FOR PROCESS UNIT CATEGORY AVERAGES BY STREAM TYPE FOR THE KCAPCD

Component Type	Units	Broad Range of Streams		Light Streams		Medium Streams[a]		Heavy Streams		All Process Units	
		At Inspect.	15 Days After Inspect.	At Inspect.	15 Days After Inspect.	At Inspect.	15 Days After Inspect.	At Inspect.	15 Days After Inspect.	At Inspect.	15 Days After Inspect.
Valves											
Gas	Fraction	22/1481	0/1156	20/1025	0/908			1/235	0/235	43/2741	0/2299
	Percent	1.49	0.00	1.95	0.00			0.43	0.00	1.57	0.00
Liquid	Fraction	16/3945	0/2534	18/1202	0/687			0/280	0/280	34/5427	5/3501
	Percent	0.41	0.00	1.50	0.00			0.00	0.00	0.63	0.00
Flanges	Fraction	9/10340	1/7520	8/3905	0/3260			0/1054	0/1054	17/15299	1/11834
	Percent	0.09	0.01	0.20	0.00			0.00	0.00	0.11	0.01
Pumps	Fraction	1/146	1/103	0/56	0/27			0/10	0/10	1/212	1/140
	Percent	0.68	0.97	0.00	0.00			0.00	0.00	0.47	0.71
Compressors	Fraction	0/9	0/7	0/1	0/1			0/2	0/2	0/12	0/10
	Percent	0.00	0.00	0.00	0.00			0.00	0.00	0.00[b]	0.00[b]
PRVs											
Gas	Fraction	0/32	0/32	0/31	0/31			0/9	0/9	0/72	0/72
	Percent	0.00	0.00	0.00	0.00			0.00	0.00	0.00	0.00
Liquid	Fraction	0/39	0/6	0/4	0/4			0/3	0/3	0/46	0/13
	Percent	0.00	0.00	0.00	0.00			0.00	0.00	0.00	0.00

ND = No data

[a] No Medium Stream process units were identified in KCAPCD.

[b] The fraction of compressors leaking at the time of inspection and 15 days after inspection for all process units (as opposed to process unit category averages by stream type) was used as the basis of extrapolation in all cases.

TABLE 4-11. BASIS FOR EXTRAPOLATION-FRACTION OF COMPONENTS LEAKING - SOUTH COAST AIR QUALITY MANAGEMENT DISTRICT

Process Unit	Valves Gas A	Valves Gas B	Valves Liquid A	Valves Liquid B	Flanges A	Flanges B	Pumps A	Pumps B	Comp. A	Comp. B	PRVs Gas A	PRVs Gas B	PRVs Liquid A	PRVs Liquid B
Crude Distillation	0.0301	0.0	0.0069	0.0	0.0028	0.0	0.0179	0.012	0.077	0.0	0.0278	0.0	0.0	0.0
Catalytic Cracking	0.0156	-	0.0072	-	-	-	0.0758	0.0	0.0	0.0	-	-	-	-
Hydrocracking	0.0746	-	0.0050	-	-	-	0.125	0.0	0.500	0.500	-	-	-	-
Thermal Operations	0.0131	0.0	0.0275	0.0046	-	-	0.0400	0.0	-	-	-	-	-	-
Fluid Coking														
Blowdown/VR/Flares	0.0135	0.0	0.0011	0.0	0.0333	-	0.0857	0.0	0.0667	0.0	-	-	-	-
Wastewater Treating	-	-	-	-	-	-	0.0	0.0	-	-	-	-	-	-
Storage/Blend/Ship	0.0132	-	0.0110	0.0	0.0054	0.0	0.0208	0.0194	0.0	0.0	-	-	-	-
Broad Range	0.0173	0.0	0.0096	0.0014	0.0036	0.0	0.0360	0.0121	0.100	0.0625	0.0278	0.0	0.0	0.0
Naphtha Hydrotreating	0.0222	-	0.0426	-	0.0081	-	0.0625	0.0	-	-	-	-	-	-
Catalytic Reforming	0.0634	-	0.0177	-	0.0020	-	0.0244	0.0196	1.00	1.00	-	-	-	-
Aromatics Extraction														
Fractionation	0.0159	0.0	0.0433	0.0	0.0	-	0.0247	0.0	0.188	0.188	-	-	-	-
Alkylation	0.0037	0.0038	0.0198	0.0010	-	-	0.0938	0.0159	-	-	-	-	-	-
Polymerization	0.0174	0.0	0.0287	0.0049	-	-	0.120	0.0800	-	-	-	-	-	-
Isomerization														
Gasoline Treating	-	-	0.0250	-	0.0	-	0.0	0.0	0.0	-	-	-	-	-
Olefins Production														
Boilers (Utilities)	0.0075	0.0	0.0273	0.0	0.0500	-	0.273	0.0	0.0	0.0	-	-	-	-
Sulfur Plant	0.0078	0.0	0.0072	0.0	-	-	0.0	0.0	0.0	0.0	-	-	-	-
Light Streams	0.0207	0.0008	0.0229	0.0016	0.0040	-	0.0749	0.0145	0.1818	0.200	-	-	-	-
Mid Dist Hydrotreating	0.0	-	0.0	-	-	-	0.0	0.0	0.0	0.0	-	-	-	-
Lubes Process - Solvents														
Hydrogen Production	0.0394	-	0.0250	-	-	-	0.0	0.0	-	-	-	-	-	-
Other Product Treating	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Other Volatile Petro														
Other Low Vol Petro	0.0665	0.0	0.0227	0.0	-	-	0.0	0.0	-	-	-	-	-	-
Medium Streams	0.0356	0.0	0.0180	0.0	-	-	0.0	0.0	0.0	0.0	-	-	-	-
Vacuum Crude Dist	0.0253	0.0	0.0	0.0	-	-	-	-	0.500	0.0	0.0	-	-	-
Gas Oil Hydrotreating	0.0	-	0.0183	-	0.0	-	0.0	0.0	-	-	-	-	-	-
Vacuum Resid Hydro	0.0	-	0.0	-	-	-	0.0	0.0	-	-	-	-	-	-
Other Lube Oil Process														
Asphalt Production														
Heavy Streams	0.0078	0.0	0.0050	0.0	0.0	-	0.0	0.0	0.500	0.0	0.0	-	-	-
All Process Units	0.0219	0.0005	0.0146	0.0014	0.0037	0.0	0.0501	0.0127	0.152	0.125	0.0244	0.0	0.0	0.0

A = At inspection.
B = Fifteen days after inspection.

TABLE 4-12. BASIS FOR EXTRAPOLATION - FRACTION OF COMPONENTS LEAKING - BAY AREA AIR QUALITY MANAGEMENT DISTRICT

	Valves										Pressure Relief Valves			
	Gas		Liquid		Flanges		Pumps		Compressors		Gas		Liquid	
Process Unit	A	B	A	B	A	B	A	B	A	B	A	B	A	B
Crude Distillation	0.0034	0.0013	0.0008	0.0	-	-	0.0462	0.0308	0.0345	0.172	-	-	-	-
Catalytic Cracking	0.0088	0.0075	0.0015	0.0	-	-	0.0238	0.0238	0.250	0.250	-	-	-	-
Hydrocracking	0.0041	0.0027	0.0034	0.0025	-	-	0.0	0.0	0.0	0.0	-	-	-	-
Thermal Operations	0.0057	0.0	0.0	0.0	-	-	0.0	0.0	-	-	-	-	-	-
Fluid Coking	0.0030	0.0	0.0	0.0	-	-	0.0	0.0	-	-	-	-	-	-
Blowdown/VR/Flares	0.0018	0.0	-	-	-	-	0.0	0.0	0.240	0.200	-	-	-	-
Wastewater Treating														
Storage/Blend/Ship	0.0150	0.0080	0.0031	0.0008	-	-	0.0503	0.0397	0.100	0.100	-	-	-	-
Broad Range	0.0058	0.0033	0.0025	0.0008	-	-	0.0399	0.0303	0.0909	0.0744	-	-	-	-
Naphtha Hydrotreating	0.0101	0.0033	0.0043	0.0	-	-	0.0	0.0	0.0	0.0	-	-	-	-
Catalytic Reforming	0.0051	0.0037	0.0094	0.0029	-	-	0.0364	0.0364	0.0769	0.0	-	-	-	-
Aromatics Extraction														
Fractionation	0.0076	0.0021	0.0041	0.0032	-	-	0.0541	0.0203	0.0388	0.0078	-	-	-	-
Alkylation	0.0160	0.0041	0.0063	0.0014	-	-	0.0805	0.0690	-	-	-	-	-	-
Polymerization	0.0279	-	0.0053	-	-	-	0.189	0.108	-	-	-	-	-	-
Isomerization	0.0422	0.0177	-	-	-	-	0.536	0.464	0.0	0.0	-	-	-	-
Gasoline Treating														
Olefins Production														
Boilers (Utilities)	0.0230	0.0	-	-	-	-	0.0	0.0	-	-	-	-	-	-
Sulfur Plant	0.0	0.0	0.0	0.0	-	-	0.0	0.0	0.0	0.0	-	-	-	-
Light Streams	0.0122	0.0042	0.0054	0.0025	-	-	0.940	0.0675	0.0390	0.0065	-	-	-	-
Mid Dist Hydrotreating	0.0028	0.0008	0.0024	0.0	-	-	0.0	0.0	0.421	0.263	-	-	-	-
Lubes Process - Solvents	0.0030	0.0	0.0010	0.0	-	-	0.0	0.0	0.250	0.0833	-	-	-	-
Hydrogen Production	0.0043	0.0027	0.0	0.0	-	-	0.0	0.0	0.125	0.125	-	-	-	-
Other Product Treating	-	-	-	-	-	-	0.0	0.0	-	-	-	-	-	-
Other Volatile Petro														
Other Low Vol Petro														
Medium Streams	0.0035	0.0013	0.0013	0.0	-	-	0.0	0.0	0.271	0.153	-	-	-	-
Vacuum Crude Dist	0.0	0.0	-	-	-	-	0.250	0.0250	-	-	-	-	-	-
Gas Oil Hydrotreating	0.0087	0.0037	0.0091	0.0073	-	-	0.0217	0.0217	0.0	0.0	-	-	-	-
Vacuum Resid Hydro														
Other Lube Oil Process	0.0	0.0	0.0	-	-	-	0.0	0.0	0.0250	0.0250	-	-	-	-
Asphalt Production					-	-					-	-	-	-
Heavy Streams	0.0077	0.0032	0.0079	0.0073	-	-	0.0156	0.0156	0.0169	0.0169	-	-	-	-
All Process Units	0.0082	0.0034	0.0035	0.0014	-	-	0.0532	0.0397	0.0865	0.0509	-	-	-	-

A = At inspection.
B = Fifteen days after inspection.

