

APPENDIX A

DOCUMENTATION OF GUIDELINES DEVELOPMENT

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CONTENTS

1. Summary of Agreements, Key Outstanding Issues, and Proposed Resolutions.
2. Fax Transmittal dated July 23, 1997 from Ray McCaffrey of Santa Barbara County APCD to Members of Correlation Equations Review Group, Re: SBCAPCD Comments on Radian's 6/18/97 Response to our 5/1/97 Draft Report [SBCAPCD report].
3. Letter dated June 18, 1997 from Ronald D. Ricks of Radian to Frank E. Holmes of Western States Petroleum Association.
4. Letter dated June 11, 1997 from Mark Boese of CAPCOA to Frank Holmes of Western States Petroleum Association, Re: Proposal for Using the Fugitive Emissions Correlation Equations Methodology.
5. Letter dated May 5, 1997 from Frank E. Holmes of Western States Petroleum Association to Mark Boese of CAPCOA.
6. Santa Barbara County APCD Draft Report, dated May 1, 1997, entitled: *Review Of The 1995 Protocol: The Correlation Equations Approach To Quantifying Fugitive Hydrocarbon Emissions At Petroleum Industry Facilities*, "SBCAPCD report".
7. Memorandum dated February 27, 1997 from David Epperson of Eastern Research Group to David Markwordt of U.S. EPA, Re: Draft Analysis of Alternative Mass Emission Calculation methods for the Blow-Through Bagging Method.

APPENDIX A - 1

Summary of Agreements, Key Outstanding Issues, and Proposed Resolutions

SUMMARY OF AGREEMENTS, KEY OUTSTANDING ISSUES, AND PROPOSED RESOLUTIONS

GENERAL AGREEMENTS

Implementation of the September 5, 1997 draft guidelines

It was agreed that for refineries and marketing terminals that no changes are necessary for the implementation of the September 5, 1997 draft guidelines. For oil/gas production, it was agreed that the September 5, 1997 draft guidelines are acceptable based on being modified to use the leak/no leak method on an interim basis and the resolution of outstanding issues discussed later in this document.

Leak/No Leak Method

A proposal was made to use the leak/no leak methodology to implement the draft guidelines on a limited basis. Industry and the districts generally agree with the methodology as outlined in the draft guidelines. However, some issues relating to component count and the averaging time of a leak remain.

Training/Certification Program

Industry and districts agree that an ARB training and certification program should be developed for conducting fugitive hydrocarbons inspections. Such a program would provide more consistency and accuracy in the collection of data that can be used for compliance and inventory purposes. The program should closely follow the field procedures used in developing the Environmental Protection Agency (EPA) correlation equations, screening value range factors, and average emissions factors. Also, suggested was that entities external to the ARB be allowed (as an option to ARB's training) to provide ARB approved training so that industry personnel can receive training on an expeditious and onsite basis. However, the ARB would administer any certification criteria and requirements. The ARB staff will establish an agency/district workgroup for those who have expressed an interest to assist in developing the training and certification program. The ARB's Compliance Division will be the lead in developing and administering the program.

Emission Factors Separated by Stream Types

There is general agreement that the oil/gas emission factors contained in the September 1997 draft guidelines should be separated by stream types. An effort has been conducted to address this objective and results were provided to the workgroup at the December 19, 1997 meeting. This item will be discussed at upcoming meetings.

OUTSTANDING ISSUES

Average Factors

ISSUE: The EPA average emission factors may not be representative of California emissions. The application of EPA emission factors to California facilities may under represent actual emissions. Some of the facilities surveyed by the EPA to develop their emission factors were controlled and should not be used to develop uncontrolled emission factors.

PROPOSED RESOLUTION: Develop California specific emission factors based on California data.

Inclusion of Data Measured with Dilution Probe

ISSUE: At issue is the inclusion of data measured with a dilution probe in the derivation of the correlation equations and the pegged emission factors. Evidence indicates that measurements made with a dilution probe can be inaccurate under certain conditions (refer to ARB laboratory test report). Therefore, the inclusion of data using a dilution probe may affect the representativeness of the correlation equations and pegged emission factors beyond 10,000 ppmv.

PROPOSED RESOLUTION: Although the ARB has determined, through laboratory experimentation, that the accuracy of dilution probe measurements is questionable, the effect of using dilution probe measurements in the derivation of EPA's correlation equations and pegged emission factors has not been determined. Therefore, districts should continue to use existing district emission estimation methods that use dilution probe measurements but consider the findings documented in the ARB laboratory test report in the implementation of those emission estimation methods.

Separation of Oil/Gas Pegged Components

ISSUE: At issue is the combining of data from oil/gas facilities, marketing terminals, and refineries to develop one set of pegged emission factors. Statistically, the amount of oil/gas data meets acceptable criteria for developing emission factors specific for this source. However, the EPA combined the oil/gas data with the data for marketing terminals and refineries since these two sources did not have sufficient data. EPA believes that the data from each source were not statistically different, therefore, combining the data allows the derivation of combined pegged emission factors. Opposed to that view is that the oil/gas data are consistently higher in emissions than marketing terminals and refineries, therefore, oil/gas should have its own emission factor. Industry does agree that if oil/gas is treated separately, marketing terminals and refineries should also be treated separately.

PROPOSED RESOLUTION: Determine the feasibility and appropriateness of developing individual pegged emission factors specific for oil/gas facilities (already done), marketing terminals, and refineries. Review EPA's data adequacy criteria for developing emission factors. Determine

the amount of data that would be needed to develop specific factors for marketing terminals and refineries. Conduct necessary field tests to generate additional data and validate the results.

Excluded Components

ISSUE: At issue is what components should be excluded when conducting an inspection and maintenance (I&M) program versus when developing an emission inventory? Originally in the September 1997 version of the draft guidelines, specific components were listed for exclusion in the component count. The basis for listing these components was that these components are excluded from inspection requirements contained in several districts' fugitive I&M rules. These components were generally thought to be a source of minor leaks (in the past) and were, therefore, excluded from the inspection requirements for reason of not being cost-effective. Upon reevaluating these components, the districts determined that these components should be included in the component count, for inventory purposes, since they do emit emissions. Additionally, these components were part of the data set used in developing EPA's emission factors and correlation equations.

PROPOSED RESOLUTION: Components that are generally excluded from I & M programs monitoring requirements should be reevaluated to determine their true emission potential. Components that have been determined not to leak or emit non-volatile organic compounds (VOC) should be excluded from the inventory. Components that are determined to leak VOCs should be included in the inventory. The use of existing emission factors or the development of new emission factors using existing data should be evaluated to determine the appropriate categorization of these components for the purpose of estimating emissions for inventory purposes.

Averaging Time of a Leak

ISSUE: At issue is the treatment of screening measurements to determine how long a leak has occurred. Although, the original draft guidelines did not address the averaging time of leaks, this issue was identified as a significant element in estimating emissions over time. Currently, there is disagreement on how to account for the duration of a leak and districts have independently developed procedures that vary.

PROPOSED RESOLUTION: EPA has developed guidance (Appendix A, Annualizing Emissions, pages A-23, 24, "Protocol for Equipment Leak Emission Estimates", 1995) in the treatment of leaks to determine emissions over time. This guidance in addition to existing district procedures should be evaluated to develop a uniform and consistent method for averaging emissions.

ARB RECOMMENDATION

A focused technical subcommittee should be formed including representatives from industry and districts to evaluate the appropriateness and feasibility of the proposed resolutions. Participants on the subcommittee should possess expertise in the area of quantifying fugitive hydrocarbon emissions. The subcommittee should evaluate the proposed resolutions on the basis of technical merit. The subcommittee should operate on a consensus basis and make recommendations on resolving the outstanding issues to the full fugitive emissions workgroup.

APPENDIX A - 2

Fax Transmittal dated July 23, 1997 from Ray McCaffrey of Santa Barbara County APCD to Members of Correlation Equations Review Group, Re: SBCAPCD Comments on Radian's 6/18/97 Response to our 5/1/97 Draft Report [SBCAPCD report].

TO: Distribution List (Correlation Equations Review Group)
 FR: Ray McCaffrey, SBCAPCD
 DT: July 23, 1997
 RE: SBCAPCD Comments on Radian's 6/18/97 Response to our 5/1/97 Draft Report

Attached please find our eight page response to Radian's comments on our Draft Report of 5/1/97. Our comments are faxed to one (bolded) individual at each company or agency. Please copy our comments to your co-workers on the distribution list.

The next teleconference call is set for **Thursday August 14, 1997** at the routine 10 am west coast/1 pm east coast time. The telephone number for the call is: 919-541-4332.

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**SBCAPCD Comments on Radian's Responses of June 18, 1997
to the May 1, 1997
Draft Final Review of the 1995 Protocol: The Correlation Equation Approach to
Quantifying
Fugitive Hydrocarbon Emissions at Petroleum Industry Facilities**

CORRECTIONS TO FUGITIVE DATA BASE USED TO DEVELOP PEGGED FACTORS AND EMISSION CORRELATION EQUATIONS

1. "Radian does not disagree with including a correction for the hydrocarbon leak contribution." (p. 2 para. 3).

Comment: None at this time.

2. Radian agrees that it would be preferable to have emission factors and emission correlation equations as precise as the current state of the art allows, but feels that it would be difficult to do now because the data is more than 4 years old. (p. 3 para. 1).

Comment: None at this time.

3. Radian recommends leaving two data points in the data set (V-2 and W-118) for the following reason:

. . . the calibration log indicates that the 5% oxygen standard was also reading 5.4% on the oxygen analyzer. Therefore, when in the field these two data points indicated on the analyzer that the final oxygen concentration was less than or equal to 5.4%, it was known that they were in reality less than or equal to 5.0%. (p. 3 para 2).

Comment: A review of the data set used by EPA in the 1995 Protocol to produce the correlation equations indicates that these subject data points with final oxygen concentrations of 5.2% and 5.4% were included without corrections in EPA's calculation of the correlation equations. The 5/1/97 Report removes these two data points.

4. Radian does not object to removing data points with final oxygen concentration of 5% or more. (p.3 para. 3).

Comment: The 5/1/97 Report is based on the removal of all such data points.

5. Radian does not object to removing the first bagging values for two components that were bagged twice. (p. 4 para. 1).

Comment: The 5/1/97 Report is based on the removal of all such data points.

VALIDITY OF DATA COLLECTION PROCESS AT REFINERIES (No Screening Values at Refineries)

6. Radian believes that not screening all of the components at a refinery does not affect the results of the default zeros factors, correlation equations, or pegged source factors. They also believe

that the factors and equations are not affected by using different parties to perform the screening (facility operator, monitoring contractor, or research company). (p. 5 para. 1).

Comment: We agree that default zero factors and correlation equations may not be affected. However, pegged factors are affected. Refinery processes vary greatly in pressure, temperature, and stream content. It is possible that the frequency and size of leaks also vary by process. Screening only a portion of the refinery may give biased results. Likewise, screening by parties not under the sanction of the research contractor adds another element of uncertainty. We suggest for future screening projects that a more uniform and stringent screening protocol be established and followed.

7. The majority of the components that were bagged as part of the Refinery Study were found by Radian and not identified by refinery operators. Refinery personnel "agreed to hold off on repairs until bagging took place." (p. 5 para. 2).

Comment: Text on page 2 of the 5/1/97 Report will be changed to: "At Refineries, some components to be bagged were pointed out to the bagging contractor by onsite operators".

8. Radian believes that 1993 Refinery Study results could be used during the development of screening range value factors. (p. 5 para. 5).

Comment: Text on page 2 of the 5/1/97 Report will be changed to: "However, this difference ~~does preclude~~ precluded EPA from using 1993 Refinery data in the calculation of screening range value factors for Refineries".

REPRESENTATIVE NATURE OF MARKETING TERMINAL DATA (Addition of Data Not Collected for the Protocol)

9. "It is unknown by Radian at this time if the screening data collected from the four marketing terminals [by Radian] for the Marketing Terminal Study were included in the data submitted to the U.S. EPA as a part of the data from the 17 marketing terminals." (p. 6 para. 3).

Comment: The subject Radian data do not appear to be included in the EPA 1995 Protocol data set. Table 1 shows the three highest screening values for pumps found by Radian at four marketing terminals included in API Report 4588 (note that all three are from the same site, Terminal D). Table 2 shows the six highest screening values for pumps in the data set compiled by API from 17 marketing terminals and submitted to EPA on April 26, 1994 (note that these six data points come from five different terminals). The data from the three pumps shown in Table 1 do not appear to be among the data for the six pumps included in Table 2. This suggests that the Radian marketing terminal data were not included in the EPA database used to calculate average and screening value range factors presented in the 1995 Protocol.

Table 1
Three Highest Pump Screening Values Found by
Radian at Four Marketing Terminals

Sample ID	Type	SV (ppmv)
D017	PUMP	6,868.0
D002	PUMP	8,945.5
D005	PUMP	10,995.0

Table 2
Six Highest Pumps Screening Values Contained in Data Base
from 17 Marketing Terminals Used by EPA to Calculated Screening Value
Range Factors and Average Factors for Marketing Terminals

Sample ID	Type	SV (ppmv)
09_NAP PUMP	PUMP	6,200
10_0107.00	PUMP	7,000
13_VT-VRU2-02-0	PUMP	9,000
11_136.00	PUMP	10,500
04_1428	PUMP	100,000
13_VT-VRU1-02-0	PUMP	100,000

10. Radian believes the SBCAPCD to be correct in stating that combined bagging data were used in the development of marketing terminal factors. (p. 6 para. 4).

Comment: None at this time.

11. Radian developed marketing terminal factors for API Publication 4588. EPA did not use these factors in the 1995 Protocol. (p. 6 para. 6).

Comment: Page 2 of the 5/1/97 Report will be changed to: "The original screening data at Marketing Terminals for 6,161 components were not used in creating screening value range factors or average factors shown in the 1995 EPA Protocol."

12. Appendix C of the EPA Protocol (page C-14) states, "The marketing terminal emission factors represent emissions from uncontrolled facilities." (p. 7 para. 2).

Comment: The Protocol statement appears to be incorrect. Table 3 shows typical data from the 17 marketing terminal data base EPA used in creating the 1995 Protocol. The repetition of tag numbers strongly suggests that regular monitoring was occurring at some of these marketing terminals. Text on page 2 of the 5/1/97 Report will be changed to: "Instead, additional screening data (for 76,387 components from several 17 API-member Marketing Terminals, with many of which appear to have had I&M programs in place) . . ."

REPRESENTATIVE NATURE OF MARKETING TERMINAL DATA (Differences in Screening Values at Production and Marketing Terminals vs. Refineries)

13. "The reason why the percentage of components leaking above 10,000 ppmv gathered as part of the Marketing Terminal Study differs from the data set used to develop the average factors as used in the U.S. EPA Protocols Document is unknown [to Radian] at this time." (p. 7 para. 6).

Comment: None at this time.

14. "It is unknown [to Radian] if results from the EPA study [on refinery emissions] are applicable to results from screening at marketing terminals." (p. 8 para. 1).

Comment: None at this time.

Table 3
Typical Data From EPA Marketing Terminal Data Base

Type	Stream	Tag	SV (ppmv)
PUMP	LL	03_00527	40
PUMP	LL	03_00527	540
PUMP	LL	03_00527	1100
PUMP	LL	03_00527	1400
PUMP	LL	03_00527	1600
PUMP	LL	03_00527	1600
PUMP	LL	03_00527	1900
PUMP	LL	03_00527	1900
PUMP	LL	03_00527	1900
PUMP	LL	03_00527	2700
PUMP	LL	10_0107.00	50
PUMP	LL	10_0107.00	7000
PUMP	LL	10_0450.00	100
PUMP	LL	10_0450.00	300
PUMP	LL	10_0506.00	10
PUMP	LL	10_0506.00	20
PUMP	LL	13_VT-METR-01-0	3
PUMP	LL	13_VT-METR-01-0	5
PUMP	LL	13_VT-METR-01-0	5
PUMP	LL	13_VT-METR-01-0	6
PUMP	LL	13_VT-METR-01-0	10
PUMP	LL	13_VT-METR-01-0	10
PUMP	LL	13_VT-P003-01-0	3
PUMP	LL	13_VT-P003-01-0	5
PUMP	LL	13_VT-P003-01-0	5
PUMP	LL	13_VT-P003-01-0	5
PUMP	LL	13_VT-P003-01-0	5
PUMP	LL	13_VT-P004-01-0	2
PUMP	LL	13_VT-P004-01-0	5
PUMP	LL	13_VT-P004-01-0	5
PUMP	LL	13_VT-P004-01-0	5
PUMP	LL	13_VT-P004-01-0	6
PUMP	LL	17_CT-P01A-01-0	5
PUMP	LL	17_CT-P01A-01-0	5
PUMP	LL	17_CT-P01A-01-0	5
PUMP	LL	17_CT-P01A-01-0	6
PUMP	LL	17_CT-P01A-01-0	6
PUMP	LL	17_CT-P01A-01-0	7
PUMP	LL	17_CT-P01B-01-0	2
PUMP	LL	17_CT-P01B-01-0	5
PUMP	LL	17_CT-P01B-01-0	5
PUMP	LL	17_CT-P01B-01-0	5
PUMP	LL	17_CT-P01B-01-0	6
PUMP	LL	17_CT-P01B-01-0	7

15. "[Radian does] not have sufficient information to determine if these data [from 17 marketing terminals] are representative or not." (p. 8 para. 2).

Comment: None at this time.

VALIDITY OF DATA COLLECTED WITH THE USE OF DILUTION PROBES

16. Radian prepared Attachment 1 to visually compare correlation equations calculated with and without data above 10,000 ppmv. From page 9 of Radian's June 18 comments: "Simply put, from this analysis there does not appear to be a statistical reason to remove dilution probe data from the data sets used to calculate emission correlation equations." (p. 8 para. 5).

Comment: The graphs cover seven orders of magnitude of emissions and are difficult to analyze. Please indicate the process used to create the equations, and include the actual equations with the graphs.

It should be recognized that these log-log graphs tend to minimize differences in equation lines, especially towards the upper end of the screening values. For example, inspection of the Attachment 1 graphs indicates that in five of six cases, the addition of data greater than 10,000 ppm (i.e., that represented by heavy black dots) causes the equations to predict lower emissions for most components with screening values of 200 ppm and above (i.e., the solid line is lower than the dashed line above 200 ppm).

17. Radian prepared Attachment 2 to compare the results of leaks found by bagging, predicted with the correlation equations, and predicted by the pegged source factors. (p. 9 para. 4).

Comment: The apparent agreement between bagged emissions and emissions predicted by the correlation equations for the 52 samples shown in Attachment 2 is to be expected as these data points were used to develop the correlation equations. The performance of a predictive relationship (in this case, the correlation equations) on the exact data set from which it was computed is likely to show good correlation because the relationship has been "tuned" to the data set to which it was fitted. Cross-validation would evaluate the performance of correlation equations more accurately.

It is improper to characterize the predictions of the pegged source factors as "overestimates" since that predictive relationship (pegged at 10,000 ppmv) was developed using 139 refinery and marketing terminal data points, but only the 52 components with lowest screening values have been included in the Attachment 2 table. The contribution of the 87 components with highest screening values that were also bagged samples has been completely ignored in the table.

18. "Radian does not contest that use of the dilution probe introduces error into the collection of screening data. In the case where all of the leak is drawn in by the dilution probe, the shortcomings of the dilution probe discussed in the SBCAPCD report are apparent. However, in cases where only a percentage of the leak is drawn into the dilution probe, the shortcomings highlighted by the SBCAPCD are diminished significantly." (p. 10 para. 2).

Comment: SBCAPCD agrees with Radian's statement and emphasizes that there is no way of knowing when the dilution probe draws in "all of the leak" or when it draws in "only a percentage of the leak". This, coupled with the fact that neither the percentage of leak drawn nor the "significantly diminished shortcoming" can be quantified leads to the conclusion that readings obtained with a dilution probe are misleading.

The question of whether the dilution probe data is accurate is the basic question; Radian's paragraph appears to say that the answer to this basic question doesn't really matter. SBCAPCD will reserve additional comments on the dilution probe until the CARB testing has been completed.

VALIDITY OF COMBINING DIFFERENT TYPES OF PROCESS STREAMS

19. "Although data were collected from various process streams, this is not an area of significant concerns." (p. 11 para. 5).

Comment: Our concerns remain about calculating a correct ROC/THC ratio for factors that were derived from a combination of various process streams. Much of the data used to prepare the pegged factors was from refineries with ROC/THC ratios approaching 1. In contrast, ROC/THC ratios in the range of 0.3 to 0.5 are common at production facilities. We see no simple way to determine an appropriate ROC/THC ratio for pegged factors for any type of facility if those factors are derived from data taken at a mix of facility types.

VALIDITY OF COMBINING PEGGED COMPONENT DATA FOR DIFFERENT FACILITY TYPES

20. Radian does not believe that Refinery data was affected by premature repair, advance notice, or the fact that some leaks were found by facility operators. (p. 12 para. 2).

Comment: Text on page 3 of the 5/1/97 Report will be changed to: "This may be due to the fact that all Refineries had I&M programs in place, whereas some Production facilities may not have; or to the possibilities that not all Refinery components with screening values over 10,000 ppmv were located and bagged; ~~reported for bagging (some high end leakers may have been repaired, and therefore not counted in the study); or that there was no third party interest in finding pegged components at Refineries;~~ or to the fact that advance notice was given to sources; or a combination of these and other considerations."

21. Two types of statistical analysis that were performed on the data did not show much statistical evidence for separating them by facility type. (p. 12 para. 6).

Comment: Detailed review of the cluster analysis (Attachment 3) is difficult because over 100 data points are listed as "hidden". However, it is obvious that for all component groupings, the highest clusters for production data extend significantly higher than the corresponding refinery or marketing terminal clusters. We find this to be strong evidence that the pegged data should remain separated by facility type.

The T-tests (Attachment 4) were based on incorrect procedures. The attachment presents the results of comparing the logarithms of the population rather than the results of comparing the actual populations. This obscures the actual variation between the groups of data. The arithmetic means of the lognormal distributions correspond to the average emissions rates that will be used in inventories. Hence, the arithmetic means of the distributions of the emissions should be analyzed, if an analysis is considered necessary.

The arithmetic mean of the distribution of production leak rates of all types of components combined is about 4.5 times as large as the corresponding arithmetic mean of refinery/marketing terminal leak rates. The magnitude of this difference is much more relevant than a somewhat artificial standard of statistically significant or insignificant differences. The 4.5 to 1 ratio makes a strong case for using separate pegged emission factors for production and refinery/marketing terminals. Table 4 below shows the EPA pegged at 10,000 ppmv factors with their upper and lower 95% confidence intervals as

published in the 1995 Protocol. The table compares these to 10,000 ppmv pegged factors that can be calculated for different facility types. More than half of the individual facility pegged factors are outside of the 95% confidence intervals of the EPA factors (shown in bold italics). This is statistically significant and merits separation by facility type. This agrees with graphic depictions of the fourfold difference between production pegged factors and refinery/marketing terminal pegged factors that were included in the materials for the teleconferences on January 10 and February 11, 1997.

