TEXAS CHEMICAL COUNCIL
1402 Nueces Street • Austin, Texas 78701-1586 • (512) 646-6400 • Fax (512) 646-6420

July 14, 2009

Mr. Vincent Meiller
Air Quality Division
Chief Engineer's Office
Texas Commission on Environmental Quality
MC-206
Post Office Box 13087
Austin, Texas 78711-3087

RE: Texas Chemical Council Comments on the Chapter 115 Leak Detection and Repair Alternative Work Practice Rulemaking Project

Dear Mr. Meiller:

On behalf of the Texas Chemical Council (TCC), please find attached comments regarding the 30 TAC Chapter 115 Leak Detection and Repair (LDAR) Alternative Work Practice (AWP) Rulemaking Project initiated by the Texas Commission on Environmental Quality (TCEQ).

TCC is a statewide trade association representing 77 chemical manufacturers with more than 200 Texas facilities. Our industry has invested more than $50 billion in physical assets in the state and pays over $1 billion annually in state and local taxes. TCC's members provide approximately 70,000 direct jobs and over 400,000 indirect jobs to Texans across the state. TCC member companies manufacture products that improve the quality of life for all Americans. The products manufactured in Texas account for 60 percent of the U.S. chemical production, which go into millions of consumer products. Chemicals are the state's largest export with over $30 billion each year.

TCC is widely supportive of the use of gas imaging technology as an AWP for finding fugitive emission leaks and appreciates the opportunity to submit informal comments on this rulemaking project. From a practicality standpoint, TCC supports TCEQ simply adopting by reference the federal AWP adopted by the U.S. Environmental Protection (EPA) on December 22, 2008 (73 Fed. Reg. 78,199-78,219) and then clarifying language in Chapter 115 that may conflict with the federal AWP rule. By virtue of the fact that TCEQ is implementing an approved federal rule, TCC believes that the use of the federal AWP rule in the state's highly reactive volatile organic compound (HRVOC) program is consistent with TCEQ's State Implementation Plan (SIP) obligations under the federal Clean Air Act. That said, pursuant to the discussions at the TCEQ

stakeholder meetings held June 23-26, 2009 across the state, TCC offers the following comments on the rulemaking project for your consideration.

Quantification of Fugitive Emissions

TCEQ noted in the stakeholder meetings that the current gas imaging technology cannot quantify emissions and that certain parts of the Chapter 115 LDAR rules are tied to quantification. Specifically, TCEQ is seeking comment on how to handle quantification with an AWP LDAR approach.

First, TCC notes that the technology's inability to quantify leaks is temporary at best. The technology is rapidly developing and improving over time and will eventually be able to quantify emissions. That said, in its final rule, EPA addressed this same concern, and its response follows:

> "The Agency recognizes the need for new approaches to estimate emissions from facilities that implement the AWP. *We will work with stakeholders to develop the necessary tools for quantification.* In the final rule, we are also requiring each facility complying with the AWP also monitor the same regulated equipment with a Method 21 monitor once per year. The data gathered from this requirement will help us address the issue of emissions quantification." 73 Fed. Reg. at 78,207 (emphasis added).

Given that in the final rule EPA has committed to working with stakeholders (which includes states) to develop the necessary tools for quantification, it follows that EPA will work with TCEQ on this aspect of the rule. According to the EPA final rule, in order for TCEQ to satisfy federal requirements, it would require each facility complying with the AWP to use a Method 21 monitor once a year.

Furthermore, TCC has attached for TCEQ's review a study conducted by the American Petroleum Institute (API) titled "Derivation of New Emissions Factors for Quantification of Mass Emissions When Using Optical Gas Imaging for Detecting Leaks" (Attachment 1). The study describes the development of new Leak/No-Leak Emission Factors that are suitable for estimating a facility's fugitive emissions when using an AWP. Leak/No-Leak Factors would be suitable for annual emission inventories. No rule changes are needed in this instance, only changes to the Emissions Inventory (EI) Guidance Document.

Chapter 115 requires quantification for HRVOC components placed on delay of repair in §115.782(c). One solution to this is to require a Method 21 reading on the component prior to placing on delay of repair until such time the AWP instrument is capable of quantification.

Demonstrating Equivalency

TCEQ notes that it must demonstrate to EPA that allowing the AWP in Chapter 115 is not backsliding under the federal Clean Air Act. Specifically, TCEQ is seeking comments on how best to demonstrate equivalency for allowing an AWP under the Chapter 115 rules, particularly the HRVOC LDAR rules.

This is another issue that EPA addressed in the final rule. One commenter asserted that optical gas imaging is not technically equivalent to Method 21 because the camera cannot detect small leaks of less than 60 grams/hour (g/hr). EPA responded:

> "In developing the AWP, EPA sought to design a program for using the optical gas imaging instrument that would provide for emissions reductions of leaking equipment at least as equivalent as the current work practice. To do so, we used the Monte Carlo model for determining what leak rate definition and what monitoring frequency were necessary for the AWP...We disagree with the commenter's assertion that optical gas imaging cannot detect leaks at or less than 60 g/hr. The tests conducted using various optical imaging devices have shown that many gas imaging instruments detect emissions significantly below the 60 g/hr limit (Docket ID No. EPA-HQ-OAR-2003-0199-0027). Moreover, equivalence has been shown at a 60 g/hr leak rate, so it is not necessary that the optical gas imager detect leaks smaller than this level." 73 Fed. Reg. at 78,202-78,203.

For reference, TCC has also attached for TCEQ's reference a study titled "Smart LDAR: Pipe Dream or Potential Reality?" (Attachment 2). The study, conducted at the ExxonMobil Complex in Baton Rouge, Louisiana, conclusively shows that using optical imaging in an LDAR program for fugitive emissions control results in lower emissions compared with the current Method 21-based regulatory procedures. TCC has also attached an API study titled "Equivalent Leak Definitions for 'Smart LDAR' When Using Optical Imaging Technology" (Attachment 3).

Operator Training

TCEQ also notes that EPA's AWP rule does not specify detailed procedures for the use of gas imaging technology, nor does it require formal training prior to using the technology. Specifically, TCEQ is seeking comment on ways to ensure gas imaging technology is used effectively to find fugitive emissions leaks and whether training should be required for operators using gas imaging technology.

TCC believes that some level of training should be required for all those in the regulated community using the technology (i.e., both regulators and those being regulated). That said,

given that the newer optical gas imaging devices are easier to use and have simpler controls, TCC does not believe that a certification program is necessary. Existing cameras can already operate in "automatic" and "manual" modes with advanced operator input settings. Users should follow the manufacturer's specifications and any manufacturer's training provided with the purchase of the camera. Short of a certification program, TCC suggests the option of all users attending four hours of annual training.

Miscellaneous Issues

Finally, TCC offers the following comments for TCEQ's consideration. First, in the proposed rule, TCEQ should include language that clarifies that state permit changes are *not* required in order for a facility to use the AWP. TCC recommends that TCEQ's Permitting Division work to ensure both the regulatory and permit aspects of this rulemaking are addressed in parallel so as not to further delay implementation of the AWP.

Second, another issue addressed in the federal rule that would be appropriate to address in the state rule is the applied scope of the technology. An owner or operator should be able to selectively apply the AWP to a part of the facility, part of a process unit, or to pieces of individual equipment. EPA agreed with this approach (*see* 73 Fed. Reg. at 78,204), and TCC requests that this be explicitly stated in TCEQ's proposal rule.

Third, TCC also supports the simultaneous implementation of HB 1526 (2007) with the Chapter 115 proposal. Implementing both rulemakings at the same time will alleviate much confusion and facilitate the creation of a robust AWP LDAR program.

Thank you in advance for your consideration of these comments. If you have any questions, please do not hesitate to contact me at (. or .

Yours respectfully,

Michael McMullen
Director of Regulatory Affairs

ATTACHMENT 1

DERIVATION OF NEW EMISSION FACTORS FOR QUANTIFICATION OF MASS EMISSIONS WHEN USING OPTICAL GAS IMAGING FOR DETECTING LEAKS

Miriam Lev-On
The LEVON Group, LLC, Thousand Oaks, California, USA

David Epperson
Consulting Statistician, Columbus, Indiana, USA

Jeffrey Siegell
ExxonMobil Research and Engineering, Fairfax, Virginia, USA

Karin Ritter
American Petroleum Institute, Washington DC, USA

ABSTRACT

This paper describes the development of new Leak/No-Leak Emission Factors that are suitable for estimating facilities fugitive emissions when using an Alternative Work Practice (AWP) that is based on optical imaging technology for detecting leaking process components. Emission factors were derived for valves, pumps and connectors/flanges and for a select range of instrument leak detection thresholds ranging from 3-to-60 gr/hour. These new Leak/No-Leak Emission Factors are designed to be used in lieu of the US EPA1995 Protocol factors, which are based on Method 21 monitoring of leaks. This derivation is based on previous results where the authors documented the use of a Monte Carlo simulation technique to quantify the required leak detection thresholds that provide equal - or better - environmental benefits for an AWP. Additionally, different methods for computing fugitive emissions from a hypothetical model refinery were compared by using these new emission factors side-by-side with the existing emission estimation methods provided in the USEPA 1995 Protocol. The results demonstrate that using the new emission factors generate an emission estimate that is the closest to that obtained from the direct determination of total emissions by Monte Carlo simulations.

IMPLICATIONS

The US EPA has issued a notice of proposed rulemaking that would encourage the use of alternative work practices for identifying and repairing the very large leakers in process equipment components. It has been demonstrated that optical imaging technologies could be used as part of this alternative work practice, however though these techniques have the potential of correctly identifying leakers 100% of the time, they do not provide a direct quantitative measure of emission rate. In contrast, the current LDAR practice produces monitoring (screening) data by employing Method 21, and these data can be used both for identifying leaks and as indicators for quantification of total emissions. Hence, when these new work practices are widely adopted, manufacturing facilities such as those in the petroleum industry will no longer have Method 21 screening data for emission quantification.

INTRODUCTION

Efforts focused for the past several years on the development and demonstration of innovative technologies - primarily optical imaging techniques - for the rapid detection of leaking process components in refineries and petrochemical facilities [1]. These technologies provide real-time imaging allowing operators to locate components that are leaking above preset regulatory threshold [2]. This new approach to Leak Detection and Repair (LDAR), which is known as 'Smart-LDAR', will allow plants the flexibility to implement inspection and maintenance procedures that are based on combinations of leak thresholds for triggering repair along with a range of monitoring frequencies.

The current LDAR practice produces monitoring (screening) data using Method 21 that can be used both for identifying leaks that ought to be repaired and as indicators for the quantification of total emissions [3,4,5]. In contrast, though optical imaging techniques being currently tested for 'Smart LDAR' monitoring have the potential of correctly identifying leakers 100% of the time, they do not provide a direct quantitative measure of emission rate. Therefore, when these new 'Smart LDAR' work practices are adopted as an alternative work practice, petroleum industry facilities will no longer have access to routine screening data obtained by Method 21 as an emission quantification method. We have previously analyzed alternative approaches to the quantification of mass emissions that could be used in conjunction with such optical imaging technologies [6]. The current work details the implementation of one such method

and the derivation of new emission factors that could be immediately available to the users community.

METHODOLOGY

The U.S. EPA's Protocol for estimating emissions from equipment leaks[7] provides several methods for estimating mass emissions from petroleum industry facilities. Using a screening dataset whose values were entered into an appropriate correlation equation to estimate applicable mass emission rates was used to develop these Emission Factors. The individual mass emission rates were then totaled and divided by the total number of components to arrive at an emission factor. The new emission factors developed in this study differ from the traditional approach used in the U.S. EPA Protocol in that a Monte Carlo (MC) software tool[8] was used to simulate mass emission distributions rather than using the correlation approach directly. Otherwise, the calculations remain the same as the traditional methodology (i.e., divide total mass emissions by total number of components).

Steps in the Monte Carlo Simulation

The EPA developed MC software tool[8] was used to simulate mass emissions distributions (in Step 1 of the methodology) from which the total mass emissions and the total number of components for Leakers and Non-Leakers were calculated. A leaking component was defined as corresponding to a mass emission rate that is equal to, or greater than, the threshold sensitivity level of the instrument being modeled. A non-leaking component is therefore defined as corresponding to a mass emission rate that is less than the respective instrument threshold. One of the key assumptions of the MC tool is that the optical imaging instrument can always detect emission rates that are higher than the instrument sensitivity threshold.

This tool is essential to the simulation of mass emissions distributions since no dataset exists that contain mass emissions data from each individual process component in a facility. The tool uses a screening dataset indirectly as a surrogate to simulate mass emissions. The vast majority of the screening values themselves are not directly used; rather, counts of components in screening value classes - based on actual screening values - are used. Four screening value classes are defined and used in the MC tool:

(1) ***Non-emitters (NE's)*** - These are components for which no VOC concentration can be detected at the component interface by a Method 21 screening instrument. This class represents the vast majority of components, typically ranging from 80% to –over 95%, depending on component type and level of facility control. This class contributes only a very small fraction of total facility emissions.

(2) ***Non-pegged Emitters (NPE's)*** - These are components for which a VOC concentration can be obtained at the process equipment interface by a Method 21 screening instrument. These concentrations typically range between 10 ppmv and 10,000 ppmv, unless a dilution probe is used, extending the detectable range to 100,000 ppmv. This class represents somewhere between <1% to 15% of all components, depending on component type and level of facility control. This class contributes more to total emissions than the NE's, but is not the dominant source of total facility emissions.

(3) ***Pegged at 10,000 ppmv Emitters (P010k)*** - These components register VOC concentrations at the seal interface that "peg" the Method 21 screening instrument at 10,000 ppmv. This class represents a minority of components, typically from <1% to 6%, depending on component type and level of facility control. However, this class contributes a very large fraction of total facility emissions, especially when a dilution probe it not used for monitoring.

(4) ***Pegged at 100,000 ppmv Emitters (P100k)*** - These are component that register a "pegged" reading with the Method 21 screening instrument at 100,000 ppmv when a dilution probe is used. While this class represents a minority of components, typically <1% it contributes the largest fraction of total facility emissions.

In order to simulate mass emissions the MC tool uses the petroleum industry (PETROL) bagging dataset (API, 1993a, 1993b, & 1994) that was used to develop the revised Petroleum Industry correlation equation in the U.S. EPA Protocol[7]. This bagging dataset contains data pairs of screening values for all four screening value classes. Method 21 was used to measure the screening values, while bagging of selected components followed by laboratory analyses was used to determine mass emission rates.

Typically, 85-99% of all components do not have a measured screening value associated with them, namely all the components in the NE, P010k, and P100k classes. For these classes of components the empirical distribution of mass emission rates is randomly sampled in accordance

with the component count in each of the screening value classes. For the one screening value class (NPE) in which measured screening values were obtained, the screening values are is used in the appropriate correlation equation with a random variability term, so that the same screening value might be associated with different mass emission rates, as is observed in the field. Thus, a given set of *X* screening values will result in a different set of *X* mass emission rates, each time they are simulated in the MC tool.

Derivation of New Leak/No-Leak Emission Factors

Emission factors were developed for three component types: valves, pumps, and flanges (including connectors), assuming four optical imaging instrument thresholds sensitivity levels of 3, 6, 30, and 60 g/hr. Emission factors for each component type and instrument threshold were simply calculated as:

$$\text{Emission Factor (g/hr/component)} = \frac{\sum_{components} \text{Emission Rates (g/hr)}}{\sum_{components} \text{Component Count}} = \frac{\text{Total Mass Emissions (g/hr)}}{\text{Total Number of Components}} \qquad \textbf{(Eq. 1)}$$

One thousand (1000) MC simulations were performed for each of the four instrument thresholds using a model refinery with a capacity of 250,000 Bbls/day that contains 50,000 valves, 150,000 flanges and 1,000 pumps. The simulations were performed using screening value distribution that has been used before[8].

Table 1 provides a mapping of the proportions of model refinery components by component type, count and service. The percent allocation of components by service type is representative of transportation fuel refineries with minimal or no production of heavy oil and asphalt products. The proportion of components by service type are not used directly in the derivation of the new Emission Factors, they are merely used to compare these newly derived factors with the existing U.S. EPA Protocol "Leak/No-Leak" factors[7]. These proportions were applied to the 1995 EPA factors to obtain one service-weighted average factor per component.

The resulting Leak/No-Leak emission factors computed using the MC tool are documented in Table 2 for the OAG screening data set. The service-weighted 1995 EPA factors are also shown in Table 2 for comparison to the new factors.

CALCULATION OF TOTAL FACILITY EMISSIONS

In order to evaluate the validity of the newly derived "Leak/No-Leak" Emission Factors we have computed total facility emissions by using these new factors along with existing estimation methods previously published by the U.S. EPA, namely, Leak/No-Leak emission factors, and the correlation approach. Additionally, we were also interested in how these results would compare to what would be computed by the more accurate correlation approach, as well as the "true" emissions derived by the MC software tool. For this comparison we have assumed a current work practice of quarterly monitoring with a 10,000ppmv leak definition. Following are the five computational permutations used to compute and compare total facility emissions:

i. "True" emissions from 1000 MC simulations that were detected by the current work practice as leakers or non-leakers (in Step 2 of the tool methodology); these are the emissions that would result had there been no repairs.

ii. The EPA Correlation equation approach using measured screening values from screening datasets (adapted to the Model Refinery via MC simulation).

iii. The EPA 1995 protocol Leak/No-Leak Emission Factors using measured screening values from screening datasets (adapted to the Model Refinery via MC simulation).

iv. EPA Leak/No-Leak Emission Factors using 1000 MC runs with simulated detected screening values, and a current work practice of 10,000 ppmv leak definition, and quarterly monitoring.

v. NEW Leak/No-Leak Emission Factors with simulated detection of emissions using 1000 MC runs for an alternative work practice involving quarterly monitoring, and different leak thresholds.

Note that for all cases with the exception of the Correlation Approach, the governing assumption is that a leaker may start leaking during the first hour, the last hour, or any hour in between during the monitoring period. To simulate this variability of the onset of leaking we have multiplied the monitoring period by ½ to average out the different leak start times (9). For non-leakers, the assumption is that they emit during the entire monitoring period since they are not repaired, whereas a leaking component would have either been deemed a non-leaker or would have been repaired the previous monitoring period. This assumption was not used in the Correlation Approach because of the added dimension that some concentration values were obtained using a dilution probe versus "pegging" the screening instrument.

Further details regarding each of the five permutations used to compute total facility emissions are provided below. For each permutation, the Monitoring Period Time intervals are the same; they equal 2160 hours, or 90 days (i.e., quarterly monitoring).

i. ***"True" Current Work Practice (CWP) Emissions*** - *Using emissions simulated in Step 1 of the MC tool methodology*

The "true" emissions are simulated in Step 1 of the MC tool methodology, and are detected in Step 2 of the methodology by the work practices being simulated, based on the operational definitions of the work practices. We are using the simulated "true" emissions based on the current work practice and Leak/No-Leak counts obtained from the MC tool. Eq. (2) below shows the details for computing the "true" CWP emissions:

$$\text{Total "True" CWP Emissions} = \left(\frac{\sum_{\text{NonLeakers}} \text{True Emission Rate} \times}{\text{CWP MonPrdTime}} \right) + \left(\frac{\sum_{\text{Lakers}} \text{True Emission Rate} \times}{\frac{1}{2} \times \text{CWP MonPrdTime}} \right) \qquad \textbf{(Eq. 2)}$$

Where:

Non-Leakers = Non-Leaking components as detected by the current work practice (CWP),

Leakers = Leaking components as detected by the current work practice,

True Emission Rate = Simulated mass emission rate for component (kg/hour/component).

