

HAZARDOUS AIR POLLUTANT EMISSIONS FROM GASOLINE LOADING OPERATIONS AT BULK GASOLINE TERMINALS

Health and Environmental Affairs Department
Publication Number 347
October 1998

American Petroleum Institute

Environmental, Health, and Safety Mission and Guiding Principles

MISSION

The members of the American Petroleum Institute are dedicated to continuous efforts to improve the compatibility of our operations with the environment while economically developing energy resources and supplying high quality products and services to consumers. We recognize our responsibility to work with the public, the government, and others to develop and to use natural resources in an environmentally sound manner while protecting the health and safety of our employees and the public. To meet these responsibilities, API members pledge to manage our businesses according to the following principles using sound science to prioritize risks and to implement cost-effective management practices:

PRINCIPLES

- To recognize and to respond to community concerns about our raw materials, products and operations.
- To operate our plants and facilities, and to handle our raw materials and products in a manner that protects the environment, and the safety and health of our employees and the public.
- To make safety, health and environmental considerations a priority in our planning, and our development of new products and processes.
- To advise promptly, appropriate officials, employees, customers and the public of information on significant industry-related safety, health and environmental hazards, and to recommend protective measures.
- To counsel customers, transporters and others in the safe use, transportation and disposal of our raw materials, products and waste materials.
- To economically develop and produce natural resources and to conserve those resources by using energy efficiently.
- To extend knowledge by conducting or supporting research on the safety, health and environmental effects of our raw materials, products, processes and waste materials.
- To commit to reduce overall emission and waste generation.
- To work with others to resolve problems created by handling and disposal of hazardous substances from our operations.
- To participate with government and others in creating responsible laws, regulations and standards to safeguard the community, workplace and environment.
- To promote these principles and practices by sharing experiences and offering assistance to others who produce, handle, use, transport or dispose of similar raw materials, petroleum products and wastes.

Hazardous Air Pollutant Emissions From Gasoline Loading Operations at Bulk Gasoline Terminals

Health and Environmental Affairs Department

API PUBLICATION NUMBER 347

PREPARED UNDER CONTRACT BY:

FRANK PHOENIX
PACIFIC ENVIRONMENTAL SERVICES, INC.
5001 SOUTH MIAMI BLVD., SUITE 300
PO Box 12077
RESEARCH TRIANGLE PARK, NORTH CAROLINA 27709-2077

OCTOBER 1998



**American
Petroleum
Institute**



Documents

Document Sharing Hub

FOREWORD

API PUBLICATIONS NECESSARILY ADDRESS PROBLEMS OF A GENERAL NATURE. WITH RESPECT TO PARTICULAR CIRCUMSTANCES, LOCAL, STATE, AND FEDERAL LAWS AND REGULATIONS SHOULD BE REVIEWED.

API IS NOT UNDERTAKING TO MEET THE DUTIES OF EMPLOYERS, MANUFACTURERS, OR SUPPLIERS TO WARN AND PROPERLY TRAIN AND EQUIP THEIR EMPLOYEES, AND OTHERS EXPOSED, CONCERNING HEALTH AND SAFETY RISKS AND PRECAUTIONS, NOR UNDERTAKING THEIR OBLIGATIONS UNDER LOCAL, STATE, OR FEDERAL LAWS.

NOTHING CONTAINED IN ANY API PUBLICATION IS TO BE CONSTRUED AS GRANTING ANY RIGHT, BY IMPLICATION OR OTHERWISE, FOR THE MANUFACTURE, SALE, OR USE OF ANY METHOD, APPARATUS, OR PRODUCT COVERED BY LETTERS PATENT. NEITHER SHOULD ANYTHING CONTAINED IN THE PUBLICATION BE CONSTRUED AS INSURING ANYONE AGAINST LIABILITY FOR INFRINGEMENT OF LETTERS PATENT.

All rights reserved. No part of this work may be reproduced, stored in a retrieval system, or transmitted by any means, electronic, mechanical, photocopying, recording, or otherwise, without prior written permission from the publisher. Contact the publisher, API Publishing Services, 1220 L Street, N.W., Washington, D.C. 20005.

