

ANALYSIS OF REFINERY SCREENING DATA

Health and Environmental Affairs Department
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Institute



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Analysis of Refinery Screening Data

Health and Environmental Affairs Department

API PUBLICATION NUMBER 310

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ABSTRACT

This report presents the findings and recommendations of a study of fugitive emissions from piping components (valves, flanges, etc.) at seven Los Angeles California refineries over a period of five and one-half years. These screening measurements, taken to determine the estimated fugitive emissions of volatile organic compounds (VOC) from those refineries, were collected and analyzed. These screening measurements comprise the detection portion of a leak detection and repair (LDAR) program designed to reduce fugitive emissions from components in process unit piping. The study was conducted to determine whether a more cost effective LDAR protocol could be developed. The study was expected to clarify the cause(s) of leaks by identifying the repeat leakers and high-rate leakers and by investigating the design and operational characteristics of those leaking components. High leakers (components screening $\geq 10,000$ ppmv) were found to occur randomly and repeat leakers (components screening $\geq 1,000$ ppmv more than once within a year) were negligible. *This finding indicates that there is not an easily identifiable cohort of leakers within the population of refinery components subject to LDAR.* Overall, only 0.13 percent of the components were high leakers, but they accounted for 92 percent of the reducible VOC emissions. Based on the current findings, a leak detection protocol that would concentrate on locating high rate leakers may be more cost effective than the current practice of monitoring all components.



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EXECUTIVE SUMMARY

This report presents the findings and recommendations of a study of fugitive emissions from piping components (valves, flanges, etc.) at seven Los Angeles California refineries over a period of five and one-half years. Screening measurements, taken to determine the estimated fugitive emissions of volatile organic compounds (VOC) from those refineries, were collected and analyzed. These screening measurements comprise the detection portion of a leak detection and repair (LDAR) program designed to reduce those fugitive emissions from components in process unit piping. The study was conducted to determine whether or not a more cost effective LDAR protocol could be developed. Data were analyzed to determine if certain component designs or component applications (e.g., gate valves vs. globe valves, different process units, or different frequencies of actuation) tend to produce more high leakers (i.e., screening $\geq 10,000$ ppmv) or repeat leakers (i.e., screening $\geq 1,000$ ppmv more than once in a four-quarter period). The data were analyzed to identify the repeat leakers and high leakers by component type, generic process unit, and refinery, as well as on an aggregated basis for all refineries.

BACKGROUND

Since the early 1980s, the U. S. Environmental Protection Agency (USEPA) has supported the development and eventually required the implementation of LDAR programs under its New Source Performance Standards. Also, many states have adopted LDAR as part of their State Implementation Plan. As the result of the adoption of the National Emission Standards for Hazardous Air Pollutants from Petroleum Refineries (40 CFR Part 63 Subpart CC), known more commonly as “Refinery MACT Rule” (MACT is an acronym for Maximum Available Control Technology), every U.S. refinery is required to implement LDAR for the processes and streams described in this rule.

The LDAR procedure (EPA Method 21) involves placing an instrument probe at the surface of a component seal and measuring the VOC concentration as the probe is moved over the surface of the seal. A correlation has been established relating the mass rate of VOC leaking from the component to the maximum concentration measured by the instrument. EPA and some state agencies have established the level of VOC concentration which determines a *leak*. If the concentration of a component is above the level defining a leak, the component must be repaired or replaced to reduce the concentration to an acceptable level. The leak definition can vary from a VOC concentration as high as 10,000 ppmv to as low as 100 ppmv depending on the type of component and the specific regulation.

The screening measurement data used in this study came from the LDAR program required by South Coast Air Quality Management District (SCAQMD), the local air agency in the Los Angeles California area. There is a SCAQMD requirement to screen all accessible components (valves, flanges, etc.) quarterly. The leak definition in the SCAQMD regulation is 1,000 ppmv. Five and a half years of screening data, comprising 11.5 million values, were analyzed in this study.

OBJECTIVE

The objective of this study was to provide guidance for conducting LDAR programs in a more cost effective manner. Information was obtained to help determine (1) the design and operational characteristics that influence emissions and (2) whether a focused LDAR program could be more cost effective while reducing emissions than the current method of monitoring all system components.