TABLE 4-13. BASIS FOR EXTRAPOLATION - FRACTION OF COMPONENTS LEAKING - KERN COUNTY AIR POLLUTION CONTROL DISTRICT

Process Unit	Valves				Flanges		Pumps		Compressors		Pressure Relief Valves			
	Gas		Liquid								Gas		Liquid	
	A	B	A	B	A	B	A	B	A	B	A	B	A	B
Crude Distillation	0.0062	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-	-
Catalytic Cracking														
Hydrocracking														
Thermal Operations	-	-	0.0	-	0.0	-	-	-	-	-	-	-	-	-
Fluid Coking														
Blowdown/VR/Flares	0.0058	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Wastewater Treating	0.0	-	0.0	-	0.0	-	0.0	0.0	-	-	-	-	0.0	-
Storage/Blend/Ship	0.0205	0.0	0.0058	0.0	0.0012	0.0003	0.0097	0.0123	-	-	0.0	0.0	0.0	0.0
Broad Range	0.0149	0.0	0.0041	0.0	0.0009	0.0001	0.0068	0.0097	0.0	0.0	0.0	0.0	0.0	0.0
Naphtha Hydrotreating	0.0065	0.0	0.0202	0.0	0.0	0.0	0.0	0.0	-	-	0.0	0.0	-	-
Catalytic Reforming	0.0401	0.0	0.0421	0.0	0.0054	0.0	0.0	0.0	-	-	0.0	0.0	-	-
Aromatics Extraction														
Fractionation	0.0155	0.0	0.0	0.0	0.0021	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Alkylation														
Polymerization														
Isomerization														
Gasoline Treating														
Olefins Production														
Boilers (Utilities)	0.0	0.0	-	-	0.0	0.0	-	-	-	-	-	-	-	-
Sulfur Plant	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-	-	0.0	0.0	0.0	0.0
Light Streams	0.0195	0.0	0.0150	0.0	0.0020	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Mid Dist Hydrotreating														
Lubes Process - Solvents														
Hydrogen Production														
Other Product Treating														
Other Volatile Petro														
Other Low Vol Petro														
Medium Streams														
Vacuum Crude Dist	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-	-	0.0	0.0	-	-
Gas Oil Hydrotreating	0.0074	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Vacuum Resid Hydro														
Other Lube Oil Process														
Asphalt Production														
Heavy Streams	0.0043	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
All Process Units	0.0157	0.0	0.0063	0.0	0.0011	0.0001	0.0047	0.0071	0.0	0.0	0.0	0.0	0.0	0.0

A = At inspection.
B = Fifteen days after inspection.

Average emission rates (AERS) are used in conjunction with nonexempt component population data and the fraction of nonexempt components leaking to estimate emissions from nonexempt components. Emission factors are used in conjunction with exempt component populations to estimate emissions from exempt components.

4.4.1 Average Emission Rates for Nonexempt Components

Tables H-1 through H-6 of Appendix H present AERs, including 95 percent confidence intervals, by leaking and nonleaking category for nonexempt valves, flanges, pumps, compressors, and pressure relief valves (PRVs). There is one table for each of the following six district, detection instrument, calibration gas, and distance from the source combinations:

- SCAQMD - OVA (methane) at 1 cm
- SCAQMD - OVA (hexane) at 1 cm
- BAAQMD - OVA (methane) at 1 cm
- BAAQMD - OVA (hexane) at 1 cm
- KCAPCD - OVA (methane) at 1 cm
- KCAPCD - TLV® (methane) at 1 cm

Two different methods were used to develop the AERs for nonexempt valves and flanges. Therefore, two complete sets of AERs, titled Method 1 and Method 2, are presented in each table. The differences between the two methods and the reasons for developing two methods are discussed in detail in Section 4.4.1.1.

The differences in the two methods result in emission estimates that differ by over an order of magnitude in some cases. Neither of the emission estimates can be stated with certainty to be accurate.

The use of different detection instrument, calibration gas, and distance from the source combinations by different refineries required the development of combination-specific AERs. The combinations presented in Tables H-1 through H-6 represent those most frequently used.

Presented in Table 4-14 are the specific sources of data used to develop AERs for leaking and nonleaking nonexempt components. In general, AERs for valves and flanges are based on screening value data provided by refineries. The AERs for pumps, compressors, and PRVs are based on data collected in previous fugitive emission studies. Different approaches were required for developing AERs with each of the two different types of data (i.e., screening value data collected by refineries and data collected in previous studies). These approaches are discussed in the following sections.

4.4.1.1 Nonexempt Valves and Flanges

AERs for leaking and nonleaking valves and flanges were based on screening value data provided by six refineries. These six refineries are indicated in Table 4-14. The data for these six refineries were pooled to develop one set of AERs for SCAQMD and BAAQMD and one set for KCAPCD and miscellaneous districts. The procedure for developing the AERs includes the following general steps:

- Original screening values were converted for instrument, calibration gas, and distance from the source to TLV® at the source with hexane.

- Emission rates were predicted from the estimated TLV® screening values for sources screening greater than zero ppmv.

- Overall average emission rate estimates for each district were computed from the predicted emission rates and fraction of sources screening greater than zero ppmv.

TABLE 4-14. SOURCES OF SCREENING VALUE DATA USED TO DEVELOP AVERAGE EMISSION RATES FOR LEAKING AND NONLEAKING NONEXEMPT COMPONENTS

Component Type	SCAQMD	BAAQMD	KCAPCD	Miscellaneous Districts
Valves				
Gas	Edgington, Wilmington Shell Oil, Carson Exxon, Benicia Tosco, Martinez	Edgington, Wilmington Shell Oil, Carson Exxon, Benicia Tosco, Martinez	Coastal, Bakersfield Texaco, Bakersfield	Coastal, Bakersfield Texaco, Bakersfield
Liquid	Edgington, Wilmington Shell Oil, Carson Exxon, Benicia Tosco, Martinez	Edgington, Wilmington Shell Oil, Carson Exxon, Benicia Tosco, Martinez	Coastal, Bakersfield Texaco, Bakersfield	Coastal, Bakersfield Texaco, Bakersfield
Flanges	Edgington, Wilmington	Edgington, Wilmington	Coastal, Bakersfield Texaco, Bakersfield	Coastal, Bakersfield Texaco, Bakersfield
Pumps	Radian, 1982a	Radian, 1982a	Radian, 1982a	Radian, 1982a
Compressors	Radian, 1982a	Radian, 1982a	Radian, 1982a	Radian, 1982a
PRVs				
Gas	Radian, 1980	AP-42[a]	Radian, 1980	Radian, 1980
Liquid	Radian, 1980	AP-42[a]	Radian, 1980	Radian, 1980

a There were no PRVs included in the inspection/maintenance data for the BAAQMD. Because no data existed to indicate the fraction of components leaking, AP-42 emission factors were used (EPA, 1985).

- Average emission rate estimates were predicted for leaking and nonleaking components.

Using these four general steps, AERs were developed using two different methods: Method 1 and Method 2. The difference between the two methods can be found in the first two steps where OVA screening values provided by refineries are converted to TLV® screening values and the TLV screening values are then correlated to emission rates.

Initially, the conversion of the OVA screening values was performed using a predictive equation relating the OVA screening values to a range of TLV® screening values. The range is based on the uncertainty associated with converting a reading from one type of detection instrument to another. In addition, the correlation of screening values to emission rates was performed using a predictive equation relating TLV® screening values to a range of emission rates. Again, the range is based on the uncertainty associated with correlating a screening value with an emission rate. Performing these conversions and correlations and incorporating uncertainty in the predictions resulted in Method 1 AERs which, following analysis and comparison with actual measured leak rates, appear to be unreasonably high.

For example, actual field measurement data for bagged sources show the maximum leak rate for gas service values screening greater than <u>100,000 ppmv</u> to be 2.5 pounds per hour (EPA, 1979). However, the Method 1 BAAQMD/SCAQMD AER for leaking gas service valves (those screening greater than <u>10,000 ppmv</u>) measured with an OVA (methane) at 1 cm, is 6.62 pounds per hour.

Comparison with existing emission factors also shows the Method 1 AERs to be unreasonably high. The overall emission factor on which the BAAQMD/SCAQMD Method 1 AER for leaking gas service valves is based on is 0.063 pounds per hour while the overall uncontrolled emission factor for gas service valves presented in AP-42 is 0.059 pounds per hour (EPA, 1985). However, the data on which the AP-42 emission factor is based indicate that the fraction of components leaking is 12.6 percent (Radian, 1980), while the data used to develop the Method 1 overall emission factor show that the fraction of components leaking is less than one percent. The lower fraction of components leaking associated with the data used to develop Method 1 AERs should yield a significantly lower overall emission rate.