Table 4
Comparison of Pegged at 10,000 ppmv Factors by Facility Type

	Connector	Flange	OEL	Valve	Other
Upper 95% Confidence Interval	2.55	13.30	2.70	4.57	10.53
EPA Factor	1.50	4.50	1.60	3.39	3.85
Lower 95% Confidence Interval	0.88	1.52	0.95	2.51	1.41
Light Crude Production	2.22	3.64	<i>0.52</i>	<i>1.74</i>	<i>0.08</i>
Gas Production	1.39	NA	<i>0.62</i>	<i>5.22</i>	0.73
Gas Processing Plant	2.40	1.91	<i>6.16</i>	<i>4.27</i>	<i>1.13</i>
Offshore	<i>0.60</i>	3.02	1.56	<i>8.17</i>	<i>0.21</i>
Refinery/Marketing Terminal	0.90	<i>0.34</i>	<i>0.41</i>	<i>0.67</i>	1.81

BLOWTHROUGH BAGGING METHODOLOGY CONCERNS

22. Radian believes that the blowthrough method is one of the better methods currently available for field measurements. (p. 12 para. 2).

Comment: None at this time.

23. A detailed analysis of the twelve nitrogen flow tests indicated that the nitrogen flow rate does not appear to have a systematic impact on emissions calculated using the blowthrough method. (p. 14 para. 4).

Comment: None at this time.

NEED FOR EXPANDED DATA SETS

24. "[Radian believes that] the need for this additional analysis at this point in time is questionable." (p. 14 para. 6).

Comment: SBCAPCD believes that additional data cannot be gathered and reviewed in time to be incorporated into the current project. The text on page 4 of the 5/1/97 Report and the attachment referring to expanding the data set will be removed.

CREATING AN IMPLEMENTATION GUIDELINES DOCUMENT

25. Radian recommends two additional references for the Implementation Guidelines Document. (p.15 para. 2).

Comment: Text on page 5 of the 5/1/97 Report will be changed to: "These two documents, and others, may be useful in creating the guidance document, which should address the following issues:"

CORRECT VERSION OF EQUATION FOR TOTAL FLOW INTO A BAG

26. Equation printed in SBCAPCD report contains a typographical error originally made by Radian and subsequently corrected. (p. 15 para. 3).

Comment: The correct equation was used for all calculations by SBCAPCD; the typographical error occurred during preparation of the report; it will be changed to the correct formula.

REVISED PEGGED COMPONENT EMISSION FACTORS FOR PUMPS

27. Radian created a pegged at 100,000 ppmv factor for pumps by increasing the pegged at 10,000 ppmv pump factor by the same ratio that the other five component factors increased when going from 10,000 ppmv to 100,000 ppmv (as an average). The factor is 0.19 kg/hr. SBCAPCD appears to have used the scale bias correction factor for all component types except pumps which appears to have been the numeric mean method. The scale bias correction factor approach lead to a lower emission factor. (p. 16 para. 1).

Comment: The corrected EPA data set contains three pumps with screening values reported to be pegged at 100,000 ppmv. They have the following leak rates: 0.041 kg/hr, 0.172 kg/hr; and 1.78 kg/hr. The pegged 100,000 ppmv factor calculated using the scale bias correction factor method is 0.61 kg/hr. Attachment 1 of the 5/1/97 Report will be changed to include this factor.

APPLICATION OF I&M PROGRAM REDUCTION EFFICIENCIES

28. "Radian agrees that average factors are the only factors or equations to which I&M production reduction efficiencies can be applied." (p. 17. para. 2).

Comment: As noted in the 1995 Protocol, it is preferred that facilities with I&M programs in place use the correlation equation method rather than average emission factors. Facilities that do not have I&M programs in place and use the average factors to calculate emission cannot expect to have any reduction credit. In addition, the 1995 EPA Protocol (page C-114) notes that there were "no significant differences between emission factors for those groups of sites with some form of inspection and maintenance program versus those sites with no such programs. Thus, the oil and gas production operation emission factors (shown in Tables 2-4 and 2-8) represent emissions from uncontrolled facilities." If average emission factors from facilities both with and without I&M programs in place are essentially the same, SBCAPCD sees no reason to assign additional emission reduction efficiencies for I&M program facilities using average factors. However, some air districts may wish to review requests for control efficiencies on a case-by-case basis.

APPENDIX A - 3

Letter dated June 18, 1997 from Ronald D. Ricks of Radian to Frank E. Holmes of Western States Petroleum Association.

June 18, 1997

Mr. Frank E. Holmes
Western States Petroleum Association
121 Gray Avenue, Suite 205
Santa Barbara, CA 93101

Dear Mr. Holmes:

This letter addresses the substantive issues raised by the Santa Barbara County Air Pollution Control District's (SBCAPCD) May 1, 1997 *Review of the 1995 Protocol: The Correlation Equation Approach To Quantifying Fugitive Hydrocarbon Emissions At Petroleum Industry Facilities*. These issues can be summarized as follows:

- ▶ Corrections to Fugitive Data Base Used to Develop Pegged Factors and Emission Correlation Equations;
- ▶ Validity of Data Collection Process at Refineries;
- ▶ Representative Nature of Marketing Terminal Data;
- ▶ Validity of Data Collected with the Use of Dilution Probes;
- ▶ Validity of Combining Different Types of Process Streams;
- ▶ Blowthrough Bagging Methodology Concerns;
- ▶ Need for Expanded Data Sets;
- ▶ Creating an Implementation Guidelines Document;
- ▶ Correct Version of Equation for Total Flow into a Bag;
- ▶ Revised Pegged Component Emission Factors for Pumps; and
- ▶ Application of I&M Program Reduction Efficiencies.

The above issues are presented basically in the order of when they are discussed in the SBCAPCD Report. The key conclusions from our review of these issues can be summarized as follows:

- ▶ There does not appear to be a compelling statistical reason to remove data collected with dilution probes from the data sets used to calculate emission correlation equations;
- ▶ There does not appear to be a compelling statistical reason to separate pegged components by facility type; and
- ▶ It seems appropriate to apply reduction factors to average emission factors for production facilities that have rigorous inspection and maintenance (I&M) programs.

Mr. Frank Holmes
June 18, 1997
Page 2

Corrections to Fugitive Data Base Used to Develop Pegged Factors and Emission Correlation Equations

SBCAPCD Concern:

“Our review of the Refinery and Marketing Terminal bagging data sets identified the need for both apparently minor corrections (e.g., two pegged components were double-counted; eight components had O₂ concentrations greater than the Protocol’s 5% criteria at the start or end of bagging; liquid leaks were not included in some calculations, some components were mistakenly omitted from the valid data sets in calculating factors or equations), and major corrections to the calculation method (hydrocarbon leak contributions to sample flow rate; courtesy Mike Garibay at SCAQMD). Triggered by concerns with the pegged source calculations such as those noted above, we reviewed correlation equations and other factors, as well as Production facility data sets, factors and equations. Questions concerning all facility types, and a hardcopy of the data summary spreadsheet (in abbreviated format) including the related corrections, are included in Attachment 1. As can be seen from that attachment, these corrections generally create relatively minor changes, on the order of a few percent to about 50 percent. However, as these factors and equations form the basis for quantifying fugitive emissions that air districts use in both planning and inventory billings, it is imperative that they be as precise as the current state of the art allows; changes due to corrections should not be considered as “just noise”. Further, although there may be some uncertainty in the data, the corrections make the data no more or less uncertain; the data are either valid, and the corrections should be incorporated into the calculations, or the data are invalid, and should not be used in creating factors and/or equations.” (Note: excludes footnotes.)

Radian Response:

As the SBCAPCD has acknowledged, these corrections generally create relatively minor changes. The most significant change is related to the hydrocarbon leak contribution to sample flow rate for pegged components. This change for refineries was understood, analyzed, and discussed in the *Study of Refinery Fugitive Emissions from Equipment Leaks*, April 1994 (API Publication Number 4612). The “uncertainty” discussed in the referenced page of this document (page 2-87) relates to the fact that the greatest impact of this correction was on the flange category where only three pegged components were bagged and one had a very large contribution of hydrocarbons relative to the total flow into the bag. This pegged component factor was more uncertain than the others because of the number of samples. The other component categories had more data points and this correction made far less of an impact.

Radian does not disagree with including a correction for the hydrocarbon leak contribution. That is why the methodology for this correction is included in API Publication 4612. However, it should be pointed out that this correction was not part of the United States Environmental Protection Agency’s (U.S. EPA) published calculation procedure for the blow-through method at the time either the Refinery Study or the Marketing Terminal Study was conducted. In fact, it is not yet part of the U.S. EPA’s published calculation procedure.

Mr. Frank Holmes
June 18, 1997
Page 3

Nearly all of the other corrections make a minimal difference to published emission factors and emission correlation equations. We agree that it would be preferable to have these factors and emission correlation equations as precise as the current state of the art allows. One problem with attempting to make revisions to earlier databases at this point in time is that not all of the information used to develop these databases is currently available. It should be realized that much of these data were collected and/or analyzed more than four years earlier. Furthermore, there are significant costs to attempt to reanalyze previous studies. Consideration for costs and the possibility of making unintentional errors due to an incomplete understanding of the data should be balanced against the amount of difference a reanalysis might make. Because nearly all of these other corrections make a minor impact on the published factors and emission correlation equations, the need for, or even the desirability of a detailed reanalysis is questionable.

For example, for at least two of the data points that the SBCAPCD removed from the data set (see Attachment 1 of the SBCAPCD report), V-2 and W-118, the rationale used to delete these data points is unintentionally incorrect. These two data points "were removed because of high final oxygen concentration in the bag (5.2%, 5.4%...)". These final oxygen concentrations were listed in the appendices for the refinery study (API Publication 4613). What SBCAPCD could not have known, but was known when the original analysis occurred, was that the calibration log for the oxygen analyzer on the days that these two data points were taken indicates that the oxygen analyzer was reading high. For sample V-2, the 5% oxygen calibration gas resulted in a reading of 5.4% for the oxygen analyzer. For sample W-118, the calibration log indicates that the 5% oxygen standard was also reading 5.4% on the oxygen analyzer. Therefore, when in the field these two data points indicated on the analyzer that the final oxygen concentration was less than, or equal to 5.4%, it was known that they were in reality less than or equal to 5.0%, and would meet the 5% criteria. For consistency, Radian recommends including these two data points in the analysis.

It should be noted that the U.S. EPA *Protocol for Equipment Leak Emission Estimates* (U.S. EPA Protocols Document), Nov. 1995, indicates that the procedure for the blowthrough method is to wait until the "oxygen concentration falls below 5 percent" before collecting a bag sample. It does not specify that both the initial and the final bag concentration remain below five percent. For the Marketing Terminal Study (API Publications 4588 and 45881), this direction was typically expanded to include only those bag samples where the initial and the average oxygen concentration were at or below 5%. Whether it is appropriate or not to delete data that met the U.S. EPA Protocols Document's criteria of having initial oxygen concentration below 5 percent and/or had an average oxygen concentration at or below 5%, as the SBCAPCD has done in a few cases, is debatable. However, for consistency with the Refinery Study data, Radian does not object to removing these data from analysis.

Mr. Frank Holmes
June 18, 1997
Page 4

Another subject of debate is whether the two data points (D007 and D054) should be removed. As indicated in API Publication 4588, p. 5-40, it appears that two components were intentionally bagged twice and intentionally included in the original Marketing Terminal Study's analysis of the data. The conditions for the second tests for these bags were different than in the original tests. One of the second tests was performed on a separate day from the original test. Unique data were included in these second tests. Again, for consistency with the Refinery Study, where this type of data use did not occur, Radian does not object to removing these data from analysis.

As previously indicated, some details surrounding most of the deleted data points are not available at this point in time. Certainly it would have been preferable to have raised these questions while the study was in progress. It should be pointed out that the SBCAPCD was invited to participate in the review of these studies while they were in progress. Representatives from the U.S. EPA, the California Air Resources Board (CARB), the Bay Area Air Quality Management District (BAAQMD), and the South Coast Air Quality Management District (SCAQMD) did participate in review of the study and data while it was in progress.

Validity of Data Collection Process at Refineries

SBCAPCD Concern:

"No Screening Values at Refineries: At Marketing Terminals and Production facilities, component screening was performed by third-party contractors according to an EPA-approved plan. At refineries, components to be bagged were pointed out to the bagging contractor by onsite operators. There is a valid reason for this procedural difference, specifically that the need for Refinery average factors was not anticipated at the time of the study. However, this difference does preclude 1993 Refinery data from being used in the calculation of screening range value factors for Refineries. Refinery factors presented in the Protocol are based on 1980 and 1982 fugitive emission studies." (Note: excludes footnote).

Radian Response:

No attempt was made for the Refinery Study to collect all of the screening data necessary to calculate average emission factors or screening value range factors. The decision to not obtain these screening data was primarily based on the perceived difficulty and costs of obtaining these data from refineries that do not have inspection and maintenance (I&M) programs. It would be preferable to use refinery data that were not influenced by I&M programs to develop uncontrolled average emission factors. Furthermore, because most refineries in the United States already have an I&M program and are routinely collecting individual screening values, it was believed that most refineries would prefer to use the emission correlation equations rather than the average emission factors.

Mr. Frank Holmes
June 18, 1997
Page 5

Not screening all of the components at a refinery during a bagging program does not in any way affect the results or the utility of the bagging data collected at these refineries. Each component to be bagged at the refineries was screened as part of the bagging protocol. The relationship between these screening values and the mass determined from bagging is the basis for the development of emission correlation equations, default zeros, and pegged factors.

The majority of the components that were bagged as part of the Refinery Study were found by Radian and not identified by the refinery operators. At times Radian obtained lists of leaking components from the refinery operators or looked for leaker tags hanging on the components in order to locate the small number of high leaking components at a refinery. At times Radian found these leaking components ourselves, and then notified the refinery operators of the leaks. All, or nearly all, of the lower ppmv leaking components were found by Radian.

To facilitate Radian's bagging efforts, refinery personnel agreed to hold off on repairs until bagging took place. In the southern California refineries in particular, this required very close communication between Radian and the refineries to ensure that the bag sample could be taken before repairs occurred because of local rules requiring repairs of the highest leaking components within 24 hours.

The fact that some components were found by refinery operators does not in any way invalidate data collected from these components. The refinery operators were aware that these components were leaking. However, they were not aware, in fact, they could not be aware without conducting their own bagging study immediately prior to ours, of the relationship of the mass emitted to the screening value obtained that is the basis for the emission correlation equations, default zeros and pegged factors. Radian saw no evidence of any independent refinery bagging study going on immediately prior to our bagging efforts and believes that the possibility of this is extremely remote. Furthermore, the regulatory auditors of this study for the U.S. EPA, CARB, the SCAQMD, and the BAAQMD that participated jointly in the Refinery Study never mentioned this possibility.

SBCAPCD's own proposal to perform additional bagging (Attachment 7 of the SBCAPCD's report) states that: "Onsite inspection personnel will be relied upon to locate the leaks in the required screening value ranges." In other words, the plan suggests facility operators be enlisted to help in finding the leaking components, as was done in the Refinery Study.

Radian disagrees with the SBCAPCD's comment that data from the 1993 Refinery Study should be precluded from being used in any future development of screening range value factors for refineries. As discussed above, the correlation between mass and screening values is not dependent on whether onsite personnel or third party contractors discover the leaking components. This correlation, which is the foundation of the emission correlation equations,

Mr. Frank Holmes
June 18, 1997
Page 6

pegged component emission factors and default zeros, could be applied to screening data gathered from other refineries to develop screening range value factors, if that is desired.

Representative Nature of Marketing Terminal Data

SBCAPCD Concern:

"Addition of Data Not Collected for the Protocol: The original screening data at Marketing Terminals for 6161 components were not used in creating screening value range factors or average factors. Instead, additional screening data (for 76,387 components from several API-member Marketing Terminals with I&M programs in place) were coupled with emissions data from all three types of petroleum facilities to create screening value range and average factors."

Radian Response:

The data used by the U.S. EPA to develop average emission factors for the marketing terminals were from 17 marketing terminals nationwide. The American Petroleum Institute (API) compiled these data and submitted this information to the U.S. EPA on April 26, 1994. It is unknown by Radian at this time if the screening data collected from the four marketing terminals for the Marketing Terminals Study were included in the data submitted to the U.S. EPA as part of the data from the 17 marketing terminals.

We believe that the SBCAPCD is correct in their statement that in order to develop the screening value range factors and average factors, the screening data from the 17 marketing terminals were applied to the emission correlation equations, default zeros and pegged factors developed from the combined bagging data for refineries, marketing terminals and production facilities.

Whether it is appropriate to combine the screening data from marketing terminals with bagging data from multiple facility types to develop average emission factors depends on whether the bagging data from these different facility types varies significantly from one facility type to another. The statistical analysis associated with the emission correlation equations, pegged component emission factors and default zero emission factors that are presented in the U.S. EPA Protocols Document indicated that bagging data from these facility types could be combined. This analysis would then support using bagging data from multiple facilities to assist in the development of the average emission factors for marketing terminals. In fact, the addition of the bagging data from these other facility types significantly increased the number of components used to develop the emission factors and equations, which could increase the confidence in the resulting average emission factors.

As a correction to the SBCAPCD report, the original screening data from the Marketing Terminals Study have been used to create average emission factors. These average emission

Mr. Frank Holmes
June 18, 1997
Page 7

factors are shown in API Publication Number 4588. However, as stated above, the average emission factors in the U.S. EPA Protocols Document are based on additional data submitted to the U.S. EPA from API.

The U.S. EPA Protocols Document appears to differ from the statement in the SBCAPCD report that the marketing terminal data are from "several API-member Marketing Terminals with I&M programs in place." In Appendix C of the U.S. EPA Protocols Document, page C-14, it states, "The marketing terminal emission factors (shown in Tables 2-3 and 2-7) represent emissions from uncontrolled facilities."

SBCAPCD Concern:

"Differences in Screening Values at Production and Marketing Terminals, vs. Refineries:

The second set of Marketing Terminal data had lower proportions of pegged screening values than either the first set from Marketing Terminals or the Production facility set. Of the 76,387 Marketing Terminal screening value data points submitted by API members, only 63 were pegged at 10,000 ppmv (0.08% of the total screened); in the other two data sets gathered by third-party contractors, Marketing Terminals showed 0.58% pegged (about 7 times, proportionally) and Production facilities showed 1.13% pegged (about 14 times, proportionally).

A review of the literature indicates that most often, regulators find more leaks than operators (see p.5 of *Summary of NEIC Leak Detection and Repair Program Investigations*, EPA Report 330/9-94-001, pp. A-12, A-13, which details that for screening data from 14 Refineries with LDAR programs in place, in all but one case, the facility reported percent leak rate is less than the NEIC determined percent leak rate). The disparities between Production and initial Marketing Terminal facilities "leaker" proportions of the second set of Marketing Terminal data may be based on absence of third-party involvement in leak detection."

Radian Response:

The number of high leaking components found at the production facilities is not particularly relevant to the number of high leaking components found at marketing terminals. The fact that differences in the number of high leaking components can be found at different facility types is one of the reasons that separate average emission factors and screening value range factors have been developed for marketing terminals.

The reason why the percentage of components leaking above 10,000 ppmv gathered as part of the Marketing Terminals Study differs from the data set used to develop the average factors as used in the U.S. EPA Protocols Document is unknown at this time.

Mr. Frank Holmes
June 18, 1997
Page 8

Note that the data mentioned from the National Enforcement Investigation Center of the U.S. EPA were collected from 14 refineries, rather than for marketing terminals. It is unknown if results from this U.S. EPA study are applicable to results from screening at marketing terminals.

Radian cannot completely address the issue of the representative nature of data collected for the marketing terminals from the 17 marketing terminals used to develop average factors. We do not have sufficient information to determine if these data are representative or not. Radian does support data collected from the four marketing terminals in conjunction with the Marketing Terminals Study. Note that all of the bagging data used for the development of emission correlation equations, default zeros, and pegged factors were collected from the four marketing terminals in the Marketing Terminals Study.

Validity of Data Collected with the Use of Dilution Probes

SBCAPCD Concern:

“Undemonstrated Reliability Of OVAs Equipped With Dilution Probes: At all three facility types – Production, Refinery, and Marketing Terminal – OVAs fitted with dilution probe kits (“dilutors”) were used in determining most screening values above 10,000 ppmv (the reading at which OVAs without dilutors “peg”), and leak rates determined by bagging were assigned to such screening values. Compelling evidence indicates that screening data taken by OVAs fitted with diluter kits are of undemonstrated reliability; the conservative approach is to assign emission leak rates taken on components that screen at over 10,000 ppmv (without dilutor) to the “pegged at 10,000” range only. That is, correlation equations should be employed up to 9,999 ppmv, above which “pegged at 10,000” factors – which incorporate all data points above 10,000 ppmv – should be used. Further discussion on the use of OVAs fitted with dilution probes is provided in Attachment 3.” (Note: excludes footnote).

Radian Response:

Because dilution probes were not used for screening values less than 10,000 ppmv and because screening values over 100,000 ppmv would be pegged with or without dilution probes on OVA's, the focus of this technical discussion will only be on components that screened between 10,000 ppmv and 100,000 ppmv. Furthermore, we have removed from our analysis any component that pegged the instrument, even if the calculated pegged value were less than 100,000 ppmv. The issue is the validity of actually measured values using the dilution probe. Pegged components, even those less than 100,000 ppmv, do not have distinctly measured values.

Figures from the Refinery Study, as presented in API Publication 4612, showing the emission correlation equations both with and without using the data collected using the dilution probe are shown in Attachment 1 to this letter. Note that the dilution probe data have the same type of scatter in relation to the emission correlation equation, as does the data collected without the

Mr. Frank Holmes
June 18, 1997
Page 9

dilution probe. A large amount of scatter in the data is inherent in these types of bagging studies, with or without the dilution probe.

A statistical evaluation of using dilution probe data in the development of the refinery emission correlation equations was performed and is discussed in API Publication 4612. The conclusion from this analysis was that: "The 95% confidence intervals for the slopes and intercepts of the line calculated with dilution-probe data were compared to the 95% confidence intervals for the slopes and intercepts of the line calculated without dilution-probe data for each of the five component categories included in this analysis. For all of the component categories, both the slope and intercept confidence intervals overlapped, lending support to the visual evidence provided by the plots that the emission correlation equations calculated using the dilution probe data do not appear to differ substantially from the emission correlation equations calculated without the dilution probe data." Simply put, from this analysis there does not appear to be a statistical reason to remove dilution probe data from the data sets used to calculate emission correlation equations. Please note that this analysis was performed on a component type by component type basis. The fact that this statistical analysis was performed on each component type should eliminate concerns that Radian's conclusions are based solely on an aggregated sample of bags without regard to component type.

Another persuasive argument for including the data collected using the dilution probe is supported by the data shown in Attachment 2. Attachment 2 shows the non-pegged component data collected using the dilution probe for refineries and marketing terminals. The SBCAPCD has indicated that the OVA 88, which doesn't require a dilution probe to measure up to 100,000 ppmv, was used to gather some of the Production Study data. Because it is unknown which samples in the Production Study between 10,000 ppmv and 100,000 ppmv were collected using the dilution probe, no Production Study data are shown on the table in Attachment 2.

The table in Attachment 2 presents the measured leak rate from these components, calculated in three different ways. The first method is the most accurate method, with the measured leak rate based on the data collected directly during the bagging procedure. The second method is based on using the U.S. EPA Protocols Document's emission correlation equations. The third method is based on using the 10,000 ppmv pegged factors from the U.S. EPA Protocols Document.

Note that, in Attachment 2, using both the emission correlation equations and the pegged component emission factors result in an overestimate of emissions compared with the most accurate calculation method, the bagging results. However, the emission correlation equations result in only a 14% overestimate, which is remarkably close agreement. This result does combine all component types together. This was done to reduce potential errors from taking a sample size that may be too small on a component type by component type basis.