CWP MonPrdTime = Total number of hours in the current work practice monitoring period.

ii. ***U.S. EPA Correlation Approach*** - *Using measured screening values from screening datasets (adapted to the Model Refinery via MC simulation)*

Emissions were calculated for the current work practice directly from the screening datasets (adapted by MC simulations for the model refinery) using the 1995 EPA combined Petroleum Industry correlation equations. The screening datasets were adapted for the model refinery since the component counts of the model refinery differ from the counts in the screening datasets. The screening values were then inserted into the appropriate correlation equation (or default zero or pegged factors) to obtain the mass emission rate in kg/hr, which was then multiplied times the number of hours (2160) in a quarter to obtain total emissions in kg/quarter.

iii. ***U.S. EPA Leak/No-Leak Factors*** - *Using measured screening values from screening datasets (adapted to the Model Refinery via MC simulation)*

Emissions were calculated for the current work practice directly from the screening datasets (adapted by MC simulations for the model refinery) using the 1995 EPA Refinery Leak/No-Leak emission factors. The leakers and non-leaker equipment counts in the screening datasets (after adaptation for the model refinery) were multiplied times the appropriate Leak/No-Leak emission factors, and the number of hours (2160) in a quarter to obtain total facility emissions for the respective Leak/No-Leak methods. As noted above, for the Leak/No-Leak methods we assumed that the average component would leak for half of the elapsed time between monitoring (and repair) events due to the randomness of the appearance of leaks.

iv. ***EPA Leak/No Leak Factors for Current Work Practice (CWP) Emissions*** – *Using 1995 EPA Protocol Emission Factors and 1000 MC simulations*

The number of leakers and non-leakers for the current work practice were calculated in the MC simulations (in Step 2 of the tool methodology) that were used to develop the new emission factors, as discussed above. Total emissions were calculated using the U.S. EPA (1995) Leak/No-Leak service-weighted factors with the assumption of a quarterly monitoring frequency, a leak definition of 10,000 ppmv, and Leak/No-Leak counts that are based on MC simulations using the model refinery, as shown in Eq. (3):

$$\text{Total CWP Emissions} = \begin{pmatrix} \#\,\text{CWP NonLeakers} \times \\ \text{EPA}:\text{EF}_{\text{NonLeakers}} \times \\ \text{CWP MonPrdTime} \end{pmatrix} + \begin{pmatrix} \#\,\text{CWP Leakers} \times \\ \text{EPA}:\text{EF}_{\text{Leakers}} \times \\ \tfrac{1}{2} \times \text{CWP MonPrdTime} \end{pmatrix} \qquad \textbf{(Eq. 3)}$$

Where:

CWP Leakers = Total number of leaking components as detected by the current work practice,

CWP NonLeakers = Total number of non-leaking components as detected by the current work practice,

$\text{EPA}:\text{EF}_{\text{NonLeakers}}$ = Service-weighted average 1995 EPA Protocol Emission Factor for Non-Leakers (kg/hour/component).

EPA:$EF_{Leakers}$ = Service-weighted average 1995 EPA Protocol Emission Factor for Leakers (kg/hour/component).

CWP MonPrdTime = Total number of hours in the current work practice monitoring period.

v. ***Alternative Work Practice (AWP) Emissions*** - *Using New Monte Carlo (MC) Emission Factors*

The number of leakers and non-leakers for the alternative work practice (AWP) were also calculated in the MC simulations (in Step 2 of the tool methodology) and were used to develop the new emission factors, as discussed above. Total emissions were calculated using the new Leak/No-Leak emission factors for each one of the instrument threshold levels and with the assumption of a quarterly monitoring frequency, and the corresponding Leak/No-Leak counts obtained for each threshold simulated using the model refinery, as shown in Eq. (4):

$$\text{Total AWP Emissions} = \begin{pmatrix} \#\,\text{AWP NonLeakers} \times \\ \text{NewMC:EF}_{\text{NonLeakers}} \times \\ \text{AWP MonPrdTime} \end{pmatrix} + \begin{pmatrix} \#\,\text{AWP Leakers} \times \\ \text{NewMC:EF}_{\text{Leakers}} \times \\ \tfrac{1}{2} \times \text{AWP MonPrdTime} \end{pmatrix} \qquad \textbf{(Eq. 4)}$$

Where:

AWP Leakers = Total number of leaking components as detected by the alternative work practice,

AWP Non-Leakers = Total number of non-leaking components as detected by the alternative work practice,

NewMC:$EF_{NonLeakers}$ = New Emission Factor for Non-Leakers derived from Monte Carlo simulations (kg/hour/component),

NewMC:$EF_{Leakers}$ = New Emission Factor for Leakers derived from Monte Carlo simulations (kg/hour/component),

AWP MonPrdTime = Total number of hours in the alternative work practice monitoring period.

ANALYSIS OF TOTAL FACILITY EMISSIONS

Total facility emissions were computed using the different methods outlined above to evaluate the results obtained and ensure that the new emission factors are self-consistent.

Impact of Sensitivity Threshold

The new Leak/No-Leak emission factors were computed for use with optical gas imaging instruments having different detection thresholds. The correlation equation method does not depend on instrument sensitivities, since it involves a one-time plugging of screening values into the correlation equation based on the screening dataset adapted to the model refinery. The same applies to the method using the existing EPA factors when they are applied to the screening dataset.

For the methods that use Monte-Carlo simulations (CWP-EPA and AWP-MC) the total emission computed with the new Leak/No-Leak factors was compared to the current work practice with the existing EPA factors. For the alternative work practice, instrument sensitivity thresholds of 3, 6, 30 and 60gr/hr were used for the comparison. The results obtained when using the OAG dataset are depicted in Figure 1. It is evident that the CWP-EPA emissions were about the same for each threshold sensitivity since the scenario always used the 10,000 ppmv leak definition, and a similar number of leakers were found each time. For the AWP-MC, although the number of "leakers" detected decreases with increasing sensitivity threshold modeled, the total mass computed is conserved as the overall sum computed increases (< 20%) with increased instrument sensitivity from 3 to 60 gr/hr.

Impact of Computation Methods Used

Figures 2 and 3 show total facility emissions by equipment type when using two different screening datasets (the OAG and REF screening datasets, respectively). The results depicted in the figures are also shown in tabular form in Table 3.

The development of the new factors considered various sensitivity thresholds, and the differences for the total emissions computed with each were not significantly different, as shown above. Hence, we have averaged over all the sensitivities for the full comparison shown below, with the average being between the 10 and 20 g/hr.

The results demonstrate that regardless of the screening dataset used, the "true" total facility emissions (solid purple bar; first in each equipment type set) are close to that obtained by using the NEW Leak/No-Leak emission factors in conjunction with the alternative work practice

(shown as the bars with brown diagonal lines; last in each set). For example, using the OAG screening dataset for valves, the "true" total facility emissions are 63,944 kg/quarter, while the total for the AWP using the NEW Leak/No-Leak emission factors is 67,007 kg/quarter.

The two methods used for the EPA Leak/No-Leak factors, either the leak/no-leak counts directly from the screening dataset (bars with red diagonal lines; third in each set), or from totaling the leak/no-leak counts from 1000 MC simulations of detecting mass emissions (bars with blue hatched lines; fourth in each set), give similar total facility emissions as well. For example, again using the REF screening dataset for valves, using directly the leak/no-leak counts with the EPA Leak/No-Leak factors gives total facility emissions of 112,313 kg/quarter versus 119,068 kg/quarter from totaling the leak/no-leak counts from 1000 MC simulations. It is clear that the totals using the EPA Leak/No-Leak factors are much larger than either the "true" total facility emissions or the totals from the AWP using the NEW Leak/No-Leak emission factors.

The results from using the correlation approach emissions (bars with green horizontal lines; second in each set) are different, depending on which screening dataset is used. In the case of the OAG screening dataset (Fig. 1), the total emissions calculated with the correlation approach are roughly in the same order of magnitude as those obtained by using the EPA Leak/No-Leak emission factors. For example, using the OAG screening dataset for valves, results in an estimated emission of 316,444 kg/quarter by the correlation approach, as compared to using the EPA Leak/No-Leak factors which result in totals of 361,791 kg/quarter (when using direct counts) and 335,813 kg/quarter (when using MC simulated counts).

However, when the REF screening dataset is used, total emissions calculated from the correlation approach are closer to the MC simulated totals and those calculated with the NEW Leak/No-Leak emission factors. For example, using the REF screening dataset, the correlation approach gives total facility emissions of 10,654 kg/quarter, compared to a "true" total of 2,547 kg/quarter and a total of 2,754 using the alternative work practice with the NEW Leak/No-Leak factors.

The reason for the difference in results when using the correlation approach is due to the key differences between the OAG and REF screening datasets. In most instances, the dilution probe was not used when collecting the OAG screening data and it resulted in many components that are designated as pegged at 10,000 ppmv, with very few measured screening values between 10,000 and 100,000 ppmv. In contrast, the REF screening dataset contains measured screening

values between 10,000 and 100,000 ppmv because the dilution probe was routinely used when collecting the data (no values are flagged as pegged at 10,000 ppmv, although there are suspicious spikes in the frequency distributions of all equipment types at 10,000 ppmv). Additionally, the OAG screening dataset is considered to be representative of an "uncontrolled" conditions resulting in more leaking components registering over 10,000 ppmv on the sensing instrument than in the "controlled" REF dataset. Therefore, when using the correlation approach with the OAG dataset the results are dominated by the components that are classified as "pegged" over 10,000ppm. For the REF dataset the components that register a "pegged" measurement (over 100,000ppm) contribute much less to the overall facility emissions.

Figure 4 illustrates the differences between emissions from the correlation equations and the pegged factors over the range up to 100,000 ppmv. This illustrates graphically that emissions calculated from the "pegged" emissions factors are much closer to those using the "Leak" factors in the "Leak/No-Leak" approach, while it differs from what would be computed using measured screening values with the correlation equation. When correlation equations are used with measured screening values between 10,000 and 100,000 ppmv, calculated emissions will be much lower than when either the factors for "pegged at 10,000 ppmv", or Leak Factors from the Leak/No-Leak approach, are used. Hence since the dilution probe was not routinely used in the OAG dataset, and it contains more "pegged" leakers, it is expected that a higher total emissions estimate will result when compared to the REF dataset. In short, the results simply reflect the differences in the screening value distributions that are partially attributable to the different data collection methods used for these two screening datasets.

CONCLUSIONS

This study has resulted in a set of new "Leak/No-Leak" emission factors that are suitable for quantifying facility mass emissions when optical imaging instruments are used to detect leaks. The Emission Factors presented here pertain to 4 distinct instrumental sensitivities thus representing different leak detection thresholds. Additional factors are available for a more complete range of instrument sensitivities and they will be published separately in future industry guidance.

In validating these new emission factors it has been illuminating to compare various methods and two different screening data sets in order to shed more light on the impact of various factors on estimated facility emissions.

The results of the comparing total facility emission results indicate that:

- Total facility emissions are lower for all the five methods compared when using the REF screening value distribution. This is consistent with the OAG distribution representing a less controlled facility.
- Using the current EPA Leak/No-Leak factors either directly or via MC simulations of the CWP yields very similar results, for either of the screening datasets used.
- The EPA correlation approach yields a substantially different result for facility emissions for well-controlled facilities (REF) vs. less controlled ones (OAG).
- Calculating the "true" emissions by MC simulations yields results similar to those obtained when simulating the AWP with the new Leak/No-Leak emission factors, for either of the datasets used.
- For both the REF and OAG distributions the "true" facility emissions from MC simulations are the lowest, followed closely by those using the new Leak/No-Leak factors.
- The MC simulations from which base "true" emissions can be compared to "calculated" emissions using either the correlation or Leak/No-Leak approaches support the contention that results from the correlation approach are closer to reality (i.e., "true" emissions) than results from the Leak/No-Leak approach. The fact that the results using the AWP with NEW Leak/No-Leak factors are much closer to the "true" emissions can be attributed to the assumption that all values above the AWP equivalency threshold (i.e., leak definition) are identified, compared to the CWP using Method 21 where the large variability of measured concentrations-to-"true" emissions results in misidentified leakers and non-leakers. Thus, application of an appropriate AWP equivalency threshold will likely increase the accuracy of the Leak/No-Leak approach in quantifying emissions using optical imaging technology.

ACKNOWLEDGEMENT

The authors would like to acknowledge the contribution of American Petroleum Institute (API) staff and the entire API LDAR Working Group. We would also like to acknowledge the use of the U.S. EPA Monte Carlo simulation software for this effort.

REFERENCES

1. American Petroleum Institute, "Analysis of Refinery Screening Data", API Publication 310, Washington DC, 1997.

2. "Smart Control Methods May Reduce Facility-Monitoring Expenses," HP In Control, Hydrocarbon Processing, August 1999.

3. Siegell, J.H., Taback, H.J., McRae, T. and Kulp, T.J., "Development of Smart LDAR for Fugitive Emissions Control," Valve World 2000, The Hague, Netherlands, Paper 10056, November 2000.

4. Smylie, M., Ronke, L-B., Robinson, D., Harris, G., Koonce, M., Stone, P., McRae, T., "The Use of a Gas-Imaging Device for Detecting Fugitive Emissions in Ethylene Facilities". Proceedings of the Air & Waste Management Association 96th Annual Conference and Exhibition, San Diego, CA 2003.

5. American Petroleum Institute, "Smart Leak Detection and Repair (LDAR) for Control of Fugitive Emissions", Washington DC, June 2004

6. Lev-On, M., Taback, H., Epperson, D., Siegell, J., Gilmer, L. and Ritter, K. "Methods for Quantification of Mass Emissions from Leaking Process Equipment when Using Optical Imaging for Leak Detection", Environmental Progress, March 2006, in print

7. U.S. EPA, "1995 Protocol for Equipment Leak Emission Estimates"; Office of Air and Radiation, Office of Air Quality Planning and Standards, EPA-453/R-95-017. Research Triangle Park, NC 27711, 1995.

8. U.S. EPA, "Monte Carlo Simulation Approach for Evaluating Alternative Work Practices for Equipment Leak"; Office of Air and Radiation, Office of Air Quality Planning and Standards, Final Report. Research Triangle Park, NC 27711, 1999.

9. Taback, H., Siegell, J. and Ritter, K, "Los Angeles Refinery Fugitive Emissions, Have They Changed After Six Years of LDAR," AWMA/EPA Specialty Conference, The Emissions Inventory: Planning for the Future, Research Triangle park, NC, October 1997.

Table 1. Proportion of components in gas, light liquid (LL) and heavy liquid (HL) service in the model refinery

Component Type	Total Count	Service Type	Service Count	Percent (*)
Valves	50,000	Gas	24,723	49.45
		LL	16,041	32.08
		HL	9,237	18.47
Pumps	1,000	LL	556	55.61
		HL	444	44.39
Flanges & Connectors	150,000	Gas + LL	113,906	75.95
		HL	36,094	24.06
TOTAL	**201,000**	**Gas + LL**	**155,226**	**77.23**
		HL	**45,775**	**22.77**

(*) The % allocations used are based on the average component count from two Los Angeles refineries

Table 2. Leak/No-Leak Emission Factors Derived from 1000 Monte Carlo Simulations

Component Type	Emission Factor Type	1995 U.S. EPA Protocol Factors (*)	Emission Factor (g/hr/component) for Specified AWP Leak Definition (g/hr)			
			3	6	30	60
Valves	No-Leak	0.88	0.019	0.043	0.17	0.27
	Leak	160	55	73	140	200
Pumps	No-Leak	13	0.096	0.13	0.59	0.75
	Leak	420	140	160	310	350
Flanges	No-Leak	0.06	0.0026	0.0041	0.0100	0.014
	Leak	38	29	45	88	120
All Components	No-Leak	0.33	0.0070	0.014	0.051	0.081
	Leak	69	56	75	150	210

(*) The 1995 U.S. EPA Protocol Factors listed were weighted by service according to the proportion of components in each type of service in the model refinery.

Table 3. Total facility emissions by equipment type from different approaches and screening datasets (kg/qtr)

Screening Dataset	Type of Calculation	Flange	Pump	Valve	Total
OAG	"True" Emissions from MC simulations	5,614	10,537	63,944	**80,096**
	EPA Correlation Approach	59,757	20,041	316,444	**396,242**
	EPA Leak/No-Leak Factors directly with screening dataset	33,650	64,445	361,791	**459,886**
	CWP using EPA Leak/No-Leak Factors in MC simulations	31,816	51,793	335,813	**419,422**
	AWP using NEW Leak/No-Leak Factors in MC simulations	6,177	10,152	67,007	**83,336**
REF	"True" Emissions from MC simulations	1,320	723	2,547	**4,590**
	EPA Correlation Approach	3,639	953	10,654	**15,246**
	EPA Leak/No-Leak Factors directly with screening dataset	21,499	30,262	112,313	**164,073**
	CWP using EPA Leak/No-Leak Factors in MC simulations	22,276	30,969	119,068	**172,314**
	AWP using NEW Leak/No-Leak Factors in MC simulations	1,453	706	2,754	**4,913**

Figure Captions

1. **Comparison of total facility emissions and the numbers of "Leakers" detected**

2. **Comparison of total emissions by component type using the OAG screening dataset for the hypothetical refinery**

3. **Comparison of total emissions by component type using the REF screening dataset for the hypothetical refinery**

4. **Emissions (kg/quarter) calculated by the correlation equation for different equipment types**

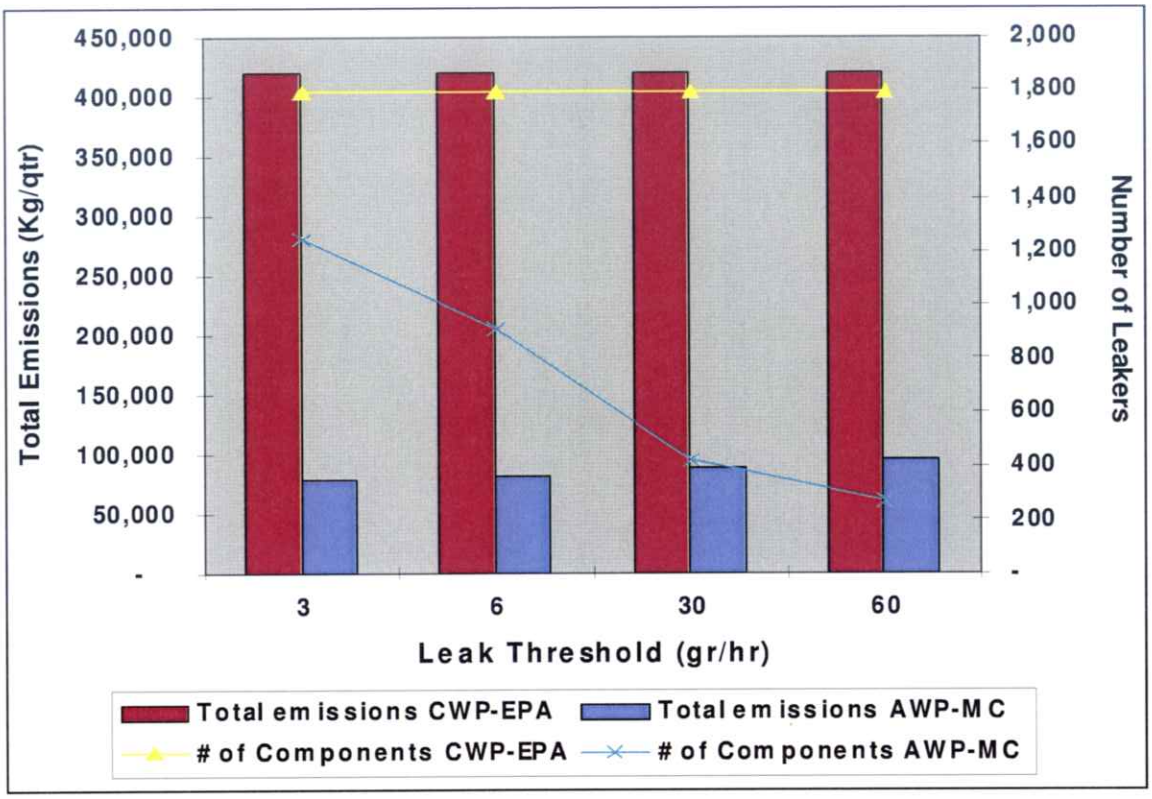

Figure 1. Comparison of total facility emissions and the numbers of "Leakers" detected