Because the Method 1 AERs appear to be high based on comparison with actual measurements, the method for developing AERs was modified slightly to become Method 2.

As mentioned previously, the difference between Method 1 and Method 2 exists in the first two steps, where OVA screening values are converted to TLV® screening values. The TLV® screening values are then correlated to emission rates. In Method 2, the conversion and correlation steps are performed without introducing uncertainty. That is, these steps are performed using mean values, as opposed to ranges of values. In summary, the key difference between the two methods is the statistical treatment of uncertainty.

Method 2 resulted in values that are closer to those expected from actual field measurements. However, Method 2 does not account for the uncertainty that exists in making the necessary conversions and correlations.

The steps used to develop AERs for leaking and nonleaking nonexempt valves and flanges are discussed below.

<u>Conversion of Original Screening Values</u>

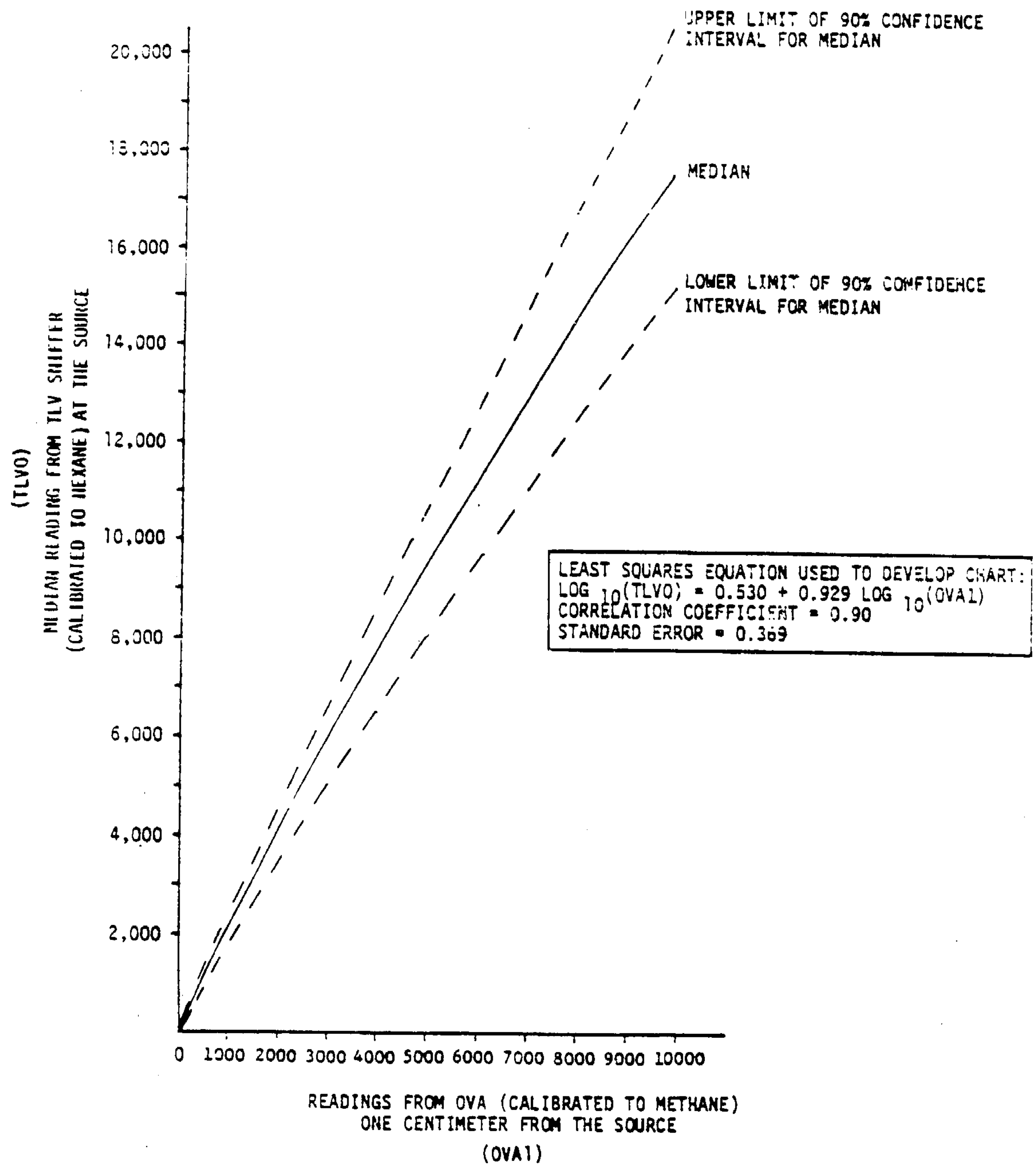
In order to develop AERs without measured emission rates, emission rates had to be estimated from the screening value data. While screening value to emission rate correlations do exist for valves and flanges (Radian, 1980), they are based on TLV® (hexane) at the source screening values. Five of the six refinery screening value data sets used to develop AERs were based on OVA (methane) screening values screened at one centimeter from the source.

The sixth refinery, Edgington Oil, also used an OVA screening at one centimeter from the source, but calibrated to hexane. Before correlations between screening values and emission rates can be made, TLV® screening values must be estimated from the original screening values.

Correlations to relate screening values obtained with different instrument/calibration gas/distance from the source combinations have been developed in previous fugitive emission studies. The correlation nomographs used to predict a TLV® (hexane) screening value at the source from an OVA (methane) screening value at one centimeter are based on predictive equations found in the report cited as Radian, 1980. An example of a nomograph used to correlate screening values is presented as Figure 4-1. The predictive equation that describes that nomograph is provided within the figure. Using this equation, predicted Log-TLV® screening values were computed for each component with a screening value less than 100,000 ppmv and greater than 0 ppmv.

For Method 1, arithmetic TLV® screening values were then computed for each source with a screening value less than 100,000 ppmv and greater than 0 ppmv by exponentiating and adjusting for error. The adjustment for error used a random number from a standard normal distribution in an attempt to yield a predicted distribution of screening values which would approximate the distribution if sources had been screened with a TLV® (calibrated to hexane) at the source. A standard error estimate of 0.386 was used in the equation. This estimate was obtained from pooling the standard error estimates for relating screening values obtained with different instrument/calibration gas/distance from source combinations (Radian, 1980).

For Method 2, TLV® screening values were computed for each source with a screening value less than 100,000 ppmv and greater than 0 ppmv using the same predictive equation as Method 1, but without the random number and the standard error of estimate adjustment. As discussed previously, the adjustment for error was not made and the conversion was made directly to the average TLV® screening value.



Source: Radian, 1980.

Figure 4-1. Nomograph for Relating TLV and OVA Screening Values.

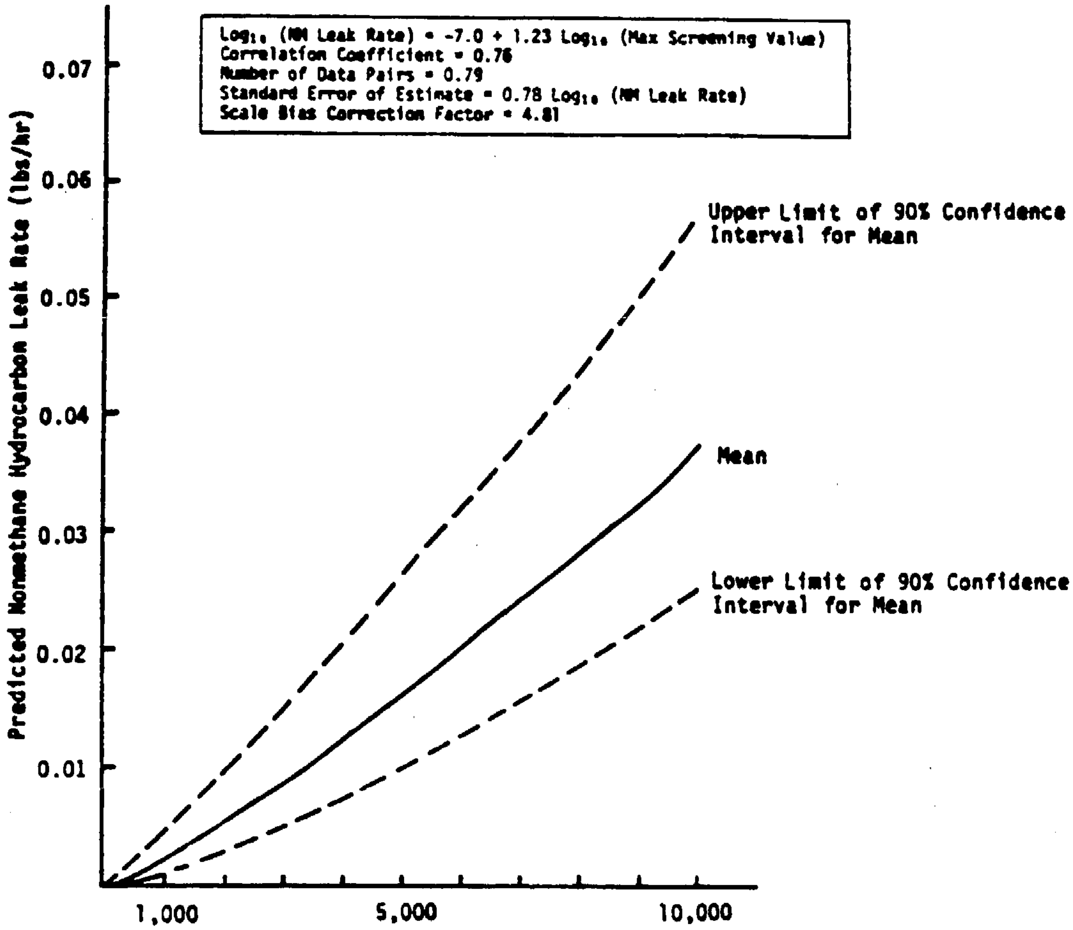
For the Edgington Oil screening value data an intermediate step was taken to estimate an OVA (methane) screening value from the original OVA (hexane) screening value. The predictive equation relating these two screening value is found in the report cited as Radian, 1980. Similarly to estimating TLV® screening values, a random number from a standard normal distribution was used to estimate an approximate range of OVA (methane) screening values for Method 1. Again, for Method 2, the conversion was made to the average OVA (methane) screening value.