Copyright © 1998 American Petroleum Institute

ACKNOWLEDGMENTS

THE FOLLOWING PEOPLE ARE RECOGNIZED FOR THEIR CONTRIBUTIONS OF TIME AND EXPERTISE DURING THIS STUDY AND IN THE PREPARATION OF THIS REPORT:

API STAFF CONTACT

Karin Ritter, Health and Environmental Affairs Department

MEMBERS OF THE STATIONARY SOURCE EMISSIONS RESEARCH GROUP

Dan Van Der Zanden, Chevron Research & Technology Company

Doug Vopat, BP Oil

Gary Kizior, Amoco Research Center

• Jeffrey Siegell, Exxon Research & Engineering Company

Lee Gilmer, Equilon

Miriam Lev-On, Arco

Robert Ettinger, Shell

API thanks Frank Phoenix of Pacific Environmental Services, Inc. for his extensive work in the preparation of this document.

TABLE OF CONTENTS

	<u>Page</u>
EXECUTIVE SUMMARY	ES-1
SECTION 1 INTRODUCTION	1-1
SECTION 2 TEST METHODS.....	2-1
SAMPLING TECHNIQUES	2-1
ANALYTICAL TECHNIQUES.....	2-1
SECTION 3 EVALUATION OF DATA SETS	3-1
SELECTION OF DATA SET LOCATIONS.....	3-3
EVALUATION PROCEDURES AND RESULTS.....	3-3
SECTION 4 EMISSION TEST RESULTS.....	4-1
SECTION 5 EXAMPLE EMISSION FACTOR CALCULATIONS	5-1
SECTION 6 REFERENCES	6-1
APPENDICES	
A SAMPLING AND ANALYTICAL PROTOCOLS	A-1
B RUN-BY-RUN EMISSION FACTORS FOR THE TWENTY DATA SETS USED TO CALCULATE OVERALL EMISSION FACTORS	B-1
C RUN-BY-RUN EMISSION FACTORS FOR THE THIRTEEN DATA SETS EXCLUDED FROM THE OVERALL AVERAGE EMISSION FACTOR CALCULATION	C-1



LIST OF TABLES

<u>Table</u>	<u>Page</u>
2-1 Hazardous Air Pollutants Measured In Samples	2-2
3-1 Summary of Data Sets	3-1
3-2 Summary of Data Set Quality Ratings.....	3-5
4-1 Ratings Summary of Data Sets Used to Develop Factors.....	4-2
4-2 Control Efficiency Summary	4-5
4-3 HAP Control Efficiencies for Vapor Control Units at Gasoline Loading Racks	4-7
5-1 Uncontrolled VOC Emission Factors For Tank Trucks	5-3
5-2 Uncontrolled Gasoline Vapor HAP-To-VOC Content	5-3
5-3 HAP EFs for Carbon Adsorber Units at Submerged Loading Operations Using Dedicated Normal Service.....	5-4
5-4 HAP EFs or Carbon Adsorber Units at Submerged Loading Operations Using Vapor Balance Service.....	5-5
5-5 HAP Emission Rates For Example Case	5-7

LIST OF FIGURES

<u>Figure</u>	<u>Page</u>
4-1 Carbon Adsorber Unit Control Efficiencies.....	4-8
4-2 Thermal Oxidizer Control Efficiencies.....	4-8

EXECUTIVE SUMMARY

This report presents hazardous air pollutant (HAP) and volatile organic compound (VOC) emission test results from gasoline loading operations at bulk gasoline terminals. These tests were conducted for the American Petroleum Institute (API) to provide more accurate HAP emission estimates from bulk gasoline terminals employing emissions control equipment. Current procedures typically assume that control efficiencies for HAPs are equal to the control efficiencies for total VOC.

For this study, API sponsored HAP emission testing at 33 bulk gasoline terminals around the United States. Each test measured emissions from facilities with a vapor control system. Emission tests from 23 carbon adsorption units (with VOC emission factors ranging from 0.7 to 70 milligrams of VOC/liter gasoline loaded), eight thermal oxidizers, and two refrigeration units were included.