Mr. Frank Holmes
June 18, 1997
Page 10

Also note, as a point of interest, that using pegged factors for the data in Attachment 2 results in an 813% overestimate of emissions.

Radian does not contest that use of the dilution probe introduces error into the collection of screening data. In the case where all of the leak is drawn in by the dilution probe, the shortcomings of the dilution probe discussed in the SBCAPCD report are more apparent. However, in cases where only a percentage of the leak is drawn into the dilution probe, the shortcomings highlighted by the SBCAPCD are diminished significantly.

For all of the leak to be swept up by an OVA with a dilution probe requires the following two conditions:

- ▶ The leak must be a well-defined pinhole leak that can be very closely approached by the probe of the OVA, such that the entire leak can be swept up by the probe; and
- ▶ The leak must have a low enough flow that a dilution probe drawing air at 0.1 liters per minute will be able to sweep up the entire leak.

For the Refinery Study and Marketing Terminals Study, the dilution probe was calibrated daily or more frequently to be at a 10:1 ratio (or the exact ratio was recorded). The dilution probe was calibrated by inserting it into a pure sample of methane at 10,000 ppmv or higher. In the calibration process, no matter what the flow rate through the dilution probe, the OVA could not influence the concentration of the pure calibration gas sample. In the example used in the SBCAPCD's report, the leak was assumed to be only 11 cc/minute. With or without the dilution probe, the OVA could potentially capture all of this leak (under the right conditions). The flow rate of the OVA would significantly affect the testing environment in this case and affect resulting readings. However, if the flow is greater than 100 cc/minute, then the OVA would capture only a portion of the total flow, and the closer the leak would approximate the calibration environment of a constant ppmv concentration regardless of analyzer flow.

If we assume that methane is the hydrocarbon leaking, then an 11 cc/min leak equates approximately to a mass leak rate of 0.00044 kg/hr. However, note that the pegged emission factors calculated by both the U.S. EPA and the SBCAPCD are approximately two orders of magnitude higher than this mass leak rate. These pegged emission factors correspond to leaks that are too large to be entirely swept up by a dilution probe, even if the physics of the component and leak would allow this.

It should be remembered that when the emission correlation equations are developed using a data set that incorporates data using the dilution probe (10,000 ppmv to 100,000 ppmv), then any bias for using dilution probes in typical field situations is built into these correlation equations. If inaccuracies are random, they will tend to be minimized over a large population. If there is a

Mr. Frank Holmes
June 18, 1997
Page 11

systematic bias, it will be minimized if the facilities use dilution probes similar to those used to develop the emission correlation equations.

We agree with the statement in the SBCAPCD's report that "...the mechanics of hydrocarbon leaks and leak capture are not well understood,...". Until these mechanics are more completely understood, we recommend that the field data, as demonstrated in Attachments 1 and 2 of our letter and as discussed above, be used as the evidence of the advantage of using the dilution probe for readings in the 10,000 ppmv to 100,000 ppmv range.

In keeping with the SBCAPCD earlier statement that "these factors and equations form the basis for quantifying fugitive emissions that air districts use in both planning and inventory billings, it is imperative that they be as precise as the current state of the art allows...", Radian recommends that data collected between 10,000 ppmv and 100,000 ppmv with a dilution probe not be routinely combined into a single pegged component emission factor for greater than 10,000 ppmv.

Validity of Combining Different Types of Process Streams

SBCAPCD Concern:

"Combining Different Process Streams: Data from facilities with very different process stream ROC content were combined to create petroleum industry-wide correlation equations, and pegged factors: see Table 1 of Attachment 4. Refinery heavy liquid (e.g., MEK, toluene, jet fuel, diesel, kerosene) data were grouped with Production heavy liquid (fluids at Production facilities handling thermally enhanced oil recovery oils such as crude oil). See Table 2 of Attachment 4."

Radian Response:

Although data were collected from various process streams, this is not an area of significant concern. The objective of developing emission correlation equations and emission factors is to develop a simplified model that approximates the complex relationship between the screening value and the mass emission rate. This simplified model is designed to incorporate multiple differences in components tested and to be applicable to a population of equally diverse characteristics.

Validity of Combining Pegged Component Data for Different Facility Types

SBCAPCD Concern:

"Comparison of Leak Rates at Different Facility Types: Mass emission rates of "pegged at 10,000" components at Production facilities average about four times higher than those at Refineries. This may be due to the fact that all Refineries had I&M programs in place, whereas some Production facilities may

Mr. Frank Holmes
June 18, 1997
Page 12

not have; or to the possibilities that not all Refinery components with screening values over 10,000 ppmv were reported for bagging (some high-end leakers may have been repaired, and therefore not counted in the study); or that there was no third party interest in finding pegged components at Refineries; or to the fact that advance notice was given to sources; or a combination of these and other considerations. See Attachment 4 Table 3."

Radian Response:

The issue of advance notice, or leaks found by refinery personnel was addressed previously in this letter. The fact that some of the leaking components were identified by refinery personnel should not be an area of concern.

Radian, as a third party contractor, did have an interest in finding pegged components at refineries. In fact, we found many of the pegged components that were later bagged.

Practically speaking, all refinery components that Radian found during the Refinery Study and Marketing Terminal Study with screening values over 10,000 ppmv were bagged. Our recollection is that only one open-ended line that pegged the OVA was not bagged at the very end of the Refinery Study data gathering process. This open-ended line was not bagged because we felt that we already had sufficient pegged component data for this component type. We actively sought out those components with screening values over 10,000 ppmv to bag them because these components were difficult to find.

As discussed by the SBCAPCD, all of the refineries involved in the bagging study had inspection and maintenance (I&M) programs. We understand that most of the production facilities did not have any type of I&M programs. Furthermore, we understand that the majority of the production facilities that did have some I&M programs did not have the rigorously applied I&M programs used at the refineries. If this is the reason for the apparent differences in pegged component emission factors for different facility types, with refineries having lower pegged component emission factors than production facilities, then it would seem reasonable to allow production facilities that have I&M programs to be allowed a reduction in their estimated emissions. This type of reduction has been allowed in the past, as discussed in the U.S. EPA Protocols Document, for facilities using average emission factors that also have I&M programs. These reductions to average emission factors are often 70% or more.

However, Radian does not see much statistical evidence to cause refinery, marketing terminal, and production facility pegged component data to be separated into different pegged component emission factors. Two types of statistical analysis of these data have been performed to address the following question: Do average leak rates from the pegged data differ significantly by facility type?

Mr. Frank Holmes
June 18, 1997
Page 13

In preparation for applying these tests, it was determined that the data follows a lognormal distribution, meaning that the log of the leak rates is normally distributed. For this reason, the tests were performed on the log transformation of the leak rate data.

Two identifications were used to group the data. The Equipment Type was either Connectors, Flanges, OELs, Pumps, Valves, or Other equipment. The Plant Type was either Refinery, Marketing Terminal, or Onshore/Offshore Production facility.

The first test, performed by Dave Epperson of Eastern Research Group (ERG), was a cluster analysis, in which the observed leak rates are divided into groups clustered around different levels indicated by the data. For each equipment type, the data were forced into three or two clusters based on their leak rate. When regrouped by plant type, each of the plant type groups contained data from the high leak rate and the low leak rate clusters. Plant type did not correspond to different leak rates. Attachment 3 shows this analysis.

Radian followed the cluster analysis with individual t-test analyses by equipment type. A t-test can be used to compare two normally distributed populations to determine if the mean is the same. For this analysis, the Refinery and Marketing Terminal plant types were combined into one group, refining, and distribution. For no equipment type was there sufficient evidence to assert that the leak rates for production facilities differed significantly from refining/marketing terminal facilities. Open-ended lines (OEL's) show the strongest differences, but even with OELs, there is approximately a 22% chance that the difference in the average leak rates observed here is an anomaly, and the true average leak rates for production and refining/distribution OELs are in fact the same. To believe that the leak rates differed, we would want to see that chance of being wrong lower than 10%, and preferably lower than 5%. This analysis is shown as Attachment 4.

In summary, based on the statistical analysis, we do not recommend that the pegged component data be separated by facility type. If the SBCAPCD still chooses to separate these data, then we recommend some type of I&M reduction factors for those production facilities that have I&M programs.

Blowthrough Bagging Methodology Concerns

SBCAPCD Concern:

Following the Criteria: In the early stages of the review process, we reviewed the rationale for and the impact of eliminating blowthrough method data points with certain commonalities, such as high variability in O₂ concentration from start to finish of bagging, high O₂ concentration, and low N₂ flow. Although we are uncomfortable with some data points (all three of the types noted above may contribute

Mr. Frank Holmes
June 18, 1997
Page 14

to a sample which is not representative of the material in the bag), we feel that there is inadequate information to allow an objective deselection of additional data points.”

Radian Response:

None of the current methods to collect samples for use in developing fugitive emission factors and equations is ideal at this point in time. However, we believe that the blowthrough method is one of the better methods currently available for field measurements.

Some of the issues related to the oxygen concentration during the bagging process are discussed previously in this letter. U.S. EPA criteria for the blowthrough method were followed.

A detailed analysis of the effects of nitrogen flow on the bagging process is provided in API Publication Number 4612, Volume II, pp. 3-44 to 3-48. As was concluded in that study, “The results of the twelve nitrogen flow tests are presented graphically in Figure 3-20. From the plot, nitrogen flow rate does not appear to have a systematic impact on emission calculations. The statistical tests applied to these data support this observation. Mann-Kendall trend analyses (Gilbert, 1987) were performed for each of the twelve components.”

Need for Expanded Data Sets

SBCAPCD Recommendation:

“Expand the Data Sets: A review of the number of valid data pairs from the 1995 Protocol is shown in Table 1 of Attachment 7. Some component types at Refinery/Marketing Terminal and at Production facilities have fewer than 6 valid data pairs, the criterion specified for the Protocol. We suggest that each data set be expanded to include a minimum of 10 data pairs per component type; see Radian memo. A draft proposal for this expansion is contained in Attachment 7.”

Radian Response:

Generally speaking, the more data that can be obtained, the less uncertainties in the analysis. However, the need for this additional analysis at this point in time is questionable, whether the data sets for refineries, marketing terminals, and production facilities are separated or not. As Table 1 of Attachment 7 of the SBCAPCD report shows, with combined data sets nearly every category of component type and screening range exceeds the six recommended bagging samples, and nearly all also exceed the ten suggested bagging samples. In fact, four different valve categories have over 100 bagging samples each.

Mr. Frank Holmes
June 18, 1997
Page 15

Creating an Implementation Guidelines Document

SBCAPCD Recommendation:

"Create An Implementation Guidelines document: To facilitate uniform and consistent application of the emission factors and equations in this document at petroleum industry facilities in different air districts in California, a statewide implementation guidance document must be created. In late February 1997, SJVUAPCD provided a draft (*Estimating Equipment Leak Emissions*) for CAPCOA's review. In addition, API published a *Calculation Workbook for Oil and Gas Production Equipment Fugitive Emissions* (July 1996). These two documents may be useful in creating the guidance document, which should address the following issues:" (Component count methodology and I&M program reduction efficiencies are discussed).

Radian Response:

Radian endorses the SBCAPCD's recommendation to develop guidance information to facilitate uniform and consistent application of the emission factors and equations. For additional information on this area, we recommend that the SBCAPCD also review the U.S. EPA's, November 1996 guidance document entitled *Preferred and Alternative Methods for Estimating Fugitive Emissions from Equipment Leaks*. This document can be found on the U.S. EPA's bulletin board. Another reference for the SBCAPCD review is the soon to be released pair of documents from API entitled *Fugitive Emissions from Equipment Leaks I: Monitoring Manual* and *Fugitive Emissions from Equipment Leaks II: Calculation Procedures for Petroleum Industry Facilities*. Radian is currently preparing the final versions of these documents for API.

Correct Version of Equation for Total Flow into a Bag

Please note that the equation to calculate the total flow into a bag, as shown in Attachment 1 of the SBCAPCD's report, has a typographical error. This typo was originally made by Radian when we distributed it to those involved in this reanalysis. We later sent a revision to the equation; however, it appears that the earlier version is shown. Both of the exponential terms are shown as 10^{-6} . The correct exponential terms should be 10^{-6} .

Revised Pegged Component Emission Factors for Pumps

SBCAPCD Value:

The 100,000 ppmv pegged component emission factor that the SBCAPCD shows on Attachment 1 for "Table "C-3" for Combined Facility Types, Corrected" for pumps is 0.664 (kg/hr).

Mr. Frank Holmes
June 18, 1997
Page 16

Radian Recalculated Value:

Radian's recalculation of the pegged component emission factors is reasonably close to the factors calculated by the SBCAPCD, with one particular exception: the 100,000 ppmv pegged component emission factor that Radian calculates for pumps is 0.19 kg/hr.

For recent studies, two approaches to calculating pegged component emission factors have been used: the numeric mean method and the "scale-bias correction factor" method. Use of either methodology can be justified in particular situations. Note that in most cases the scale-bias correction factor method results in significantly higher estimated emissions than the numeric mean method (usually two to three times higher). For the SBCAPCD calculations, it appears that they may have used the scale-bias correct factor method for all of the component types, with the exception of pumps. For pumps, it appears that the numeric mean method was used by the SBCAPCD. Pumps is one of the very few cases where a scale-bias correction factor approach leads to a lower pegged component emission factor. We recommend that a consistent methodology be used.

Pumps provided a particular challenge for development of pegged component emission factors for the 1995 U.S. EPA Protocols Document because of limited data (in the greater than 100,000 ppmv range) for this component type. However, an approximation of the 100,000 pegged factor can be made using the following procedure:

- ▶ A cumulative total emission factor is computed for all components screened above 10,000 ppmv.
- ▶ The ratio of the pump 10,000 ppmv factor to the total 10,000 ppmv emission factor is computed.
- ▶ A scale-bias corrected cumulative total emission factor is computed for all components screened above 100,000 ppmv.
- ▶ The ratio of the pump 100,000 ppmv factor to the cumulative total 100,000 ppmv emission factor is assumed to be equivalent to the ratio at 10,000 ppmv. Thus, the 100,000 ppmv pegged component emission factor for pumps can be approximated from the cumulative total 100,000 ppmv factor using this ratio.

Application of I&M Program Reduction Efficiencies

SBCAPCD Comment:

"I&M program reduction efficiencies: The need for the use of average factors at major facilities in the state is not known. As average factors are the only factors or equations to which I&M program reduction efficiencies can be applied, we do not see the need to define in this document a set of arbitrary reduction

Mr. Frank Holmes
June 18, 1997
Page 17

efficiencies, and suggest that future industry requests for reduction efficiencies be handled on a case-by-case basis.”

Radian Response:

Radian agrees that average factors are the only factors or equations to which I&M program reduction efficiencies can be applied. There is a long history of U.S. EPA acceptance of I&M program reduction factors being applied to average factors in the calculation of fugitive emissions. As early as in 1982, the U.S. EPA prepared *VOC Fugitive Emission in Petroleum Refining Industry – Background Information for Proposed Standards, Draft EIS*, where a methodology for calculating I&M reduction factors is presented. Appendix B of that document lists four factors that can be used to determine the appropriate reduction factor for a particular I&M program. These four factors are:

- ▶ A factor: percent of total mass emissions affected at various leak definitions (theoretical maximum control efficiency);
- ▶ B factor: leak occurrence and recurrence factor (function of inspection interval);
- ▶ C factor: non-instantaneous repair correction factor (function of allowable repair time); and
- ▶ D factor: imperfect repair correction factor (accounts for fact that some components which are repaired are not reduced to zero ppmv leaks).

In 1995, the U.S. EPA published in the U.S. EPA Protocols Document reduction factors for refineries that have I&M programs and use the average emission factor calculation method. The reduction factors shown in the U.S. EPA Protocols Document range from a low of 45% to a high of 88%. Use of reduction factors for refineries is based on something more than an arbitrary standard.

The data used to calculate average emission factors for refineries were from refineries that did not have I&M factors at the time that the screening data were collected. The U.S. EPA acknowledged the benefits of I&M programs in reducing emissions at refineries, when the I&M program was based on set leak definitions (i.e. 1000 ppmv or 10,000 ppmv), routine monitoring (monthly, quarterly, annually), and a set allowable time for repairing leaking components (1 day, 5 days, or 15 days).

The question remains whether production facilities with I&M programs should use reduction factors to more accurately depict the emissions from these facilities if they use the average emission factor method. The answer to the question should be focused on what type of I&M program was in place at the production facilities where the screening data used to develop the average emission factors were collected. Clearly, if these facilities were completely

Mr. Frank Holmes
June 18, 1997
Page 18

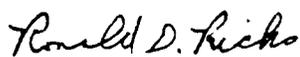
uncontrolled, with no I&M program in place, then a reduction factor similar to refinery reduction factors (or the same factors) would be appropriate, and not arbitrary. The reduction factor would appropriately acknowledge the reduction in emissions from maintaining I&M programs.

It is our understanding that the majority of the production facility data were taken from facilities with no I&M program at all. They were uncontrolled. We further believe that the few facilities that did have any type of inspection program did not have the rigorous I&M program that was the foundation of the original reduction factors published by the U.S. EPA. In other words, it is our understanding few, if any, of these production facilities had a program that had specified leak definitions, routine monitoring, and a set allowable repair time for leaking components. They could be considered "uncontrolled" based on the criteria used by the U.S. EPA to develop reduction factors. Therefore, it seems appropriate to use some type of reduction factors at production facilities that have rigorous I&M programs. For simplicity, we recommend use of the refinery reduction factors published by the U.S. EPA.

Please note that Radian further understands that other regulatory agencies recognize the above stated need to use I&M reduction factors to more accurately estimate emissions from production facilities that use the average emission factor method. For example, we understand that the state of Texas allows this type of reduction factor use.

If you have any questions related to this, please call me at (916) 857-7409.

Sincerely,



Ronald D. Ricks
Senior Engineer

c: Buzz Harris - Radian

Attachment 1

**Analysis of the Impact of Data Collected
Using Dilution Probes for the Refinery Study
(From API Publication 4612, April 1994)**

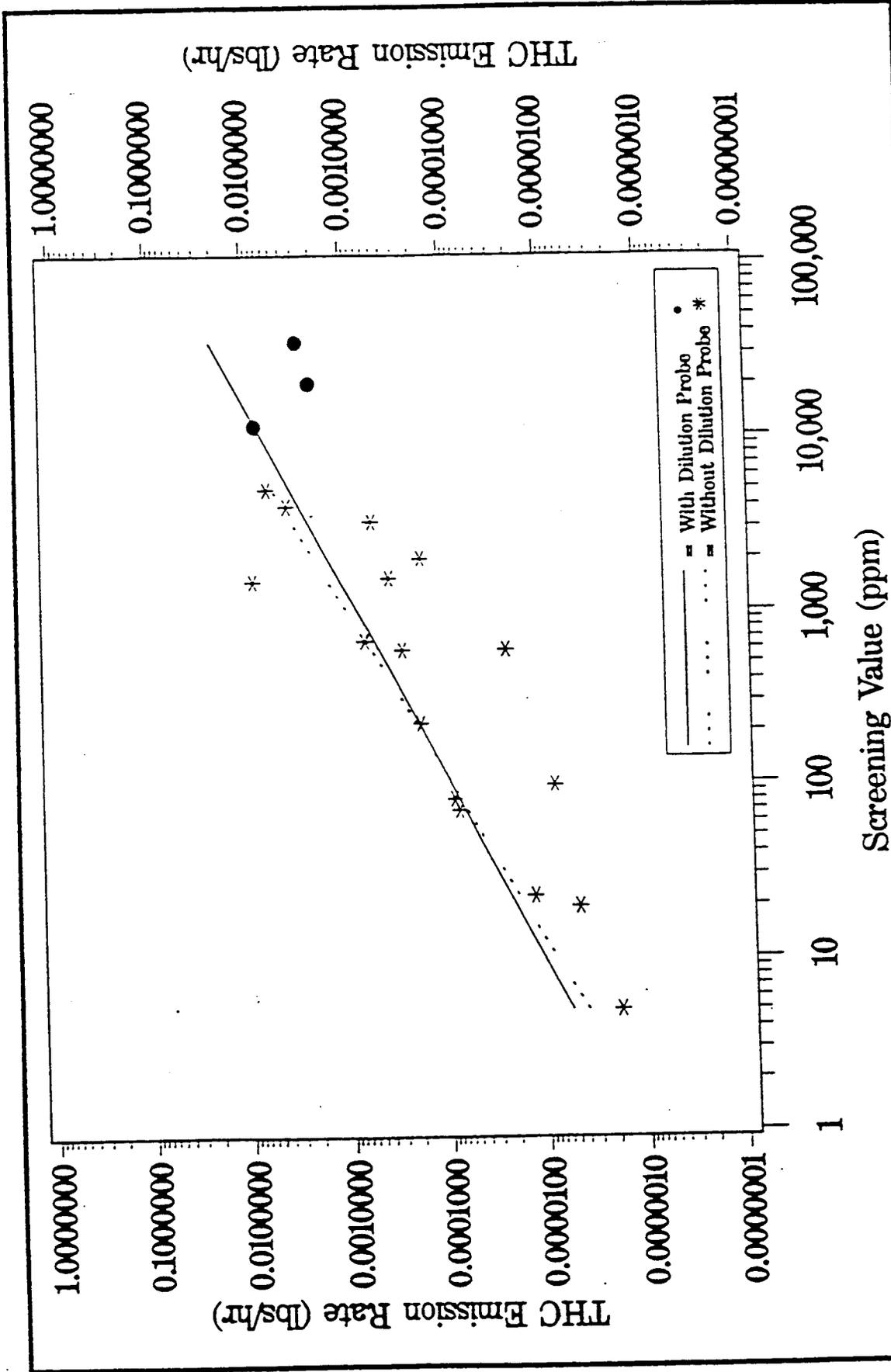


Figure 3-23. Comparison of Emission Rate/Screening Value Data Pairs and Emission Correlation Equations With and Without the Dilution Probe Data - Connectors (Flanges) in All Services