Correlation of Predicted Emission Rates

The TLV® screening values estimated in the previous step were used to predict emission rates for sources screening greater than zero ppmv. The correlation between TLV® screening values and emission rates was based on nomographs presented in the reference cited as Radian, 1980. Using the prediction equations presented with each nomograph, predicted log-emission rates were computed for each source with an original screening value less than 100,000 ppmv and greater than 0 ppmv. An example correlation nomograph for relating the predicted mean leak rate as a function of the maximum TLV® (hexane) screening value measured at the source is presented as Figure 4-2. Emission rates (lb/hr) were then computed for each source by exponentiating and adjusting for error using the method described in the previous step. The standard error of the estimate used is presented along with the prediction equations found in the report cited as Radian, 1980.

Development of District-Specific AERs

A lognormal distribution was used to model the distribution of components screening greater than 0 ppmv. This distribution has the property that when the original data are transformed by taking logarithms, the transformed data will follow a normal distribution. Past experience has shown that screening values and leak rates approximately follow lognormal distributions. The screening value data from the six refineries used to generate AERs appear to fall in line with that experience.



Maximum Screening Value (ppmv, calibrated to hexane) Using J.W.Bacharach TLV Sniffer at the Source.

Source: Radian, 1980.

Figure 4-2. Nomograph for Predicting Total Nonmethane Hydrocarbon Leak Rates From Maximum Screening Values - Valves - Gas Service.

Care must be exercised when transforming between scales because not all statistics transform correctly. The median is preserved by the logarithmic transformation of lognormal data, but the mean is not. The median is the middle value while the mean is the arithmetic average. The mean and median have the same value on the logarithmic scale, but the mean is higher in value than the median on the arithmetic scale. Hence, the reverse transformation (exponentiation) of the mean logarithm is biased for estimating the mean on the arithmetic scale. An adjustment based on the properties of the lognormal distribution corrects this bias (scale bias correction factor). Lognormal distribution theory indicates that this procedure is more precise than directly computing the mean on the arithmetic scale.

As described previously, the development of AERs is a multi-step process. First, TLV® screening values were predicted from OVA screening values. Then emission rates were predicted from the estimated TLV® screening values for all sources with original screening values above zero ppmv using emission rate/screening value correlations. The mean logarithmic emission rate was then computed. These results were transformed to the arithmetic scale, including adjustment for the scale bias correction factor.

Finally, district-specific AERs were computed by assigning sources with zero screening values an emission rate equal to zero and then computing the mean leak rate for the screened populations.

There was some difficulty in fitting the lognormal distribution to the predicted emission rate values. There are a number of cases in which the original screening value was reported as "greater than 100,000 ppmv." This was due to the inability of the screening device to measure beyond 100,000 ppmv.

To overcome the bias caused by the censoring at 100,000 ppmv, only log emission rates predicted from original screening values less than 100,000 ppmv were used to estimate the parameters of this distribution. Formulas from "censored" normal distribution theory developed by Cohen were then used to arrive at unbiased estimates of the entire distribution (Bliss, 1959). The problem was to compute from the censored sample, estimates of the mean and standard deviation of the complete parent population. The computing routine was described by Cohen for a maximum likelihood solution of a censored sample.

Only log emission rates predicted from original screening values less than 100,000 ppmv were used to estimate the parameters of the "measured" part of the censored distribution.

Development of AERs for Leaking and Nonleaking Components

This step entails developing AER estimates for leaking and nonleaking components. AER estimates for components with screening values less than 10,000 ppmv (nonleaking components) were developed as outlined in the previous step, development of district-specific AERs. The number of sources in the nonleaking category depends on which of the four district, detection instrument, calibration gas, and distance from the source combinations the AER is being estimated for. As such, AER estimates for nonleaking components will vary based on the screening instrument, calibration gas, and distance from the source. Censored distribution theory does not have to be considered in this case. AER estimates for components screening greater than or equal to 10,000 ppmv (leaking components) are based on the overall AER estimate and the AER estimate for nonleaking components:

$$X2 = \frac{(X * N) - (X1 * N1)}{N2}$$

where X1 = AER for leaking components,

X2 = AER for nonleaking components,

X = AER for all components,

N1 = number of leaking components,

N2 = number of nonleaking components, and

N = total number of components = N1 + N2

4.4.1.2 Nonexempt Pumps, Compressors, and Pressure Relief Valves

AERs for leaking and nonleaking pumps, compressors, and pressure relief valves (PRVs) were based on data collected in previous fugitive emission studies. As indicated previously in Table 4-14, the specific sources of data used to develop AERs for pumps and compressors is the report cited as Radian, 1982a and the source of data for PRV AERs is the report cited as Radian, 1980. AERs for pumps, compressors, and PRVs were developed for each specific data set.

Tables H-7, H-8, and H-9 of Appendix H present summaries of data obtained from previous fugitive emission studies used to develop AERs for pumps, compressors, and PRVs. These data are presented for the following three different detection instrument, calibration gas, and distance from the source combinations.

- OVA (methane) at 1cm
- OVA (hexane) at 1cm
- TLV® (methane) at 1cm

Tables H-7, H-8, and H-9 also contain component population size, total leakage, and fraction of total leakage due to leaking and nonleaking components. These values are used to estimate the AER:

$$X1 = \frac{(L)\ (F1)}{N1}$$

and

$$X2 = \frac{(L)\ (F2)}{N2}$$

where X1 = average emission rate per nonleaking component, lb/hr-source,

X2 = average emission rate per leaking component, lb/hr-source,

N1 = number of nonleaking components,

N2 = number of leaking components,

F1 = fraction of total leakage due to nonleaking components,

F2 = fraction of total leakage due to leaking components,

L = total leakage, lbs/hr.

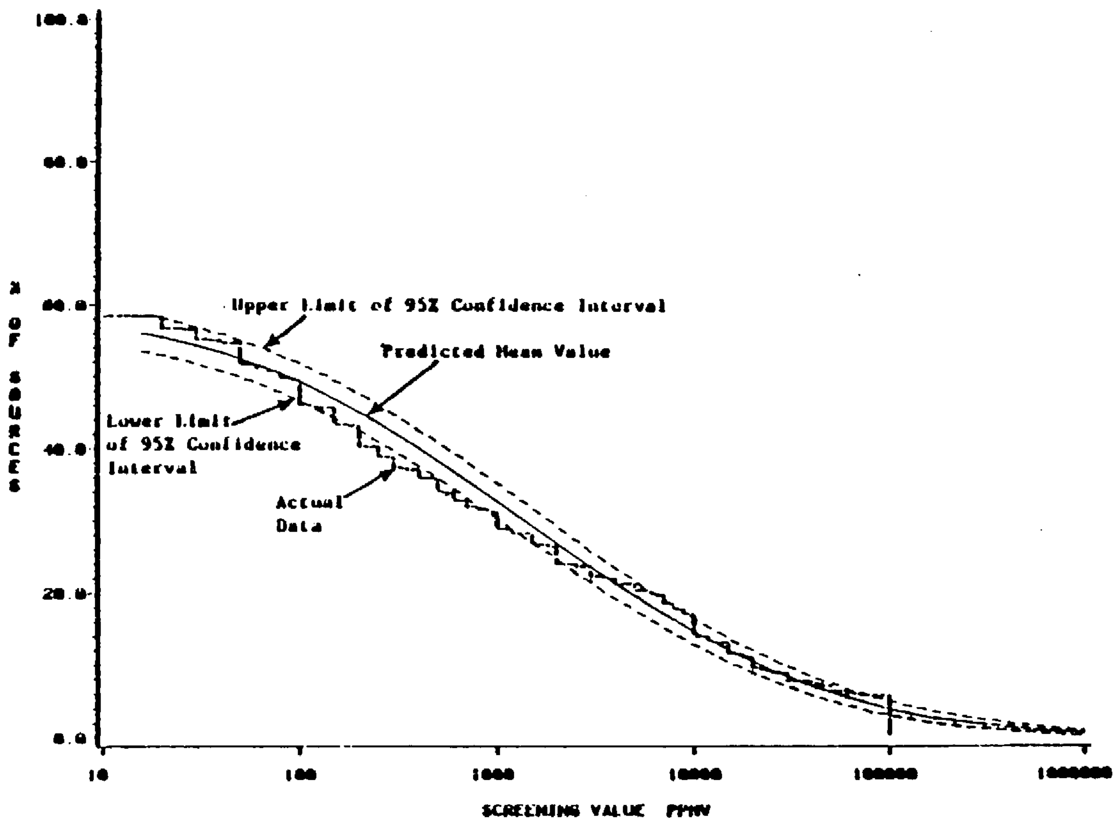
Estimates for the values used in the above equation were based on emission factors and nomographs presented in the report cited as Radian, 1982 for pumps and compressors and the report cited as Radian, 1980 for PRVs. The average emission rate estimates and number of sources screened were used to calculate total leakage:

$$L = (n)(X)$$

where n = total number of sources screened (includes leaking, nonleaking, and 0 ppmv sources), and