Control efficiencies for eight HAP compounds were derived for carbon adsorption units and thermal oxidizers (no control efficiencies are reported from the refrigeration units due to the limited data collected). Table ES-1 summarizes the average control efficiencies found in this study. The results from the carbon adsorption units indicate that control efficiencies for HAPs average over 99% and are insensitive to the total VOC control efficiency of the treatment unit. This is observed even at VOC control efficiencies below 90%. These conclusions are illustrated in Figure ES-1. The limited data from the thermal oxidizer emission tests indicate that the control efficiencies for HAPs are similar to the control efficiencies for total VOCs.

Finally, the HAP control efficiencies presented in this report have been used to develop HAP emission factors. Derivation of these emission factors is dependent on facility operation parameters (e.g., vapor balancing, bottom loading) and gasoline speciation characterization (i.e., HAP content in gasoline). These HAP emission factors can be used to determine HAP emissions based on the volume of gasoline loaded at a facility.

TABLE ES-1. HAP CONTROL EFFICIENCIES (CE) FOR VAPOR CONTROL UNITS AT GASOLINE LOADING RACKS

HAP Compound	Carbon Adsorbers			Thermal Oxidizers		
	Average CE %	Min. CE %	Max. CE %	Average CE %	Min. CE %	Max. CE %
MTBE	99.65	98.49	100.0	99.79	99.63	99.96
Benzene	99.97	99.86	100.0	99.83	99.16	100.0
Toluene	99.93	99.62	100.0	98.86	96.42	100.0
Ethylbenzene	99.66	98.54	100.0	100.0	100.0	100.0
m,p-Xylene	99.55	97.98	100.0	99.21	96.06	100.0
o-Xylene	99.61	97.69	100.0	100.0	100.0	100.0
Xylene Average	99.58	na	na	99.60	na	na
Hexane	99.88	99.00	100.0	99.48	98.29	100.0
Isooctane	99.62	97.51	100.0	99.76	99.39	100.0
Total HAP	99.74	98.77	100.0	99.56	99.42	99.97
Total HAP w/o MTBE	99.82	99.02	100.0	99.52	99.32	100.0
Average HAP CE %	99.73	98.59	100.0	99.61	98.62	100.0
Total VOC	97.30	87.44	99.94	99.47	99.00	99.77