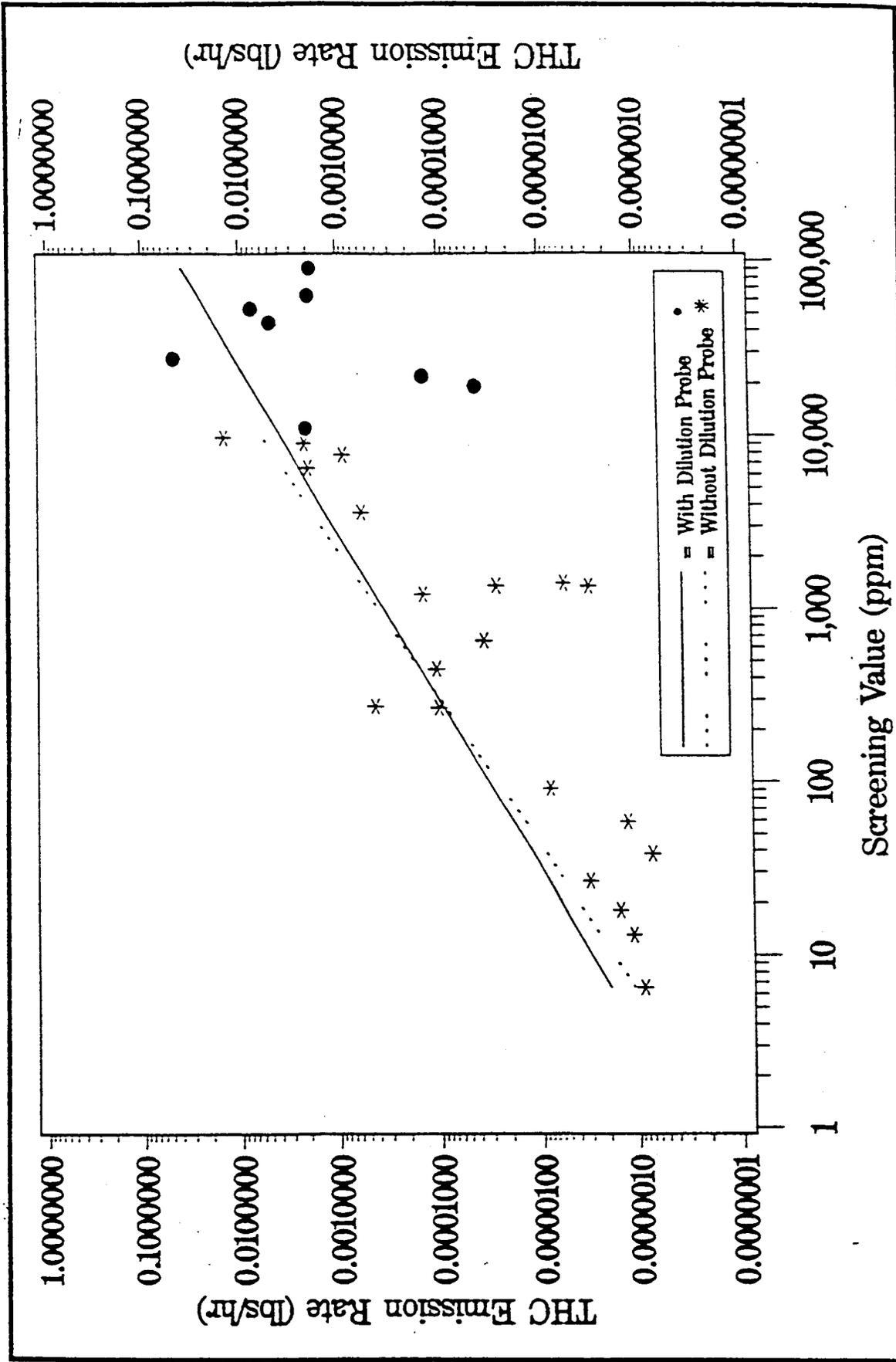


Figure 3-24. Comparison of Emission Rate/Screening Value Data Pairs and Emission Correlation Equations With and Without the Dilution Probe Data - Connectors (Non-Flanges) in All Services

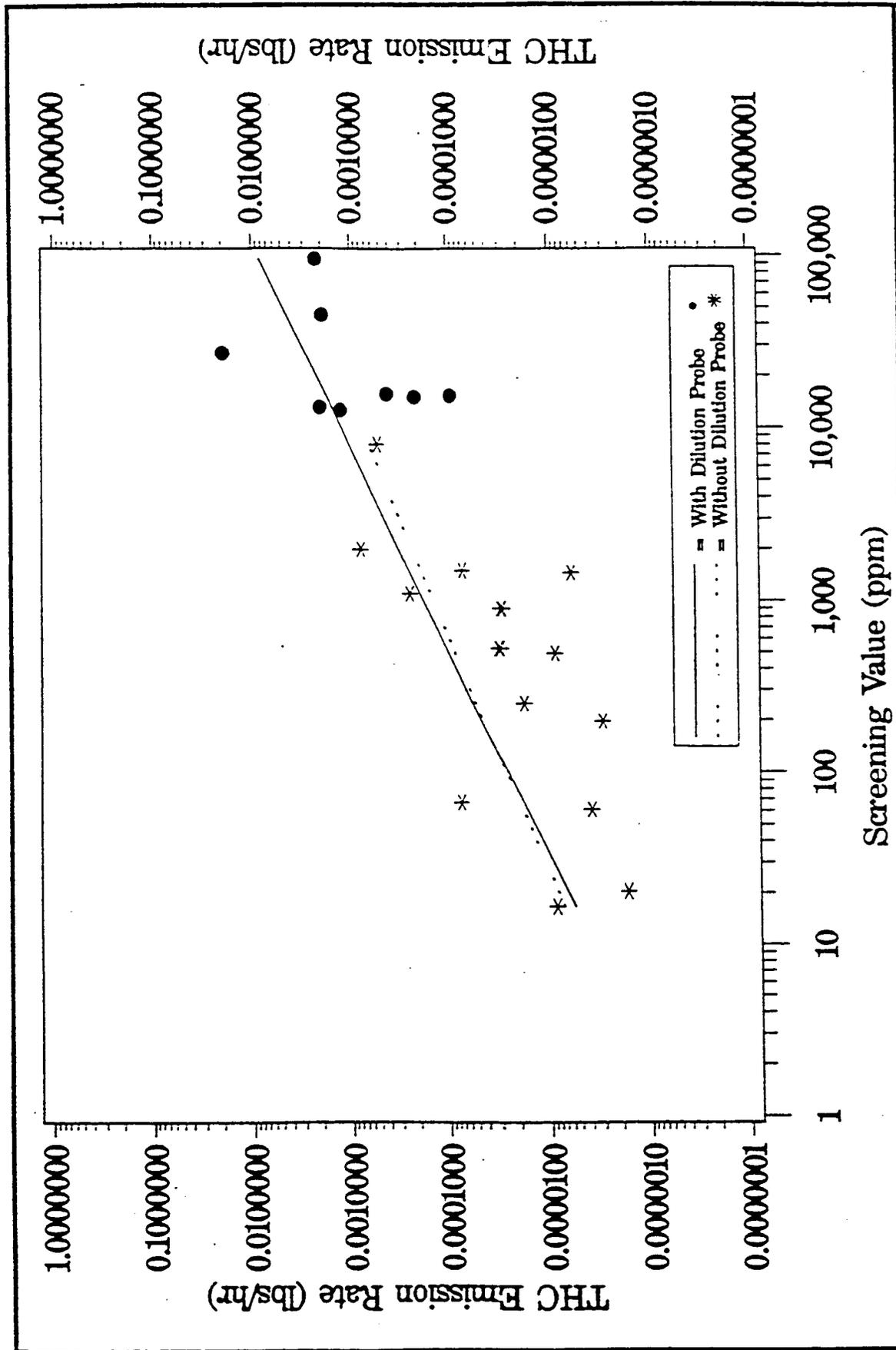


Figure 3-25. Comparison of Emission Rate/Screening Value Data Pairs and Emission Correlation Equations With and Without the Dilution Probe Data - Open-Ended Lines in All Services

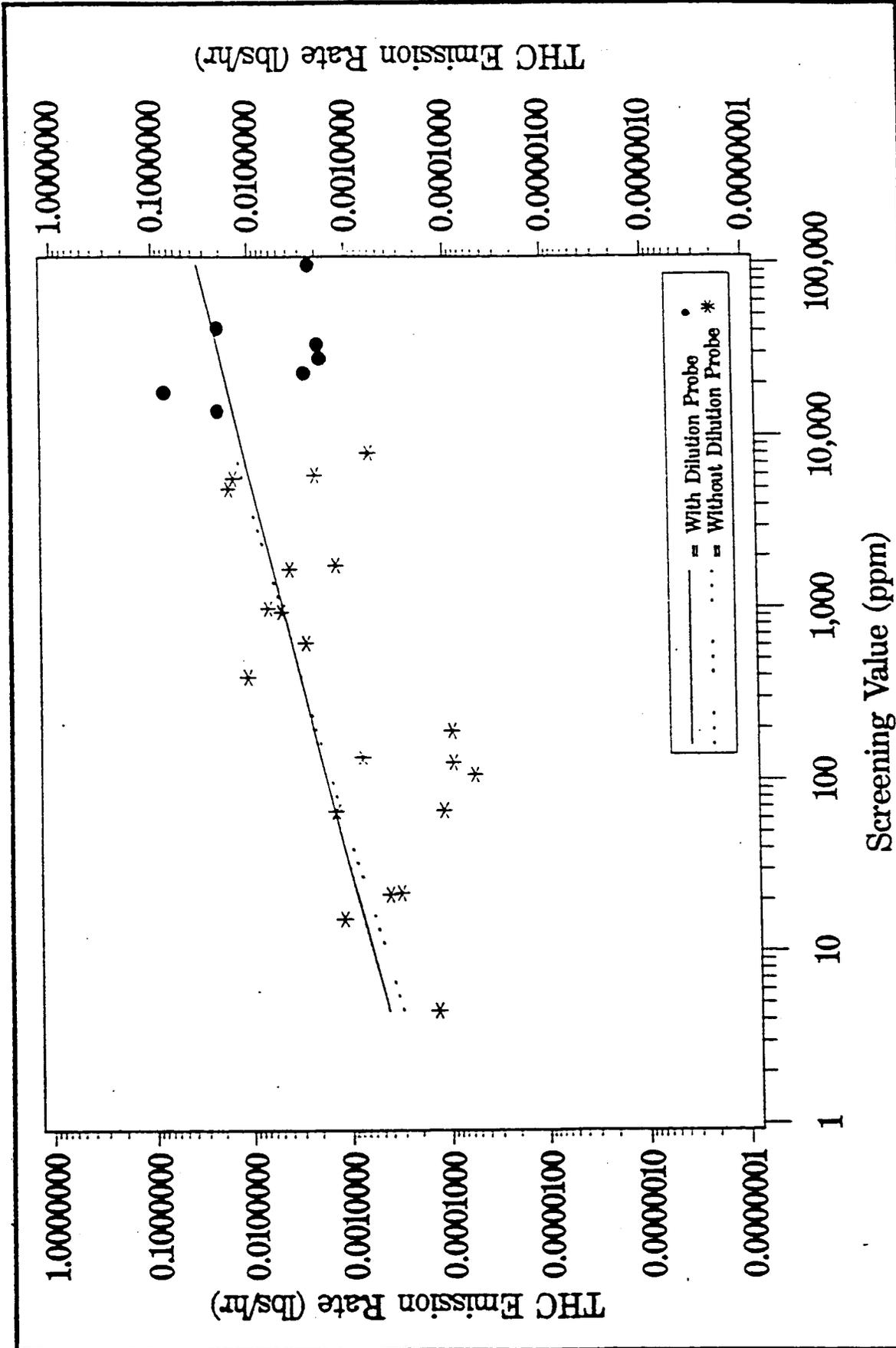


Figure 3-26. Comparison of Emission Rate/Screening Value Data Pairs and Emission Correlation Equations With and Without the Dilution Probe Data - Pump Seals in Light Liquid Service

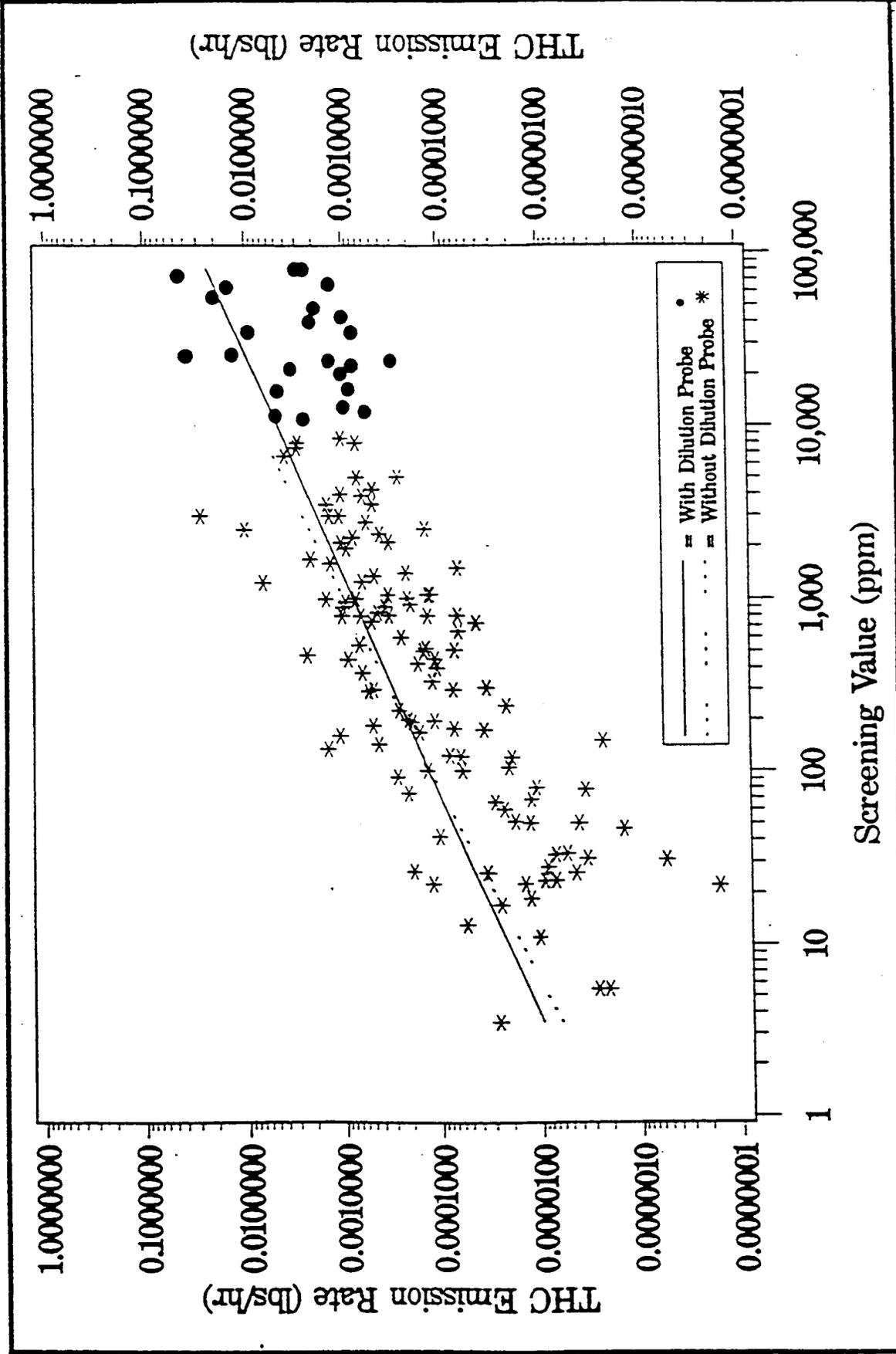


Figure 3-27. Comparison of Emission Rate/Screening Value Data Pairs and Emission Correlation Equations With and Without the Dilution Probe Data - Valves in All Services

Attachment 2

**Comparison of Calculation Method
Results for Components that Screen
Between 10,000 ppmv and 100,000 ppmv**

**Comparison of Calculation Method Results for Components
that Screen between 10,000 ppmv 100,000 ppmv**

Site Number	Sample ID	Eqpt Type	Plant Type	Screening Value (ppmv) adj for BkGnd	Measured Leak	Leak Predicted by	Leak Predicted by
					Rate Corrected for ambient temperature, and HC flow, (kg/hr)	Correlation Equation (kg/hr)	10,000 PPM Pegged Factor (kg/hr)
X	3056	Conn	REF	10995	0.000940	0.001429	0.028
Z	5039	Conn	REF	19304	0.000019	0.002161	0.028
X	3054	Conn	REF	20740	0.042518	0.002278	0.028
Y	4113	Conn	REF	21996	0.000063	0.002379	0.028
Z	5070	Conn	REF	27493	0.022301	0.002802	0.028
V	1100	Conn	REF	43995	0.002249	0.003959	0.028
Z	5059	Conn	REF	49271.5	0.013849	0.004303	0.028
W	2093	Conn	REF	52843	0.003457	0.004530	0.028
W	2110	Conn	REF	89996.5	0.000833	0.006700	0.028
X	3061	Flange	REF	11547	0.003461	0.003308	0.085
Y	4091	Flange	REF	20246	0.000957	0.004910	0.085
X	3114	Flange	REF	34995.5	0.001256	0.007213	0.085
D	9059	Other	MT	15594.5	0.060408	0.004011	0.073
W	2134	OEL	REF	12493.5	0.000567	0.001685	0.03
W	2142	OEL	REF	12990	0.000927	0.001731	0.03
Y	4098	OEL	REF	14846	0.000097	0.001902	0.03
V	1083	OEL	REF	15068	0.000042	0.001922	0.03
X	3066	OEL	REF	15496.5	0.000186	0.001960	0.03
Y	4068	OEL	REF	26795	0.009120	0.002883	0.03
V	1032	OEL	REF	44998	0.000886	0.004152	0.03
D	9005	Pump	MT	10995	0.001802	0.014679	0.074
Y	4057	Pump	REF	13995	0.011087	0.017006	0.074
Y	4050	Pump	REF	17694.5	0.039138	0.019622	0.074
Y	4124	Pump	REF	22995	0.001193	0.023023	0.074
X	3042	Pump	REF	27996	0.000821	0.025960	0.074
W	2141	Pump	REF	33744.5	0.000878	0.029092	0.074
Y	4056	Pump	REF	41995	0.010047	0.033244	0.074
D	9025	Valve	MT	10981	0.001466	0.002367	0.064
D	9032	Valve	MT	20897	0.000246	0.003825	0.064
D	9033	Valve	MT	21994	0.000460	0.003974	0.064
Y	4102	Valve	REF	10996	0.000240	0.002369	0.064
X	3013	Valve	REF	10997	0.001136	0.002369	0.064
Z	5053	Valve	REF	11494	0.002337	0.002449	0.064
Y	4059	Valve	REF	12145.5	0.000260	0.002552	0.064
W	2119	Valve	REF	12991	0.000434	0.002683	0.064
Y	4054	Valve	REF	16496	0.000390	0.003206	0.064
Y	4043	Valve	REF	16995	0.000696	0.003278	0.064
Y	4085	Valve	REF	20246.5	0.000479	0.003736	0.064
X	3120	Valve	REF	21495	0.001538	0.003906	0.064
Y	4104	Valve	REF	22495	0.000355	0.004041	0.064
Z	5006	Valve	REF	22499	0.005762	0.004042	0.064
W	2019	Valve	REF	23994.5	0.000608	0.004240	0.064
Y	4052	Valve	REF	23996	0.000140	0.004241	0.064
W	2070	Valve	REF	25490	0.017720	0.004436	0.064
W	2136	Valve	REF	25895.5	0.006152	0.004488	0.064
W	2080	Valve	REF	34996.5	0.000355	0.005619	0.064
Z	5074	Valve	REF	39996.5	0.000956	0.006208	0.064
Y	4083	Valve	REF	42745.5	0.000445	0.006523	0.064
Z	5071	Valve	REF	49995	0.008629	0.007332	0.064
Z	5063	Valve	REF	65699	0.000617	0.008989	0.064
X	3107	Valve	REF	72924	0.020771	0.009717	0.064
V	1097	Valve	REF	79997	0.001360	0.010412	0.064
TOTALS					0.302652	0.345847	2.908

KEY: REF = Refinery
 MT = Marketing Terminal
 OEL = Open-ended Lines
 Conn = Connector

Attachment 3

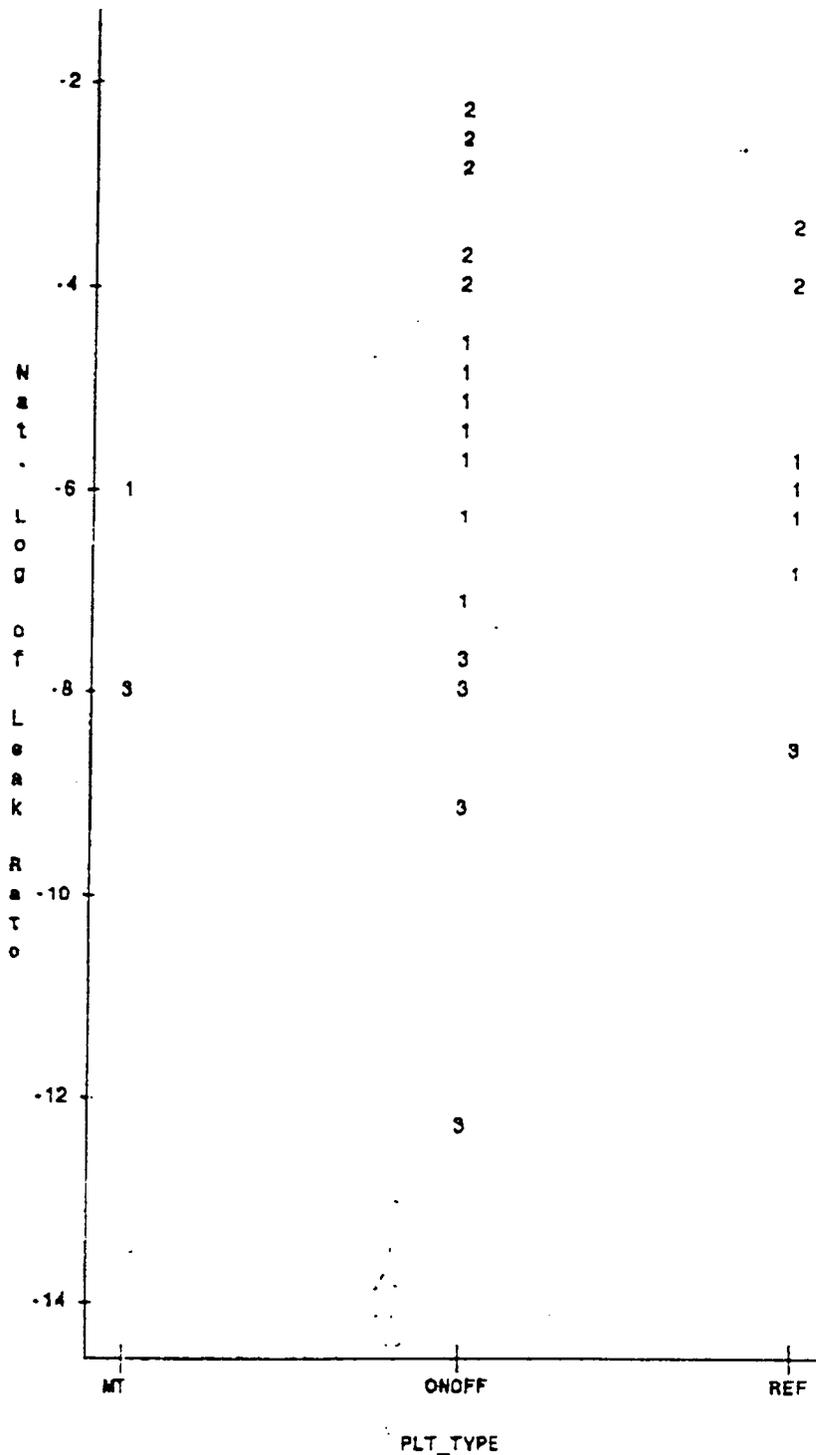
Cluster Analysis of Pegged Component Data
(From Dave Epperson, Eastern Research Group, April 1996)

Clusters for 1993 PLANT TYPES data

09:51 Tuesday, April 8, 1997 14

Equipment Type=CONNECTOR PHASEB=ALL PEGLEVEL=100

Plot of LN_CONC*PLT_TYPE. Symbol is value of CLUSTER.