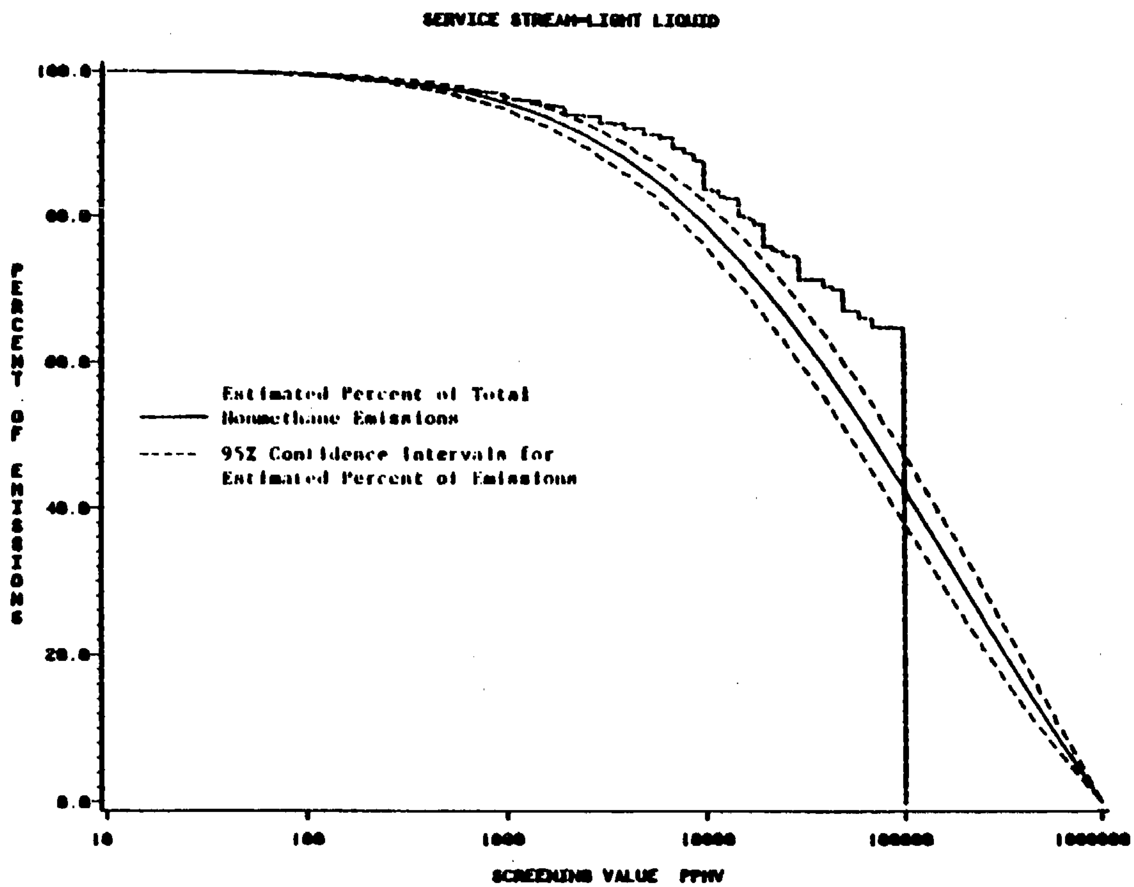
X = average emission rate estimate (lb/hr-source).

Figures in the above-referenced documents present the percentage of each source type expected to have screening values above any selected values. Other nomographs presented in the same reports indicate the percentage of total mass emissions which can be expected from sources with screening values greater than any given value. These nomographs were used to estimate the number of sources and fraction of total leakage for leaking and nonleaking components. An example figure presenting screening value distributions is presented as Figure 4-3. An example nomograph showing the percentage of total mass emissions is presented as Figure 4-4.



Source: Radian, 1980.

Figure 4-3. Percent of Sources with Screening Values Greater Than Any Selected Value - Pumps - Light Liquid Service, Predicted Mean Value for First Inspection.



Source: Radian, 1980.

Figure 4-4. Cumulative Distribution of Uncontrolled Nonmethane Emissions by Screening Values for Pumps - Light Liquid Service.

The nomographs for pumps and compressors are based on emission measurements using an OVA calibrated to methane and screened at a distance of 1 cm from the source. The nomographs for PRVs are based on emission measurements using a TLV® calibrated to hexane and screened at the source. Before the nomographs could be used directly, a screening value of 10,000 ppmv (the break point between leaking and nonleaking components) for the detection instrument, calibration gas, distance from the source combinations mentioned above were corrected to that used in the nomographs.

Nomographs based on predictive equations, presented in the above-mentioned references, provide correlations developed to relate screening values obtained with different detection instrument, calibration gas, distance from the source combinations. These predictive equations were used to convert the 10,000 ppmv screening values so that the nomographs could be used directly, with the appropriate detection instrument, calibration gas, and distance from the source combination screening value equivalent. The percent of components greater than a given corrected screening value is read directly from the nomographs. This percentage is then multiplied by the total number of components screened (and divided by 100) to estimate the number of components leaking. The number of nonleaking components is then taken as the difference between the total number of components screened and the number of leaking components. The percent of total emissions attributable to components with screening values greater than a given corrected screening value is read directly from the nomographs. The percentage is divided by 100 to estimate the fraction of leakage attributable to leaking components. The fraction of leakage attributable to nonleaking components is simply the fraction remaining.

Nomographs for PRVs were not available by service type category (i.e., gas or liquid service). PRV estimates were, therefore, based on the assumption that the fraction of leaking components and the percent of total leakage attributable to leaking components is the same for all service type categories.

4.4.2 Emission Factors for Exempt Components

Emission factors for exempt components are based on uncontrolled emission factors presented in the current version of AP-42 (EPA, 1985). In some cases, the AP-42 emission factor was modified slightly. The use of these emission factors may lead to the overestimation or underestimation of emissions for different exemption types. The emission factor used for each type of exempt component is discussed below:

- Low PROC -- Low PROC streams are generally defined as containing less than 20 percent PROC. Therefore, the PROC content of these streams is expected to range between 0 and 20 percent. It can be assumed that the amount of material emitted is the same as for components handling high PROC streams, and the PROC content of the material emitted is 10 percent. Therefore, an emission factor that is 10 percent of uncontrolled AP-42 emission factors was used. Because many low PROC streams have close to 0 percent PROC, these emission factors should result in some overestimation of emissions.

- Low RVP -- For valves and pumps, emission factors for heavy liquid streams with RVPs less than 0.1 psi are available from AP-42. Although this low RVP cutoff is different than the 1.55 psi definition of low RVP in the rules, these heavy liquid emission factors represent the best available and were, therefore, used. For flanges and PRVs, heavy liquid emission factors do not exist so the standard light liquid AP-42 emission factors were used. Because the emission factor used was for heavier streams than the streams it was applied to, emissions should be underestimated to some degree.

- Inaccessible -- Emission factors for inaccessible components were assumed to simply be uncontrolled emission factors.

Therefore, standard AP-42 emission factors were used. These emission factors should be representative.

- High Temperature -- A previous study of fugitive emissions evaluated the effect of temperature on leak frequencies (Radian, 1980). The results did not demonstrate any clear relationship between leak frequencies and temperature. Therefore, the emission factors used for high temperature components were AP-42 standard emission factors. Data on fugitive emissions as a function of component temperature do not indicate a significant relationship between emissions and temperature. Therefore, these emission factors should be representative.

- Vented to Vapor Recovery -- It was assumed that emissions from components vented to vapor recovery systems were negligible.

- Other -- A number of components were exempt for reasons other than those listed above. Because of the variability in these reasons, it was not feasible to develop emission factors or estimate emissions from these components. One example of this is emissions from reciprocating and vertical in-line pumps. The exclusion of these components from the exempt component emission estimates results in an underestimation of exempt component emissions.

4.5 Emission Calculation Approach

Different emission calculation approaches were developed for nonexempt and exempt components. These emission calculation approaches are described below.

4.5.1 Nonexempt Components

For nonexempt components, the approach to calculating emissions assumed that leak identification, repair, occurrence, and recurrence resulted in the sawtooth pattern of emission reduction and growth presented in Figure 4-5. Within this approach, Point 1 is the number of leaking components (by refinery, process unit, component type, and service type) at the time of inspection. Point 2 is the number of leaking components 15 days after inspection. Point 3 is the number of leaking components at the next inspection period. In this approach, the number of leaking components a Point 1 is assumed to be equal to Point 3. There are a number of assumptions included in this approach and a number of considerations that this approach does not take into account. These assumptions and considerations are discussed below.