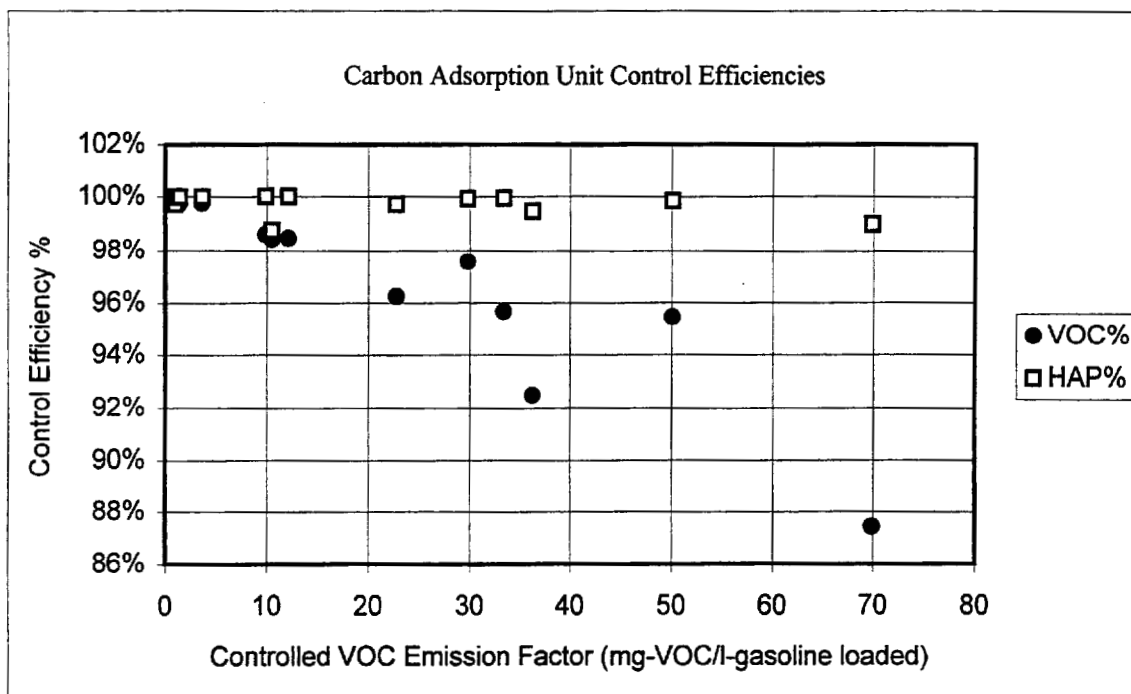


FIGURE ES-1. CARBON ADSORPTION UNIT CONTROL EFFICIENCIES

SECTION 1

INTRODUCTION

The American Petroleum Institute (API) has conducted this study to measure the controlled emission rate of volatile organic compounds (VOCs) and volatile organic hazardous air pollutants (HAPs) from gasoline loading operations at bulk gasoline terminals. The results of these emission tests have been used to develop new controlled emission factors for HAPs at bulk gasoline terminals.

In developing the emission factors presented in this report, API followed the most recent EPA procedures for preparing AP-42 emission factors (EPA, 1992). In preparing this report, API followed the suggestions for submitting emission factors to EPA as outlined in the draft report "Public Participation Procedures for EPA's Emissions Estimation Guidance Materials" (EPA, 1994).

During the development of the Gasoline Distribution National Emission Standards for Hazardous Air Pollutants (NESHAP), it was estimated that of the 1,024 bulk terminals, approximately 70 percent were controlling VOC emissions from the loading racks. Additionally, it was estimated that 63,520 megagrams (Mg) of VOC and 3,460 Mg of HAP are released from loading racks at bulk terminals on an annual basis.²

To estimate the HAP emissions from bulk terminals, it was previously assumed that the relative HAP and VOC compositions of the vapor stream after control are equal to the relative compositions prior to control. This study was launched to measure HAP emissions and test the validity of this assumption.

The objective of this study is to measure emissions from the loading of gasoline cargo tanks at loading facilities (i.e., bulk terminals) and present a method for determining emission factors for these sources. The emission factors apply to loading facilities which utilize carbon adsorption units or thermal oxidizers to reduce gasoline emissions.

Section 2 presents the test methods used for the study. Section 3 evaluates the quality of each of the 33 tests included in the study. Section 4 presents the results of the emission tests and summarizes the calculated control efficiencies for HAPs. Section 5 presents example calculations illustrating the development of emission factors using the test results and currently available bulk terminal emission information. A discussion of sensitive parameters that may impact these results is also presented in

Section 5. Section 6 lists the references used or referred to in this report. Appendix A contains the sampling and analytical protocols used in this study. Appendix B presents detailed information on the 20 data sets used to calculate the emission factors. Appendix C presents detailed information on the 13 data sets excluded from the emission factor calculations.

SECTION 2

TEST METHODS

For this study, API sponsored HAP emissions testing at 33 bulk gasoline terminals around the United States. Each test measured emissions from facilities with a vapor control system. Emission tests from 23 carbon adsorption, eight thermal oxidizers, and two refrigeration units were included. This section describes the sampling and analytical procedures used.

SAMPLING TECHNIQUES

Simultaneous with the VOC emissions testing, testing was performed for selected HAPs using a test protocol developed by API for this study.³ Six gas samples were extracted (three inlet samples simultaneous with three outlet samples) at set two hour intervals during the first six hours of the VOC emissions test. EPA Method 18, Section 7.1 sampling procedures were followed. To prevent contamination, new Teflon[®] tubing and new Tedlar[®] bags were used for each test. After the initial sampling, all Tedlar[®] bag gas samples were sub-sampled into SUMMA[®] polished canisters following the general guidelines of EPA-600/4-89-017 Method TO-14. For more details refer to the API test protocol presented in Appendix A.

Simultaneous with the VOC emissions testing, testing was performed for selected HAPs using a test protocol developed by API for this study.³ Six gas samples were extracted (three inlet samples simultaneous with three outlet samples) at set two hour intervals during the first six hours of the VOC emissions test. EPA Method 18, Section 7.1 sampling procedures were followed. To prevent contamination, new Teflon[®] tubing and new Tedlar[®] bags were used for each test. After the initial sampling, all Tedlar[®] bag gas samples were sub-sampled into SUMMA[®] polished canisters following the general guidelines of EPA-600/4-89-017 Method TO-14. For more details refer to the API test protocol presented in Appendix A.