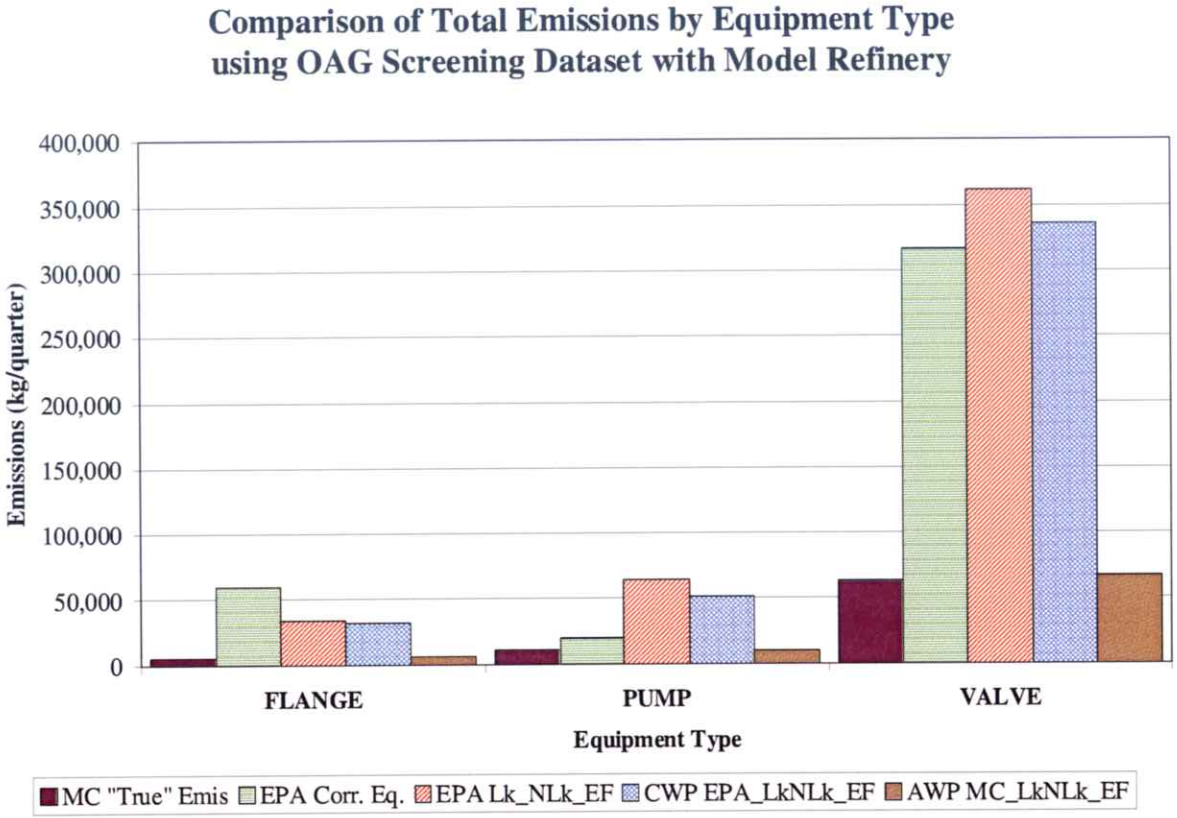

Figure 2. Comparison of total emissions by component type using the OAG screening dataset for the hypothetical refinery

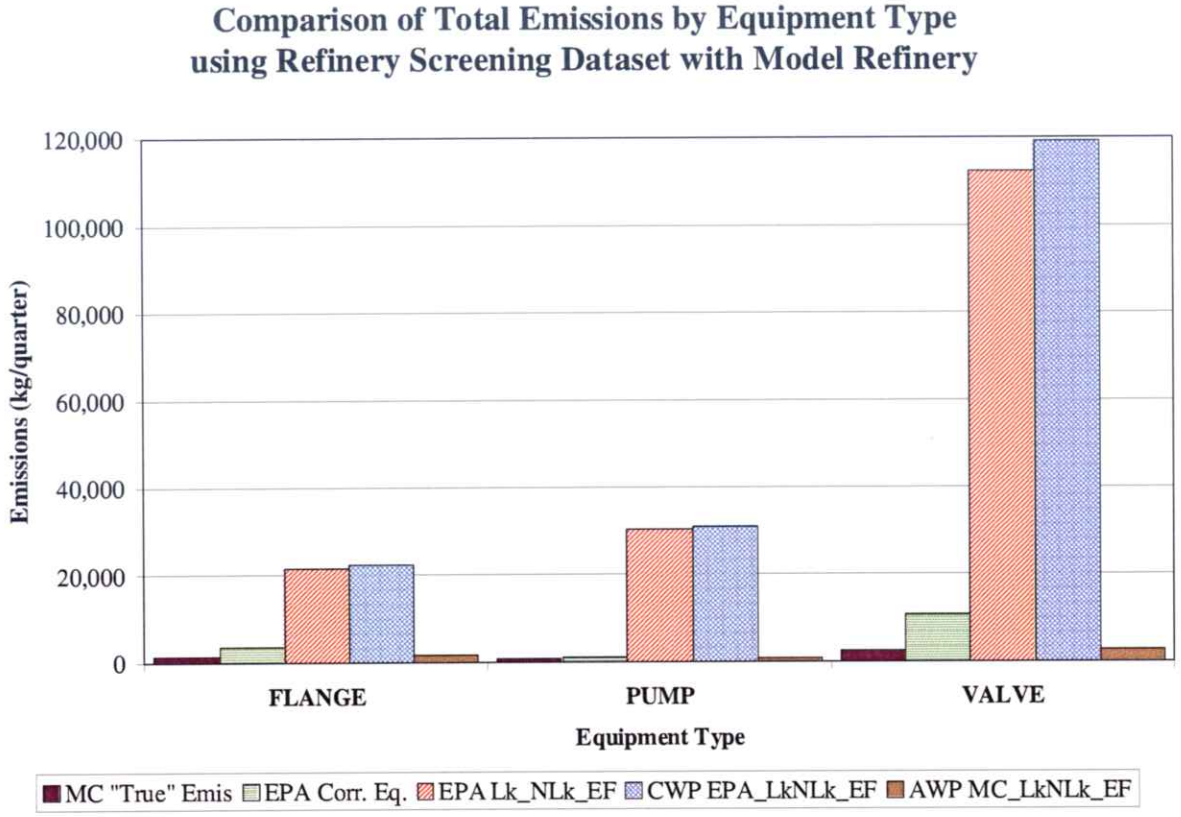

Figure 3. Comparison of total emissions by component type using the REF screening dataset for the hypothetical refinery

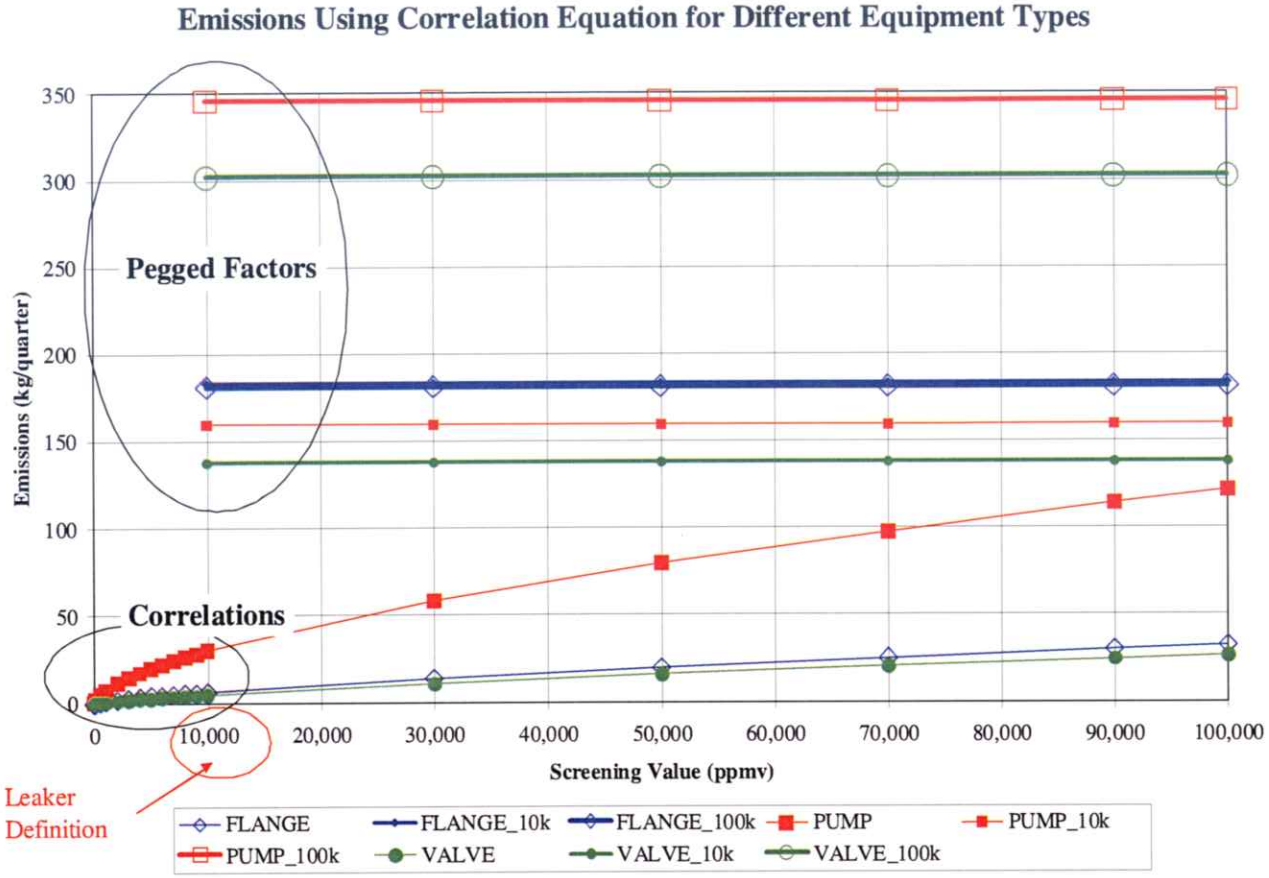

Figure 4. Emissions (kg/quarter) calculated by the correlation equation for different equipment types

ATTACHMENT 2

Smart LDAR: Pipe Dream or Potential Reality?

Paper # 731

Derek Reese and Charles Melvin ExxonMobil Chemical Company, 4999 Scenic Highway, Baton Rouge, LA 70821

Wayne Sadik, ExxonMobil Chemical Company, 4500 Bayway Drive, Baytown, TX 77520

SUMMARY

This study, conducted at the ExxonMobil Complex in Baton Rouge, Louisiana, has conclusively shown that using optical imaging in a Smart LDAR[1] program for fugitive emissions control results in lower emissions compared with the current Method 21[2]-based regulatory required procedures. Also, the smaller concentration leaks were shown to not generally increase over time and become significant leakers. This study demonstrated that finding the larger mass rate leakers sooner and repairing them more quickly offset the smaller mass rate leakers that would not be detected using the AWP (alternative work practice). Also, the study showed that fewer personnel can monitor a facility in a fraction of the time using the AWP compared to the CWP (current work practice). The combination of all these benefits demonstrates that optical imaging should[3] replace Method 21 for fugitive emissions control.

INTRODUCTION

A great deal of time and expense has been invested to develop optical-imaging technology for use in LDAR programs. Numerous studies have been conducted to validate the technical merits of this new technology. The U.S. Environmental Protection Agency ("EPA") has even proposed a rule defining this technology as a viable AWP to the CWP (Method 21) used in LDAR programs across industry. The AWP has been affectionately dubbed, “Smart LDAR.” The question now is whether the time has truly come for “Smart LDAR” to take its place as a viable technology or will it just remain an interesting technical discussion topic at industry symposiums? Is Smart LDAR just a pipe dream or will it become a reality for petrochemical LDAR programs?

The study results are very promising and indicate that any concerns are easily addressed or unfounded. Smart LDAR is indeed a viable alternative paradigm for successful LDAR compliance and emission reductions and should be approved for use for regulatory compliance.

Previously, the key obstacle standing in the way of Smart LDAR implementation was that only a limited number of practical side-by-side studies of the alternate and current work practices had been completed to the satisfaction of regulatory agencies. The

regulators do not want to risk endorsing or enabling technologies that do not produce emissions reductions comparable to existing LDAR programs.

This paper presents the joint efforts of industry and the Louisiana Department of Environmental Quality to conduct a practical study that responds to the concerns about Smart LDAR implementation. Key concerns the study sought to address include:

- Will the technology produce equivalent emissions?
- Will the technology find the leaks effectively as the current work practice?
- Is the technology as efficient as advertised?

THE FACTS SUPPORTING SMART LDAR

A study by the American Petroleum Institute (API) found that over 90% of controllable fugitive emissions come from only about 0.13% of the process equipment components in a refinery, and that these leaks are largely random.[4] The majority of the mass emissions come from a small number of components with high leak rates. A more efficient and smarter method for fugitive emissions control would more cost-effectively locate these large leakers so that they could be repaired sooner. Optical gas imaging technology has been identified as an alternative work practice to Method 21 to locate large leaks sooner and allow repair more quickly.[5] This alternative method for control of fugitive emissions is generally referred to as “Smart LDAR.”

The leading technology emerging for use in Smart LDAR is optical imaging. A handheld passive infrared optical imaging camera is available that efficiently and consistently detects fugitive leaks. The current unit utilizes infrared absorption to form an image in the eyepiece so that the operator can actually "see” emissions, real time, with the help of a special lens and filter arrangement developed specifically for a broad suite of volatile organic compounds (VOC's) in ambient air. Releases of VOC's are seen as plumes (moving cloud-like images) in the camera's eyepiece that result from absorption of radiant energy by the VOC's that leak from process equipment. The optical imaging system has been proven to be more efficient at finding large leaks than the CWP currently in use.

FIELD STUDY OBJECTIVES

Smart LDAR must be as effective as the current work practice (traditional Method 21 LDAR programs) at reducing fugitive emissions to be considered a viable alternative work practice. The key metric for this determination is whether the total fugitive emissions from an AWP are equal to or less than emissions from a program utilizing the CWP. Reports in the docket for the proposed federal rule (EPA-HQ-OAR-2003-0199) demonstrate that a Smart LDAR program using optical imaging is as effective for emissions control as the current Method 21 procedures. However, additional field tests were requested by regulatory agencies to confirm the emissions control equivalency in different process environments.

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A six-month field study, of which this study was a part, was designed by Louisiana Mid-Continent Oil and Gas Association (LMOGA), Louisiana Department of Environmental Quality (LDEQ) and Louisiana Chemical Association (LCA) to meet this need. The objectives of the field study were to:

1. Compare the ability of an optical imaging instrument based program to the US EPA Reference Method 21 based program for locating large leakers in a process plant environment.
2. Validate the US EPA proposed monitoring intervals, in the alternative work practice, for leak detection limits.
3. Identify what types of facilities or manufacturing processes are the best candidates for use of the alternative work practice.
4. Provide a quantitative measurement of the emissions between the two different approaches for a defined time period.
5. Enhance the technical basis for rule-making efforts by LDEQ for the alternative work practice (Smart LDAR).

FIELD TEST PROTOCOL

The field test protocol used the CWP and AWP to monitor the same process units over a 6 month period of time to validate emissions reduction equivalency. An isopropyl alcohol (IPA) manufacturing unit was selected to conduct the field tests. The field test included using both optical imaging and Method 21 to monitor all regulated fugitive emission components (FECs) within the selected process unit. Further, optical imaging was used to monitor all piping, major equipment, and vessels within the unit as well as other nearby units. All surveys with the camera were conducted by operators trained and certified in its use.

All leaks found with optical imaging were also required to be monitored with Method 21 to establish a comparative concentration value. A visible image in the camera's eyepiece was considered a leak. Leaks on regulated FECs were compared against the underlying leak definitions for the unit regulatory program requirements (LA. ADMIN CODE. tit. 33, pt. III, § 2122 (2005) & 40 C.F.R. pt. 60 Subpart VV).

For purposes of this field test, a monitoring frequency of about 60 days was used for optical imaging and quarterly for Method 21. This is intended to simulate the monitoring frequencies proposed by EPA for the AWP and existing regulations requiring quarterly monitoring for the CWP.

Leaks found on any regulated FECs with optical imaging were repaired utilizing a 5/15 day repair methodology (e.g. 1st attempt within 5 days, final repair within 15 days). Delay of repair was allowed per the current regulatory program applicable to the IPA process unit. However, only leaks $\geq$10,000 parts per million (ppm) using Method 21 were repaired during the field test time period. This was done to allow data gathering to determine the change in leak rate with time. Leaks found on non-regulated equipment (i.e., heat exchanger heads, piping, etc.) were repaired within 30 days. Delay of repair

criteria was followed consistent with the current regulatory program applicable to the process unit. Difficult to repair and Unsafe to Repair criteria was the same as that set forth in the current regulatory program applicable to the process unit.

A leak repair was considered successful once the leak was no longer detectable using either optical imaging or by a concentration reading below the applicable regulatory leak definition. It is important to note that any leak found on non-regulated equipment was subject to release reporting and repair requirements.

Emission quantification for the CWP data was based on currently applicable EPA correlation curves for the units surveyed and the monitoring readings recorded (pre- and post-repair).[6] Emission estimation for optical imaging monitoring was based on the new leak/no-leak emission factors developed by API for use in optical imaging programs.[7]

Emissions from non-regulated equipment were not included for components not found to be leaking by optical imaging. Mass emissions rate for leaking non-regulated equipment was determined by using the "leak" emission factor for a similar type regulated component, i.e. personnel access - flange), engineering calculations or alternative measurement conducted post-discovery and consistent with release reporting determinations.

When calculating the emissions reduction potential on non-regulated equipment it was assumed that the equipment would have possibly leaked a full year (365 days) if not detected by optical imaging.

FIELD SURVEY PROCEDURE

To be consistent with the requirements in the AWP optical imaging, a passive infrared camera was used to detect leaking equipment. All camera operators were trained and certified by the Flir Infrared Training Center in the operation of the camera and recording and editing of video images. Camera operators would start the camera and allow it to reach operating temperature as required by the manufacturer. The first image recorded was of a known mass rate (6 g/hr) of propylene to demonstrate that an image was visible to the operator.