- The approach assumes that any leak repaired within 15 days was repaired at the time of inspection. This assumption is acceptable because:
  - most repairs are made within two or three days of inspection;
  - even if they were not repaired until 15 days after inspection, the effect on annual refinery fugitive emissions is less than a few percent.
- The approach does not account for leaks repaired more than 15 days after inspection. This assumption should be acceptable because the effect of components being repaired at a later date is just a slight variation on the linear leak occurrence and recurrent assumption.
- The approach does not account for emission reductions achieved at the time of a process unit turnaround unless the turnaround

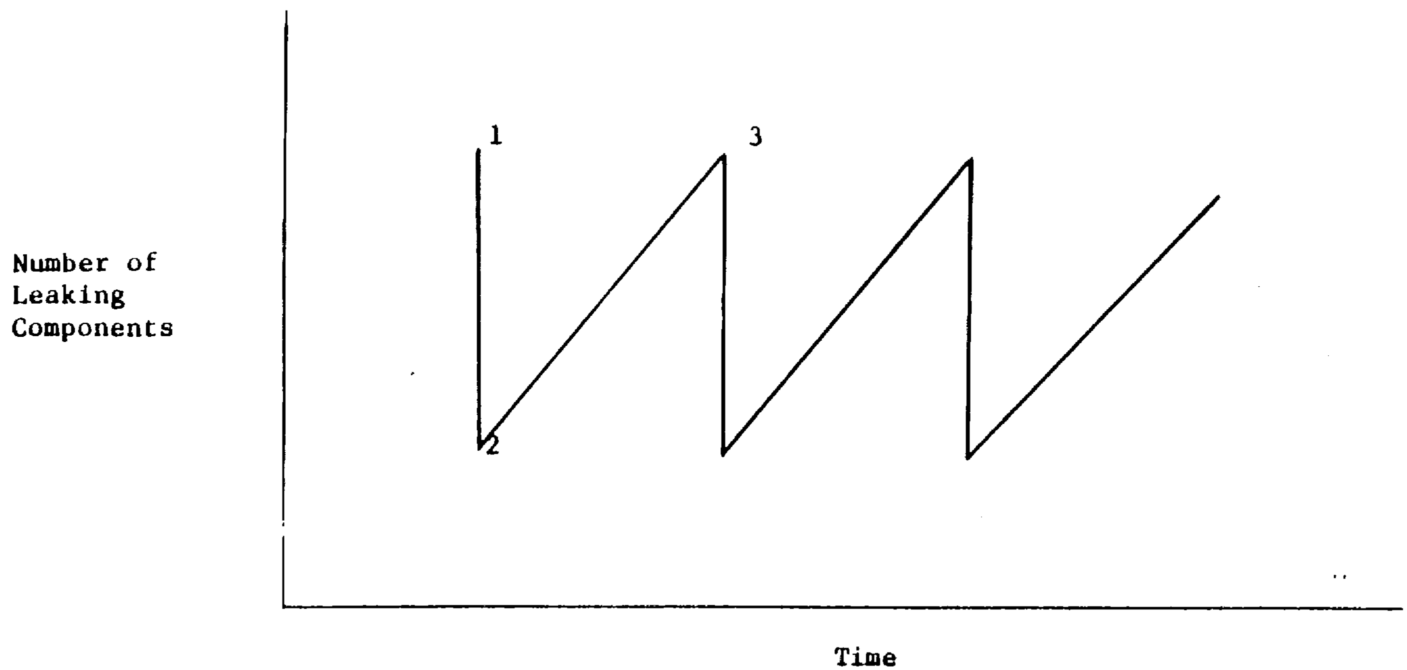


Figure 4-5. Basic Model of Leak Identification, Repair, Occurrence, and Recurrence.

coincides with a regularly-scheduled inspection. The effects of this assumption are discussed in the paragraph above.

- The approach assumes a long-term steady-state for refinery fugitive emissions. That is, the number of leaking components at Point 3 is assumed to be equal to the number at Point 1. This assumption of a long-term steady-state is supported by data presented in a previous fugitive emission study (Radian, 1982b). In this study, variability in emissions was found over four years but no trends were identified.

In order to estimate emissions from nonexempt components using the approach described above, the number of leaking (i.e., components with screening values greater than 10,000 ppmv) and nonleaking components were multiplied by average emission rate (AERs) for leaking and nonleaking components. The derivation of these AERs is discussed previously in Section 4.4.1.

4.5.2 Exempt Components

The approach to calculating emissions from exempt components involved using data presented previously in Table 4-3. The calculation approach consists of multiplying exempt component populations (by refinery, process unit, component type, service type, and type of exemption) by emission factors that are on a per component basis. The derivation of the exempt component emission factors is discussed previously in Section 4.4.2.

5.0 EVALUATION OF DISTRICT RULES

Presented in Table 5-1 is a summary of the key requirements of rules controlling fugitive emissions from sources such as valves, flanges, pumps, compressors, and pressure relief valves for the following California air pollution control and air quality management districts:

- Bay Area Air Quality Management District
- South Coast Air Quality Management District
- Kern County Air Pollution Control District
- Kings County Air Pollution Control District
- Ventura County Air Pollution Control District

Key requirements summarized in Table 5-1 include inspection frequency, allowable repair period, reinspection requirements, detection instrument and calibration method, and the number and type of different exemptions allowed. A complete set of district rules for refinery fugitive emissions is presented in Appendix C.

TABLE 5-1. EVALUATION OF FUGITIVE EMISSION CONTROL RULES

District and Applicable Rule	Leak Definition	Inspection Frequency	Allowable Repair Period	Reinspection Requirements	Exemptions	Recordkeeping Requirements
Bay Area Air Quality Management District						
Rule 18: Valves and Flanges at Petroleum Refinery Complexes (Adopted March 17, 1982)	> 10,000 ppm methane at 1 cm	Valves: Annual Flanges: No inspection requirement. However, a non-identified leak constitutes a violation	Not Essential: Repair within 15 days Essential: Minimize within 15 days ($\geq$ 10,000, repair at PU T/A)	Valves: 3 months following repair	Inaccessible. Low RVP (< 1.5 psia). Natural gas. Instrument valves.	Maintain records of inspection for at least one year. Leakers must be tagged.
Rule 25: Pump and Compressor Seals at Petroleum Refineries and Chemical Plants (Adopted July 2, 1980)	> 10,000 ppm methane at 1 cm	Pumps: Annual Compressors: Quarterly	Not Essential: Repair within 15 days Spare and Essential: Either repaired within 30 days Essential: Minimize within 15 days ($\geq$ 10,000, repair at PU T/A)	15 days following repair	Low RVP (< 1.5 psia). Seal oil systems. Compressors with emission rate < 0.4 lb/hr. Vented to vapor recovery with at least 95% control efficiency.	Maintain records of inspection for at least two years. Leakers must be tagged.
Rule 28: Pressure Relief Valves at Petroleum Refineries and Chemical Plants (Adopted July 16, 1980)	Failure to reseat upon depressurization of the PRV	Quarterly unless vented to a vapor recovery system with at least 95% control efficiency.	NA	NA	Inaccessible. Externally regulated valves. Protected by a rupture disc. Liquid service. PRV's on storage tanks. Vented to Vapor recovery with at least 95% control efficiency.	None.

TABLE 5-1. EVALUATION OF FUGITIVE EMISSION CONTROL RULES (Continued)

District and Applicable Rule	Leak Definition	Inspection Frequency	Allowable Repair Period	Reinspection Requirements	Exemptions	Recordkeeping Requirements
South Coast Air Qualtiy Management District						
Rule 466.1: Valves and Flanges (Adopted November 3, 1978)	Liquid: > 3 drops/minute or visible mist Gas: > 10,000 ppm hexane at 1 cm	Annually	Repair within 2 days.	30-90 days following repair	Low RVP (< 1.55 psi). Natural gas. Inaccessible. > 80% H_2. > 80% H_2O.	Maintain records of inspection for valves adequate to demonstrate compliance for one year. No requirements for flanges.
Rule 466: Pumps and Compressors (Adopted May 7, 1976)	Liquid: > 3 drops/minute or visible mist Gas: > 10,000 ppm hexane at 1cm	Compressor: Quarterly Pumps: Annually	Not Essential: Repair within 15 days Essential: Minimize within one day, repair at next PU T/A	Within 6 months following repair	Lov RVP (< 1.55 psia). Operating Temperature >260°C. Vented to a vapor recovery system. > 80% H_2O. > 80% H_2. Natural gas. Dual seal system. < 1 hp.	Maintain records in a manner specified by the APCD.
Rule 467: Pressure Relief Devices (Adopted May 7, 1976)	Liquid: > 3 drops/minute or visible mist Gas: >10,000 ppm hexane at center of leakage path	Quarterly for 4 non-leaking quarters, then annually. 15 days following venting to atmosphere.	Not Essential: Repair within 15 days Essential: At next PU T/A	Within 3 months following repair	Low RVP (< 1.55 psi). Vented to a vapor recovery system. Safety hazard. PRV's on storage tanks. ≤ 1 inch size.	Maintain records in a manner specified by the APCD.

TABLE 5-1. EVALUATION OF FUGITIVE EMISSION CONTROL RULES (Continued)

District and Applicable Rule	Leak Definition	Inspection Frequency	Allowable Repair Period	Reinspection Requirements	Exemptions	Recordkeeping Requirements
Kern County Air Pollution Control District						
Rule 414.1: Valves, Pressure Relief Valves and Flanges at Petroleum Refineries and Chemical Plants Effective: April 5, 1982 (valves and flanges), July 1, 1982 (PRV's)	Valves/Flanges: Liquid - > 3 drop/minute Gas - > 10,000 ppm methane within 1 cm PRV's: > 10,000 ppm in plane at the centroid	Valves: Liquid - Quarterly, no leak then annually Gas - Quarterly Flanges: Annually PRV's: Gas - Quarterly and 15 days following venting to atmosphere	Repair within 15 days	Valves/Flanges: 3 months following repair	Low RVP ($\leq$ 1.55 psi). Natural gas. Inaccessible. Low PROC (< 20%).	Maintain records of inspection for at least one year.
Rule 414.5: Pump and Compressor Seals at Petroleum Refineries Effective: August 27, 1984	> 10,000 ppm methane at 1 cm	Compressors: Quarterly Pumps: Annually	Repair within 15 days		Low RVP ($\leq$ 1.55 psi). < 1 hp. Natural gas. Low PROC (< 20%). > 80% H_2O. Emission rate < 0.4 lb/hr.	Maintain records for at least 2 years. Leakers must be identifiable. Maintain schedule for leak reduction.