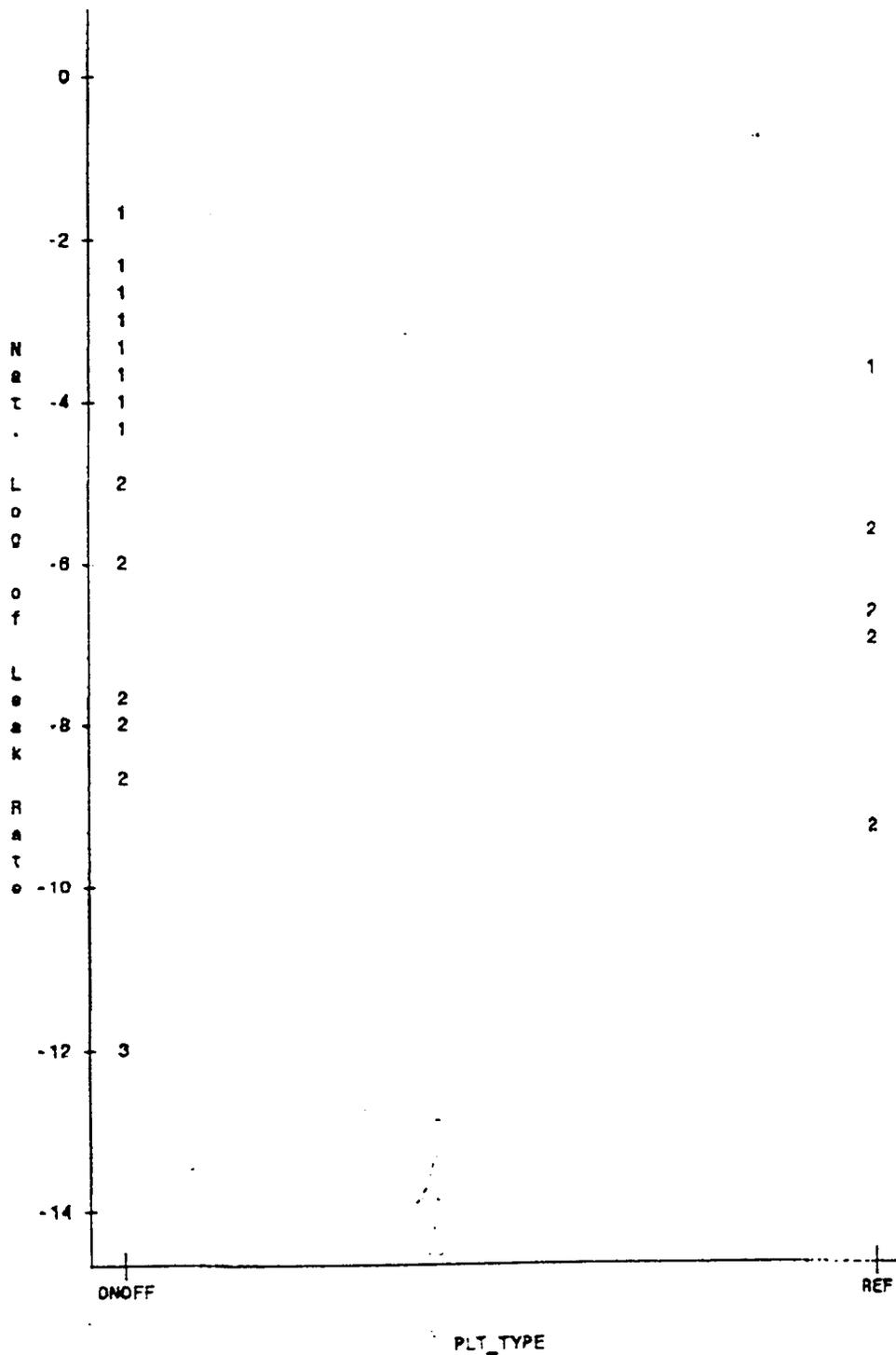
NOTE: 8 obs hidden.

Clusters for 1993 PLANT TYPES data

09:51 Tuesday, April 8, 1997 15

Equipment Type=FLANGE PHASEB=ALL PEGLEVEL=10

Plot of LN_CONC*PLT_TYPE. Symbol is value of CLUSTER.



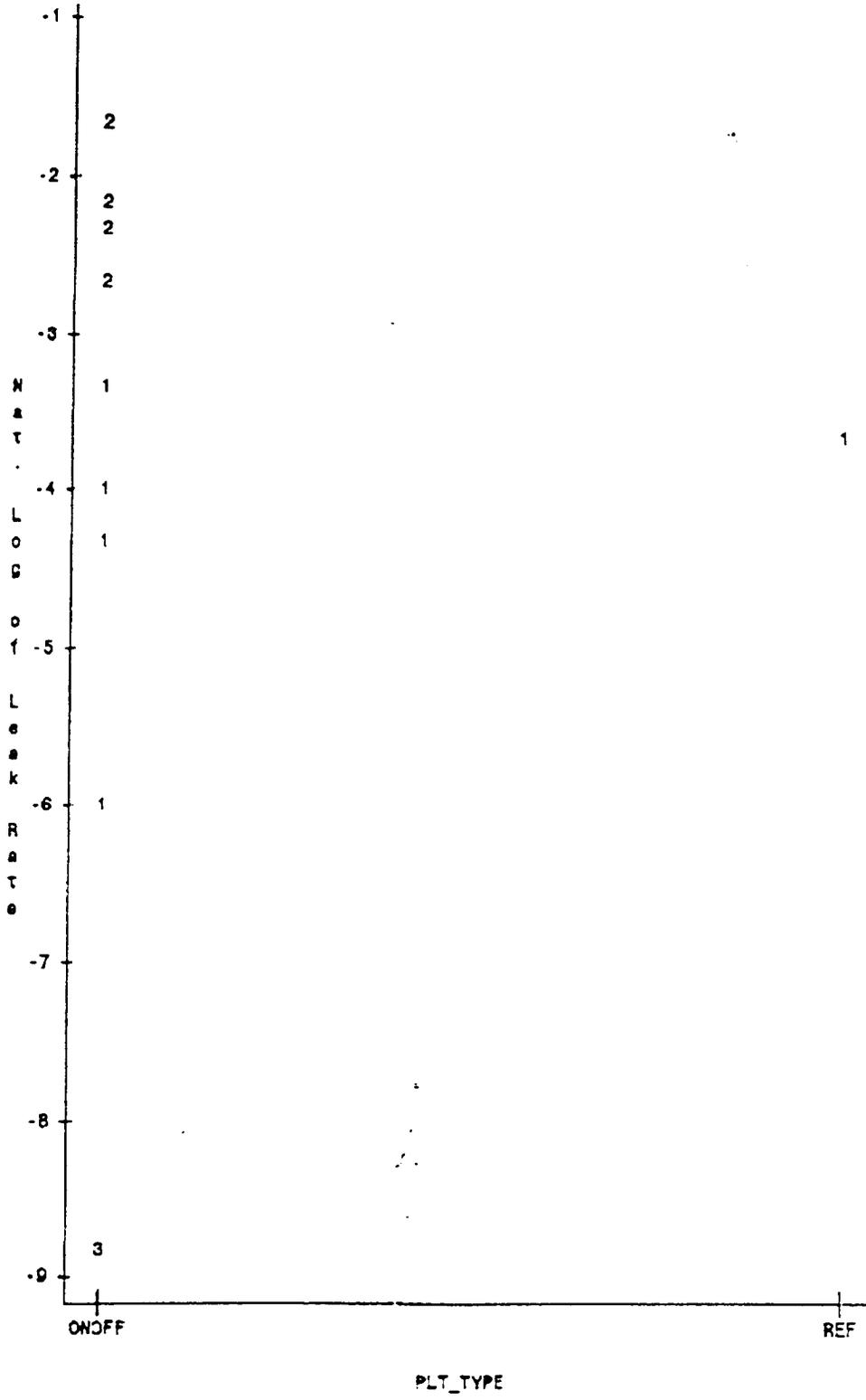
NOTE: 5 obs hidden.

Clusters for 1903 PLANT TYPES data

09:51 Tuesday, April 8, 1997 18

Equipment Type=FLANGE PHASE=ALL PEGLEVEL=100

Plot of LN_CONC*PLT_TYPE. Syabol is value of CLUSTER.



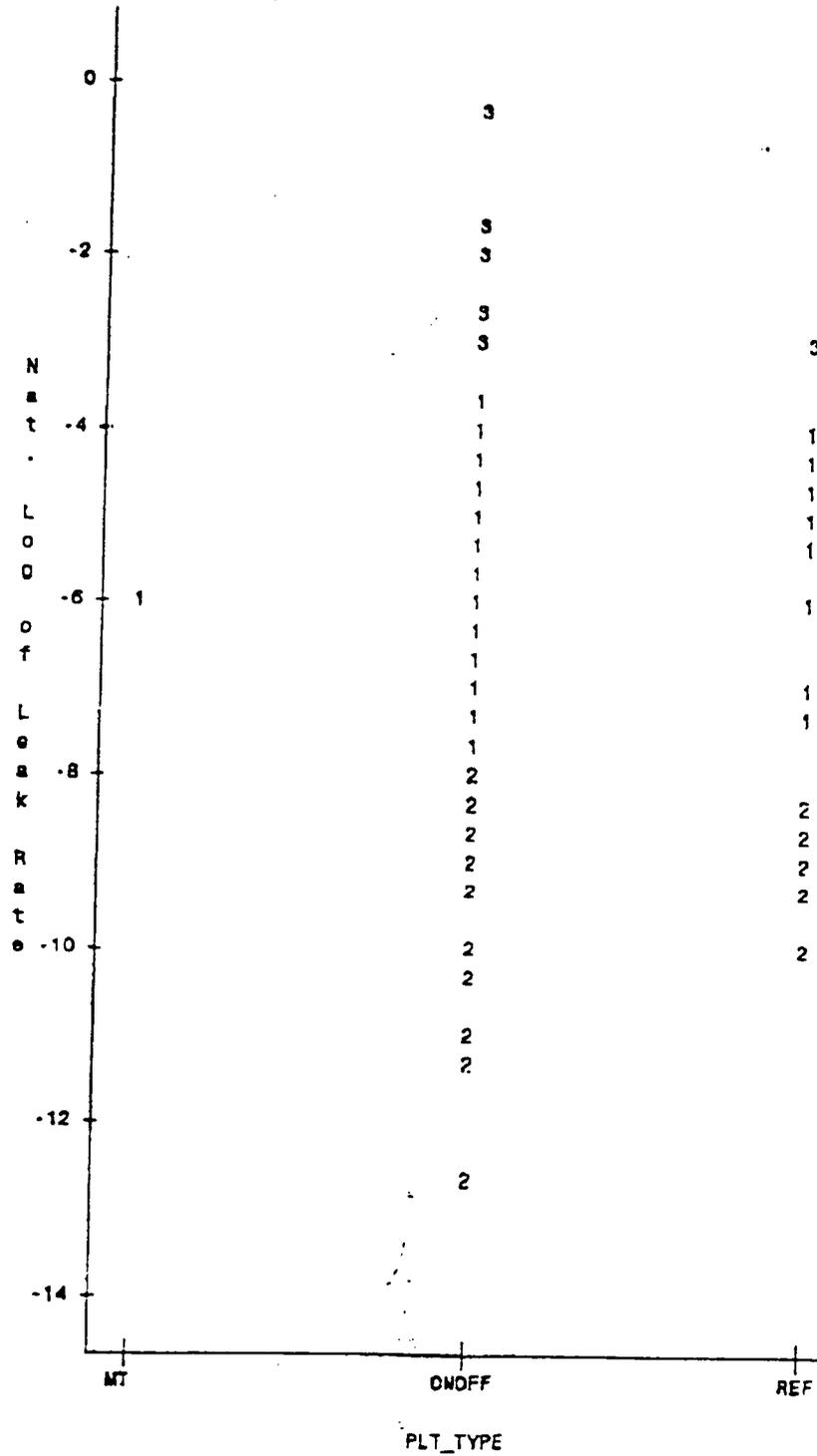
NOTE: 2 obs hidden.

Clusters for 1993 PLANT TYPES data

09:51 Tuesday, April 8, 1997 17

Equipment Type=OEL PHASEB=ALL PEGLEVEL=10

Plot of LN_CONC*PLT_TYPE. Symbol is value of CLUSTER.



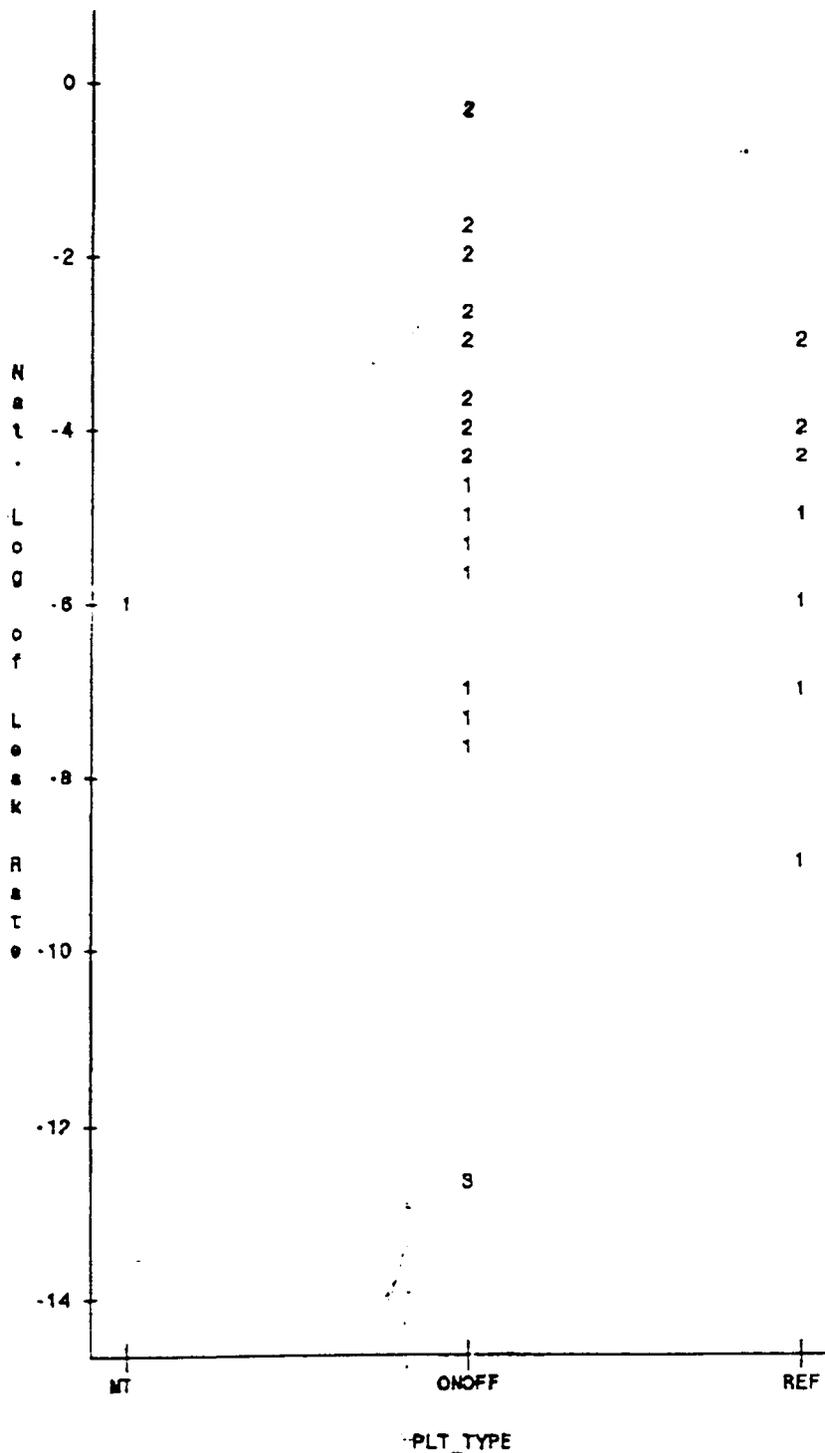
NOTE: 44 obs hidden.

Clusters for 1993 PLANT TYPES data

09:51 Tuesday, April 8, 1997 18

Equipment Type=OEL PHASEB=ALL PEGLEVEL=100

Plot of LN_CONC*PLT_TYPE. Symbol is value of CLUSTER.



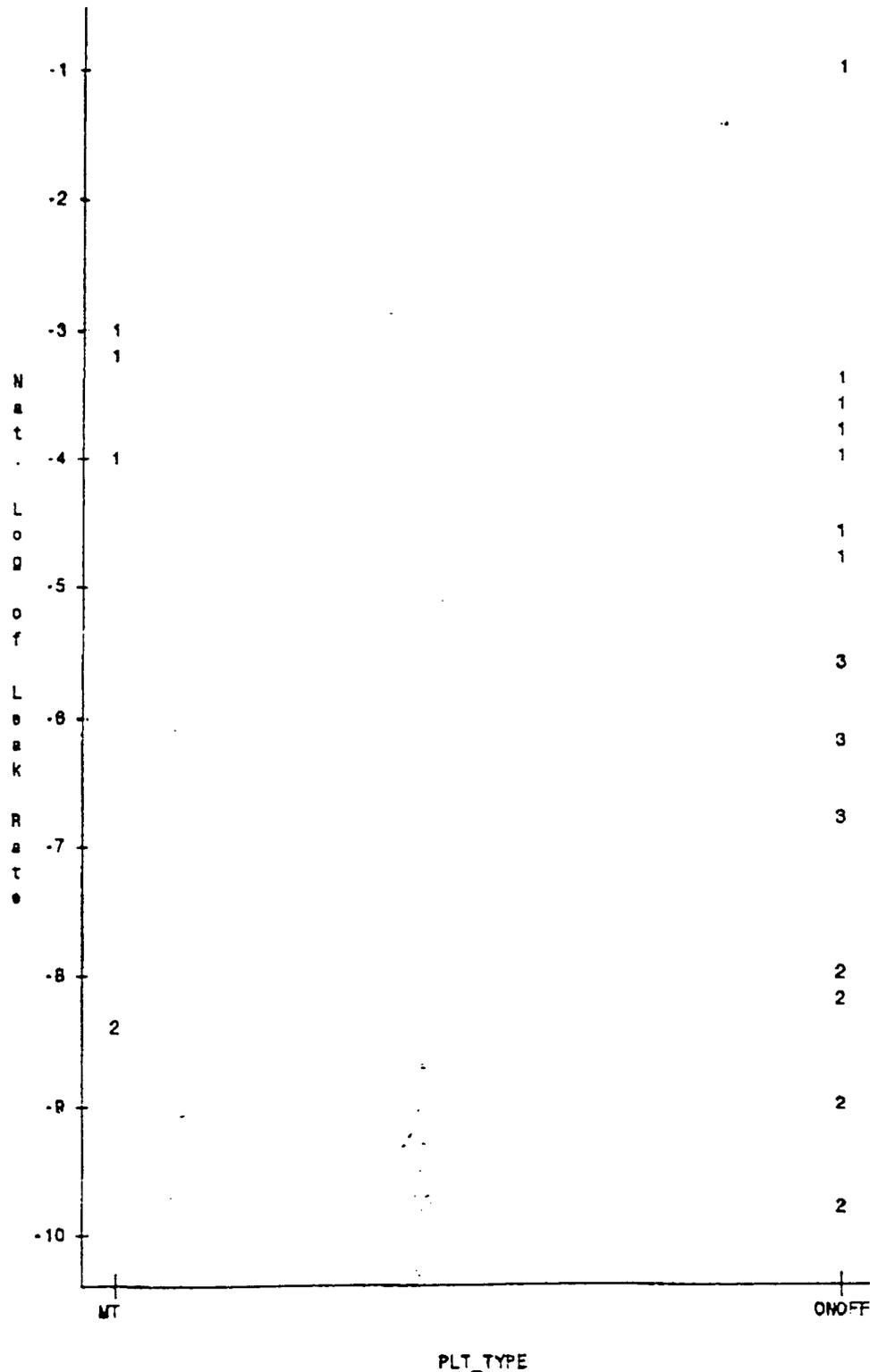
NOTE: 12 obs hidden.

Clusters for 1993 PLANT TYPES data

09:51 Tuesday, April 8, 1997 19

Equipmnt Type=OTHER PHASES=ALL PEGLEVEL=10

Plot of LN_CONC*PLT_TYPE. Symbol is value of CLUSTER.



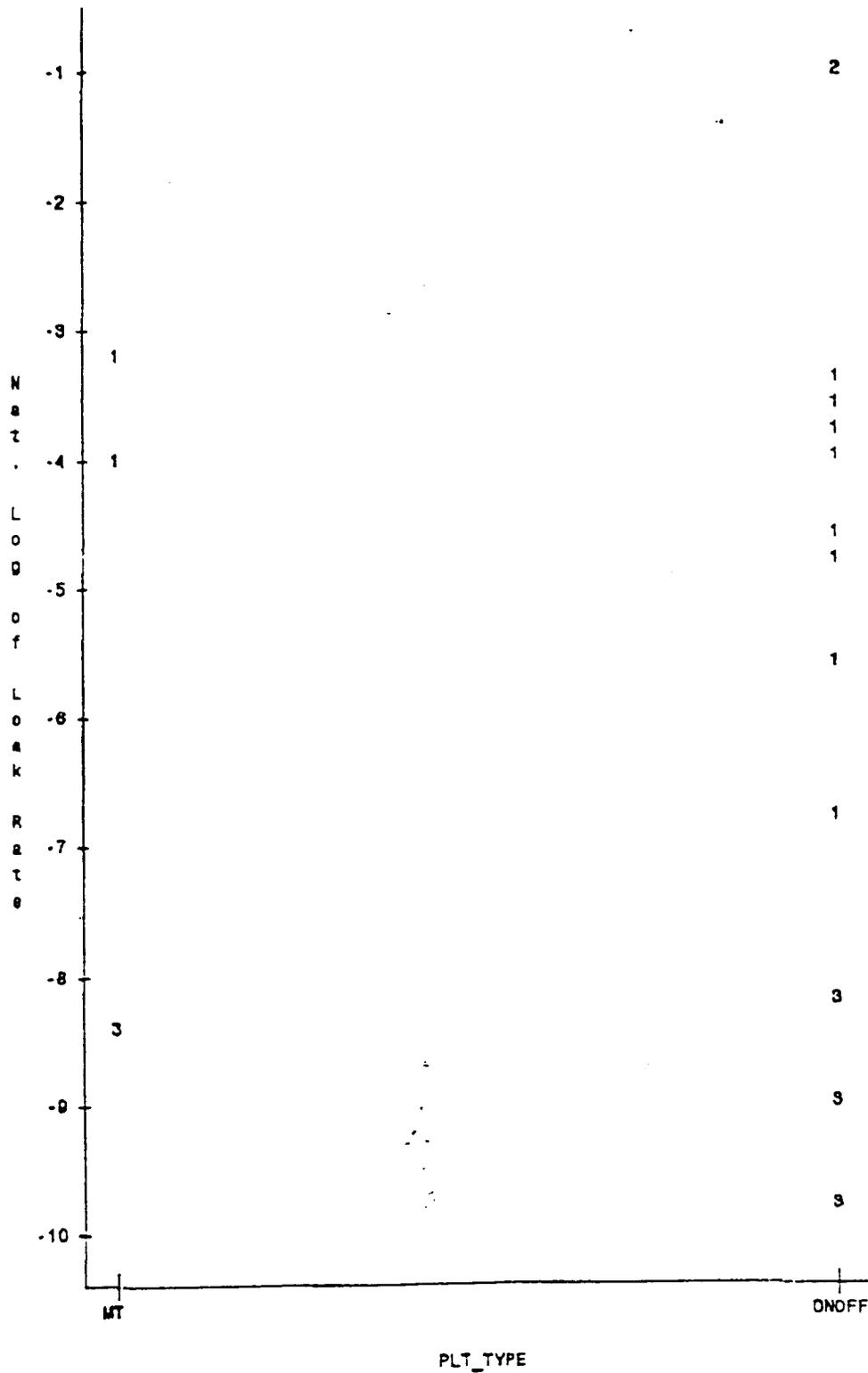
NOTE: 7 obs hidden.