Unit surveys were conducted along a preplanned route, similar to the route utilized by the CWP technicians to reduce the possibility that equipment would be missed. At varying locations the camera operator would stop and survey the equipment in the unit by looking through the camera eyepiece and moving the camera up and down and left to right. Care was taken to allow camera and operator to adjust to variations in lighting so that a sharp image was achieved by focusing the lens and by frequently switching between automatic and manual and adjusting various camera settings to assure that observable leaks were not missed. This methodology was repeated frequently at stops through the unit to assure that the same equipment was viewed from numerous angles. Observations were always taken while standing still to prevent accidents and to assure that a leak was not missed.

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When a leak was detected with the camera a video image was recorded and identified with a unique video tag and an entry in the log sheet was made to document results. Both ExxonMobil and LDEQ personnel verified that the image was visible. When a tagged leak from the Method 21 survey was encountered, the camera was used to verify if an image could be observed. When a leak was visible by the camera a video recording was made with a unique video tag.

SURVEY RESULTS

Staffing

The traditional Method 21 monitoring survey effort required 4 monitoring technicians over a four day period (approx. 160 person-hours) to complete the entire IPA manufacturing unit. The optical imaging method required 2 camera operators over a two day period (approx. 40 man-hours). These survey times were based on three survey efforts and were consistent in the reduced manpower needs for the AWP. This result was expected by the study participants.

April 2007

In the initial monitoring survey conducted in April, a total of thirty five (35) leaks ($\geq$1000 ppm) were identified out of 3,542 FECs monitored using the CWP. The highest leak concentration was 113,494 ppm. The average leak concentration was 10,057 ppm. The lowest leak concentration was 1,050 ppm. All detailed results are presented in Table 1.

Monitoring using the AWP during the same survey identified a total of fifteen (15) leaks (visible image detected/recorded) out of 3,542 FECs surveyed. The highest leak concentration was 113,494 ppm. The average leak concentration was 18,071 ppm. The lowest leak concentration was 918 ppm. Four (4) leaks were found independently of the CWP method with the AWP.

Seven (7) of the smaller leaks identified by the CWP were selected to be monitored by the camera for comparison. None of these seven leaks could be visibly detected. The highest leak concentration of the sample population was 5,580 ppm. The average leak concentration was 3,694 ppm. The lowest leak concentration was 1,050 ppm.

June 2007

A total of five (5) leaks (visible image detected/recorded) were identified out of 3,542 FECs and process equipment surveyed. The highest leak concentration was 148,000 ppm. The average leak concentration was 68,400 ppm. The lowest leak concentration was 18,000 ppm. These five (5) leaks were found independently of the CWP method using the AWP. Interestingly, a leak not detected by AWP was noted by the monitoring personnel by odor upon entry into the unit area. The leak was subsequently found by the CWP with a concentration of 1,000 ppm.

ATTACHMENT 2

July 2007

In the July monitoring survey, a total of nineteen (19) leaks (≥1000 ppm) were identified out of 3,542 FECs monitored using the CWP. The highest leak concentration was 135,700 ppm. The average leak concentration was 10,699 ppm. The lowest leak concentration was 1,012 ppm. All detailed results are presented in Table 1.

August 2007

Monitoring using the AWP during the same survey identified a total of three (3) leaks (visible image detected/recorded) out of 3,542 FECs surveyed. Two (2) of the leaks detected by the AWP were unable to be measured by the CWP due to the large leak concentrations "pegging" the measurement device. As result the average leak concentration could not be calculated. The lowest leak concentration was 50,000 ppm. Three (3) leaks were found independently of the CWP method with the AWP.

October 2007

One (1) leak (visible image detected/recorded) was identified out of 3,542 FECs and process equipment surveyed using the AWP. The leak concentration was 210,000 ppm. This single (1) leak was found independently of the CWP method using the AWP. Two leaks greater than 10,000 ppm were repaired before the AWP was able to detect the leaks. Optical Imaging has been consistent with finding leaks greater than 10,000 ppm but since direct observation was available credit was not taken for the two leaks since they were not detected using the camera. The two leaks were calculated to contribute approximately 260 pounds of emissions on an annual basis.

A total of nine (9) leaks (≥1000 ppm) were identified out of 3,542 FECs monitored using the CWP. The highest leak concentration was 19,888 ppm. The average leak concentration was 5,817 ppm. The lowest leak concentration was 1,181 ppm.

Observations

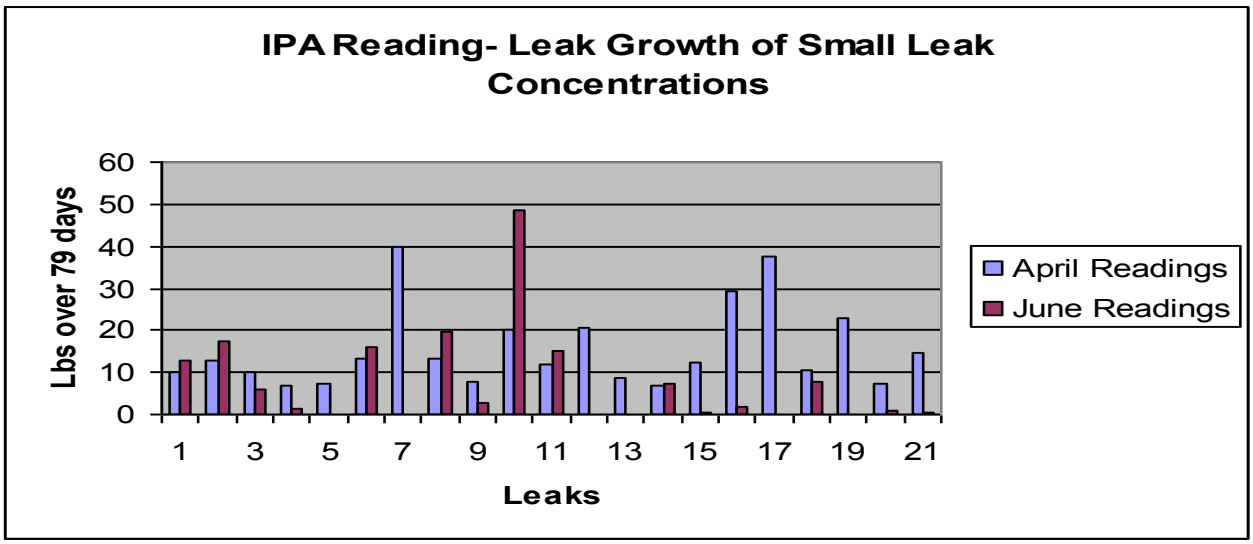
It is important to note that the average leak concentration dropped substantially from the Method 21 survey in April (10,057 ppm) compared to October (5,817 ppm). This is thought to be a direct correlation of detecting and repairing significant leakers sooner using the AWP. It was also observed that the number of leaks ≥1,000 ppm detected by both the AWP and CWP dropped in every subsequent survey. This was encouraging because this showed that leaks were being repaired and new leakers were not created between surveys.

ATTACHMENT 2

SUBSEQUENT MONITORING RESULTS FROM FIRST SURVEY

A common perception is that leaks if left unchecked will grow into larger leaks. One of the objectives of the field test was to address the concern of what happens to those smaller leaks that are not detected by optical imaging yet are above the regulatory leak threshold.

The initial monitoring survey allowed valves leaking <10,000 ppm to be temporarily exempted from repair during the test period. This was done to evaluate "the leak growth potential of small leak concentrations" over an extended period of time. Table 2 provides the subsequent monitoring data. During the 3 month period, April 3, 2007 to June 21, 2007, fourteen (14) out of twenty one (21) of the leaks decreased in concentration. The largest decrease was 9,521 ppm (9,531 ppm to 10 ppm). The smallest decrease was 587 ppm (1,816 ppm to 1,229 ppm). The average decrease in leakage was 2,611 ppm. An increase in leakage was found in only seven (7) out of twenty one (21) of the leaks. The largest increase was 8,086 ppm (4,114 ppm to 12,200 ppm). The smallest increase was 6 ppm (1,094 ppm to 1,100 ppm). The average increase in leakage was 1,827 ppm. These decreases and increases indicate that changes in smaller leaks tend to average out so there is no significant net increase in emission rate if left unrepaired.



Emissions from the valves with leak concentrations <10,000 ppm, that were not repaired during the 3 month period used the SOCMI correlation equation (for light liquid valves)[8] to convert Method 21 concentrations into mass flow rates. The initial readings gathered on April 3, 2007 demonstrated a total of 324 pounds emitted over a 3 month period if the leak concentrations had remained constant. However, utilizing the follow-up monitoring readings, a total of 159 pounds were calculated to be the actual emissions. This lower emission rate was the result of the decreased rate of some of the leakers. Extrapolating these emissions to an annual basis shows a maximum emission potential of less than one ton per year.

ATTACHMENT 2

Although conclusions based on a single monitoring data set are preliminary at best, it is still important to note that the assumption that leaks grow in concentration does not appear to be supported by the data in this study. Moreover, even assuming the higher leak concentrations remained constant, the corresponding emissions potential was still relatively small. This reinforces the conclusion that the majority of emissions comes from a very small set of large leaks, FECs (>10,000 ppm).

DEEPER LOOK

This observation concerning the leak growth potential of small leakers required the need to do an analysis of a larger population of leak data. Monitoring readings were collated for the Baton Rouge Refinery, Baton Rouge Chemical Plant and IPA Unit regulated fugitive emission components (FECs) for calendar years 2000-2006. Information such as component type, number of increase/decrease in leak concentration, number of consecutive increases/decreases in leak concentration, maximum/ average readings, total number of monitoring events per component and number of times a component reached the leak threshold was collected to help gain a better understanding of the leak growth potential of small leak concentrations.

The data was then analyzed to validate/confirm the observations of the smaller population. A series of six separate analyses were performed on the data. These included:

1. *Leak Distribution* – The goal was to determine the range where majority/minority of leaks falls, in terms of concentration (ppm).
2. *Probability of Increase/Decrease in Leak Concentration* – The goal was to evaluate the tendency for a leak to increase or decrease after initial monitoring event.
3. *Probability of Consecutive Increase/Decrease in Leak Concentration* – The goal was to explore the tendency for a leak to "grow" into a larger leak over a period of time would be indicative by period of consecutive growth.
4. *Number of Components That Reached Leak Threshold (≥ 1,000 ppm)* – The goal was to determine the likelihood that leaks will actually reach the leak definition threshold.
5. *Emissions for Equivalent Time Intervals (15 days)* – The goal was to compare emissions at different leak definitions over an equivalent time interval.
6. *Actual Annual Emissions at Various Leak Thresholds* – The goal was to evaluate the actual emission contribution at various leak thresholds.

Analysis #1: Leak Distribution

Leak distribution analysis was done on the IPA unit to serve as a validation of API study data previously published. The maximum readings for every component in the IPA unit were put into a scatter plot. When looking at the scatter plot it became obvious that only a small number of leaks grew into very significant leaks comparative to the number of leaks that were ≤ 1,000 ppm. In fact, out of 3,666 components less than 1% was greater

than 10,000 ppm, while, 94% of the components were below 1,000 ppm. This was consistent with previous API studies. Data from the analysis is presented in Figures 1, 2 and 3.

Figure 1

Leak Distribution		
Maximum Leak Concentration (ppm)	# of Components	% of Components
0 - 999	5330	94
1,000 - 9,999	292	5
≥10,000	44	1

Figure 2

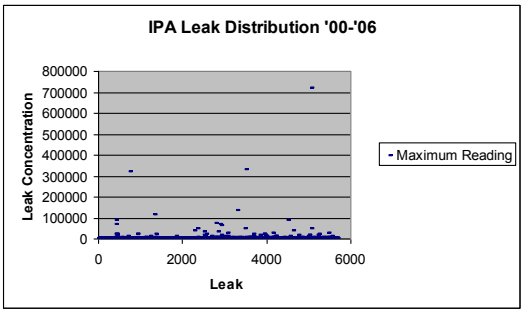
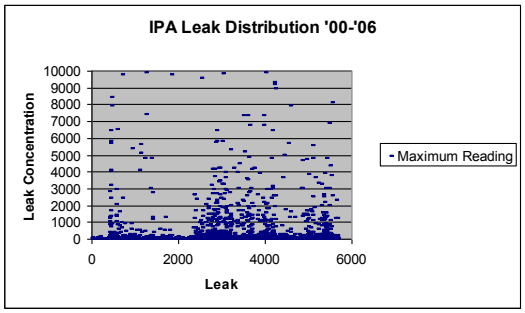


Figure 3



Analysis #2: Probability Leak will Increase/Decrease in Leak Concentration

Data was accumulated to give the total number of times the leak concentration increased, decreased or stayed the same after the initial monitoring event for every component. This was done for the IPA unit and as well as Baton Rouge Chemical Plant (BRCP) and Refinery (BRRF). Using simple statistics it was possible to use historical data to determine the probability of a leak increasing, decreasing or staying the same after an initial monitoring event.

The probability analysis indicated that leaking FECs were just as likely to decrease or stay the same rather than increase in leak concentration after an initial monitoring event. This observation was consistently observed in all three (3) datasets (IPA Unit, Chemical Plant and Refinery). All three (3) showed over a 55% trend of decreasing or staying the same after the initial monitoring event. Data from the analysis is presented in Figures 4 - 9.

Figure 4

IPA Unit				
	Increase	Decrease	Same	Total
# of Monitoring Events	20946	20597	6569	48112
Probability	44	43	14	100
	# of Components -	5666		

ATTACHMENT 2

Figure 5

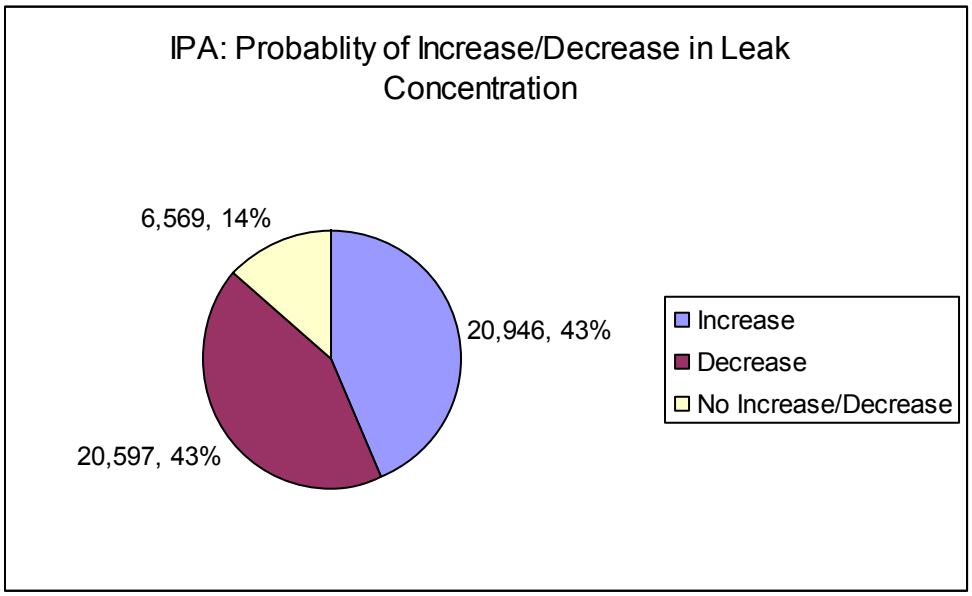
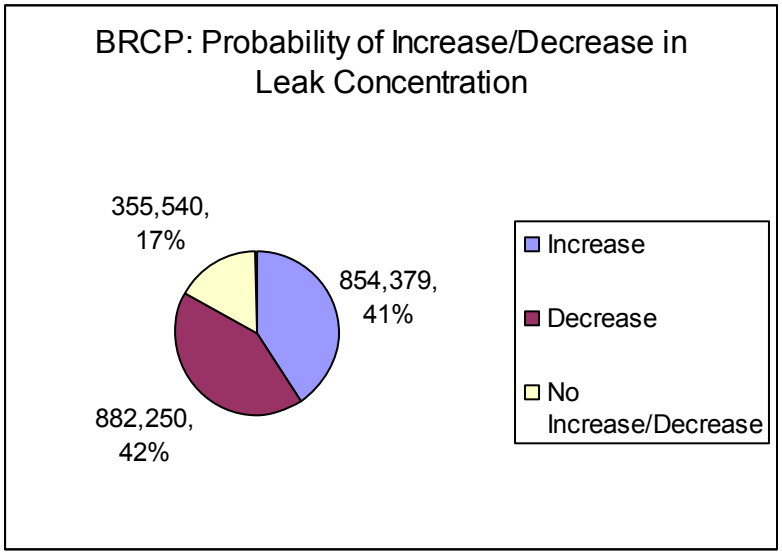


Figure 6

BRCP				
	Increase	Decrease	Same	Total
# of Monitoring Events	854,379	882,250	355,540	2,092,169
Probability	41	42	17	100
	# of Components -	176,543		

Figure 7

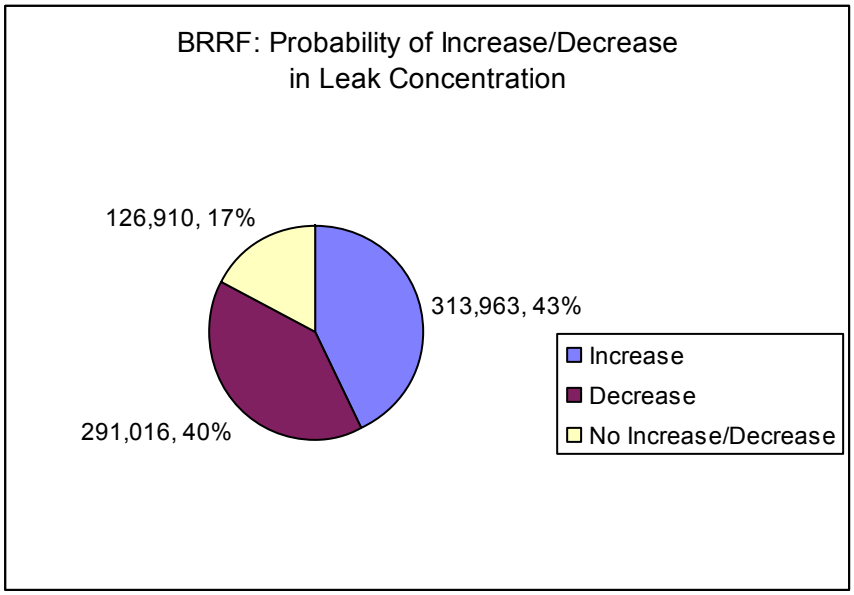


ATTACHMENT 2

Figure 8

BRRF				
	Increase	Decrease	Same	Total
# of Monitoring Events	313,963	291,016	126,910	731,889
Probability	43	40	17	100
	# of Components -	108,095		

Figure 9



Analysis #3: Probability of Consecutive Increase/Decrease in Leak Concentration

Data was accumulated to determine the total number of times that two (2) or more consecutive increases or decreases in leak concentration were detected or that no change in leak concentration was detected after an initial monitoring event. This frequency is important because consecutive increases/decreases are considered an indicator of leak trends. Leak concentration will fluctuate over time, however it is logical to assume that consecutive leak growth indicates a potential to grow into a leak greater than the leak definition or significant mass rates.