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TABLE 5-1. EVALUATION OF FUGITIVE EMISSION CONTROL RULES (Continued)

District and Applicable Rule	Leak Definition	Inspection Frequency	Allowable Repair Period	Reinspection Requirements	Exemptions	Recordkeeping Requirements
Ventura County Air Pollution Control District						
Rule 74.7: Fugitive Emissions of ROC at Petroleum Refineries and Chemical Plants (Adopted May 29, 1979)	Valves/Flanges/Pumps/Compressors: Liquid - > 3 drops/minute or visible mist Gas - > 10,000 ppm methane at 1 cm PRV's: > 200 ppm ROC, except during releases	Valves/Flanges/Pumps/Compressors: Monthly for three months, then quarterly except for flanges which go to annual inspections PRVs: Quarterly	Within 15 days. 1st attempt within 5 days. Essential: At next PU T/A or within 90 days.		PRV: Vented to a vapor recovery system with $\geq$ 95% contol efficiency. Protected with a rupture disc.	Maintain inspection log for at least 2 years with the following information about each component: - location - type - date of leak - date of reinspection - critical process unit - total number of components inspected - total number of leaks detected
Kings County Air Pollution Control District						
Rule 414.1: Valves, Pressure Relief Valves, and Flanges at Petroleum Refineries and Chemical Plants (Adopted June 5, 1979)	Valves/Flanges: > 1,000 ppm hexane at source PRV: > 10,000 ppm in plane at the centroid	Valves/PRV's: Gas - Quarterly Liquid - Annually	Repair within 2 working days.	Valves: 3 months following repair	Natural gas. Methane only. Low PROC. Inaccessible.	Maintain records of inspection for one year.

6.0 REFERENCES

Bliss, 1959, Statistics in Biology, Vol. 1.

EPA, 1979, Emission Factors and Frequency of Leak Occurrence for Fitting in Refinery Process Units, EPA-600/2-79-044, EPA IERL, Research Triangle Park, NC February 1979.

EPA, 1985, Compilation of Air Pollutant Emission Factors, 4th Edition, EPA OAQPS, Research Triangle Park, NC, September 1985.

OGJ, 1986, "Annual Refining Report," Oil and Gas Journal, March 24, 1986.

Radian, 1980, Assessment of Atmospheric Emissions from Petroleum Refining. EPA-600/2-80/075a, EPA IERL, Research Triangle Park, NC, April 1980.

Radian, 1982a, Evaluation of Leak Detection and Repair for Control of Fugitive Emissions from Refinery Pump and Compressor Seals, Radian, Austin, TX, June 1982.

Radian, 1982b, Evaluation of the Maintenance Effect on Fugitive Emissions from Refineries in the South Coast Air Quality Management District, Radian, Austin, TX, June 1982.

Radian, 1983, A Model for Evaluation of Refinery and Synfuels Hydrocarbon VOC Emission Data, EPA IERL, Research Triangle Park, NC July 1983.

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APPENDIX A

September 10, 1985 Questionnaire

STATE OF CALIFORNIA GEORGE DEUKMEJIAN, *Governor*

AIR RESOURCES BOARD
1102 Q STREET
P.O. BOX 2815
SACRAMENTO, CA 95812

Radian Corporation is under contract to the Research Division of the California Air Resources Board (ARB) to assess fugitive emissions of photochemically reactive organic compounds (PROC)[1] from petroleum refineries. These fugitive emissions result from leaking components such as valves, pumps, and connections. Between 1978 and 1982, the ARB approved suggested control measures (SCMs) for the control of PROC emissions from leaking components in refineries. Subsequently, air quality management and air pollution control districts adopted rules partially based on these SCMs. These rules included requirements for the inspection and maintenance of leaking components. This research project will estimate fugitive emissions from refineries, and will quantify those factors which contribute significantly to differences in fugitive emission rates between refineries.

The primary basis of Radian's research contract will be existing fugitive emission inspection data collected by refineries, contractors to the refineries, and regulatory agencies. This letter is a request for all fugitive emission inspection data that have been collected by your staff or contractors at your refinery. All of the inspection data that have been collected at your refinery are requested. Examples of these data include data collected prior to implementation of refinery fugitive emission rules, data collected for components exempt from these rules, and data collected to demonstrate compliance with the rules.

Included with this letter is a questionnaire. This questionnaire should be filled out by an individual who is knowledgeable in your refinery's inspection/maintenance program and the data that are generated by the program.

This request for data is a formal one made pursuant to Sections 39607, 39701, and 41511 of the California Health and Safety Code and Section 91100, Title 17 of the California Administrative Code, which authorize the ARB, or its duly appointed representative, to require the submission of air pollution related information from owners and operators of air pollution emission sources.

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(1) PROC is any compound containing at least one atom of carbon except methane, carbon monoxide, carbon dioxide, carbonic acid, metallic carbides, or carbonates.

AIR RESOURCES BOARD
1102 Q STREET
P.O. BOX 2815
SACRAMENTO, CA 95812

In accordance with Title 17, California Adminsitrative Code, Sections 91000 et seq., and the California Public Records Act (Government Code Sections 6250 et seq.), the information which you provide may be released (1) to the public upon request, except trade secrets which are not emission data or other information which is exempt from disclosure or the disclosure of which is prohibited by law, and (2) to the federal Environmental Protection Agency, which protects trade secrets as provided in Section 114(c) of the Clean Air Act and amendments thereto (42 U.S.C. 7401 et seq.) and in federal regulations.

If you wish to claim that any of the information you submit is trade secret or otherwise exempt from disclosure under applicable law, you must identify in writing the portion of the submittal claimed to be confidential and provide the name, address, and telephone number of the individual to be consulted if the ARB receives a request for disclosure or seeks to disclose the data claimed to be confidential. Emissions data shall not be identified as confidential. Data identified as confidential will not be disclosed unless the ARB determines in accordance with the above-referenced regulations that the data do not in fact qualify for a legal exemption from disclosure. The regulations establish substantial safeguards before any such disclosure. Please note that Radian has formally agreed with the ARB to protect the disclosures of trade secrets to the public.

Information on ARB policy may be obtained from the ARB research contract monitor, Mr. Joseph Pantalone, whose telephone number is 916/323-1535. The ARB contract number for this research project is A4-153-32. Questions regarding the legal aspects of this request may be directed to the ARB's Office of Legal Affairs 916/322-2884.

Please complete and return the questionnaire forms within thirty (30) days to:

Mr. Scott Peoples
Radian Corporation
10395 Old Placerville Road
Sacramento, CA 95827

All questions concerning the survey should be directed to Mr. Bill Oliver or to Mr. Scott Peoples with Radian Corporation. They can be reached at 916/362-5332.

Thank you very much for your cooperation and assistance.

Sincerely yours,

John R. Holmes, Ph.D.
Chief, Research Division

Attachment

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QUESTIONNAIRE INTRODUCTION

The purpose of this questionnaire is to obtain information and data on the fugitive emissions from your refinery. The information that is being sought includes all fugitive emission inspection data that have been collected by your staff or contractors at your refinery.

The enclosed questionnaire has two parts. Part I requests general information about your refinery. This general information includes information on the number of components (e.g., valves, pumps, compressors, etc.) that are covered by local air pollution rules as well as the number of components that are exempt from the rules for various reasons. These reasons may include inaccessibility, low vapor pressure of the material being handled, low hydrocarbon content of the material being handled, etc. These component counts are very important to the study that is being conducted. Therefore, it is important that these component counts be provided.

A copy of Part II of the questionnaire should be completed for each inspection data set that exists for your refinery. Examples of different inspection data sets that might exist would be a special study conducted prior to implementation of refinery fugitive emission rules, data collected for components exempt from these rules, and data collected to demonstrate compliance with the rules. These data could have been collected by your staff or by contractors.

In order to provide insight into the type of refinery fugitive emission inspection data that we are trying to obtain, we will describe what could be termed an ideal fugitive inspection data base. Hopefully, this description will provide an understanding of the types of data that would be useful in evaluating emissions from refinery fugitives. The following parameters would ideally be included in a fugitive emission inspection data base:

- Component identifying number;
- Process unit that the component is part of;
- Specific component type (e.g., gate valve, block valve, centrifugal pump, reciprocating pump, etc.);
- Specific material handled by each component (e.g., crude oil, naphtha, gasoline, etc.);
- Reid or true (specify) vapor pressure (psia) of the material handled by each component;
- Photochemically Reactive Organic Compound (PROC)[1] content (percent) of the material handled by each component;
- Temperature (°F) of the stream handled by each component;
- Line pressure (psig) of the stream handled by each component;
- Date that the component was inspected;

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(1) PROC is any compound containing at least one atom of carbon except methane, carbon monoxide, carbon dioxide, carbonic acid, metallic carbides, or carbonates.

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- o Inspection value (ppm or soap score) for each component (whether requiring maintenance or not);
- o Date of component maintenance (if required);
- o Inspection value immediately before maintenance;
- o Type of maintenance performed (e.g., new seal, injection, etc.);
- o Inspection value immediately after maintenance;
- o Date of followup inspection;
- o Followup inspection value.

The questionnaire should be completed and returned along with your fugitive inspection data within 30 days after receipt. We expect that your fugitive inspection data may be in the form of magnetic tape, microfiche, copies of log books, etc. If you have any questions about this request or the questionnaire, please contact Bill Oliver or Scott Peoples with Radian. Both of them can be contacted at 916/362-5332.

Please send the questionnaire and fugitive inspection data to:

Mr. Scott Peoples
Radian Corporation
10395 Old Placerville Road
Sacramento, CA 95827

FUGITIVE EMISSION QUESTIONNAIRE
PART I

A. GENERAL FACILITY INFORMATION

1. Date ______________

2. Facility Name and Address ______________________
____
____

3. Individual to be contacted with questions regarding this questionnaire.

Name ______________________
Title ______________________
Phone No. ______________________

4. Please complete Table 1 by providing the most current component counts for each major process unit in your refinery.

5. In Table 1, were the connections for in-line valves, pumps, and compressors counted as connections in the total component counts, or were they considered part of the valve, pump, or compressor and not counted separately?