Clusters for 1993 PLANT TYPES data

09:51 Tuesday, April 8, 1997 20

Equipment Type=OTHER PHASES=ALL PEGLEVEL=100

Plot of LN_CONC*PLT_TYPE. Symbol is value of CLUSTER.



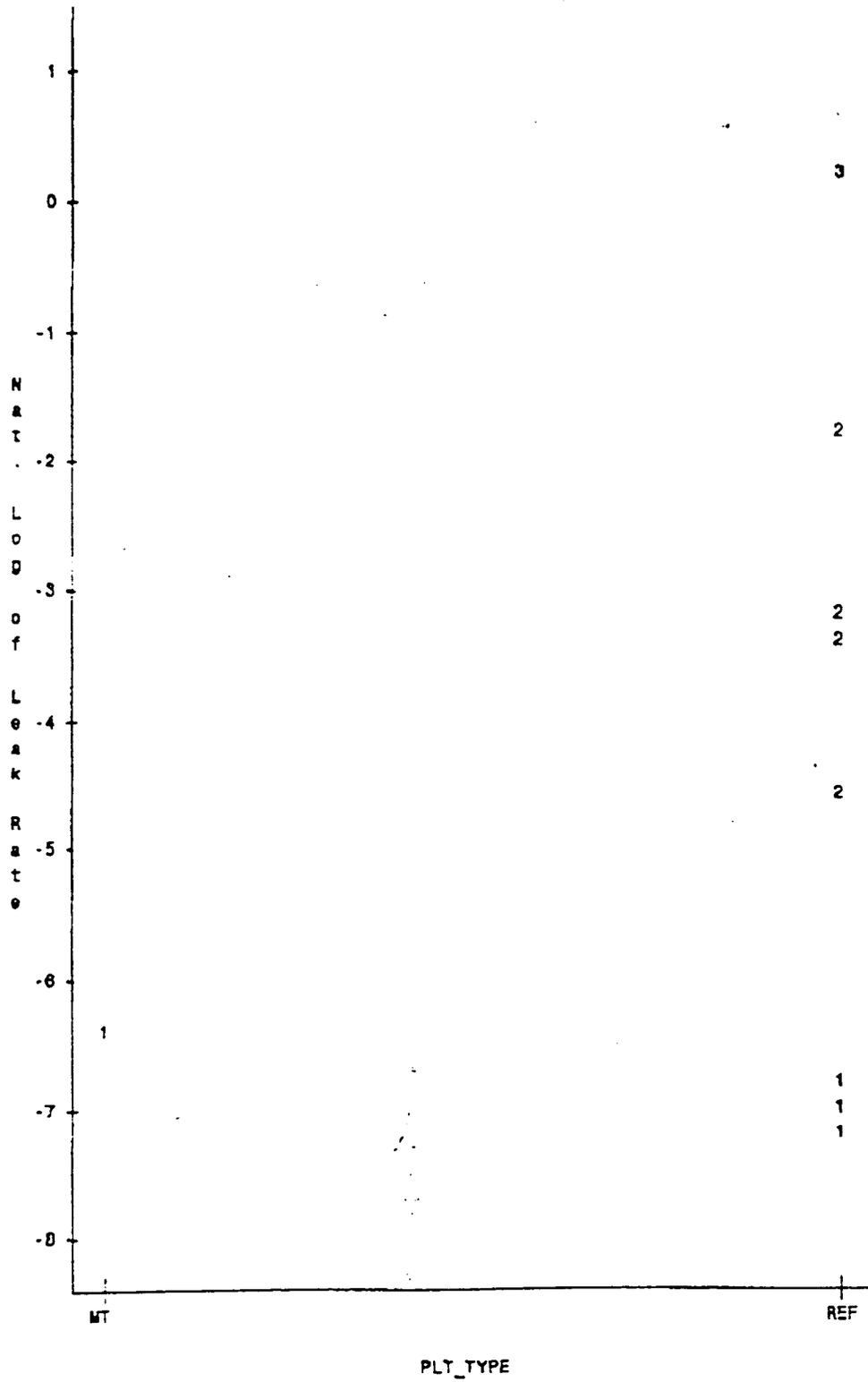
NOTE: 4 obs hidden.

Clusters for 1993 PLANT TYPES data

09:51 Tuesday, April 8, 1997 21

Equipment Type=PUMP PHASES=ALL PEGLEVEL=10

Plot of LN_CONC*PLT_TYPE. Symbol is value of CLUSTER.



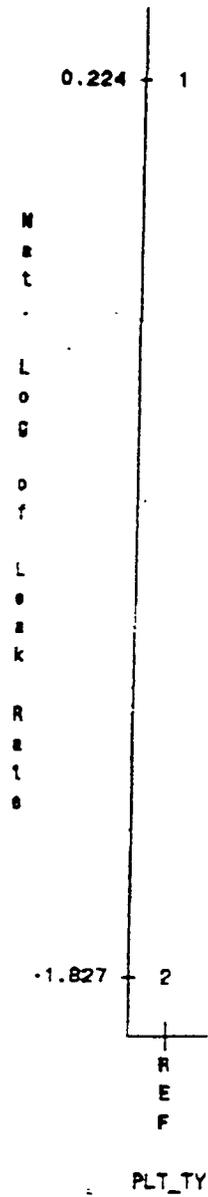
NOTE: 9 obs hidden.

Clusters for 1983 PLANT TYPES data

09:51 Tuesday, April 8, 1997 22

Equipment Type=PUMP PHASEB=ALL PEGLEVEL=100

Plot of LN_CONC*PLT_TYPE. Symbol is value of CLUSTER.



Attachment 4

T-Test Statistical Analysis of Pegged Component Data

T-test on log of leak rates

TTEST PROCEDURE

..... EQ_TYPE=Valve

Variable: L_LKRATE

PL_TYPE	N	Mean	Std Dev	Std Error	Variates	T	Method	DF	Prob> T
Production	136	-4.91712608	2.52975904	0.21692505	Unequal	0.4116	Satterthwaite	122.4	0.6814
Refin./Distrib.	42	-5.04504215	1.44246011	0.22257643			Cochran	.	0.6821
					Equal	0.3120		176.0	0.7554

For H0: Variances are equal, F = 3.08 DF = (135,41) Prob>F = 0.0000

T-test on log of leak rates
 All equipment grouped together - plant types aggregated into Prod./Mktng.

TTEST PROCEDURE

Variable: L_LKRATE

PL_TYPE	N	Mean	Std Dev	Std Error	Variances	T	Method	DF	Prob> T
Production	272	-5.41090854	2.61388999	0.15849036	Unequal	-1.1652	Satterthwaite	203.8	0.2453
Refin./Distrib.	85	-5.11789933	1.79996645	0.19523377			Cochran		0.2463
					Equal	-0.9641		355.0	0.3357

For H0: Variances are equal, F = 2.11 DF = (271,84) Prob>F = 0.0000

T-test on log of leak rates

TTEST PROCEDURE

..... EQ_TYPE=Conn

Variable: L_LKRATE

PL_TYPE	N	Mean	Std Dev	Std Error	Variances	T	Method	DF	Prob> T
Production	46	-6.17691905	2.36365658	0.34850215	Unequal	-1.0944	Satterthwaite	38.5	0.2806
Refin./Distrib.	17	-5.57504828	1.75424612	0.42546718			Cochran	.	0.2859
					Equal	-0.9552		61.0	0.3433

For H0: Variances are equal, F = 1.82 DF = (45,16) Prob>F = 0.1941

..... EQ_TYPE=Flange

Variable: L_LKRATE

PL_TYPE	N	Mean	Std Dev	Std Error	Variances	T	Method	DF	Prob> T
Production	18	-4.97001122	2.71162569	0.63913630	Unequal	0.4565	Satterthwaite	2.5	0.6863
Refin./Distrib.	3	-5.89014814	3.31065425	1.91140712			Cochran	.	0.6894
					Equal	0.5306		19.0	0.6018

For H0: Variances are equal, F = 1.49 DF = (2,17) Prob>F = 0.5065

..... EQ_TYPE=OEL

Variable: L_LKRATE

PL_TYPE	N	Mean	Std Dev	Std Error	Variances	T	Method	DF	Prob> T
Production	54	-6.16685741	2.78131526	0.37848907	Unequal	-1.2504	Satterthwaite	31.4	0.2204
Refin./Distrib.	13	-5.43122414	1.62397683	0.45041013			Cochran	.	0.2277
					Equal	-0.9135		65.0	0.3643

For H0: Variances are equal, F = 2.93 DF = (53,12) Prob>F = 0.0453

..... EQ_TYPE=Other

Variable: L_LKRATE

PL_TYPE	N	Mean	Std Dev	Std Error	Variances	T	Method	DF	Prob> T
Production	18	-5.35717772	2.50489549	0.59040953	Unequal	-0.8027	Satterthwaite	6.9	0.4491
Refin./Distrib.	5	-4.40191647	2.31029903	1.03319714			Cochran	.	0.4594
					Equal	-0.7653		21.0	0.4526

For H0: Variances are equal, F = 1.18 DF = (17,4) Prob>F = 0.9746

APPENDIX A - 4

Letter dated June 11, 1997 from Mark Boese of CAPCOA to Frank Holmes of Western States Petroleum Association, Re: Proposal for Using the Fugitive Emissions Correlation Equations Methodology.



3232 Western Drive
Cameron Park, CA 95682
(916) 676-4323 FAX 0325

PRESIDENT

Mark Boese
San Joaquin Valley

June 11, 1997

Frank Holmes
Western States Petroleum Association
121 Gray Avenue, Suite 205
Santa Barbara, California 93101

PRESIDENT ELECT

Michael Kussow
Shasta County AQMD

PAST PRESIDENT

Peter Hess
Bay Area AQMD

RE: Proposal for Using the Fugitive Emissions Correlation Equations Methodology

Thank you for your May 5, 1997 letter on this subject, articulating WSPA's proposal for an interim agreement to initiate the use of the correlation equation methodology in quantifying fugitive emissions at oil and gas production facilities.

**SECRETARY/
FINANCIAL OFFICER**

Douglas W. Allard
Santa Barbara County APCD

WSPA's five-point proposal for production facilities essentially calls for using the equations and factors detailed in the 1995 EPA Protocol (EPA-453/R-95-017) – after incorporating the corrections to the blowthrough method and issues detailed in Case 8 of ERG's February 27, 1997 memo to EPA – with implementation to follow South Coast AQMD's June 1995 "Guidelines." As you know, CAPCOA and California air districts have expressed several concerns with using the Protocol as written; these concerns have been expressed to EPA and, more recently, to the "correlation equations review group" in the form of letters, teleconference calls, memos and a report.

VICE PRESIDENTS

Norman D. Covell
Sacramento Metro APCD

Ellen Garvey
Bay Area AQMD

Richard G. Johnson
Placer County APCD

Barbara A. Lee
Northern Sonoma APCD

Pat Leyden
South Coast AQMD

Douglas Quetin
Monterey Bay Unified APCD

Ed Romano
Glenn County APCD

Richard Sommerville
San Diego County APCD

On June 5, 1997, the CAPCOA Fugitive Emissions Subcommittee met on this subject and on June 6, 1997 the CAPCOA Engineering Managers Committee further reviewed and discussed your proposal. CAPCOA fully supports the idea of implementing a process for redefining the fugitive emissions and production facilities. We, too, are interested in moving ahead with a workable solution to allow the use of the correlation equation methodology. As such, CAPCOA proposes to implement the following more broadly-based program that addresses production facilities, Marketing Terminals and Refineries, and which includes many of the elements of your proposal:

EXEC. DIRECTOR

Stewart J. Wilson

- A. For Refineries and Marketing Terminals, we will use default zero factors, correlation equations, "pegged at 10,000 ppmv" and "pegged at 100,000 ppmv" factors derived from the pooled data set (as published, and corrected as you suggest for the blow-through

method, where applicable). Additionally, the average factors for Marketing Terminals and screening value range factors for Refineries and Marketing Terminals will be as published in the 1995 Protocol (with any appropriate corrections, as applicable). Average factors will be used to estimate overall emissions from a facility when reliable site-specific data are not available to be used with the correlation equations, default zero and pegged factors. No control credit will be assumed when the average factors are used.

- B. For production facilities, we will use default zero factors and correlation equations up to 10,000 ppmv (pooled data set) and "pegged at 10,000 ppmv" factors (production data set). At its discretion, a district may choose to use default zero factors, correlation equations up to 100,000 ppmv, and "pegged at 100,000 ppmv" factors (pooled data set). Average factors and screening value range factors derived from the production data set will be used. Average factors will be used to estimate overall emissions from a facility when reliable site-specific data are not available to be used with the correlation equations, default zero and pegged factors. No control credit will be assumed when the average factors are used.

The factors and equations discussed above are detailed in Attachment 1 of the Review of the 1995 Protocol (May 1, 1997), except for average factors and screening value range factors for Refineries and Marketing Terminals, which are detailed in the 1995 Protocol. Also, at its discretion, a district may accept the use of site-specific factors (in lieu of average factors) for new projects, provided the facility operator can fully demonstrate, to the satisfaction of the district, that such factors are representative of the emissions of the new project.

To facilitate uniform state-wide implementation, CAPCOA and the Air Resources Board will continue to work on an implementation guideline document. As you know, the target date for completion of this guideline is early September. Some districts already have local implementation guidelines that may be used in the interim in conjunction with the program described above. It is anticipated that all districts will use the CAPCOA/ARB guideline document upon its completion. The issues this guideline will address include, among other things: standardized component counting, reporting, and emissions calculation methods; standardization of hydrocarbon analyzer usage and certification of operators; the role of regulatory agencies in ensuring compliance; and, leak quantification methods for site-specific correlation equation development.

The obvious benefit of this approach is that it will allow the use of the new emissions estimating methodologies in a reasonably short timeframe, while allowing the air districts and other agencies to address the implementation issues associated with the new factors and equations. We hope that you will see the value of implementing this alternative to your proposal. If you would like to discuss this matter further, please feel free to call Peter Cante, Chair of CAPCOA's Engineering Committee at 805/961-8800.

Sincerely,

A handwritten signature in black ink, appearing to read "Mark Boese". The signature is fluid and cursive, with the first name "Mark" being more prominent than the last name "Boese".

Mark Boese, President
California Air Pollution Control Officers Association

cc: Stew Wilson, Secretariat, CAPCOA
Peter Cattle, SBCAPCD
Stan Cowen, VCAPCD
David Dixon, SLOAPVD
Steve Hill, BAAQMD
Mohsen Nazemi, SCAQMD
Seyed Sadredin, SJVUAPCD
Gary Yee, ARB
David Markwordt, EPA

APPENDIX A - 5

Letter dated May 5, 1997 from Frank E. Holmes of Western States Petroleum Association to Mark Boese of CAPCOA.



May 5, 1997

Fugitive Emissions: Correlation
Equations and Average Factors
Endorsement

Mr. Mark Boese
CAPCOA
3232 Western Drive
Cameron Park, CA 95682

Dear Mr. Boese:

It is now approaching six months since Western States Petroleum Association's (WSPA) last corresponded formally with CAPCOA regarding your progress on reviewing and endorsing the EPA Protocol for Equipment Leak Emission Estimates, November 1995. As noted by the March 12, 1997 progress report from the Engineering Manager's Committee, joint CAPCOA, CARB, EPA and industry teleconferences have been and are continuing to take place. However, as Mr. Cantle points out, while progress is being made, concern has been expressed about meeting the scheduled completion of late August. WSPA would like to propose an interim agreement designed to relieve that schedule pressure, while affording affected industry the opportunity to utilize the most scientifically sound emissions calculations tools. We believe that the following proposal could be implemented almost immediately.

WSPA proposes that CAPCOA endorse the following interim Oil & Gas Production Fugitive Emission Calculation Protocol for use by the affected regulated community:

1. Allow use of the EPA November 1995 correlation equations, for screening values up to 100,000.
2. Allow use of EPA November 1995 pegged source factors (10,000 ppm and 100,000 ppm) adjusted for blow through method and other corrections (Case 8, ERG February 27, 1997 memo to EPA)
3. Calculate and allow use of separate pegged source factors for oil and gas production operations without established RACT I&M programs. Where established RACT I&M programs are in place, affected permit holders could use the published EPA November 1995 combined pegged factors (a).
4. Allow use of EPA average factors for new and existing sources which don't have sufficient screening data needed for use of the correlation equations.

Page 2
Mark Boese, CAPCOA
May 5, 1997

Average factors would be applied as "uncontrolled" factors and adjusted according to accepted methodologies (e.g. Texas NSR program control efficiencies).

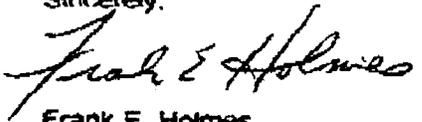
5. Use the South Coast AQMD "Guidelines for Fugitive Emission Calculations, Petroleum Industry", June 1995, for program implementation.

Notes: a) Statistical tests on each of the pegged datasets for production and refining marketing indicate that they can be treated as part of the same data population (i.e., combine the data as EPA did); however, this is subject to technical arguments to the contrary. Santa Barbara County APCD suggested in their March 12, 1997 memorandum that the lack of an I&M program at production facilities could serve as a reason to split the data; therefore, the above approach to use the separate pegged factors only at "uncontrolled" facilities until CAPCOA can technically show otherwise.

Endorsement of the above approach will allow CAPCOA to set a schedule consistent with member agency's available resources and other priority issues. Since the agreement is interim, any new information and findings can be accommodated in the final guidelines. New issues, such as Santa Barbara APCD's concern about the use of the dilution probe use, and existing issues, such as separation of production pegged emission factors, uncontrolled vs. controlled average factors and implementation guidelines, could be thoroughly reviewed and debated by CAPCOA and the regulated community prior to any changes being proposed.

WSPA believes that acceptance of the interim agreement will help mitigate unnecessary change to regulatory measures at high cost with little environmental benefit (e.g. BACT exemption limits, Title V major source determinations, and NSR threshold exceedances and resulting unnecessary permitting, offsets and additional controls). An interim approach offers a win-win situation where the regulators, regulated and the public all benefit. We request that CAPCOA consider this proposal for immediate adoption.

Sincerely,



Frank E. Holmes
Coastal Coordinator

APPENDIX A - 6

Santa Barbara County APCD Draft Report, dated May 1, 1997, entitled: *Review Of The 1995 Protocol: The Correlation Equations Approach To Quantifying Fugitive Hydrocarbon Emissions At Petroleum Industry Facilities*, "SBCAPCD report".

**Review Of The 1995 Protocol:
The Correlation Equation Approach To
Quantifying Fugitive Hydrocarbon Emissions
At Petroleum Industry Facilities**

Prepared by:

**Santa Barbara County Air Pollution Control District
26 Castilian Drive B-23
Goleta, CA 93117**

With Assistance from:

**Mike Webb
STAR Environmental
P.O. Box 2132
St. George, Utah 84771**

May 1, 1997

GOAL

The California Air Pollution Control Officers Association (CAPCOA) is interested in obtaining an accurate picture of the amount of fugitive hydrocarbon emissions from petroleum industry facilities. Using data from studies summarized in the *Protocol for Equipment Leak Emissions Estimates* (EPA-453/R-95-017, of 11/95: "the Protocol"), our goal is to derive equations and factors which, when applied to the refineries, marketing terminals and oil and gas production facilities in the state, neither underestimate nor overestimate fugitive emissions. Underestimation means local air districts may expend less resources than is prudent towards reducing fugitive emissions, while overestimation means districts may expend too many of their limited resources on emissions which do not really exist.

INITIAL FOCUS OF THIS REVIEW OF THE 1995 PROTOCOL

As the lead agency in making this assessment for CAPCOA, the Santa Barbara County Air Pollution Control District's (SBCAPCD) initial focus in reviewing the Protocol was to concentrate on pegged source factor calculations based on data from Refinery and Marketing Terminal components in which the blowthrough bagging method was used in quantifying emissions, to ensure that the process and the numbers it generated were accurate and repeatable. Although we concentrated on Refinery pegged source data, our intent was to apply any significant questions raised by the review to other facility types, measurement methods and screening value ranges.

In our attempts to duplicate the Protocol's pegged source factors for Refineries, we realized that not all data on which the Protocol is based were included with the Protocol. With assistance from the South Coast Air Quality Management District (SCAQMD) and the California Air Resources Board (ARB), we assembled in electronic format full data sets for Refineries, Marketing Terminals and Production facilities. We created summary spreadsheets of data used in the Protocol to create default zero factors, correlation equations, pegged emission factors, screening value range factors and average factors. Using Microsoft Excel, we were able to duplicate the factors and correlation equations given in the 1995 Protocol. See Attachment 1.

Our review of the Refinery and Marketing Terminal bagging data sets identified the need for both apparently minor corrections (e.g., two pegged components were double-counted; eight components had O₂ concentrations greater than the Protocol's 5% criteria at the start or end of bagging; liquid leaks were not included in some calculations, some components were mistakenly omitted from the valid data sets in calculating factors or equations), and major corrections to the calculation method (hydrocarbon leak contributions to sample flow rate; courtesy Mike Garibay at SCAQMD). Triggered by concerns with the pegged source calculations such as those noted above, we reviewed correlation equations and other factors, as well as Production facility data sets, factors and equations. Questions concerning all facility types, and a hardcopy of the data summary spreadsheet (in abbreviated format¹) including the related corrections, are included in Attachment 1. As can be seen from that attachment, these corrections generally create relatively minor changes, on the order of a few percent to about 50 percent. However, as these factors and equations form the basis for quantifying fugitive emissions that air districts use in both planning and inventory billings, it is imperative that they be as precise as the current state of the art allows; changes due to corrections should not be considered as "just noise". Further, although there may be some uncertainty in the data², the

¹ Copies on disk of full files used in this review process are available from SBCAPCD.

² See p. 2-87 of *1993 Study of Refinery Fugitive Emissions from Equipment Leaks*.

corrections make the data no more or less uncertain; the data are either valid, and the corrections should be incorporated into the calculations, or the data are invalid, and should not be used in creating factors and/or equations.

EXPANDED REVIEW

As part of the review process, we realized that we did not fully understand how the Protocol was developed. The flow chart of Attachment 2 summarizes the sequence by which default zero factors, correlation equations, pegged at 10,000 and pegged at 100,000 factors, screening value ranges, and average factors were derived. Review of the chart focused our attention on the following items:

No Screening Values at Refineries: At Marketing Terminals and Production facilities, component screening was performed by third-party contractors according to an EPA-approved plan. At Refineries, components to be bagged were pointed out to the bagging contractor by onsite operators. There was a valid reason for this procedural difference, specifically that the need for Refinery average factors was not anticipated at the time of the study. However, this difference does preclude 1993 Refinery data from being used in the calculation of screening range value factors for Refineries. Refinery factors presented in the Protocol are based on 1980 and 1982 fugitive emissions studies.³

Addition of Data Not Collected for the Protocol: The original screening data at Marketing Terminals for 6161 components were not used in creating screening value range factors or average factors. Instead, additional screening data (for 76,387 components from several API-member Marketing Terminals with I&M programs in place) were coupled with emissions data from all three types of petroleum facilities to create screening value range and average factors.