The data proved intriguing. Analysis indicated that leaks tend to remain at a lower leak concentration rather than "grow" into leaks greater than the regulatory leak threshold, consistent with probability observations. Data from the analysis is presented in Figures 10 - 15. The next step was to determine how many of those leaks that "grow" in concentration would grow to reach the leak definition threshold.

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Figure 10

IPA Unit				
	Increase	Decrease	Same	Total
# of Monitoring Events	20946	20597	6569	48112
Probability	44	43	14	100
	# of Components -	5666		

Figure 11

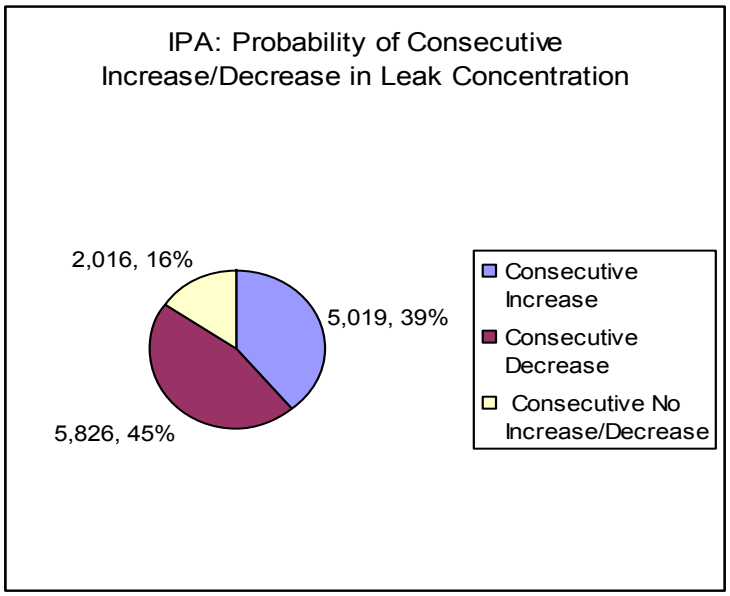

Figure 12

BRCP				
	Consec. Increase	Consec. Decrease	Consec. Same	Total
# of Monitoring Events	227,668	270,569	182,412	680,649
Probability(%)	33	40	27	100
	# of Components -	176,543		

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Figure 13

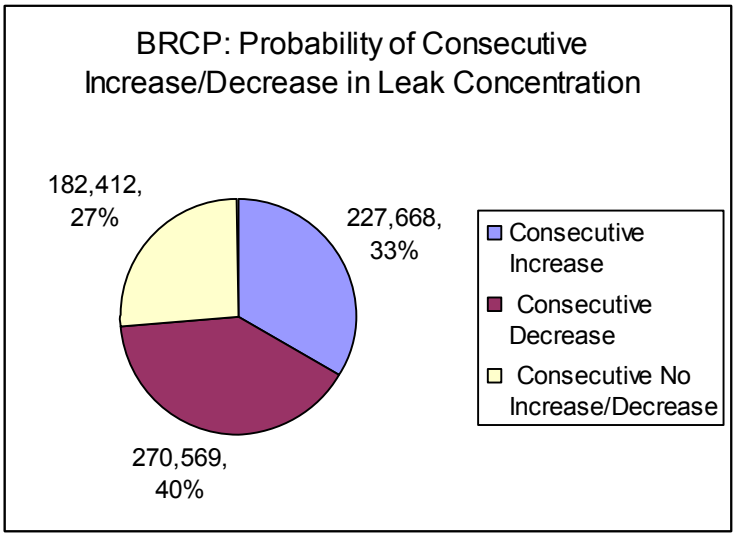
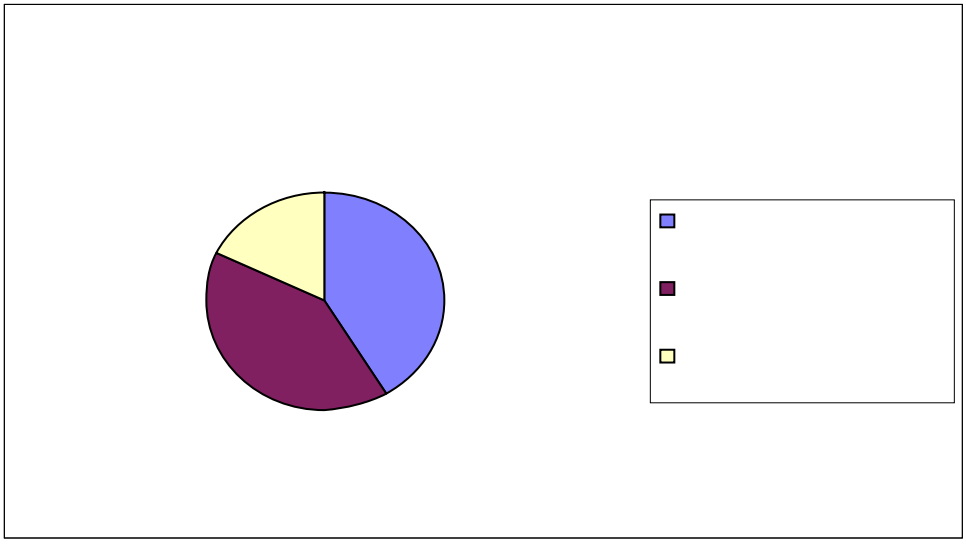


Figure 14

BRRF				
	Consec. Increase	Consec. Decrease	Consec. Same	Total
# of Monitoring Events	116,016	115,621	51,174	282,811
Probability(%)	41	41	18	100
	# of Components -	108,095		

Figure 15



Analysis #4: Number of Components that Reached Leak Threshold

The monitoring data was evaluated to determine the number of components that reached 1,000 ppm. The data showed only a small percentage of "growing" leakers actually reached the regulatory definition (4% - BRCP). The findings were not surprising since

this substantiated the results of prior API studies. Data from this analysis is presented in Figures 16 – 18.

The next question was to determine if these leakers would be a significant source of emissions. To answer this question it was decided to compare the amount of emissions that components at different leak thresholds would contribute on an equivalent time interval if they remained at their maximum reading.

Figure 16

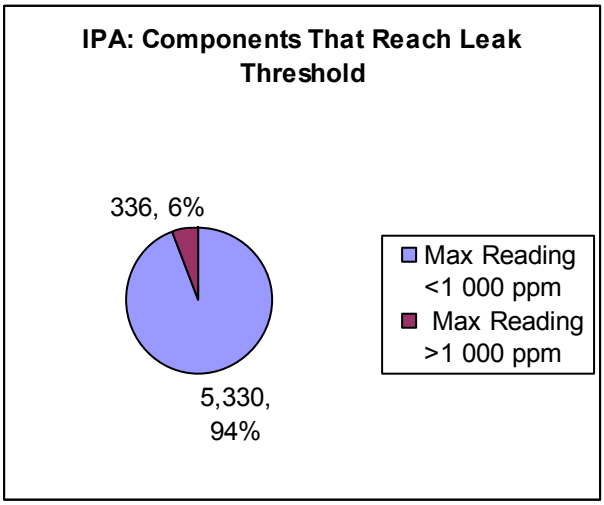


Figure 17

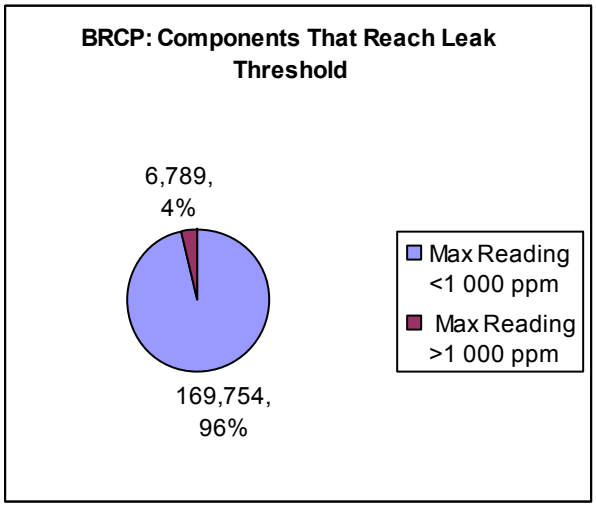
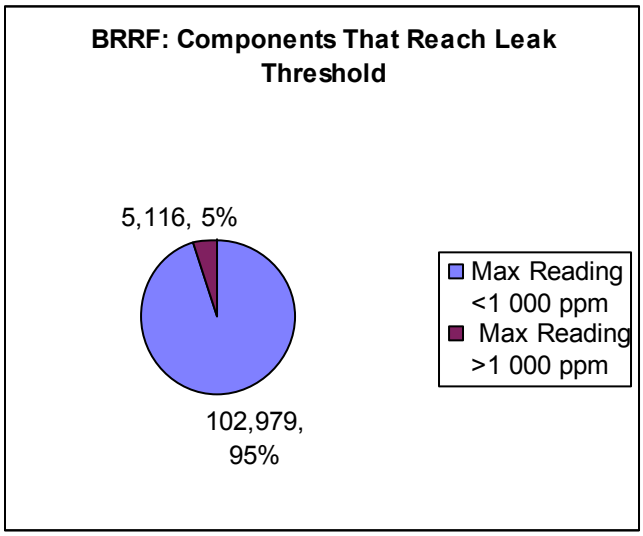


Figure 18



Analysis #5: Emissions for Equivalent Time Intervals (15 days)

Monitoring data was organized so that components with maximum readings (ppm) within a distinctive leak threshold were grouped together. The emission contribution from each

group of components was then calculated to cover a span of 15 days. This time interval was used to be consistent with regulatory repair deadlines.

The Synthetic Organic Chemical Manufacturing Industry (SOCMI) and the API correlation equations were used to convert Method 21 concentrations into mass leak rates for the IPA Unit, Baton Rouge Chemical Plant and Refinery, respectively.

The major observations were that approximately one percent of the FECs reached ≥10,000 ppm while approximately 95% of FECs were less than 1,000 ppm. The emissions from this one percent were equivalent or greater than the emissions from the other 95% of the FECs. This occurred because the mass rate (lbs/hr) of the FECs ≥10,000 ppm were on average 250 times greater than the FECs <1,000 ppm. Data from this analysis is presented in Figures 19 – 21.

These observations lead to the inquiry of the emission contribution from various leak thresholds using actual annual emissions and are discussed further in Analysis #6.

Figure 19

IPA Unit: Emissions On Equivalent Time Interval				
Maximum Leak Concentration (ppm)	# of Components	% of Components	Emissions (lbs/15 days)	% of Emissions
0 - 999	5,330	94.1	427	16
1,000 - 9,999	292	5.2	909	35
≥10,000	44	0.8	1,285	49
Total	**5,666**	**100**	**2,622**	**100**

Figure 20

BRCP Unit: Emissions on Equivalent Time Interval				
Maximum Leak Concentration (ppm)	# of Components	% of Components	Emissions (lbs/15 days)	% of Emissions
0 - 999	169,754	96.2	14,236	17
1,000 - 9,999	4,844	2.7	18,621	23
≥10,000	1,945	1.1	49,182	60
Total	**176,543**	**100**	**82,039**	**100**

Figure 21

BRRF Unit: Emissions on Equivalent Time Interval				
Maximum Leak Concentration (ppm)	# of Components	% of Components	Emissions (lbs/15 days)	% of Emissions
0 - 999	102,979	95.3	23,912	37
1,000 - 9,999	3,898	3.6	16,285	25
≥10,000	1,218	1.1	24,189	38
Total	**108,095**	**100**	**64,386**	**100**

Analysis #6: Actual Annual Emissions at Various Leak Thresholds

Actual annual emissions were collected for the calendar years 2004 – 2006. The components were grouped in distinctive leak threshold groups and the emissions from those distinctive groups were calculated. The emission contribution from each group was then calculated and averaged to compute an average annual emission.

Even though only a small percentage of components reached the regulatory definition, they still were found to contribute a significant amount of emissions on an annual basis.

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Components that reached 1,000 ppm contributed 35%, 45% and 31% of annual emissions for the IPA Unit, BRCP and BRRF, respectively. The small numbers of large leakers (≥10,000 ppm) were consistently found to contribute a significant amount of emissions compared to the overall component population**.**

Figure 22

IPA UNIT: Actual Annual Emissions at Various Leak Thresholds				
Maximum Leak Concentration (ppm)	# of Components	% of Components	Average Annual Emissions	% of Average Annual Emission
0 - 999	5,330	94.1	1,701	38
1,000 - 9,999	292	5.2	1,194	27
≥10,000	44	0.8	1,554	35
Total	**5,666**	**100**	**4,449**	**100**

Figure 23

BRCP: Actual Annual Emissions at Various Leak Thresholds				
Maximum Leak Concentration (ppm)	# of Components	% of Components	Average Annual Emissions	% of Average Annual Emission
0 - 999	169,754	96.2	58,025	37
1,000 - 9,999	4,844	2.7	28,545	18
≥10,000	1,945	1.1	70,790	45
Total	**176,543**	**100**	**157,360**	**100**

Figure 24

BRRF: Actual Annual Emissions at Various Leak Thresholds				
Maximum Leak Concentration (ppm)	# of Components	% of Components	Average Annual Emissions	% of Average Annual Emission
0 - 999	102,979	95.3	29,176	50
1,000 - 9,999	3,898	3.6	11,025	19
≥10,000	1,218	1.1	17,714	31
Total	**108,095**	**100**	**57,915**	**100**

Determination from a Deeper Look

Based upon the historical data gathered, components observed at low concentrations (ppm) were found to not generally "grow" into significant leakers over time. This analysis eases concern regarding what happens to the leaks that were not found leaking by Smart LDAR programs. Historical data also proves that the majority of the mass emissions come from a small number of components with high leak rates. All of these findings support using Smart LDAR as a viable alternative work practice.

COMPARISON OF EMISSIONS POTENTIALS AND REDUCTIONS

For the process areas monitored, annual emission estimates were calculated using the API, et al.-derived leak/no-leak emission factors for leaks detected using optical imaging, while EPA's correlation curves were used to calculate emissions from leaks detected by Method 21. An annual emissions estimate of 7,774 pounds per year was calculated based on leaks found by using optical imaging. Annual emissions of 9,099 pounds per year were calculated based on the leaks found by the CWP utilizing Method 21 leak detection technology. The small difference between the two estimates shows that the two methods are essentially equivalent in annual emission estimations, therefore, eases concern of reporting overly conservative emissions or "busting" permits.

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Optical imaging found thirteen (13) leaking components that were also found with Method 21, which would be repaired sooner under a Smart LDAR program, resulting in a potential emissions reduction of 2,131 pounds per year. The much smaller leaks that were not detected via optical imaging that would not be repaired resulted in emissions of only 28 pounds per year. Therefore, the emission credit realized from finding & repairing the leaks sooner by the AWP is magnitudes greater than the emissions resulting from FECs with leak concentrations below the detection threshold of the camera. The emissions from those smaller leaks offset the potential emission reductions due to leaks being repaired sooner resulting in a net reduction of 2,103 pounds. Optical imaging also found an additional six (6) non-regulated leaking components that would not have been found using Method 21, resulting in an additional reduction of 8,688 pounds per year. A total net reduction of 10,791 pounds per year would be achieved by switching to the AWP for fugitive emissions control.

CONCLUSION

This study has conclusively shown that using optical imaging in a Smart LDAR program for fugitive emissions control results in lower emissions compared with the current Method 21-based regulatory required procedures. Also, small concentration leaks were shown to not generally increase over time. This study demonstrated that finding the larger mass rate leakers sooner and repairing them more quickly offset the smaller mass rate leakers that would be not have been detected using the AWP. With regard to monitoring efficiency, fewer personnel will be required. Using the AWP, they will be able to monitor a facility in a fraction of the time that would have been required using the CWP. The combination of all these benefits demonstrates that optical imaging should be allowed to replace Method 21 for fugitive emission control.

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TABLE 1 Survey Results								
Month of Survey	**Work Practice Applied**	**Number of Operators**	**Person Hours Required**	**Leaks/Visible Images Detected**	**Total Components**	**Highest Leak Concentration (ppm)**	**Lowest Leak Concentration (ppm)**	**Average Leak Concentration (ppm)**
April	Smart LDAR Method 21	2 4	40 160	15 35	3,542 3,542	113,494 113,494	918 1,050	18,071 10,057
June	Smart LDAR Method 21	2 NA	40 NA	5 NA	3,542 NA	148,000 NA	18,000 NA	68,400 NA
July	Smart LDAR Method 21	NA 4	NA 160	NA 19	NA 3,542	NA 135,700	NA 1,012	NA 10,699
August	Smart LDAR Method 21	2 NA	40 NA	3 NA	3,542 NA	>100,000 NA	50,000 NA	NA NA
October	Smart LDAR Method 21	2 4	40 160	1 9	3,542 3,542	210,000 19,888	210,000 1,181	210,000 5,817

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TABLE 2
IPA READING-LEAK GROWTH OF SMALL LEAK CONCENTRATIONS

Tag Number	Initial Survey	Post (3 mo.) Survey	Last Reading				New Reading				Delta			
	(ppm)	(ppm)	(kg/hr)	(lbs/hr)	(lbs/79 days)	(lbs/yr)	(kg/hr)	(lbs/hr)	(lbs/79 days)	(lbs/yr)	(kg/hr)	(lbs/hr)	(lbs/79 days)	(lbs/yr)
W1G021	1691	2270	0.002	0.005	10	46	0.003	0.007	13	59	(0.00)	(0.00)	(3)	(12)
W1G024	2270	3345	0.003	0.007	13	59	0.004	0.009	17	80	(0.00)	(0.00)	(5)	(21)
W1G051	1739	868	0.002	0.005	10	47	0.001	0.003	6	27	0.00	0.00	4	20
WGG124	1050	129	0.002	0.004	7	32	0.000	0.001	1	6	0.00	0.00	6	26
WGG428	1145	10	0.002	0.004	7	34	0.000	0.000	0	1	0.00	0.00	7	33
139602	2365	3000	0.003	0.007	13	60	0.004	0.008	16	73	(0.00)	(0.00)	(3)	(13)
139780	9531	10	0.010	0.021	40	184	0.000	0.000	0	1	0.01	0.02	40	183
139966	2363	4000	0.003	0.007	13	60	0.005	0.010	20	92	(0.00)	(0.00)	(7)	(32)
340066	1216	367	0.002	0.004	8	36	0.001	0.002	3	14	0.00	0.00	5	22
424345	4114	12200	0.005	0.011	20	94	0.012	0.026	48	224	(0.01)	(0.01)	(28)	(130)
424347	2101	2875	0.003	0.006	12	55	0.004	0.008	15	71	(0.00)	(0.00)	(3)	(16)
206276	4183	10	0.005	0.011	21	95	0.000	0.000	0	1	0.00	0.01	20	95
383655	1400	10	0.002	0.005	9	40	0.000	0.000	0	1	0.00	0.00	8	39
WGE003	1094	1100	0.002	0.004	7	33	0.002	0.004	7	33	(0.00)	(0.00)	(0)	(0)
WGE079	2158	22	0.003	0.006	12	56	0.000	0.000	0	1	0.00	0.01	12	55
WGE159	6451	179	0.007	0.015	29	135	0.000	0.001	2	8	0.01	0.01	27	127
WGE480	8927	10	0.009	0.020	38	174	0.000	0.000	0	1	0.01	0.02	38	174
430312	1816	1229	0.003	0.006	11	49	0.002	0.004	8	36	0.00	0.00	3	13
430333	4750	10	0.005	0.012	23	105	0.000	0.000	0	1	0.01	0.01	23	105
430366	1153	99	0.002	0.004	7	34	0.000	0.001	1	5	0.00	0.00	6	29
430373	2756	19	0.004	0.008	15	68	0.000	0.000	0	1	0.00	0.01	15	67
Total	**64273**	**31762**	**0.078**	**0.171**	**324**	**1497**	**0.038**	**0.084**	**159**	**733**	**0.040**	**0.087**	**165**	**764**
													(48)	(223)