TECHNICAL APPROACH

All available screening data, compiled under SCAQMD Rule 1173, were obtained for the ARCO, Chevron, Mobil, Shell¹, Texaco, Ultramar, and Unocal¹ refineries. The data were processed to standardize the file formats and entered into a Microsoft® Access™ database. Queries were run to find:

- Repeat Leakers - Screening $\geq 1,000$ ppmv more than once in a four-quarter period.
- High Leakers - Screening $\geq 10,000$ ppmv.
- Process-by-Process Variations.
- Refinery-by-Refinery Variations.
- Mean Time Between Failures - a failure was defined as screening ≥ 500 ppmv.

Finally, by analyzing the above results, recommendations were made regarding a more cost effective approach to LDAR than the current practice of monitoring all components.

RESULTS

It was found that 84 percent of the estimated refinery hourly emissions were from high leakers (screening $\geq 10,000$ ppmv) which were only 0.13 percent of the total number of components. The average emission rate for these high leakers was approximately 1,000 times higher than the overall average for all components. Of the remaining 16 percent of the estimated emissions, 9.5 percent were from non-leakers

¹ Shell refinery was acquired by Unocal in 1994. The Unocal refinery and the former Shell refinery were acquired by Tosco in 1997 prior to the completion of this report.

(screening ≤ 100 ppmv), which constitute 99 percent of the components, and whose estimated emissions are based primarily upon an EPA specified, zero default, value for components that screen at the background concentration. This leaves approximately 6.5 percent of the total emissions due to leakers in the range of 100 ppmv to 9,999 ppmv. Thus, the high leakers account for 92 percent of the controllable (i.e., non-default zero) emissions. In comparison, in 1980 an EPA refinery investigation found that, on an equivalent basis, 4 percent of the components were high leakers, *30 times higher than the percentage observed in this study* (Radian 1980).

Relatively few components were found to be repeat leakers. Only 5.4 percent of all emissions were from repeat leakers. It was suspected that there would be certain chronic leakers, for reasons of design, operation, or maintenance, which would repeatedly exceed the leak definition. This was not observed. Instead, the high leakers were found to occur randomly. No systematic explanation for their occurrence was apparent.

There were noticeable differences when comparing the data from the different refineries. However, the overall percentage of high leakers (screening $\geq 10,000$) in any refinery was less than 0.2 percent.

The three processes with the highest mass emissions were (1) catalytic reforming, emitting 13 percent of total emissions; (2) alkylation, emitting 10 percent; and (3) crude distillation, 7.5 percent. When normalized, based on the number of components in the process, isomerization units had the highest emissions per component. On the other hand, thermal crackers, sulfur plants, vacuum distillation towers, polymerization units, sour water strippers, MTBE plants, and flare systems had negligible emissions.

Data from one refinery indicated that components in liquefied petroleum gas (LPG) service tend to account for more than half of the high leakers and most of the repeat leakers. This refinery was the only one that provided a description of the stream fluid in the component. Therefore, this observation could not be confirmed for other locations.

CONCLUSIONS

For practical purposes, this study indicates that there is no easily identifiable cohort of leakers within the population of refinery components subject to LDAR. The percentage of repeat leakers is small in absolute terms and the percentage of components, with more than two leaks within a year, is negligible.

A more cost effective LDAR program may be one that emphasizes the location and repair of high leakers rather than screening all components. Currently, LDAR programs involve extensive screening inspections of what are found to be non-leaking components. Considering that high leakers account for 92 percent of the controllable hourly emissions and that the average hourly emission rate is a thousand times greater for high leakers than that for the average component, a focus on the detection and repair of only the high leakers would reduce emissions more cost effectively than an inspection of all components.

Section 1

INTRODUCTION

This report presents the findings and recommendations of a study of fugitive emissions from piping components (valves, flanges, etc.) at seven Los Angeles California refineries over a period of five and one-half years. Screening measurements, taken to determine the estimated fugitive emissions of volatile organic compounds (VOC) from those refineries, were collected and analyzed. These screening measurements comprise the "detection" portion of a leak detection and repair (LDAR) program designed to reduce fugitive emissions from components in process unit piping. The study was conducted to determine whether a more cost effective LDAR protocol could be developed.