Differences in Screening Values at Production and Marketing Terminals, vs. Refineries: The second set of Marketing Terminal data had lower proportions of pegged screening values than either the first set from Marketing Terminals or the Production facility set. Of the 76,387 Marketing Terminal screening value data points submitted by API members, only 63 were pegged at 10,000 ppmv (0.08% of the total screened); in the other two data sets gathered by third-party contractors, Marketing Terminals showed 0.58% pegged (about 7 times, proportionally) and Production facilities showed 1.13% pegged (about 14 times, proportionally).

A review of the literature indicates that most often, regulators find more leaks than operators (see p. 5 of *Summary of NEIC Leak Detection and Repair Program Investigations*, EPA Report 330/9-94-001, pp. A-12, A-13, which details that for screening data from 14 Refineries with LDAR programs in place, in all but one case, the facility reported percent leak rate is less than the NEIC determined percent leak rate). The disparities between Production and initial Marketing Terminal facilities “leaker” proportions and “leaker” proportions of the second set of Marketing Terminal data may be based on absence of third-party involvement in leak detection.

³ EPA Report 450/3-82-010, *Fugitive Emissions Sources of Organic Compounds - Additional Information on Emissions, Emission Reductions and Costs*, and EPA Report 600/2-80-075c, *Assessment of Atmospheric Emissions from Petroleum Refineries (1980)*.

Undemonstrated Reliability Of OVAs Equipped With Dilution Probes: At all three facility types - Production, Refinery, and Marketing Terminal - OVAs fitted with dilution probe kits ("dilutors") were used in determining most screening values above 10,000 ppmv (the reading at which OVAs without dilutors "peg"), and leak rates determined by bagging were assigned to such screening values.⁴ Compelling evidence indicates that screening data taken by OVAs fitted with diluter kits are of undemonstrated reliability; the conservative approach is to assign emission leak rates taken on components that screen at over 10,000 ppmv (without dilutor) to the "pegged at 10,000" range only. That is, correlation equations should be employed up to 9,999 ppmv, above which "pegged at 10,000" factors - which incorporate all data points above 10,000 ppmv - should be used. Further discussion on the use of OVAs fitted with dilution probes is provided in Attachment 3.

USING PRODUCTION FACILITY DATA IN CREATING PRODUCTION FACTORS AND EQUATIONS

Review of individual data points at different facility types indicated that subjective choices were made in how data were grouped to create combined emission factors and equations. Examples of these groupings follow; details of the effects are included in the referenced attachments:

Combining Different Process Streams: Data from facilities with very different process stream ROC content were combined to create petroleum industry-wide correlation equations, and pegged factors; see Table 1 of Attachment 4. Refinery heavy liquid (e.g., MEK, toluene, jet fuel, diesel, kerosene) data were grouped with Production heavy liquid (fluids at Production facilities handling thermally enhanced oil recovery oils such as crude oil). See Table 2 of Attachment 4.

Comparison of Leak Rates at Different Facility Types: Mass emission rates of "pegged at 10,000" components at Production facilities average about four times higher than those at Refineries. This may be due to the fact that all Refineries had I&M programs in place, whereas some Production facilities may not have; or to the possibilities that not all Refinery components with screening values over 10,000 ppmv were reported for bagging (some high-end leakers may have been repaired, and therefore not counted in the study); or that there was no third party interest in finding pegged components at Refineries; or to the fact that advance notice was given to sources; or a combination of these and other considerations. See Attachment 4 Table 3.

Refinery Data from Non-Protocol Studies: Bagging data from Production, Marketing Terminal and Refinery facilities were used in creating separate screening value ranges and average factors for Production facilities and Marketing Terminals. Refinery screening value ranges and average factors were derived from the 1980 and 1982 EPA reports noted on the flow chart.

The SBCAPCD, which has numerous oil and gas Production facilities within its jurisdiction, but no Refineries or Marketing Terminals, has calculated and intends to apply factors and correlation equations based on Production data only. This is not the first time such a separation has been performed using the same or similar data; see Radian's memo to EPA.⁵ Further discussion on the merits of creating Production-only factors are provided in Attachment 5.

⁴ Monitoring at Production facilities was performed using both OVA 108s (which peg at 10,000 ppmv), and OVA 88s (which peg at 100,000 ppmv). No diluter kits were used on the OVA 88s.

⁵ Memo dated August 4, 1994, Epperson/Radian to Markwordt/EPA, entitled *Interim Correlations, Default Zero Emission Factors, and Pegged Emission Factors Based on the Results of the Comparison and Analysis of the 1993 Refinery Data, the 1993 Marketing Terminal Data, the 1993 Oil and Gas Production Operations Data, and the 1980 Refinery Data.*

ROC/THC ratios for non-methane, non-ethane ROCs: Several data points in each data set (Refineries, Marketing Terminals, and Production) had zero non-methane or non-methane non-ethane THC. Due to the fact that factor and correlation equations were performed in log space, defining ROC/THC ratios based on the facility data sets is not possible without more subjective decisions. We have chosen not to make those decisions in this paper, and suggest that ROC/THC ratios be based on each air district's standard values, or that sources provide data to document ROC/THC ratios for streams for which they wish to use non-standard ROC/THC ratios.

Following the Criteria: In the early stages of the review process, we reviewed the rationale for and the impact of eliminating blowthrough method data points with certain commonalities, such as high variability in O₂ concentration from start to finish of bagging, high O₂ concentration, and low N₂ flow. Although we are uncomfortable with some data points (all three of the types noted above may contribute to a sample which is not representative of the material in the bag), we feel that there is inadequate information to allow an objective deselection of additional data points.

REVISED EMISSION FACTORS AND CORRELATION EQUATIONS:

Three full sets of factors and correlation equations are presented in Attachment 1: factors and equations for combined facilities (Refinery, Marketing Terminal and Production) both from the 1995 Protocol and corrected, and a similar set of factors and equations for Production facilities only. We recommend that districts with production facilities only use the production facility only factors and equations; combined facility factors and equations are suitable for districts with mixed facilities.

In the Production-only table, it should be noted that only "Pegged at 10,000" pegged factors are provided; a column of factors for "Pegged at 100,000" is not included (i.e., all entries are "NA") because of the above-noted undemonstrated reliability of dilutor-equipped OVAs to distinguish one concentration range from the other. Consequently, we have included data based on all screening values equal to or greater than 10,000 ppmv in the "Pegged at 10,000" factors.

It should be noted that neither the Protocol nor our review considers "weighting" averages for "Pegged at 10,000" and "Pegged at 100,000" factors. This question is discussed further in Attachment 6.

RECOMMENDATIONS FOR FURTHER WORK

Expand The Data Sets: A review of the number of valid data pairs from the 1995 Protocol is shown in Table 1 of Attachment 7. Some component types at Refinery/Marketing Terminal and at Production facilities have fewer than 6 valid data pairs, the criterion specified for the Protocol. We suggest that each data set be expanded to include a minimum of 10 data pairs per component type; see Radian memo.⁶ A draft proposal for this expansion is contained in Attachment 7.

Use "Pegged at 10,000" Factors, and "Weighting": SBCAPCD is unsure of the accuracy of OVAs equipped with dilutor probes, and has demonstrated that an OVA, first without then with dilutor probe,

⁶ Memo dated January 27, 1995, Epperson/Radian to Markwordt/EPA, entitled: *Petroleum Industry Equipment Leaks: Revised Correlations, Default Zero Emission Rates, and Pegged Emission Rates for Estimating VOC Emissions, Developed from 1993 Data from Refineries, Marketing Terminals, and Oil and Gas Production Operations*

can give unpredictable and conflicting results for the same leak. ARB is considering performing a lab study to further evaluate this concern. A preliminary draft of the proposed study is included as Attachment 8.

Create An Implementation Guidelines document: To facilitate uniform and consistent application of the emission factors and equations in this document at petroleum industry facilities in different air districts in California, a statewide implementation guidance document must be created. In late February 1997, SJVUAPCD provided a draft (*Estimating Equipment Leak Emissions*) for CAPCOA's review. In addition, API published a *Calculation Workbook for Oil and Gas Production Equipment Fugitive Emissions* (July 1996). These two documents may be useful in creating the guidance document, which should address the following issues:

- Component count methodology: We recommend that the Protocol be revised to include a clear definition (including pictorial descriptions of each component type) of the component count methodology used at the facilities from which the Protocol draws its data. Absent such revision, the guidelines should include that definition, to ensure that facility component counts duplicate the methodology used in quantifying fugitive emissions for the 1995 Protocol.
- I&M program reduction efficiencies: The need for the use of average factors at major facilities in the state is not known. As average factors are the only factors or equations to which I&M program reduction efficiencies can be applied, we do not see the need to define in this document a set of arbitrary reduction efficiencies, and suggest that future industry requests for reduction efficiencies be handled on a case-by-case basis.

The Air Resources Board and several local air districts are creating a draft guidelines document at this time.

OVA Operator Training and Certification: To ensure that all operators are trained in the use of OVAs - including when the use of diluter kits is acceptable - we recommend that a training program be established, similar to the Visible Emissions program or the California smog check program, to include certification by ARB or by local districts. Additionally, the implementation guidelines document or an "OVA Certification Agreement" should clarify under what circumstances a certificate is to be revoked (e.g., if district inspectors following close behind a certified OVA operator find >10% more "pegged at 10,000" leakers, or find more than 20% difference in more than 10% of the total components read in a day).

BIBLIOGRAPHY

API/Rockwell International study dated March 1980, *Fugitive Hydrocarbon Emissions from Petroleum Production Operations, Vols. I and II*.

EPA Report 450/3-82-010, *Fugitive Emissions Sources of Organic Compounds - Additional Information on Emissions, Emission Reductions and Costs*, and EPA Report 600/2-80-075c, *Assessment of Atmospheric Emissions from Petroleum Refineries (1980)*.

Development of Fugitive Emission Factors and Emission Profiles for Petroleum Marketing Terminals. (API document 4588, of 3/93; aka "Marketing Terminal Study").

Fugitive Hydrocarbon Emissions from Oil and Gas Production Operations (API Pub. No. 4589, of 12/93).

1993 Study of Refinery Fugitive Emissions from Equipment Leaks. (aka "1993 Refinery Study"). (Radian document of 2/94; we do not have the official 4/94 API document).

Summary of NEIC Leak Detection and Repair Program Investigations (EPA-330/9-94-001, of 1/94).

Memo dated August 4, 1994, Epperson/Radian to Markwordt/EPA, entitled *Interim Correlations, Default Zero Emission Factors, and Pegged Emission Factors Based on the Results of the Comparison and Analysis of the 1993 Refinery Data, the 1993 Marketing Terminal Data, the 1993 Oil and Gas Production Operations Data, and the 1980 Refinery Data*.

Emission Factors for Oil and Gas Production Operations (API publication 4615, of 1/95; aka "Production Facility Study").

Memo dated January 27, 1995, Epperson/Radian to Markwordt/EPA entitled: *Petroleum Industry Equipment Leaks: Revised Correlations, Default Zero Emission Rates, and Pegged Emission Rates for Estimating VOC Emissions. Developed from 1993 Data from Refineries, Marketing Terminals, and Oil and Gas Production Operations*

Protocol for Equipment Leak Emissions Estimates (EPA-453/R-95-017, of 11/95; aka "1995 Protocol").

ATTACHMENTS (By request only - 11/1998)

1. EPA Protocol and SBCAPCD Corrected Databases (includes existing and revised Tables C-3)
 - Default Zeros
 - Correlation Equations
 - Pegged at 10,000 ppmv
 - Pegged at 100,000 ppmv
 - Average Factors
 - Screening Value Range Factors
 - Tables C-3 (from Protocol; Combined; Production-only)
2. Flowchart
3. Analysis of Dilution Probe Failure Potential
4. Tables
 1. Comparison of Non-Methane HC Leaks
 2. Refinery Bagging Data for Heavy Liquid (aka Heavy Oil)
 3. Comparison of Arithmetic Average of Leak Rates for Pegged at 10,000 components
5. Justification for Developing Production Pegged Source Factors Exclusively from Production Data
6. Suggestions for Improving Pegged at 10,000 ppmv Factors
7. Proposal to Expand Data Sets by Gathering Additional Fugitive Emissions Data
8. Proposed Guidelines for Testing Foxboro OVA Equipped With Dilution Probe

APPENDIX A - 7

Memorandum dated February 27, 1997 from David Epperson of Eastern Research Group to David Markwordt of U.S. EPA, Re: Draft Analysis of Alternative Mass Emission Calculation methods for the Blow-Through Bagging Method.



Eastern Research Group, Inc.

COPY

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Software Applications
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Technology Evaluation

Environmental
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MEMORANDUM

TO: David Markwordt, U.S. Environmental Protection Agency, Chemicals and Petroleum Branch, MD-13, Durham, NC

FROM: David Epperson, Eastern Research Group, Morrisville, NC

DATE: February 27, 1997

SUBJECT: Draft Analysis of Alternative Mass Emission Calculation Methods for the Blow-Through Bagging Method

Introduction

A comparison analysis was recently undertaken by the U.S. Environmental Protection Agency (EPA) to evaluate the effects of some alternative mass emission calculation methods for the blow-through bagging method. (In the blow-through method, an equipment piece is enclosed with a bag, and an inert carrier gas, such as nitrogen, is blown into the bag). The primary reason for this comparison analysis is because concerns have been raised that the total hydrocarbon (THC) content of the bag was not fully accounted for in calculations for petroleum industry data that were presented in the 1995 Protocol (U.S. EPA, November 1995). The primary objective of this draft memorandum is to present the results of the comparison analysis and to describe the technical details of the alternative calculations methods. Further analysis may be necessary to fully understand the results.

In the comparison analysis, mass emissions calculated from alternative calculation methods were compared to emissions reported in the 1995 Protocol. Also, pegged emission rates using mass emissions calculated from alternative calculation methods were compared to the pegged emissions rates reported in the 1995 Protocol. A number of technical issues regarding the calculations and specific data points are also addressed in this memorandum.

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DRAFT

In order to efficiently prepare this memorandum, all tables and figures are presented in Appendices A and B, respectively, which are located at the end of the memorandum. Correspondence regarding calculations used in this analysis is reproduced in Appendix C through Appendix G. Statistical Analysis System (SAS) programs used to generate the analyses are reproduced in Appendix H and Appendix I. A brief table of contents is presented below, to help navigate this memorandum.

Table of Contents

Introduction	1
Table of Contents	2
Overview of Results	2
Overview of Alternative Emission Rate Calculation Methods for the Blow-through Method ...	3
Methodology	5
• <i>Calculation Methodology for 1995 Protocol Mass Emission Rates</i>	5
• <i>Special Cases for Calculating 1995 Protocol Emissions</i>	8
• <i>Methodology for Alternative Mass Emission Rate Calculations</i>	11
• <i>Other Calculation Issues and Resulting Alternative Data Scenarios</i>	11
Results	12
• <i>Comparison of Adjusted versus Reported for Individual Equation Terms</i>	12
• <i>Comparison of Alternative Calculations of Mass Emission Rates</i>	13
• <i>Comparison of Pegged Emission Rates Resulting from Alternative Calculations of Mass Emission Rates</i>	14
References	17
Appendices (By request only - 11/1998)	
• Appendix A: Tables	A-1
• Appendix B: Figures	B-1
• Appendix C: Russ Henning email (1/09/97), Identification of Appropriate SAS Variables and Issues for Mass Emission Calculations	C-1
• Appendix D: Russ Henning email (2/03/97), Typical Value for RHO for Calculation of Dripping Portion of Mass Emissions for Dripping Components	D-1
• Appendix E: Russ Henning fax (1/21/97), Revised Emission Rates for Dripping Components at Refineries	E-1
• Appendix F: Basis for Protocol Adjustment (SCAQMD, April 1995)	F-1
• Appendix G: Russ Henning memorandum (2/14/97), Correcting the Fugitive Emission Rates to Account for the HC Flow	G-1
• Appendix H: Listing of SAS Program RMO96.SAS	H-1
• Appendix I: Listing of SAS Program DZPEG96.SAS	I-1

Overview of Results

Two basic types of comparisons were made to aid in evaluating the differences between alternative mass emission calculation methods and the methods used in the 1995 Protocol. In the first comparison, the average pegged emission rates and 95% confidence intervals reported in the

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1995 Protocol were plotted against the average pegged emission rates and 95% confidence intervals resulting from the alternative calculation methods. These plots (Figures B-23 through B-33) showed that visually the differences were small, because the average pegged emission rates from alternative calculation methods fell near the center of the 95% confidence intervals reported in the 1995 Protocol. In the second comparison, differences were quantified by showing the percent differences between the pegged emission rates calculated using alternative methods and those reported in the 1995 Protocol. For the alternative calculation methods of most interest, the percent differences from the 1995 Protocol values for the pegged at 10,000 ppmv emission rates were as large as 48% for pumps, but more generally the differences were less than $\pm 20\%$ (Figure B-34). For the pegged at 100,000 ppmv emission rates the differences were as large as 28% for flanges, but more generally the differences were less than $\pm 15\%$ (Figure B-35). Plots showing the percent differences versus the sample size suggest that the largest percent differences may be a result of the increased sample size error associated with small sample sizes. Thus, even though the percent differences between pegged emission rates using alternative calculations and those presented in the 1995 Protocol approached 50% in the worst cases (for the alternative methods of greatest interest), the pegged emission rates resulting from alternative calculations were still near the center of the 1995 Protocol confidence intervals. This indicates that the overall variability of the pegged emission rates, as exemplified by the confidence intervals, is far greater than differences between the 1995 Protocol and alternative calculation methods.

Overview of Alternative Emission Rate Calculation Methods for the Blow-through Method

Eight alternative mass emission calculation methods were considered in the comparison analysis. A calculation method identification (ID) number was assigned to each alternative method to provide a consistent reference to each method throughout the memorandum, and to provide a convenient mechanism for plotting the results. A benchmark method ID number of zero was assigned to the results presented in the 1995 Protocol (U.S. EPA, November 1995). Each of the eight alternative calculation methods are briefly discussed in this section.

The first alternative method (method ID=1) does not refer to any changes in calculations, rather it was used to represent the inclusion of revised mass emission data for six dripping components (Henning, 1/21/97). These revised data were not provided to the EPA for use in the 1995 Protocol. Data for this method are referred to as "reported emissions" for the remainder of this memorandum. A comparison of results using the revised emissions from the dripping components is necessary because these components were used in the pegged emission rate calculations. Two comparisons with the results from this method are of interest. First, a comparison to the results presented in the 1995 Protocol will identify differences induced by the revised dripping component emissions. Secondly, comparisons to method ID number 2 (below) will verify that the emissions data reported in the 1995 Protocol can be replicated using calculations for the blow-through method described in the 1995 Protocol.

The second alternative method (method ID=2) represents a verification of the emissions reported in the 1995 Protocol, using the blow-through method as described in the 1995 Protocol (U.S. EPA, November 1995). For the remainder of this memorandum, data from this method are

DRAFT

referred to as “calculated emissions”, and data from subsequent methods are referred to by the specific adjustment for the particular method. Because all subsequent calculation methods rely on adjustments to certain portions of the mass emission calculations, method 2 was set aside for comparisons to the remaining alternative methods, after first verifying that emissions data reported in the 1995 Protocol could be replicated.

In the third alternative method (method ID=3), the bag THC content was adjusted for background concentration, as described in the 1995 Protocol for the blow-through method (U.S. EPA, November 1995). This adjustment was not performed on data supplied to the EPA for use in the 1995 Protocol, because background bags were not collected. This method is referred to as the “background adjustment” for the remainder of this memorandum. A surrogate for background bags, the screening value measured from the OVA, was used to evaluate the potential impact of adjusting for background. The expected impact on calculated emissions for this method is a reduction of emissions, because the bag THC content is being reduced by the background amount.

The fourth alternative method (method ID=4) is one of two methods of greatest interest in the overall comparison analysis, because the adjustment performed in this method prompted many of the recent concerns. In this method, referred to as the “Q-adjustment” for the remainder of this memorandum, the flow rate out of the bag was adjusted to include the THC content of the outflow (API, April 1994). It is expected that this adjustment will increase emissions, with the biggest impact on equipment pieces with the largest leaks.

In the fifth alternative method (method ID=5), the adjustments from methods 3 and 4 are combined. That is, the bag THC content was first adjusted for background, and then the flow rate out of the bag was adjusted to include the THC content of the outflow.

The sixth alternative method (method ID=6) uses the adjustment that accounts for the total flow through the bag, which was described in the 1995 Protocol (U.S. EPA, November 1995) for the blow-through method. This is referred to as the “protocol adjustment” for the remainder of this memorandum. The basis for the protocol adjustment (SCAQMD, April 1995) is shown in Appendix F. Preliminary analyses performed by the EPA showed that this adjustment impacted resulting emission rates by 15% or less, with an average of only 5%. Therefore, the mass emissions data were not adjusted for correlation equations, default zero emission rates, or pegged emission rates in the 1995 Protocol. It is expected that this adjustment will increase emissions, with the biggest impact equipment pieces with the largest leaks.

In the seventh alternative method (method ID=7), the adjustments from methods 4 and 6 were combined. That is, the flow rate out of the bag was first adjusted to include the THC content of the outflow (Q-adjustment), and then the protocol adjustment was applied to the resulting mass emissions.

The eighth alternative method (method ID=8) is the second of two methods of greatest interest in the overall comparison analysis, because it is an enhancement of method 4, and is referred to as the “all-adjustment” for the remainder of this memorandum. The all-adjustment results from rearranging the mass emission calculation that contains the Q-adjustment for the blow-through

DRAFT

method, and canceling terms (Henning, February 14, 1997). It also contains modifications for the nitrogen fraction of the diluent stream and for the calculation of the bag molecular weight. It is expected that this adjustment will increase emissions, with the biggest impact equipment pieces with the largest leaks.

Methodology

One result of the QA/QC analyses shown in Appendix A of the January 1995 technical memorandum from David Epperson, Radian, now at Eastern Research Group (ERG), to David Markwordt, U.S. EPA (Epperson, January 1995) that impacts the current investigation was that the EPA was unable to precisely recalculate the reported mass emission rates. The magnitude of the differences was relatively small, and was attributed to a few special case calculations and rounding. However, in order to perform the adjustments discussed in this memorandum, certain elements of the mass emission calculations need to be extracted, adjusted, and re-entered into the overall calculation. Thus, the first step in performing these adjustments was to precisely calculate and match the reported mass emission rates, so that when a particular adjustment was made, its impact could be evaluated without the influence of other confounding errors resulting from approximations or unknown circumstances in the mass emission calculations. In order to do this, several steps were performed to isolate differences between calculated and reported mass emission rates, and to identify how to reconcile the differences. As this process unfolded additional questions arose and were addressed.

Ron Ricks and Russ Henning (Radian, Sacramento) were consulted regularly during the analysis because of their knowledge of the refinery and marketing terminal datasets. Initially they were consulted to identify and verify the appropriate data fields (i.e., variables in SAS datasets or column names in Excel spreadsheets used by the Santa Barbara County Air Pollution Control District, SBAPCD) used in the mass emission calculations. As further questions arose, they were consulted to explain or provide guidance regarding questions about specific data points or calculation issues. During this process some memoranda, emails, and faxes were transmitted that will be referenced in the following discussion.