6. For each major process unit, describe the frequency of process turnaround and the typical time(s) of year a turnaround is scheduled, if applicable.

B. COMMENTS

1. On a separate page or below, please include any comments that you would like to include about the fugitive emissions control rule or your I/M program.

TABLE 1.

COMPONENT POPULATIONS BY TYPE OF EXEMPTION

Refinery ______________ Date that Counts or Estimates Were Made ______________

Process Unit ______________ (Specify as Counts or Estimates)

	Valves	Pump Seals	Compressor Seals	Connections		Pressure Relief Valves		
				Threaded	Flanged	Liquid Service	Gas Service	
							On Pressure Vessels	Other
Total Number of Components								
Number Covered by District Rule								
Number Exempt as Low RVP								
Number Exempt as Low PROC Content								
Number Exempt As High Temperature								
Number Exempt as Inaccessible								
Number Otherwise Exempt (Specify Reason for Exemption)								
Number Designated as Part of a Critical Process Unit								

Note: The components that should be included in this table are components that handle PROC materials. If component counts exist for your refinery or can be developed, please provide. Otherwise, provide the best estimates possible of component populations.

FUGITIVE EMISSIONS QUESTIONNAIRE
PART II

Please provide to Radian a copy of each fugitive emission inspection data set that exists for your facility. A separate fugitive emission inspection data set may be defined by a lapse in the program, a change in the inspection procedures, or a change in the form of data storage. For example, separate data sets may exist for special studies conducted prior to implementation of refinery fugitive emission rules, data collected for components exempt from the rules, and data collected to demonstrate compliance with the rules. We expect that your inspection data may be in the form of magnetic tape, microfiche, copies of log books, etc.

A. GENERAL INSPECTION PROGRAM INFORMATION

1. List the type of detection instrument(s) used: OVA, TLV, AID, soap solution, other (specify).

2. Indicate the distance from the source that the measurements were made.

3. Describe the frequency and method of instrument calibration (i.e., type of calibration gas used, singlepoint or multipoint calibration, etc.)

4. Describe the monitoring interval for each component type (i.e., the average time between inspections).

5. Define the threshold (ppm or soap score) used to determine if a component was leaking and therefore required maintenance.

6. Describe the approach used for maintenance for each component type.

7. Are summary statistics available on the effectiveness of the different approaches used for maintenance in reducing fugitive emissions? If so, please provide.

8. Are summary statistics available on the time until leak recurrence after maintenance is performed? If so, please provide.

PART II (continued)

B. INSPECTION DATA BASE

1. Describe the form of data storage: magnetic tape, microfiche, log book, other (specify).

2. List the time periods for which this data set was collected (e.g., 10/83 - present).

3. Are all refinery components included in the data base or only those components that have inspection values above the threshold?

4. Are components that are exempt from the inspection requirements included in the data base? If so, describe these components and the exemptions that are applicable.

5 ~~6.~~ If the data base is stored in a fixed format on magnetic tape, please provide an example record of the data base that includes the headings for each parameter (e.g., component type, service, date of inspection, inspection value prior to repair, etc.). If the data is stored in a computer and can be provided in various formats, please call Bill Oliver or Scott Peoples with Radian to discuss the format that the data should be provided in. Also, please indicate the following parameters of data storage: density (BPI), number of tracks, code (EBCDC or ASCII), labeling (labeled or unlabeled), volume serial number, record type (fixed length or variable length), logical record length, blocking (unblocked or blocked), blocksize and file number.

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APPENDIX B

March 26, 1986 Questionnaire

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March 11, 1986 243-069-03

Radian Corporation is under contract to the Research Division of the California Air Resources Board (ARB) to assess fugitive emissions of photochemically reactive organic compounds (PROC) from petroleum refineries. The primary basis of Radian's research contract is fugitive emission inspection/maintenance data collected by refineries and/or contractors to the refineries. A letter sent to California refineries on September 10, 1985 requested such data. Included with the letter was a questionnaire requesting information and data on refinery fugitive emissions.

Radian is currently in the process of conducting a detailed review and evaluation of all of the questionnaire responses and fugitive emission inspection/maintenance data received from refineries through the formal September 10, 1985 ARB request.

At the time of the formal request it was anticipated that the refinery fugitive emission inspection/maintenance data sets would contain a number of parameters. Such parameters include component identifying number, process unit that the component is part of, specific component type (e.g., valve, flange, pump, etc.), and stream service type of each component (i.e., gas or liquid service). Following review of the refinery data received, it has been realized that the majority of the data sets do not provide one or more of these parameters.

For example, a number of the data sets do not provide service type for components subject to the rule and components exempt from the rule. Because the applicable emission factors are service-specific, distinction of service type for all components is essential in estimating fugitive emissions of PROC from refineries.

Therefore, with complete ARB concurrence this letter represents a follow-on to the previous ARB refinery fugitive emission data and information request. The following data parameters are requested for your refinery:

As with the previous ARB formal request for data, the information which you provide may be released (1) to the public upon request, except trade secrets which are not emission data or other information which is exempt from disclo-

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sure or the disclosure of which is prohibited by law, and (2) to the federal Environmental Protection Agency, which protects trade secrets as provided in Section 114 (c) of the Clean Air Act and amendments thereto (42 U.S.C. 7401 et seq.) and in federal regulations.

If you wish to claim that any of the additional information you submit is trade secret or otherwise exempt from disclosure under applicable law, you must identify in writing the portion of the submittal claimed to be confidential and provide the name, address, and telephone number of the individual to be consulted if the ARB receives a request for disclosure or seeks to disclose the data claimed to be confidential. Emissions data shall not be identified as confidential in accordance with the above-referenced regulations that the data do not in fact qualify for a legal exemption from disclosure. The regulations establish substantial safeguards before any such disclosure. Please note that Radian has formally agreed with the ARB to protect the disclosures of trade secrets to the public.

Information on ARB policy may be obtained from the ARB research contract monitor, Mr. Joseph Pantalone, whose telephone number is 916/323-1535. The ARB contract number for this research project is A4-153-32. Questions regarding the legal aspects of this request may be directed to the ARB's Office of Legal Affairs 916/322-2884.

Please complete and return the additional requested data within forty-five (45) days to :

Ms. Caroline Thurn
Radian Corporation
10395 Old Placerville Road
Sacramento, CA 95827

All questions concerning the survey should be directed to Ms. Caroline Thurn or to Mr. Scott Peoples with Radian Corporation. They can be reached at 916/362-5332.

Thank you very much for your cooperation and assistance.

Sincerely yours,

Scott H. Peoples
Department Head
Environmental Services Department

SHP/let

Bullet Items

Bullet 1 o Please complete Table A, "Component Populations for Exempt and Non-Exempt Components with Service Type Distinctions" by providing service type distinctions for the most current component counts for each major process unit in your refinery. Please complete a separate table for each process unit. Enclosed are the completed component population tables you had previously provided as part of the questionnaire response (Enclosure 1). These tables can be used as a guide in completing the Table A provided with this request.

Bullet 2 o Please complete Table A, "Component Populations for Exempt Components with Service Type Distinctions" by providing service type distinctions for the most current component counts for each major process unit in your refinery. Please complete a separate table for each process unit. Enclosed are the completed component population tables you had previously provided as part of the questionnaire response (Enclosure 1). These tables can be used as a guide in completing the Table A provided with this request.

Bullet 3 o Please provide a master list of all valves and pressure relief valves inspected with a direct correlation between component identification numbers and component service type. This information will allow a determination of the frequency of leaking components by process unit with service type distinctions.

Bullet 4 o Please provide a direct correlation between component identification numbers and component service type for the leaking components indicated in the 1983, 1984, and 1985 inspection/maintenance data sets you had previously provided (Enclosure 2). This information will allow a determination of the frequency of leaking components by process unit with service type distinctions.

TABLE A.

COMPONENT POPULATIONS FOR NON-EXEMPT AND EXEMPT COMPONENTS WITH SERVICE TYPE DISTINCTIONS

Refinery ______________ Date that Counts or Estimates Were Made ______________

Process Unit ______________ (Specify as Counts or Estimates)[(1)]

	Valves		Pump Seals	Compressor Seals	Connections		Pressure Relief Valves		
	Liquid Service[(2)]	Gas Service[(3)]			Threaded	Flanged	Liquid Service[(2)]	Gas Service[(3)] On Pressure Vessels	Gas Service[(3)] Other
Total Number of Components									
Number Covered by District Rule									
Number Exempt as Low RVP (vapor pressure less than 1.55 psia and greater than that of kerosene)(4)									
Number Exempt as Low RVP (vapor pressure less than or equal to that of kerosene)[(4)]									
Number Exempt as Low PROC Content[(5)]									
Number Exempt as High Temperature									
Number Exempt as Inaccessible									
Number Otherwise Exempt (Specify Reason for Exemption)									
Number Designated as Part of a Critical Process Unit									

(1) If component counts with service type distinctions exist for your refinery or can be developed, please provide. Due to the relatively small numbers of pumps and compressors that exist at refineries, we expect to receive counts rather than estimates for these components. For other component types, if counts are not available, provide the best possible estimates of component populations. If estimates are provided, please provide the basis, or a description of the method used to develop these estimates.

(2) Liquid service streams include two-phase (i.e., gas/liquid) streams at process conditions.

(3) Gas service streams are defined as streams that are completely vaporized at process conditions.

(4) The vapor pressure of kerosene is assumed to be 0.1 psia at 100

(5) This category should include components handling streams with low photochemically reactive organic compound (PROC) content as defined in the applicable APCD's ...