BACKGROUND

Since the early 1980s, the U.S. Environmental Protection Administration (EPA) has supported the development, and eventually required the implementation, of LDAR programs as part of its New Source Performance Standards. As the result of the adoption of the National Emission Standards for Hazardous Air Pollutants from Petroleum Refineries (40 CFR Part 63 Subpart CC), known more commonly as "Refinery MACT Rule" (MACT is an acronym for Maximum Available Control Technology), every U.S. refinery is required to implement LDAR for the processes and streams described in this rule.

The LDAR procedure, known as EPA Method 21, involves placing a screening instrument probe on the surface of a joint seal in the component (or within 1 cm of the seal for rotating equipment) and measuring the VOC concentration, expressed in parts per million by volume (ppmv), as the probe is moved over the entire exterior surface of the component joint. Through many tests, a correlation has been established relating the mass rate of VOC leaking from the component to the ppmv value measured by the screening instrument. EPA, state and local environmental agencies have established levels of VOC concentration which determine that the component has a *leak*. If the measured ppmv level of a component is above the level defined as indicating a leak, the component must be repaired or replaced to reduce the leak to below the acceptable level. The leak definition level of VOC concentration can vary from a high of 10,000 ppmv, as specified in EPA's New Source Performance Standards (NSPS) to as low as 100 ppmv required by some state and local agencies.

The screening measurement data, used in this study, came from the LDAR program required by South Coast Air Quality Management District (SCAQMD), the local air agency in the Los Angeles California area. SCAQMD has a regulation requiring an LDAR program (Rule 1173 - adopted in 1989) which was implemented in 1991. At that time, refineries began recording their screening data and submitting them to SCAQMD each quarter. There is a general requirement to screen all accessible components (valves, flanges, screwed connections, pumps, compressors, and other components with sealed joints) quarterly. The leak definition adopted by SCAQMD is 1,000 ppmv. Approximately 70 percent of the screening data for 22 quarters, over 11 million values, were compiled for this study. Over one million components are screened each quarter in the seven major Los Angeles refineries included in this study.

Because of the great expense involved in performing this screening effort, the American Petroleum Institute (API) was interested in learning whether a more cost effective approach to LDAR could be developed rather than screening every component each quarter. Past experience shows that in these LDAR programs, approximately 99 percent of the components are already in compliance. If efforts could be redirected to only those components that leak more frequently or at higher rates, greater emission reductions may be achieved at lower costs.

OBJECTIVE

The objective of this program, then, was to provide guidance for conducting LDAR programs in a more cost effective manner. Information was obtained to characterize the leak rate distribution among various components, processes and refineries to help determine

- (1) the design and operational characteristics that influence emissions and
- (2) whether a focused LDAR program could be more cost effective at reducing emissions than the current method of monitoring all system components.

APPROACH

All available screening data, compiled under SCAQMD Rule 1173, were obtained for the ARCO, Chevron, Mobil, Shell², Texaco, Ultramar, and Unocal² refineries. The data were processed to standardize the file formats and entered into a Microsoft® Access™ database allowing the following queries to be run:

² Shell refinery was taken over by Unocal. The Unocal refinery and the former Shell refinery were acquired by Tosco in 1997 prior to the completion of this report in 1994.

- Repeat Leakers, by quarter, for components leaking 2, 3, and 4 times in the preceding four quarters (i.e., chronic leakers). Runs were made for "leak" definitions of greater than 500, 1,000, 10,000, 50,000, and 100,000 ppmv respectively. Total number of components, percent of total components and percent of total emissions were determined for each category.
- High Leakers, by quarter, for components screening $\geq 10,000$ ppmv. Total count by component type, percent of total components and percent of total emissions were determined.
- Process-by-Process Variation, average for all quarters, comparing repeat ($\geq 1,000$ ppmv) and high ($\geq 10,000$ ppmv) leakers for valves, connectors, pumps and an aggregate of all components.
- Refinery Specific Data, by quarter, comparing overall average emissions and comparing percentage of components that were high leakers ($\geq 10,000$ ppmv), repeat leakers ($\geq 1,000$ ppmv) and all leakers ($\geq 1,000$ ppmv). (Over 99 percent of the components do not leak; i.e., screen below 1,000 ppmv.)
- Finally, determine a more cost-effective approach to LDAR than the current practice of monitoring all components.