Mass emission rates were calculated for each alternative calculation method and data scenario described in this section, and the resulting emissions were compared to one another. Pegged emission rates were also calculated, following the same methodology used in the 1995 Protocol, and the resulting pegged emission rates were compared to one another. Specific calculation methods, data scenarios, and technical issues relating to the calculations are described in this section.

Calculation Methodology for 1995 Protocol Mass Emission Rates

Table A-1 shows the mass emission calculation for the blow-through method, as shown in the 1995 Protocol (U.S. EPA, November 1995). However, the protocol adjustment term has been inserted into the more appropriate location in the equation to adjust only the non-dripping portion, rather than at the end of the equation, where both the dripping and non-dripping portions

DRAFT

were shown to be adjusted in the 1995 Protocol. Table A-2 shows the contents of the refinery and marketing terminal SAS datasets received by the EPA in January 1994, including detailed descriptions for each SAS variable, corresponding SBAPCD Excel spreadsheet column headers, mathematical formulas for calculating certain variables, and other information relating to how EPA processed the data. Additional SAS variables used in the current analysis are also included in Table A-2, which can be used as a central glossary of terms and definitions for this memorandum. Certain portions of the information presented in Table A-2 have been reproduced in other sections of this memorandum to emphasize specific points, when necessary.

An email from Russ Henning (1/09/97), shown in Appendix C, describes SAS variable names in the refinery and marketing terminal SAS datasets, and addresses related issues, for the mass emission calculation terms shown in Table A-1. Mass emissions from refineries and marketing terminals were calculated with slightly different terms than those defined in Table A-1 (API, April 1994; and API, March 1993). The hydrocarbon concentration was combined with the diluent gas flow rate through the bag by converting the molar concentration of the mixed hydrocarbons measured by the flame ionization detector (FID) into parts per million by weight (ppmw), using the molecular weight of the calibration gas. The molecular weight of the diluent stream plus hydrocarbons in the bag was multiplied by the hydrocarbon concentration in ppmw, instead of the molecular weight of the organic compounds in the bag, as defined in Table A-1.

Relevant information from the Table A-1, SAS datasets (and Excel spreadsheets), and the Russ Henning email (1/09/97) are summarized below:

$$\text{1995 Protocol Mass Emission Rate (kg/hr)} = \left[\left(\frac{1.219 \times 10^{-5} (Q) (MW) (GC)}{T + 273.15} \right) \times \left(\frac{10^6 \text{ppmv}}{10^6 \text{ppmv} - GC} \right) \right] + \left[\frac{(\rho) (V_L)}{16.67 (t)} \right] \quad (1)$$

- TERM "Q": Flow rate out of bag (m³/hr). Referred to by SAS variable named "Q" and Excel spreadsheet column named "Q, m3/hr". The reported SAS value has not been adjusted to include the THC content of the outflow, but has been nitrogen- and oxygen-adjusted, per the 1995 protocol requirement. The reported Q is resolved to 2 decimal positions.
- TERM "N₂": Nitrogen flow rate (l/min). Referred to by SAS variable named "N2_L" and Excel spreadsheet column named "N2, l/min".
- TERM "O₂": Bag oxygen concentration (%). Referred to by SAS variable named "O2" and Excel spreadsheet column named "Ave, O2%".

DRAFT

- TERM "MW": Molecular weight (MW) of organic compounds in the sample bag or alternatively in the process stream contained within the equipment piece being bagged (kg/kg-mol). In the case of the refinery and marketing terminal data, this MW represents the molecular weight of the diluent (N₂ and O₂) plus the hydrocarbons of the total bag exhaust. Referred to by SAS variable named "MW_BAG" and Excel spreadsheet column named "MW, Bag".
- TERM "GC": Sample bag organic compound concentration (ppmv), corrected for background bag organic compound concentration (ppmv). If a background bag is not collected, assume the background concentration is zero ppmv. The Henning email (1/09/97) indicates that GC was *not* adjusted for background concentration in either the refinery or the marketing terminal datasets. Referred to by SAS variable named "THC_PPM" and Excel spreadsheet column named "THC, ppmv(C3H8)". Data from marketing terminals A, B, and D, required an initial adjustment for mislabeled propane canisters containing 35% more propane than indicated on the label (API, March 1993); therefore, the THC (ppmv) value above was multiplied by 1.35 to account for this problem. For the refinery and marketing terminal data, adjustments for the calibration gas were made to GC as follows (API, April 1994; and API, March 1993):

$$\text{THC (ppmw)} = \text{THC (ppmv)} \times \left(\frac{\text{calibration gas MW}}{\text{diluent+THC gas MW}} \right)$$

The calibration gas was always propane, which has a molecular weight of 44.1. The diluent+THC gas MW is referred to by the SAS variable name "MW_BAG" and by the Excel spreadsheet column name "MW, Bag".

- TERM "T": Temperature in the bag (°C). Referred to by SAS variable named "TEMP_F" (Fahrenheit) and by Excel spreadsheet column named "Avg., deg F". The Fahrenheit temperature must be converted to degrees Celsius for use in the emission calculations.

"Protocol Adjustment" This term was recommended for the 1995 Protocol, but was not applied to the petroleum industry mass emission rate calculations:

Term:

$$\left(\frac{10^6 \text{ppmv}}{10^6 \text{ppmv} - \text{GC}} \right)$$

DRAFT

- TERM “ ρ ”: Relevant only if component is dripping, density of organic liquid collected (g/ml). Not included in the SAS datasets or Excel spreadsheets. In the email from Russ Henning (2/03/97), shown in Appendix D, a value of 0.747 is recommended as a close approximation for what was actually used.
- TERM “ V_L ”: Relevant only if component is dripping, this term represents the volume of dripping liquid collected (ml). Referred to by SAS variable named “COMMENTS” (for drippers, this variable included a reported collection rate of ml/min—the numerator represents V_L) and Excel spreadsheet column named “Comment”.
- TERM “t”: Relevant only if component is dripping, this term represents the time in which dripping liquid was collected (min). Referred to by SAS variable named “COMMENTS” (for drippers, this variable included a reported collection rate of ml/min—the denominator represents t) and Excel spreadsheet column named “Comment”.

Special Cases for Calculating 1995 Protocol Emissions

During the initial efforts to match the calculations of the reported mass emission rates for refineries and marketing terminals, it became apparent that several special cases were involved. The SAS program, RMO96.SAS, listed in Appendix H, contains comments and programming to address these special cases. Listed below are these cases, and a description of the solutions for addressing them:

- Tracor instrument readings (ppmw) were used instead of the usual Byron instrument readings (ppmv) for marketing terminal sample IDs 7099, 7102, 7108, 7120, 7121, 7131, 9003, 9039, 9042, 9054, and 9059. Comments associated with these sample IDs indicate that the Tracor readings were used to calculate mass emissions or that other instruments were off scale.

Solution: These sample IDs were singled out and the GC was assigned the Tracor value. First the ppmv value was back calculated from the reported ppmw value, using the following equation, which was rearranged from the diluent+MW adjustment, shown for the GC term in Equation (1) above:

$$\text{THC (ppmv)} = \text{THC (ppmw)} \times \left(\frac{\text{diluent+THC gas MW}}{\text{calibration gas MW}} \right)$$

The calibration gas was always propane, which has a molecular weight of 44.1. The diluent+THC gas MW is referred to by the SAS variable name “MW_BAG” and by the Excel spreadsheet column name “MW, Bag”. Data from marketing terminals A, B, and

DRAFT

D, did not require the adjustment for mislabeled propane canisters (API, March 1993) when Tracor readings were used. The THC value in units of ppmv was used for the case of adjusting Q for the THC content of the bag outflow, and for the all-adjustment. The GC was then assigned in the same manner as when using the Byron readings. See term "GC" for equation (1) discussion for details.

- Reported mass emission rates for six refinery dripping components have been revised. These revisions are shown in Appendix E (Henning, 1/21/97) and impact sample IDs 1066, 1077, 3005, 3009, 3010, and 3017.

Solution: Another SAS variable, CONC93KG, was created to retain the original reported mass emission rates received by the EPA in January 1994. The revised mass emission rates were then assigned to the SAS variable, CONC_KG, that was used in the development of correlations, default zero emission rates, and pegged emission rates. The revisions were also assigned to the SAS variable, THC_HR, which was the original name of the variable for the reported mass emission rates and because "THC_HR" also forms the root of all the SAS variable names for the alternative mass emission calculation methods.

- The volume of the sample and time in which the sample was collected were not reported for dripping components as individual data fields readily available to the mass emission calculations.

Solution: Because only six dripping components were identified, these values were hard-wired into the SAS program, RMO96.SAS, and thus became readily available variables for use in calculations.

- Adjustments for mislabeled propane gas canisters containing 35% more propane than indicated on the label, were not made for some of the marketing terminal data.

Solution: Marketing terminals A, B, and D required this adjustment (API, March 1993) and were therefore singled out and the Byron (ppmv) value was multiplied by 1.35. For the cases where the Tracor readings were used instead of the Byron readings, the Tracor readings were not adjusted, because they were calibrated for individual species, not propane.

- Adjustments for background concentration were not made to the laboratory instrument readings of THC concentrations for all refinery and marketing terminal data.

Solution: A special case was constructed to carry out this adjustment and to compare to the other alternative methods for calculating mass emissions (this background adjustment

DRAFT

case is referred to as calculation method ID number 3; see the section describing the overview of alternative calculation methods above) .

- The reported Q was rounded to two decimal positions, inducing differences as large as 15% from the precise Q needed for the mass emission calculations. Figure B-1 shows a plot of the reported Q versus the calculated Q. The Pearson correlation coefficient, 0.9989, shows that the two are highly correlated, but not 100%. The percent differences between the calculated and reported Q, for each data sample, are shown in Figure B-2. The percent differences ranged from -9.4% to +15.1%, and the average percent difference was 0.2%. Figure B-3 shows a plot of the reported Q versus the calculated Q, which was rounded to two decimal positions for this comparison. The Pearson correlation coefficient, 1.0000, shows that the two are 100% correlated, and there were no differences between the reported Q versus the calculated, rounded Q. This example demonstrates the necessity of retaining all decimal precision while performing calculations (rounding error can be as large as 15%), especially for terms used in a calculation before the final result. Only the final result should be rounded, if rounding is desired.

Solution: Calculate Q and use the calculated value, with its full decimal precision, in the appropriate places in the mass emission rate calculations, and in the calculations requiring an adjustment of this term.

- Some Byron instrument readings were reported in units of ppmw, instead of ppmv, which was needed for adjustments accounting for THC content of the bag outflow.

Solution: Byron readings in ppmv were back calculated from the ppmw values as follows, using the following equation, which was rearranged from the diluent+MW adjustment, shown for the GC term in Equation (1) above:

$$\text{THC (ppmv)} = \text{THC (ppmw)} \times \left(\frac{\text{diluent+THC gas MW}}{\text{calibration gas MW}} \right)$$

The calibration gas was always propane, which has a molecular weight of 44.1. The diluent+THC gas MW is referred to by the SAS variable name "MW_BAG" and by the Excel spreadsheet column name "MW, Bag".

- The ambient temperature was not reported for all marketing terminals and for some of the refinery data. This temperature value is preferred for the all-adjustment method for calculating mass emissions (Henning, 2/14/97).

DRAFT

Solution: When ambient temperature was not available or not reported, the average bag temperature was used instead. Whichever temperature was used, it was converted to degrees Celsius before inserting into the equation.

All of the above special cases had to be researched and hard-wired into the mass emission rate calculation algorithms. These special cases also had to be considered for the alternative mass emission calculations.

Methodology for Alternative Mass Emission Rate Calculations

Table A-3 provides a concise overview of all emission rate calculation methods (including the names of the SAS variables used in the calculations) that were examined in this memorandum. Mass emissions were calculated for each of the methods that are shown in Table A-3. Because these methods were described in an earlier section of this memorandum, the descriptions will not be repeated in this section.

Other Calculation Issues and Resulting Alternative Data Scenarios

Three other issues arose during the analysis that necessitated the exclusion or inclusion of certain data points. These three issues, along with the case of not considering any of them, are referred to as “alternative data scenarios” in this memorandum. As with the different calculation methods, where each method was assigned a method ID code, the four alternative data scenarios were assigned codes to provide a consistent reference to each alternative data scenario throughout the memorandum, and to provide a convenient mechanism for plotting the results. Listed below are the alternative data scenario IDs, along with a short description of each, and the identification of the data points referred to:

- (1) *Alternative data scenario ID=0.00* – This code is for the benchmark scenario, using all data exactly as used in the 1995 Protocol.
- (2) *Alternative data scenario ID=0.25* – Data points with high O₂ readings were excluded from all calculations (average O₂ readings of 5.0 or larger were excluded). Table A-4 shows the data points with initial, final, or average O₂ readings 5.0 or larger.
- (3) *Alternative data scenario ID=0.50* – Dripping components were included in all of the calculations for the 100,000 ppmv pegged emission rates (drippers were only included for the 10,000 ppmv pegged emission rate in the 1995 protocol). There are only six dripping components and they are identified, along with other pertinent information, in Table A-5.
- (4) *Alternative data scenario ID=0.75* – Data points that were inadvertently omitted from the pegged emission rate calculations in the 1995 Protocol, where the SAS variable DATACODE is equal to “CORREQ/PEG/SVVAR/BKGD” (see Table A-2 for details

DRAFT

regarding DATACODEs) were included in all calculations. Table A-6 lists the two data samples assigned this value for DATACODE.

Each of the above four alternative data scenarios were applied to the eight different calculation methods, so that a total of 32 different mass emission rates were calculated and compared.

Results

Results are presented in tables and figures, located in Appendix A and Appendix B, respectively. Only limited discussion regarding the results is presented. Three points of interest regarding the data results warrant mention here:

- (1) When data were plotted against sample ID, refineries can be identified by sample IDs ranging between 1000-5999, and marketing terminals can be identified by sample IDs ranging between 6000-9999. Furthermore, data from refinery V range between sample IDs 1000-2999, data from refinery W range between 2000-3999, and so on. See Table A-2 for the SAS variable SAMPID for all of the refinery and marketing terminal definitions.
- (2) When percent differences were plotted, the -10%, 0%, and +10% differences are emphasized by darkened reference lines to help identify which data points have percent differences larger than $\pm 10\%$.
- (3) All alternative mass emission rate calculations were applied for the blow-through method only. Thus, all refinery and marketing terminal data used in the 1995 Protocol for correlations, default zero emission rates, and pegged emission rates, were subjected to the alternative mass emission rate calculations. However, when pegged emission rates were calculated, all petroleum industry mass emission rates used in the 1995 Protocol, including those from oil and gas production operations, were included in the calculations.

Comparison of Adjusted versus Reported for Individual Equation Terms

Before mass emissions calculated from different methods are presented, the results of the comparisons for certain terms used in the mass emission calculation equations are presented. Adjustments were performed for both the GC and Q terms, therefore comparisons were made between the reported and adjusted values of these terms individually.

Figure B-4 shows the comparison between the calculated GC versus the calculated GC adjusted for background concentration. The two were highly correlated, as shown by the Pearson correlation coefficient of 0.9997. The percent differences between the calculated GC and the calculated GC adjusted for background concentration, for each data sample, are shown in Figure B-5. The percent differences ranged from -100% to 0%, and the average percent difference was -7.6%. The overall reduction of the GC value was expected, because subtracting the background concentration from the GC results in lower GC values.

Figure B-6 shows the comparison between the calculated Q versus the calculated Q adjusted for THC content of the bag outflow. The two were highly correlated, as shown by the Pearson correlation coefficient of 0.9997. The percent differences between the calculated Q versus the calculated Q adjusted for THC content of the bag outflow, for each data sample, are shown in Figure B-7. Though the percent differences ranged from 0% to +412%, the average percent difference was +2.5%, 95% of the differences were less than 5.3%, and 99% were less than 42.5%.

Figure B-8 shows the percent difference between the calculated Q versus the calculated Q adjusted for THC content of the bag outflow, for each sample, versus the calculated GC (ppmw) of the bag. These differences were expected to be most pronounced for the largest leakers. This expectation was verified as follows: for leaks with bag THC content less than 100,000 ppmw, the percent differences were 10% or less; for bag THC contents between 100,000 and 400,000 ppmw, the differences were between approximately 8% and 70%; and for bag THC contents larger than 400,000 ppmw, the differences ranged between approximately 50% and 410%.

Comparison of Alternative Calculations of Mass Emission Rates

The reported mass emission rates were verified by applying the 1995 Protocol calculation methodology for the blow-through method. The calculated emissions used to verify the reported emissions are referred to by calculation method ID number 2 (see Table A-3) and the reported mass emissions are referred to by method ID number 1. Method ID number 0 actually represents what was reported in the 1995 Protocol; since that time, six dripping component emissions were revised, and the revised emission rates were used in all comparisons to calculations using methods 2 through 8.

Figure B-9 shows the reported (method 1) versus calculated (method 2) mass emission rates for the refinery and marketing terminal data. The Pearson correlation coefficient, 0.999986, indicates that for all practical purposes the reported emission rates were verified by the calculations. Table A-7 shows summary statistics for the mass emission rates, as reported in the 1995 Protocol, or as calculated by all of the alternative methods described in this memorandum. Also shown in Table A-7 are the percent differences between mass emissions rates resulting from the different calculation methods. For this case, the percent difference between the reported and calculated emission rates ranged between -12% and +11%, the average percent difference was 0.3%, and the range between the 5th and 95th percentiles (i.e., 90% of the data points) was -1.2% to +5.2%. Figure B-10 shows the percent differences between the reported and calculated mass emission rates versus the sample IDs.

As shown earlier with the example of the calculated Q versus the reported Q (with only 2 decimal positions), the range of percent differences between the reported (method 1) and calculated (method 2) emission rates, from -12% to +11%, can easily be attributed to rounding. This is especially true, considering the fact that the method 1 and method 2 mass emission rates were calculated using two different computer platforms (UNIX for method 1 versus PC/NT for method 2) and using two different versions of the SAS[®] software (a SAS version available in

DRAFT

1993-94 for method 1 versus SAS Version 6.12 for method 2). Thus, the emissions using alternative calculation methods 3 through 8 were compared to the calculated emissions using method 2, rather than to reported emissions using method 1, to minimize sources of error related to differences in operating systems or calculation software.

The results from the alternative mass emission calculation methods (methods 3-8) versus the calculated mass emissions that verified those reported in the 1995 Protocol (method 2) are presented in the following series of pairs of figures. The first figure in the pair shows a plot of the calculated 1995 Protocol emission rate (method 2) rate versus the specified alternative calculation of the emission rate (one of methods 3-8), and the second figure in the pair shows a plot of the percent differences versus the sample ID, similarly to pairs of figures already presented:

- Figures B-11 and B-12: Calculation method 3, using the background-adjusted GC
- Figures B-13 and B-14: Calculation method 4, using the Q-adjustment to include the THC content of the bag outflow
- Figures B-15 and B-16: Calculation method 5, using the combined Q-adjustment to include the THC content of the bag outflow, and the background-adjusted GC
- Figures B-17 and B-18: Calculation method 6, using the protocol adjustment to include the total flow through the bag
- Figures B-19 and B-20: Calculation method 7, using combined protocol adjustment to include the total flow through the bag, and the Q-adjustment to include the THC content of the bag outflow
- Figures B-21 and B-22: Calculation method 8, using the all-adjustment to include the THC content of the bag outflow, the nitrogen fraction of the diluent stream, and the calculation of the bag molecular weight

The supporting summary statistics for the alternative and 1995 Protocol mass emission rates, as well as the percent differences between mass emissions rates resulting from the different calculation methods and the calculated 1995 Protocol mass emission rates, are shown in Table A-7.

Comparison of Pegged Emission Rates Resulting from Alternative Calculations of Mass Emission Rates

Once the mass emissions were calculated using the alternative calculation methods, pegged mass emission rates were calculated for each equipment type, facility type, and summarized over all facility types, using alternative data scenario numbers 0.00, 0.25, 0.50, and 0.75. Thus, a large amount of data were generated to compare. Space constraints limit the volume of details that can

DRAFT

be presented. Summary tables and figures were generated to maximize the amount of information shown in the smallest number of tables and figures.

Table A-8 shows a summary of the pegged emission rates resulting when mass emissions from the alternative calculation methods were used. The pegged emission rates shown in Table A-8 were summarized over all facility types, as in the 1995 Protocol, and are shown only for the benchmark data scenario (using all 1995 Protocol data points), for each calculation method. The results from the alternative data scenarios are shown in figures described below. Data from oil and gas production operations were not subjected to the alternative calculation methods because bagging data from these facilities were collected using the vacuum method. Also, due to small sample sizes or absent data, emission rates could not be calculated for every equipment type/facility type combination.

The following series of figures show the upper and lower 95% confidence bounds and the mean mass emission rate resulting from mass emissions calculated using calculation methods 0 through 8, and using the benchmark data scenario. Method 0 represent what was reported in the 1995 Protocol, and should be used as the benchmark to gauge the differences between the other methods shown in the figures. The emission rates are summarized over all facility types in this series of figures, and each figure represents a different equipment type/PEGLEVEL combination. The codes for PEGLEVEL shown on each figure can be interpreted as follows: 10=pegged at 10,000 ppmv, and 100=pegged at 100,000 ppmv. The figures are presented as follows:

For pegged at 10,000 ppmv emission rates—Figure B-23 shows connectors, Figure B-24 shows flanges, Figure B-25 shows open-ended lines, Figure B-26 shows the “other” equipment type, Figure B-27 shows pumps, and Figure B-28 shows valves.

For pegged at 100,000 ppmv emission rates—Figure B-29 shows connectors, Figure B-30 shows flanges, Figure B-31 shows open-ended lines, Figure B-32 shows the “other” equipment type, and Figure B-33 shows valves. The 100,000 ppmv mass emission rate for pumps was estimated in the 1995 Protocol, due to an inadequate amount of data; therefore, no comparisons with alternative emission calculation methods are relevant here.

Because the previous series of figures compared only the pegged emission rates and confidence intervals from the 1995 Protocol versus the those resulting from alternative calculation methods, another set of figures was constructed to show the percent difference of each alternative calculation method, relative to the 1995 Protocol values. Figure B-34 shows the percent differences for the 10,000 ppmv pegged emission rates and Figure B-35 shows the percent differences for the 100,000 ppmv pegged emission rates for each of the alternative calculation methods and alternative data scenarios described in this memorandum. All facility types were combined for these figures, as in the 1995 Protocol, and different symbols were used to identify the equipment types. The -10%, 0%, and +10% difference lines are highlighted to help visually isolate the largest differences.

Because some of the percent differences shown in Figures B-34 and B-35 were larger than 20%–30%, and some were as large as 160%, one final series of figures was generated to provide

DRAFT

a cursory examination of the percent differences. Figure B-36 shows the percent differences for the 10,000 ppmv pegged emission rates and Figure B-37 shows the percent differences for the 100,000 ppmv pegged emission rates, plotted against the sample size, for each of the alternative calculation methods and alternative data scenarios described in this memorandum. The largest percent differences were associated with the smallest sample sizes on both figures. Thus, the sample size error appears to at least be a component of the largest percent differences. Further examination of these differences may be necessary to fully understand the impact of the alternative calculation methods and alternative data scenarios described in this memorandum.

DRAFT

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