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REFERENCES

1. Smart LDAR, or Smart Leak Detection and Repair, is the efficient locating and repair of items of process equipment leaking fugitive emissions.
2. Method 21 – Determination of volatile organic compound leaks, 40 C.F.R. Pt. 60, App.A-7 (2006).
3. Analysis of Refinery Screening Data, American Petroleum Institute, Publication Number 310, November 1997.
4. Analysis of Refinery Screening Data, American Petroleum Institute, Publication Number 310, November 1997.
5. Alternative Work Practice to Detect Leaks From Equipment, 71 Fed. Reg. 17,401 (April 6, 2006) (to be codified at 40 C.F.R. pt. 60) (EPA-HQ-OAR-2003-0199).
6. *Protocol for Equipment Leak Emission Estimates*. Office of Air Quality and Standards. U.S Environmental Protection Agency. EPA-453/R-95-017 (November 1995).
7. Miriam Lev-On, et.al., *Derivation of New Emission Factors for Quantification of Mass Emissions when Using Optical Gas Imaging for Detecting Leaks*, Journal of Air and Waste Management Association (September 1, 2007) at 1061.
8. Leak rate/screening value correlations are used to estimate emissions from equipment leaks in the Synthetic Organic Chemical Manufacturing Industry (SOCMI). *See Protocol for Equipment Leak Emission Estimates, supra* note 5 at 2-28, 2-29.[8]

KEYWORDS

Alternative Work Practice, Current Work Practice, Leak Detection and Repair, Method 21, Optical Imaging, Smart LDAR

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JAWMA Manuscript – Draft4 (rev)

EQUIVALENT LEAK DEFINITIONS FOR 'SMART LDAR' (LEAK DETECTION AND REPAIR) WHEN USING OPTICAL IMAGING TECHNOLOGY

David Epperson
Consulting Statistician, Columbus, Indiana, USA

Miriam Lev-On
The LEVON Group, LLC, Thousand Oaks, California, USA

Hal Taback
Hal Taback Company, Carlsbad, California, USA

Jeffery Siegell
ExxonMobil Research and Engineering, Fairfax, Virginia, USA

Lee Gilmer
Shell Global Solutions (US) Inc., Houston, Texas, USA

Karin Ritter
American Petroleum Institute, Washington DC, USA

ABSTRACT

Controlling fugitive emissions from leaks in petrochemical industry process equipment now requires periodic monitoring of valves, flanges, pumps etc., typically on a quarterly basis. Previous studies have shown that over 90 percent of the reducible emissions come from approximately 0.1 percent of the components, i.e. the large leakers. A new, and more cost-effective approach for controlling these large leakers would entail more frequent monitoring of process equipment, allowing for the detection and repair of the highly leaking components that contribute the most to emissions. This approach has been called 'Smart LDAR'. New optical imaging instruments, which significantly reduce monitoring costs, are now available to implement such an alternative work practice. This work describes the determination of the leak detection sensitivity that an optical imaging instrument must achieve to ensure that it will provide at least the equivalent emission control of the current leak detection and repair practice. This leak detection sensitivity is referred to as the equivalency threshold. Equivalency

thresholds were developed for various monitoring intervals. The analysis demonstrates that optical imaging, which is capable of identifying all of the largest leakers, can provide better control of fugitive emissions.

IMPLICATIONS

Identifying and repairing the very large leakers in any process equipment has been shown to address over 90 percent of the controllable fugitive emissions from processing plants. Emerging optical imaging technology could be used for more efficient identification of these large leakers resulting in improved control of emissions. Detection sensitivity can be defined for optical imaging instruments that are equivalent to the control afforded by the current methodology. Employing an alternative work practice (with concurrent repairs of the identified leakers) more frequently than is the current practice enables better control of overall fugitive emissions.

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INTRODUCTION

Background

Since the early 1980s, the U.S. Environmental Protection Agency (EPA) has required the implementation of leak detection and repair (LDAR) programs for control of fugitive emissions (i.e., emissions from piping components such as valves, connectors, pumps, compressors, etc.). These LDAR programs have been adopted by many states. The passage of the Clean Air Act Amendments of 1990 resulted in adoption of LDAR provisions into Maximum Achievable Control Technology (MACT) rules. These programs have been found to be quite burdensome and, under the Common Sense Initiative (CSI) and the National Advisory Council for Environmental Policy and Technology (NACEPT), the U.S. EPA and industry have worked together to identify "cleaner, cheaper, and smarter" methods to attain the same, or better, environmental control of emissions from leaking process equipment.

The current work practice (CWP) for LDAR relies on U.S. EPA Reference Method 21 to identify leaking components. Method 21 involves placing a gas sampling instrument probe at the surface of each piping component seal and measuring the Volatile Organic Compound (VOC) concentration as the probe is moved along the surface of the seal. The instrument readings, referred to as screening values, are compared to levels established by the U.S. EPA and/or state and local air quality management agencies to determine if the component leaks. If the measured VOC concentration at a component is above the level defining a leak, the component must be repaired or replaced within a specified period of time and the repeated measurement of emissions following such maintenance should be below the leak concentration level. Rather than measuring the actual mass leak rate, the Method 21 procedure only measures ambient concentration levels in the vicinity adjacent to the component leak. These screening measurements have been related by a relatively poor correlation to the actual mass emissions rate.

Analyses by the American Petroleum Institute (API) have shown that over 90% of controllable fugitive emissions come from only about 0.13% of the piping components.[1,2] This study showed that major reductions in costs and emissions could be realized if a method can be devised that more economically locates the very high leaking components without having to monitor every individual piping component in the plant using Method 21. This concept was

called 'Smart LDAR'. Smart LDAR is a work practice framework for efficiently locating and repairing the relatively small number of large leaks.

Efforts have focused for the past several years on the development and demonstration of new innovative technologies for the rapid detection of leaking components. These technologies provide real-time imaging, allowing operators to locate components that are leaking above a threshold. Additional details on the Smart LDAR concept, potential monitoring technologies, plant demonstrations and laboratory test results are available in the references.[3,4]

U.S. regulations for control of fugitive emissions contain a provision that allows stakeholders to petition the U.S. EPA Administrator to recognize alternative controls (or work practices, in this case) that will provide equal or better environmental protection to the specific current requirements[5]. Since field demonstration of new fugitive emissions control technology or work practices is potentially quite costly, the U.S. EPA Steering Committee for Alternative Leak Detection Work Practices developed a protocol to demonstrate equivalent control effectiveness. This protocol allows a combination of laboratory testing, field testing, and mathematical analysis to quantify the performance of an alternative technology and to determine if it can achieve equivalent fugitive emissions control to that achieved using Method 21.

To facilitate demonstration of emissions control equivalence for new technology, the U.S. EPA developed Monte Carlo simulation software. This is used to evaluate technologies or work practices that may be alternatives for LDAR programs[6]. The software uses Statistical Analysis System (SAS) programming to perform Monte Carlo simulations (i.e., random statistical simulations) of simultaneous equipment screenings by the CWP that uses Method 21 and by an Alternative Work Practice (AWP) using a proposed control technology.

The Monte Carlo simulation software calculates emission reductions attainable for repairing components identified as leakers. It quantifies and compares the environmental benefit derived from using either the current work practice (CWP) or an alternate work practice. Equivalency of environmental benefit is demonstrated when the emission reduction attainable by an AWP is the same as, or larger than, the CWP emission reduction. Or in other words, AWP equivalency is demonstrated when the total plant fugitive emissions, over a period of time, are the same, or lower, than, the corresponding emissions using the CWP.

In this study we used the U.S. EPA Monte Carlo software tool to determine equivalency thresholds for optical imaging systems for monitoring. These simulations evaluated different

monitoring frequencies for AWP and compared them to CWP with leak definitions of 10,000, 1,000, and 500 ppm.

Study Objectives

The objective of this analysis was to evaluate the equivalency (required detection threshold) for approval of alternative work practices when using optical imaging technologies as alternative work practice for a variety of current control scenarios specified in either federal and/or state regulations.

METHODOLOGY

Description of U.S. EPA Monte Carlo Model

The approach used in the U.S. EPA Monte Carlo simulation software is to simulate mass emission rates for a set of process equipment, and then continue to simulate the side-by-side detection of the mass emission rates individually by both the current and the alternative work practices. This is followed by the calculation of the resulting emissions and emissions reductions for the entire set of process equipment for each work practice. A specific leak definition for the AWP can be assessed for CWP equivalency, or a series of AWP leak definitions can be simulated to determine the equivalency threshold; i.e., the largest AWP leak definition needed for CWP equivalency (note that values smaller than the equivalency threshold would provide better environmental benefit than the CWP). The Monte Carlo simulation approach entails four primary steps, as shown in Table 1.

Table 1. Steps in the Monte Carlo Simulation Process

Simulation Steps	Tasks performed
Step 1	▪ Simulate mass emission rates for a specified set of process equipment components (e.g., valves, connectors, pumps, etc.). ▪ For each equipment type in the set, specify the total number of components and the percentages of components that are non-emitters (NE's), non-pegged emitters (NPE's), and pegged emitters (PE's).
Step 2	▪ Simulate the detection of the mass emission rates simulated in MC Step 1 by the CWP and by the AWP. ▪ For the CWP using Method 21 screening, simulate the monitoring frequencies and leak definitions specified by the regulation being simulated for each equipment type. ▪ For the AWP, the specifications are dependent on the monitoring technologies being used and they would apply to all the component types that are being simulated.
Step 3	▪ Identify detected leakers for the CWP and for the AWP using the specified leak definition for each equipment type for each work practice.
Step 4	▪ Sum the mass emission rates for the CWP and for the AWP using the specified monitoring frequency for each, assuming that all detected leakers are repaired. ▪ Calculate the resulting total emissions and emission reductions.

When the Monte Carlo simulations show that the AWP emission reduction is the same or larger than the CWP emission reduction, the environmental benefit from the AWP is demonstrated to be equivalent to, or better than, the CWP.

Screening values are used as surrogates in Step 1 of the MC software to simulate the mass emission rates to be detected in Step 2 by the work practices being evaluated. Screening values obtained using Method 21 have a relatively narrow measurable range compared to the range of mass being emitted by the individual components due to limitations of the measuring equipment. This results in a large number of non-detects (also called "default zeros") and pegged readings, with only a relatively small percentage of components emitting in the measurable range. Therefore, Step 1 simulations must account for these groupings of screening data. The Petroleum (PETROL) industry bagging dataset[7,8,9], which consist of screening/bagging data pairs, are used in Step 1 to convert the screening values into mass emission rates, using the available bagging data. For the non-measurable data groups (i.e., non-detect and pegged readings), the empirical mass emission distributions in the PETROL bagging dataset are

randomly sampled for the corresponding group. For the measured screening values, the appropriate correlation equation with a random variability term, based on the PETROL screening/bagging data pairs, is used to generate mass emission rates. The simulated mass emission rates are then used in Step 2 and from there; Steps 3 and 4 follow based on the specific scenario being simulated.

When modeling the response of optical imaging technologies, mass emission rates are "detected" in the software by using a "Yes/No" leakers response; i.e., mass emission rates above a specified leak definition (in units of kg/hr) always result in a "Yes" response, and mass emission rates below the specified leak definition always result in a "No" response. In contrast, CWP Method 21 is modeled using the empirical PETROL bagging data,[7,8,9] with its inherent variability in quantifying emissions. Although CWP simulations always result in a "Yes" leakers response for detections above a specified leak definition (in units of ppm), the PETROL bagging data reveal that a given mass emission rate (kg/hr) does not always result in a CWP detection (i.e., ppm value) above or below the specified leak definition, due to the inherent variability of data collected using Method 21. Comparisons between simulation results for the AWP and the CWP are valid since there exists a mass emission rate level, above which detections will always result in a "Yes" leakers response for either work practice.

The Monte Carlo software is designed to accept user input for a number of parameters to tailor the simulations for a specific technology and/or regulation scenario for evaluation. These parameters are specified for several SAS macro variables and are described in the software documentation and its attachments[6] together with relevant details and specific parameter values for the macro variables used in the simulations for optical imaging technologies.

Assumptions for Simulating Leak Monitoring by Optical Imaging

We modified the EPA SAS software code for the assessment of optical imaging technologies and to accommodate different monitoring frequencies for the AWP and the CWP for a given set of simulated mass emission rates[6]. Following are the basic assumptions made for these modifications while maintaining the underlying basis for comparisons of work practices when using the Monte Carlo approach:

(1) Monitoring by optical imaging technologies has no associated variability above the detection threshold,

(2) Steady-state conditions apply,

(3) There are no repeat leakers within a given time interval,

(4) Repair of components occurs immediately upon detection of all leakers,

(5) The mass emission rate from each component is constant,

(6) One thousand (1000) Monte Carlo simulations are performed to minimize "sample size" error,

(7) Only leaking components are analyzed, since non-leakers provide no change in emissions,

(8) A common number of hours are defined for each monitoring frequency,

(9) The basis for assessing equivalency was changed from emission reduction to overall emissions over a specified time interval,

(10) Calculations were expanded to account for different monitoring periods and equivalency threshold, and

(11) All repairs are satisfactory reducing the emissions to non detect.

Initially we showed that the Monte Carlo simulation tool was effective for simulating and evaluating an AWP compared to the CWP for a single component types (e.g. valves, pumps, connectors, etc.). However, these single component simulations do not reflect the manner in which optical imaging technologies would be employed in the field. Additional changes were made to the software code to accommodate simulations where all component types are simultaneously monitored. This enables simulations that are compatible with how facilities would use the technology to meet their regulatory requirements. These changes primarily deal with expanding the SAS code to simulate up to six different equipment types simultaneously by expanding the single value macro variables that control various simulation settings to macro variable arrays containing six elements.

ANALYSIS OF DATASETS

Description of Screening Values Used

Two different facilities types were used in these simulations. Screening values reported from the Oil and Gas (OAG) production operations report[10] were used as surrogates in Step 1 of the MC software to simulate the base mass emission rate distribution representative of uncontrolled facilities. Screening values from the API Refinery Study (REF)[1] were used as surrogates in Step

1 for the distribution in controlled facilities. Comparing the control effectiveness of the AWP to the CWP using the OAG, or uncontrolled facility, as a starting point provides a direct measure of the emission results expected by each work practice.

Table 2 shows the equipment counts (in boldface) and percentages (in parentheses) for each screening value class (SVC), by equipment type for the OAG and REF screening data used in the MC simulation analyses. The emitters that are combined into the "ALL Pegged Emitters" (PE's) totals in Table 2 are the largest leakers that would contribute the most emissions.

Table 2. Counts (and Percentages) Of Components In Each Screening Value Class (SVC) For Screening Datasets Used In Monte Carlo Simulations As Surrogates To Simulate Mass Emission Rates

Screening Value Class	Screening Dataset	Equipment Type			
		Flange (Fitting)	Pump	Valve	TOTAL
Non-Emitters (NE)	OAG[1]	**38,977** (99.11%)	**202** (80.80%)	**35,925** (93.87%)	**75,104** (96.47%)
	REF[2,3]	**5,076,551** (99.81%)	**14,139** (95.80%)	**1,507,145** (99.01%)	**6,597,835** (99.62%)
Non-Pegged Emitters (NPE)	OAG[1]	**266** (0.68%)	**26** (10.40%)	**1,246** (3.26%)	**1,538** (1.98%)
	REF[2,3]	**9,080** (0.18%)	**601** (4.07%)	**14,173** (0.93%)	**23,854** (0.36%)
Pegged @ 10,000 ppm Emitters (P010k)	OAG[1]	**61** (0.16%)	**15** (6.00%)	**572** (1.49%)	**648** (0.83%)
	REF[2,3]	-	-	-	-
Pegged @ 100,000 ppm Emitters (P100k)	OAG[1]	**23** (0.06%)	**7** (2.80%)	**529** (1.38%)	**559** (0.72%)
	REF[2,3]	**548** (0.01%)	**19** (0.13%)	**891** (0.06%)	**1,458** (0.02%)
ALL Pegged Emitters (pegged at 10,000 and 100,000 ppm combined)	OAG[1]	**84** (0.21%)	**22** (8.80%)	**1,101** (2.88%)	**1,207** (1.55%)
	REF[2,3]	**548** (0.01%)	**19** (0.13%)	**891** (0.06%)	**1,458** (0.02%)
TOTAL	OAG[1]	**39,327** (100%)	**250** (100%)	**38,272** (100%)	**77,849** (100%)
	REF[2,3]	**5,086,179** (100%)	**14,759** (100%)	**1,522,209** (100%)	**6,623,147** (100%)

Notes

(1) American Petroleum Institute, 1995: *Emission Factors for Oil and Gas Production Operation,* API Publication Number 4615, Washington, D.C. 20005.

(2) American Petroleum Institute, 1997: *Analysis of Refinery Screening Data*, API Publication Number 310, Health and Environmental Affairs Department. Washington, D.C. 20005. Only Fittings, Pumps, and Valves are tallied in detail in the Appendix of this report. Totals shown are only for the 1993-Q2 1995 and Q1 1996 to match the emitter data period that was used in the Monte Carlo simulations. Nonemitter (NE) totals were calculated by subtracting the emitter total (NPE+ALL Pegged Emitters) from the total number of components,

because they were not available in the ACCESS Emitter database (see next note 3). Because part of the analyses performed for the API report was the examination of repeat leakers (for various leak definitions), there are multiple measurements for some components for some quarters, primarily for those components with measurable concentrations (e.g., > 100 ppm).

(3) Emitter counts are from the ACCESS Emitter database provided by Hal Taback Co., are only for screening values 100 ppm and greater, and are for distinct measurements per component per quarter (i.e., no multiple measurements were counted; the maximum measured value per quarter was used in the Monte Carlo simulations). Only data from 1993-Q2 1995 and Q1 1996 were used in the Monte Carlo simulations as this period was more stable and represents consistent controls.

Comparison of Screening Value Distributions

Figures 1 and 2 show the distribution of mass emissions and number of components contributing to those emissions for the OAG and REF screening datasets. Figure 1 shows that for the OAG dataset more than 80% of components emit less than 10^{-5} g/hr, while over 70% or 90% of facility emissions are attributable to the small number of components emitting either over 100 gr/hr or 10 gr/hr, respectively. Similarly, Figure 2 shows that for the REF dataset close to 90% of the components emit less than 10^{-5} gr/hr, while over 50% or 90% of the emissions are attributable to the small number of components emitting more than either 100 gr/hr or 10 gr/hr, respectively.