REPORT ORGANIZATION

Section 2 presents the data collection and processing effort; Section 3 presents the data summaries and the findings those data reveal. Section 4 presents a discussion of those findings with regard to more cost effective LDAR concepts and presents some suggestions for further work.

Section 2

DATA FROM THE LOS ANGELES REFINERIES

The screening data were obtained for seven Los Angeles refineries; ARCO, Chevron, Mobil, Shell, Texaco, Ultramar, and Unocal. As the data were collected and processed, several preliminary analyses were conducted to determine whether the data were sufficient to reach a valid conclusion or whether additional data would be needed. This section discusses the quantity and quality of those data.

Ultimately, 11.5 million screening runs were entered into the program database.

ACQUISITION

Initially, permission was obtained from the seven refineries to acquire their screening data from SCAQMD. The data requested were for the first quarter of 1992 through the second quarter of 1995. Approximately 50 percent of the requested data were obtained from SCAQMD. The refineries were then requested to provide as much of the missing data as possible. The results of the initial data collection effort are summarized in Table 2-1. It was apparent that the data collection and reporting by the refineries and the data storage by the agency improved with time. Therefore, after SCAQMD received the next annual data submittal from the refineries, another request for data was made. As shown in Table 2-1, the data collection for the last two quarters of 1995 and the first two quarters of 1996 were complete. The total count of components in each category increased each quarter. For example, in the third quarter of 1994 (the first quarter for which data were available for all seven refineries) approximately 780,000 component screening events were reported. In the second quarter of 1996, there were just over one million screening events reported. It was not apparent whether this growth in reported screenings reflected more thoroughness in the screening process or whether there was indeed an increase in the number of components in the plants. This study was conducted over a period when these refineries were undergoing modifications to produce *clean* fuels. Therefore, it is likely that an actual growth of components occurred although more specific information is not available.

The early data had many refinery-to-refinery differences in their file formats. Generally, the data included were component identification number, component type (valve, connector, etc.), service type (gas or light liquid), date of testing and screening value in ppmv. Some refineries had a process code which was interpreted for the project by the refinery staff. One refinery even had a word description of the product in the stream (e.g., gas oil, propane, crude oil). However, as SCAQMD worked to achieve a more uniform format for the data submittal, less information was submitted, although in more readily

processable form. The last four quarters of data had no process or stream identification. However, in many cases, it was possible to recover the process information by comparing the component ID numbers from previous years.

Table 2-1. Summary of the Screening Data Collection Effort
(Overall - 108 Quarters of good data of 154 possible = 70%)

Yr	Qtr	REFINERY DESIGNATION						
		<u>A</u>	<u>B</u>	<u>C</u>	<u>D</u>	<u>E</u>	<u>F</u>	<u>G</u>
91	1	X	X	<u>u</u>	◆	■	■	■
91	2	X	X	<u>u</u>	◆	X	■	X
91	3	X	X	<u>u</u>	◆	X	X	X
91	4	X	X	<u>u</u>	◆	■	■	■
92	1	X	X	<u>u</u>	◆	■	X	■
92	2	X	X	<u>u</u>	◆	■	X	■
92	3	X	X	<u>u</u>	◆	■	X	■
92	4	X	X	<u>u</u>	◆	X	■	■
93	1	■	X	X	X	■	X	⌘
93	2	■	X	X	X	■	X	⌘
93	3	■	X	X	X	■	X	⌘
93	4	■	X	X	X	X	X	⌘
94	1	X	X	X	X	■	X	■
94	2	X	X	X	X	■	X	■
94	3	X	X	X	X	X	X	X
94	4	X	X	X	X	X	X	X
95	1	X	X	X	X	X	X	X
95	2	X	X	X	X	X	X	X
95	3	X	X	X	X	X	X	X
95	4	X	X	X	X	X	X	X
96	1	X	X	X	X	X	X	X
96	2	X	X	X	X	X	X	X

- X --- Screening data available in Microsoft® Access™ database
 ■ --- Indicates that data were not available at the refinery or the SCAQMD
u --- Refinery indicated that its data were not reliable, therefore were not used.
 ◆ --- Data received but corrupted. Refinery indicated that they had no other data.
 ⌘ --- Data received had an ID system different from the that for other data. Data were not used because of the extensive effort to convert the ID code.