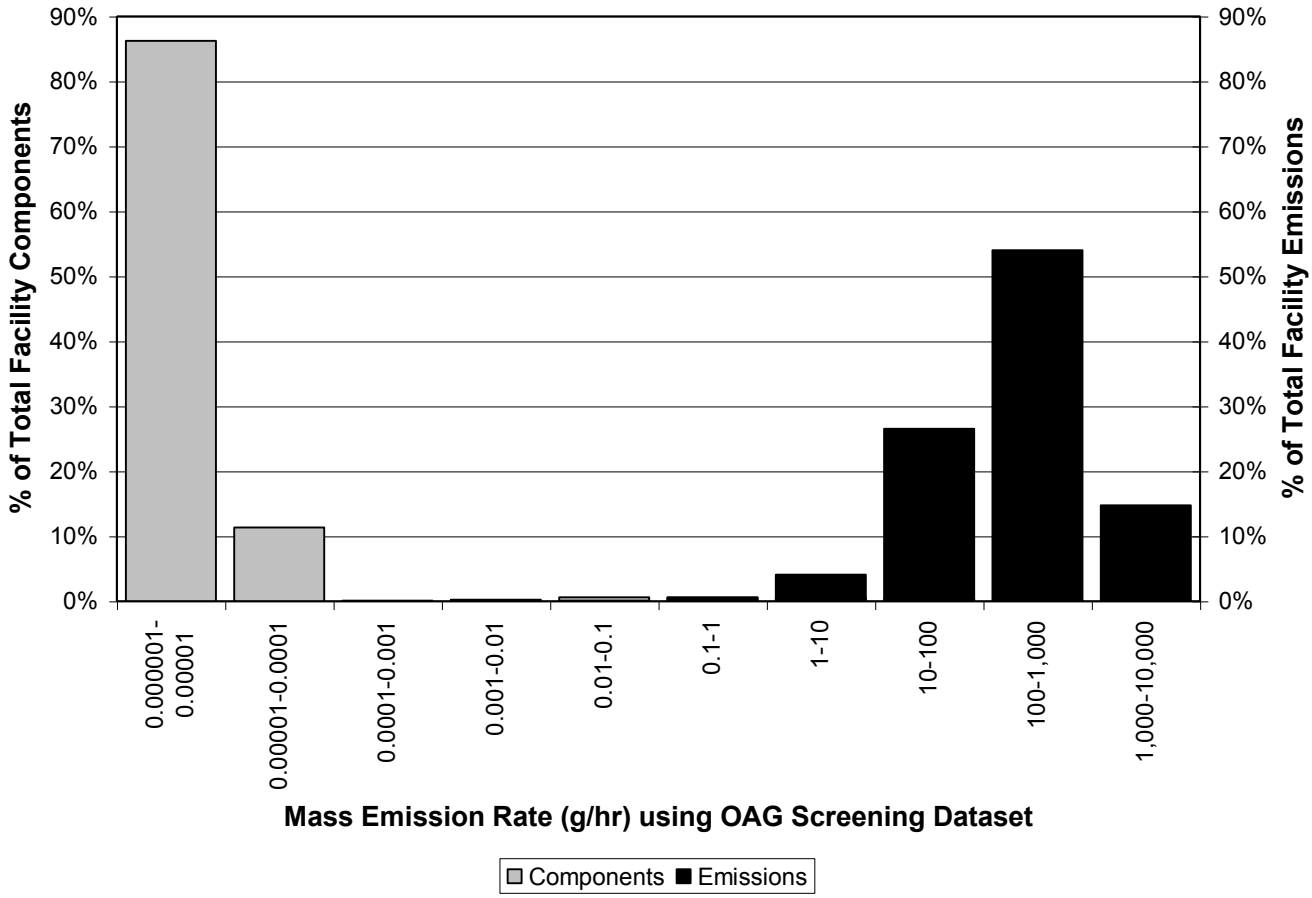

Figure 1. Component Counts and Emissions Distribution for the OAG Dataset

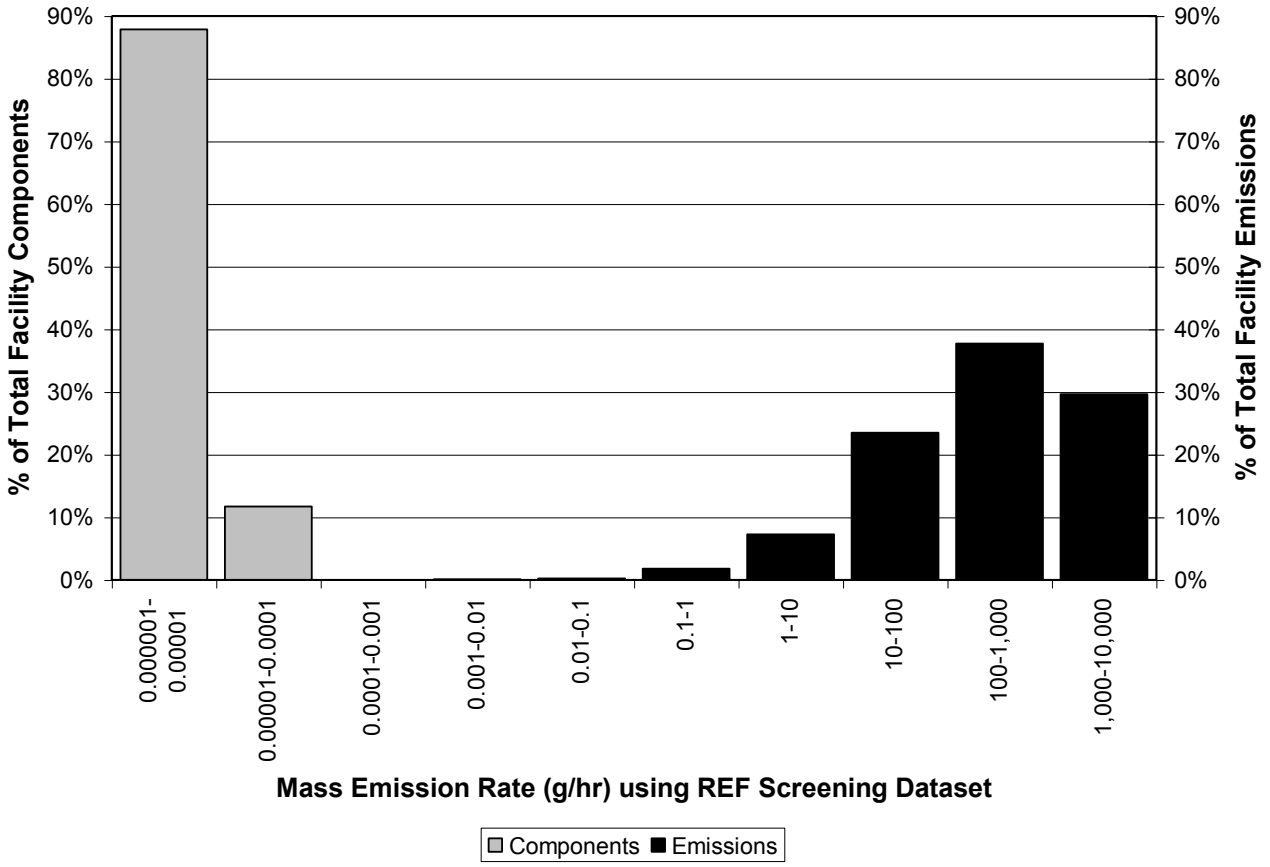

Figure 2. Component Counts and Emissions Distribution for the REF Dataset

ATTACHMENT 3

MONTE CARLO SIMULATIONS

Monte Carlo simulations were performed to determine the alternative work practice (AWP) equivalency thresholds for the simultaneous monitoring of different component types when using optical imaging to identify leaking components. In addition to performing the simulations for individual components we have also considered seven current work practice (CWP) regulatory scenarios. We have computed equivalency thresholds for three different monitoring intervals:

1) Bi-Monthly (BM) – every 60 days;
2) Semi-Quarterly (SQ) – every 45 days; and
3) Monthly (M) – every 30 days.

For all Monte Carlo simulations, the equipment types and counts were based on a model hypothetical refinery with an average crude throughput capacity of 250,000 Bbls/day, and a total of 201,000 components. These components are assumed to consist of: 150,000 flanges, 1,000 pumps, and 50,000 valves.

The mass emission rates equivalency thresholds were derived in this study under the following assumptions:

- AWP emission reduction $\geq$ CWP emission reduction,
- AWP emissions $\leq$ CWP emissions, over the same time period (i.e. quarter), and
- Emission reductions for both AWP and CWP assume identical time duration until the "leakers" are repaired.

Moreover, it is important to note two additional key factors that guided the computations:

- When different component types were on different CWP monitoring schedules, equivalency evaluations were performed on the basis of the components with the longest monitoring frequency (i.e., components monitored monthly would be evaluated on the quarterly basis to dovetail with monitoring frequencies for the other components).
- AWP equivalency thresholds were determined for using optical imaging technology on only one monitoring schedule in contrast to the CWP, in which different component types are monitored on different schedules and/or with different leak definitions.

Emissions Differences by Equipment Type

Only the measured screening values (i.e., non-zero and non-pegged emitters) from an input screening dataset are actually used in the MC simulations, and these are ‘sampled’ as appropriate. The overall mass emission rates are directly linked to the percent of components

specified within each of the Screening Value Classes (SVC), sometimes referred to as 'SVC percentage'. These simulated mass emission rates may vary considerably for the same input screening dataset when different SVC percentages are applied to a set of MC simulations.

One important check of the approach is to assess how the input screening distribution and the specified SVC percentages impact the calculation of total emissions from the hypothetical refinery studied. To make such an assessment, simulations were performed using two different sets of SVC percentages for the OAG input screening dataset. These two SVC percentages vary primarily in the percentage of large leakers (i.e., pegged emitters), which were specified as 0.05% for Set #1 and 2.24% for Set #2.

Figure 3 shows the average total emission rate for each component type simulated for the two SVC percentages specified. For both sets, the average total emission rates were greatest for valves, followed by pumps, and least for flanges, even though flanges accounted for nearly 75% of the total components in the hypothetical refinery studied. However, the average total emissions were quite different for the two different sets of SVC percentages. Figure 3 shows that considerably higher total emission rate (89,567 g/hr) is calculated for Set #2 in which more pegged emitters were specified (2.24%) for the hypothetical refinery. This is compared to a total emission rate of 4,450 g/hr when using Set #1 with only 0.05% pegged emitters.

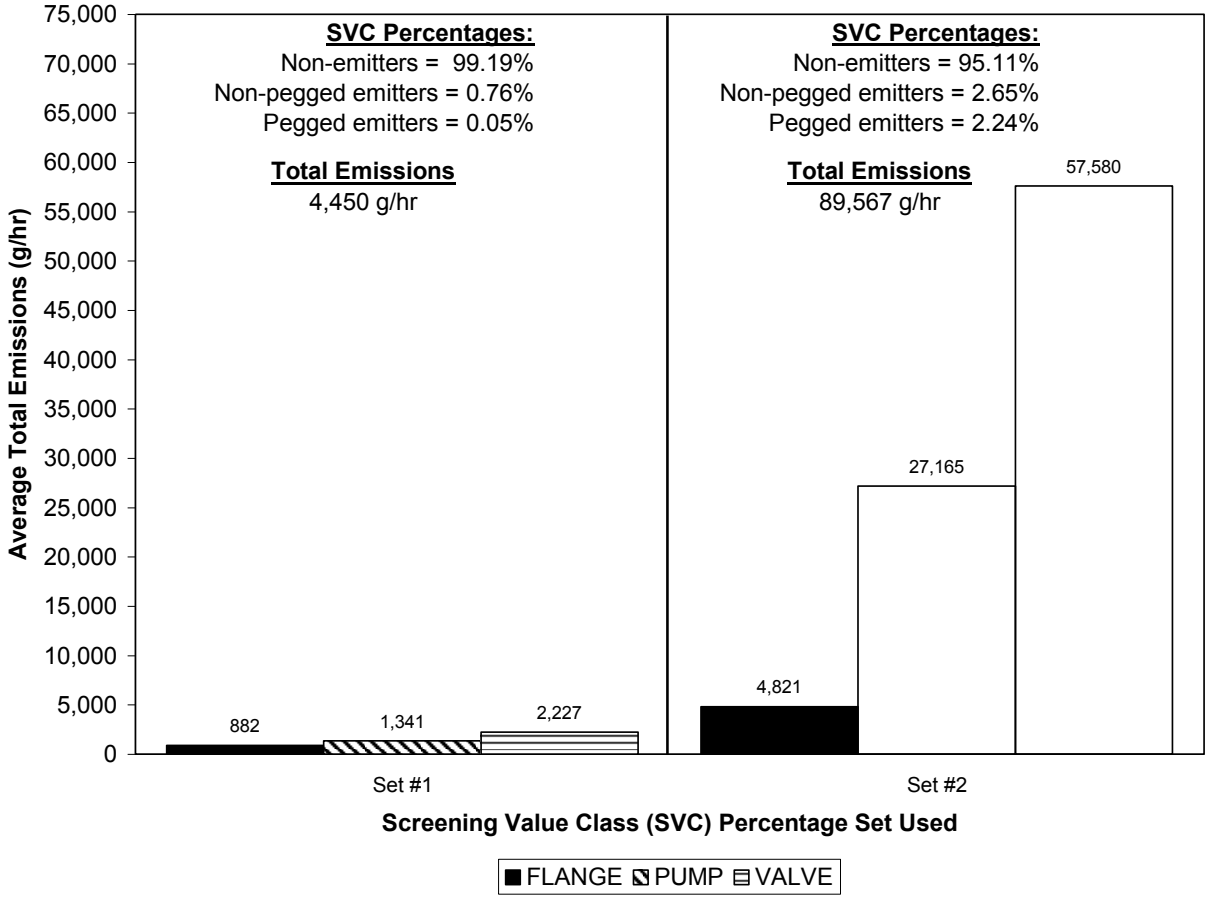

Figure 3. Comparison of total facility mass emissions, by equipment type, for the OAG screening dataset

In Figure 4 the average total emission rates are shown for each of the screening value classes used in Step 1 of the Monte Carlo simulations. Clearly, for both of the SVC percentage sets, the results provided in Figure 4 indicate that the greatest average total emission rates are attributable to the pegged, followed by the non-pegged emitters screening value classes. Emissions from the non-emitter class seem to be quite negligible though the non-emitters are by far the majority of the components (>99% of total components for Set #1 and >95% for Set #2). Here again the large difference in average total emission rates computed are directly attributable to the differences in percentage of pegged emitters specified; i.e. 2.24% vs. 0.05%, respectively.

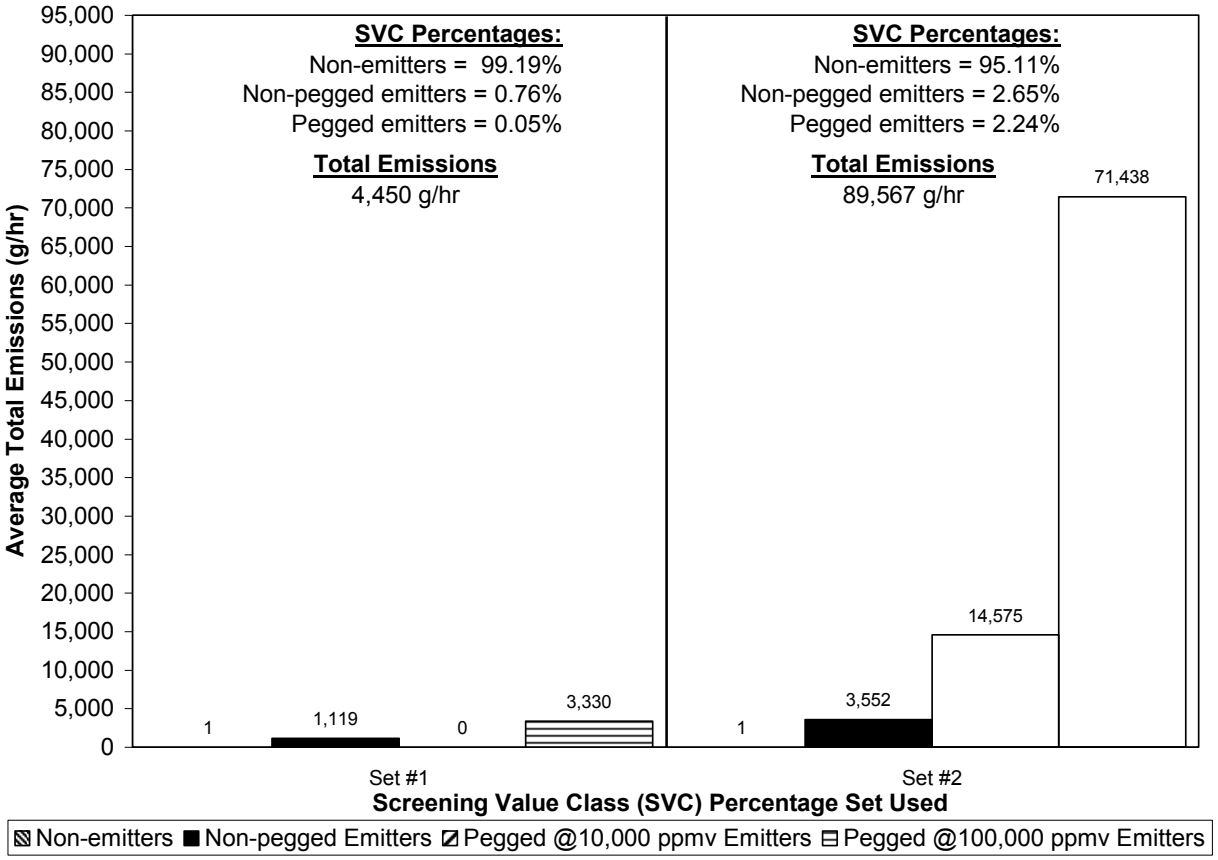

Figure 4. Contribution of Screening Value Classes to the total facility mass emissions for the OAG screening dataset

ATTACHMENT 3

Equivalency Thresholds for Individual Components

To demonstrate the equivalency of control effectiveness for the AWP as compared to the CWP we have performed Monte Carlo simulation for valves, pumps and connectors individually. For this stage of the analysis we have used the OAG screening dataset to represent screening value distributions that would typify an uncontrolled facility.

The results of the simulations are summarized in Table 3, for valves, pumps, and flanges, respectively. The results demonstrate that it is possible to find threshold emission rates that would need to be detected by optical imaging techniques, when they are used to identify leaking components as part of an AWP. These threshold emission rates for valves, pumps and flanges are applicable for an AWP with monitoring frequencies of 60, 45 or 30 days as compared to a CWP that is based on quarterly monitoring (every 90 days). For identifying individual process components, the average required detection threshold for an AWP with bi-monthly monitoring (i.e. every 60 days) to be equivalent to the CWP is over 90 g/hr.

As shown in Table 2, the OAG screening value class percentages consist of 96.47% non-emitters, 1.98% non-pegged emitters, and 1.55% of "pegged" emitters. The "pegged" emitters consist of components emitting both over 10,000 ppmv and over 100,000 ppmv, since the dilution probe, which allows the extension of the OVA range from 10,000ppmv to 100,000ppmv, was not always used when the screening data were collected in the field. In addition, due to the small number of pumps in the OAG dataset, the analyses were run both for the actual number of pumps in the OAG screening dataset, and for an expanded number (30,000 pumps). This "expanded number of pumps" was attained by repeat simulations until a number that is closer to the number of valves (approx. 38,000) was reached.

ATTACHMENT 3

Table 3. Results of Monte Carlo Simulations for Individual Process Components Using OAG Screening Data					
Component Type	CWP Monitoring Frequency	CWP Leak Definition (ppmv)	AWP Leak Definition (g/hr)		
			Bi-Monthly	Semi-Quarterly	Monthly
Valve	Quarterly	500	60	85	100
		1,000	61	85	110
		10,000	69	90	130
Pump	Quarterly	500	180	210	280
		1,000	180	220	280
		10,000	210	280	430
Connectors & Flanges	Quarterly	500	24	33	44
		1,000	24	33	44
		10,000	28	44	60

ATTACHMENT 3

Regulatory Scenarios Simulations

To investigate the effect of monitoring all components on a common schedule, the LDAR control scenarios shown in Table 4 were created. The simulations for the multi-component scenarios were carried out separately for each type of component first and then the total emissions and the emission reductions were summed up according to the scenario simulated. Threshold mass emission rates were computed to ensure that the AWP would attain the same, or better, emissions reduction as compared to the CWP.

The Monte Carlo simulations show that the simulations of different AWP leak definitions converged very quickly over a relatively narrow range of potential mass emission rate values (i.e., within a narrow band within one order-of-magnitude) to the reported AWP equivalency thresholds.

Table 4. Regulatory Scenarios Simulated

Scenario Designation	Primary Characteristics
A0: Typical MACT	▪ 1,000 ppm leak threshold; ▪ Valves are subject to quarterly monitoring and control; ▪ Pumps are subject to monthly monitoring and control; and ▪ Flanges are not controlled.
A1: Alternative MACT	▪ 1,000 ppm leak threshold; ▪ Valves are subject to quarterly monitoring and control; ▪ Pumps are subject to monthly monitoring and control; and ▪ "Extra credit" is available for the AWP for controlling flanges.
B: Non-Attainment SIP	▪ 500 ppm leak threshold; ▪ Valves, pumps, and flanges are monitored and controlled quarterly.
C: Modified MACT	▪ 1,000 ppm leak threshold; ▪ Valves and flanges are monitored and controlled quarterly; ▪ Pumps are monitored and controlled monthly.
D: Typical HON	▪ 500 ppm leak threshold for valves and flanges; ▪ Valves and flanges are monitored and controlled quarterly; ▪ 1,000 ppm leak threshold for pumps; and ▪ Pumps are monitored and controlled monthly.
E0: Basic NSPS	▪ 10,000 ppm leak threshold; ▪ Valves are subject to quarterly monitoring and control; ▪ Pumps are subject to monthly monitoring and control; and ▪ Flanges are not controlled.
E1: Alternative NSPS	▪ 10,000 ppm leak threshold; ▪ Valves are subject to quarterly monitoring and control; ▪ Pumps are subject to monthly monitoring and control; and ▪ "Extra credit" is available for the AWP for controlling flanges

RESULTS

Table 5 lists the AWP required minimum detection for the simultaneous identification and control of multiple components for different monitoring frequencies. It provides a side-by-side comparison of the computed sensitivity thresholds required for using alternative monitoring frequencies with optical imaging instruments. For comparison purpose, the results are presented for both screening value distributions, i.e. for uncontrolled (OAG) and controlled (REF) facilities. However, appropriate equivalency comparisons should only be made using the OAG database since the required comparison is between the effectiveness of both the AWP and CWP as applied to an uncontrolled facility. Use of the REF (controlled) database is provided for illustrative purposes only since the leak rate distributions are representative of a facility that has been highly controlled for a number of years. For a given current regulation scenario and an alternative monitoring frequency, the computed equivalency threshold will be higher for uncontrolled facilities than for the ones that are controlled, in most scenarios simulated. This is because the REF data set is reflective of an already controlled facility, whereas the OAG data comes from applicability of both the CWP and AWP at an uncontrolled facility.

For the current regulation scenarios corresponding to A1 and E1 the predicted equivalency threshold is higher for the controlled facilities (REF) than in the uncontrolled facilities due to the fact that in these scenarios the emission reduction for monitoring and controlling a large number of flanges (150,000) more than compensates for the fact that pumps will be monitored now on an harmonized basis. The emission reduction from controlling flanges, combined with the fact that the pumps are better controlled in the REF distribution results in higher threshold values for these two scenarios.

For simultaneous identification and control of multiple components, the average required detection threshold for an AWP with bi-monthly monitoring (i.e. every 60 days) is shown to be equivalent to the CWP at a detection threshold of about 40 g/hr. With semi-quarterly monitoring (i.e. every 45 days) it is about 80 g/hr. Since application of the optical imaging type of broad detection capability technology currently being demonstrated will facilitate identification of emissions from unregulated sources as a part of normal monitoring, the appropriate leak definition for this AWP would be higher than that calculated by the current analysis. Since the number of unregulated emission points and their rates is plant specific, credit could not be included in the current predicted thresholds. However, consideration of this additional

environmental benefit should be included when setting required detection thresholds for an AWP using optical imaging. In addition, greater emission reductions are expected based on field and laboratory testing that has shown detection limits for many chemical species to be in the 1 to 20 g/hr range and under proposed procedures, all those components would be considered for repair.

Table 5
Comparative Results for the Simulations of Multiple Components Monitoring by Optical Imaging Using The Two Screening Data Sets [1]

CWP Regulation Scenario [2]	AWP Leak Definition (g/hr) Applied To ALL Equipment Types					
	Bi-Monthly		Semi-Quarterly		Monthly	
	OAG [3]	REF [4]	OAG [3]	REF [4]	OAG [3]	REF [4]
A0: Typical MACT (no flanges)	25	7.7	69	38	100	89
A1: Typical MACT (with flanges)	37	74	85	100	120	170
B: Non-Attainment SIP	82	34	100	66	170	90
C: Modified MACT	25	9.5	67	31	95	61
D: Typical HON	25	8.2	67	28	95	60
E0: Basic NSPS (no flanges)	30	8.7	77	38	110	89
E1: Alternative NSPS (with flanges)	44	74	89	100	150	180

Notes
(1) Results shown were obtained from 1000 Monte Carlo simulations
(2) For all CWP Regulation Scenarios the refinery modeled contains: 50,000 valves, 1,000 pumps, and 150,000 flanges.
(3) OAG screening value data set represents less controlled facilities
(4) REF screening value data set represents more controlled facilities

Variability of Equivalency Threshold with Monitoring Frequency

As shown in Figures 5 and 6, the AWP equivalency thresholds show a similar trend with decreasing time intervals between subsequent leak screenings, for both datasets used (OAG and REF), though the numerical results are not equal. The AWP equivalency thresholds increase as the AWP monitoring frequency increases, and when all components are monitored by the CWP

with the same frequency the AWP equivalency threshold is more easily attainable (i.e., it is at a higher threshold level).

The curves depicting CWP regulation scenario B in Figures 5 and 6 are different from the scenarios without monitoring connectors because it is the only current regulatory scenario in which pumps are monitored at the same frequency as other component types (i.e., quarterly). In the other scenarios it is the monthly (i.e., more frequent) monitoring of pumps that is the forcing variable that results in lower equivalency thresholds for alternative monitoring frequencies. Simulating the ability to detect more, and lower, emitting valves (and possible flanges) is how the simulation accounts for the need to offset excess emissions that might occur due to the pumps being monitored less frequently (i.e. every 45 or 60 days).

The curves depicting CWP regulation scenarios A1 and E1 in Figures 5 and 6,fall closer to those derived for scenario B. They also have notably higher values throughout the range when compared to the curves for regulatory scenarios A0 and E0. This is due to the fact that scenarios A1 and E1 are based on the assumption that emission reduction credit could be obtained by using the alternative work practice due to the detection and control of leaking connectors, which could offset the emissions from pumps that are currently controlled more frequently. In scenarios A0 and E0 such potential emission reduction credit is not taken into account since it is assumed that flanges are neither monitored nor repaired in the respective alternative work practices.

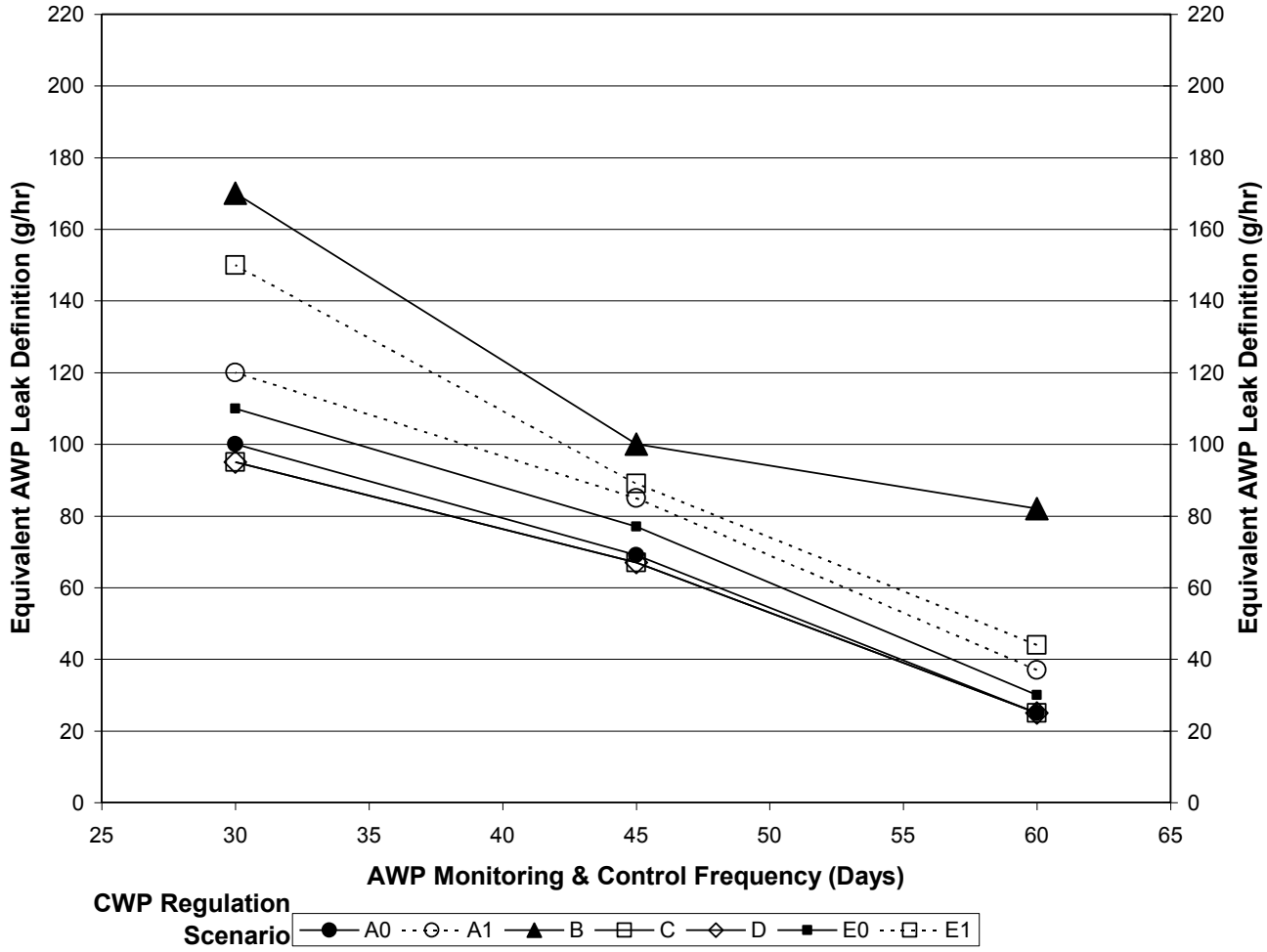

Figure 5. Variation of AWP Equivalency Thresholds, for a set of CWP control scenarios at a less controlled facility, as a function of leak monitoring frequency

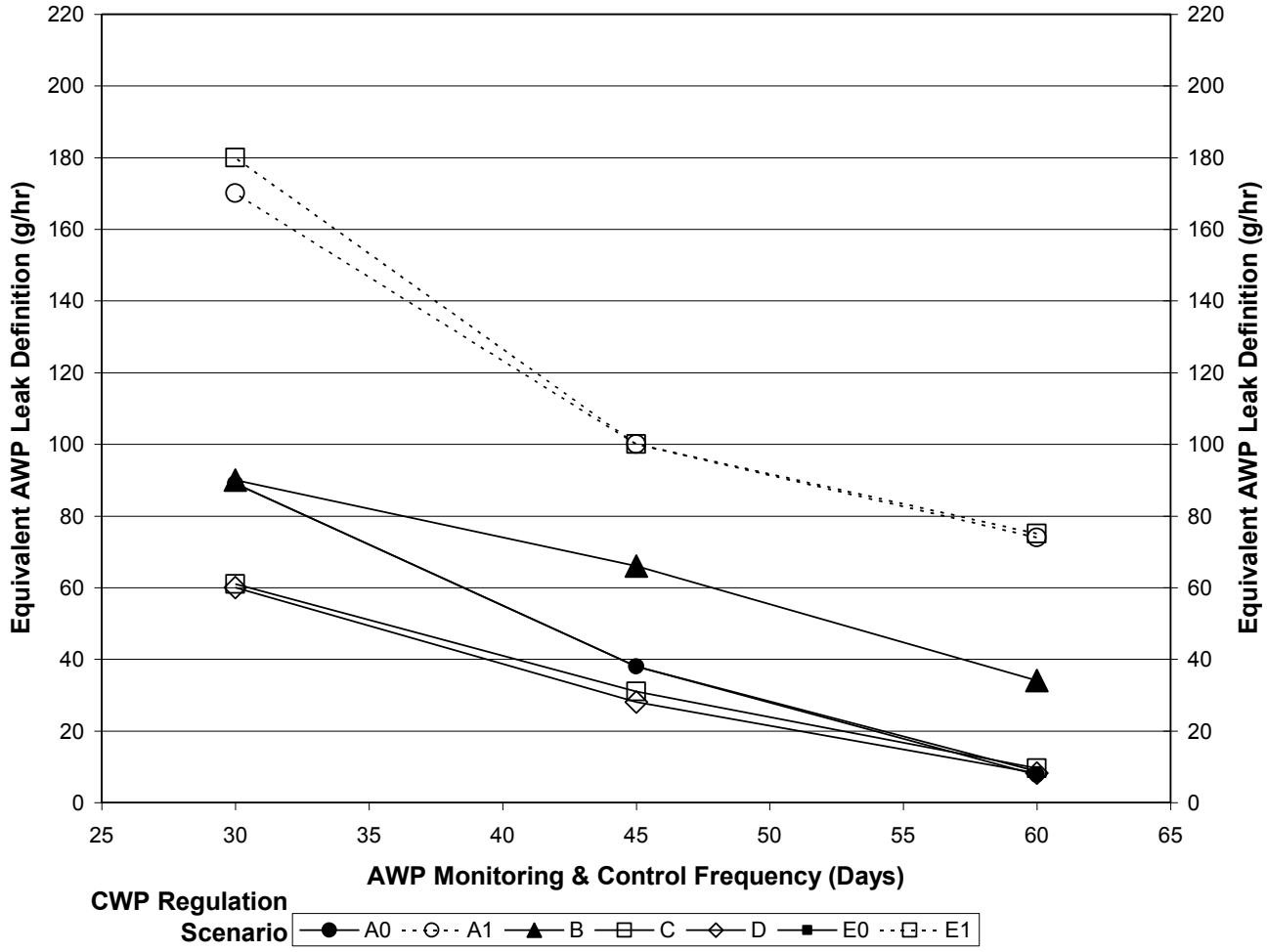

Figure 6. Variation of AWP Equivalency Thresholds, for a set of CWP control scenarios at a more controlled facility, as a function of leak monitoring frequency

Figures 5 and 6 show that the curves for current regulation scenarios C and D are very similar. In both scenarios C and D, valves and flanges are monitored on a quarterly basis, while pumps are monitored monthly. The only differences between scenarios C and D are the CWP leak definitions for valves and flanges (1,000 ppm for C and 500 ppm for D). The screening value distributions demonstrate that only a very small percentage of components are in the 500-1,000 ppm range in both screening datasets; only a few of these could possibly be detected as leaks by the CWP, and none of them would be detected by the AWP since their simulated mass emission rates are smaller than the equivalency thresholds.

CONCLUSIONS

This study demonstrates that using an AWP in which all components are monitored and large leaks are repaired on a common schedule can attain the same or better environmental control as the CWP using Method 21. Required leak detection thresholds for these AWP have been determined using a Monte Carlo simulation technique developed by the US EPA. Using an AWP that is based on optical imaging, plants can focus their efforts on identifying the very large leakers that account for the vast majority of emissions and thus control them more cost-effectively.

By simulating total component emissions it is possible to demonstrate that AWP leak detection thresholds can meet or exceed the control achieved under the current LDAR requirements. The AWP that uses simultaneous monitoring of different process component types assumes more frequent monitoring of these components with the exception of pumps. Longer leak times for pumps are more than off-set by the more frequent monitoring and earlier repair of other high leaking components.

For simultaneous identification and control of multiple components, the average required detection threshold for an AWP with bi-monthly monitoring (i.e. every 60 days) is shown to be equivalent to the CWP at about 40 g/hr. With semi-quarterly monitoring (i.e. every 45 days) it is about 80 g/hr. Since application of the optical imaging type of broad detection capability technology currently being demonstrated will facilitate detection of emissions from unregulated sources as a part of normal monitoring, the appropriate leak definition for this AWP would be higher than that calculated by the current analysis. Since the number of unregulated emission

points and their rates is plant specific, credit could not be included in the current predicted thresholds. However, consideration of this additional environmental benefit should be included when setting required detection thresholds for an AWP using optical imaging. In addition, greater emission reductions are expected based on field and laboratory testing that has shown detection limits for many chemical species to be in the 1 to 20 g/hr range and under proposed procedures, all those components would be considered for repair.

ACKNOWLEDGEMENTS

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REFERENCES

1. American Petroleum Institute, "Analysis of Refinery Screening Data", API Publication Number 310, Washington, D.C., 1997
2. Taback, H. J., Siegell, J. H. and Ritter, K. C., 1997: *Los Angeles Refinery Fugitive Emissions, Have They Changed After Six Years of LDAR?* AWMA/EPA Specialty Conference, The Emissions Inventory: Planning for the Future, Research Triangle Park, NC, October 1997
3. American Petroleum Institute, "Smart Leak Detection and Repair (LDAR) for Control of Fugitive Emissions", Washington DC, June 2004
4. Siegell, J.H., Taback, H.J., McRae, T. and Kulp, T.J., "Development of Smart LDAR for Fugitive Emissions Control," Valve World 2000, The Hague, Netherlands, Paper 0056, November 2000.
5. United States Environmental Protection Agency, Code of Federal regulations, "Standards of Performance for Equipment Leaks of VOC in Petroleum Refineries," New Source Performance Standard GGG, 1990.
6. U.S. EPA, "Monte Carlo Simulation Approach for Evaluating Alternative Work Practices for Equipment Leak"; Office of Air and Radiation, Office of Air Quality Planning and Standards, Final Report. Research Triangle Park, NC 27711, 1999.

7. American Petroleum Institute, " 1993 Study of Refinery Fugitive Emissions from Equipment Leaks, Volumes I, II, and III", API Publications Number 4612 and 4613, Washington, D.C., April 1994
8. American Petroleum Institute, "Development of Fugitive Emission Factors and Emission Profiles for Petroleum Marketing Terminals, Volumes I and II", API Publication Number 4588, Washington DC, May 1993
9. American Petroleum Institute, "Fugitive Hydrocarbon Emissions from Oil and Gas Production Operations", API Publication Number 4589, Washington D.C., October 1993
10. American Petroleum Institute, "Emission Factors for Oil and Gas Production Operations", API Publication Number 4615, Washington, D.C. 20005, 1995