ANALYTICAL TECHNIQUES

Analysis for selected HAPs was performed using a protocol developed by API for this study. This protocol followed the guidelines of EPA Methods 18, TO-3, and SW846-8020 and SW846-8015. Sample aliquots from the SUMMA[®] polished canisters were analyzed on a gas chromatograph (GC) with a photo ionization detector (PID) and

a flame ionization detector (FID) in series. The GC was calibrated with a 5-level curve with quantification performed by the external standards technique. Standards were purchased as commercial gas standards or prepared by the static dilution technique by the laboratory. The method detection limit (MDL) was 10 parts per million by volume (ppmv) for inlet samples and 0.2 ppmv for outlet samples for all pollutants except for methanol. For methanol, the MDL was 100 ppmv for inlet samples and 2 ppmv for outlet samples. Samples exhibiting matrix interference on compound identification were confirmed by GC/MS. Table 2-1 presents a list of the HAP compounds measured in this study. For more details refer to the API analytical protocol presented in Appendix A.

TABLE 2-1. HAZARDOUS AIR POLLUTANTS MEASURED IN SAMPLES

CAS No.	Compound Name	Molecular Weight	Analysis Method
106-99-0	1,3-Butadiene	54.09	PID
1634-04-4	Methyl Tert-Butyl Ether	88.15	PID
71-43-2	Benzene	78.11	PID
108-88-3	Toluene	92.13	PID
100-41-4	Ethylbenzene	106.16	PID
108-38-3	m,p-xylene	106.16	PID
95-47-6	o-xylene	106.16	PID
98-82-8	Cumene	120.19	PID
91-20-3	Naphthalene	128.16	PID
67-56-1	Methanol	32.04	FID
110-54-3	Hexane	86.17	FID
540-84-1	Isooctane	114.22	FID

SECTION 3

EVALUATION OF DATA SETS

This study consisted of the evaluation of 33 emissions tests performed on gasoline loading racks at 29 bulk gasoline terminals. Two of the 29 bulk terminals had two separate loading racks accounting for two additional tests. At one of the bulk terminals, three separate tests were performed on the same vapor control system accounting for two additional tests. Each of the 33 tests measured emissions from a vapor control system. Of the 33 tests or data sets, 23 quantify emissions from carbon adsorber units (CAU), eight from thermal oxidizers (TO), and two from refrigeration systems. To preserve the anonymity of each terminal, a code was assigned to each data set as follows: C-1 through C-21C were assigned to terminals with carbon adsorbers, T-1 through T-8 to terminals with thermal oxidizers, and R-1 and R-2 to terminals with refrigeration systems. Table 3-1 provides a summary of the data sets evaluated in this study.

TABLE 3-1. SUMMARY OF DATA SETS

API CODE	Sampling Date	Vapor Control Unit Type	Vapor Control Unit Manufacturer	VOC Compliance Limit (mg/l)	Accountable Gasoline Loaded (gal)	Total Product Loaded (gal)
C-1	8/10/95	Carbon Adsorber	John Zink	INA	35,200	42,700
C-2	8/14/95	Carbon Adsorber	John Zink	INA	183,500	183,500
C-3	9/6/95	Carbon Adsorber	John Zink	INA	733,404	733,404
C-4	8/22/95	Carbon Adsorber	McGill	35	10,100	154,625
C-5	8/30/95	Carbon Adsorber	McGill	80	58,810	69,535
C-6	9/1/95	Carbon Adsorber	McGill	80	42,750	62,0505
C-7	9/15/95	Carbon Adsorber	INA	INA	INA	INA

TABLE 3-1. (Continued)

API CODE	Sampling Date	Vapor Control Unit Type	Vapor Control Unit Manufacturer	VOC Compliance Limit (mg/l)	Accountable Gasoline Loaded (gal)	Total Product Loaded (gal)
C-8	9/19/95	Carbon Adsorber	McGill	35	188,400	199,100
C-9	9/21/95	Carbon Adsorber	John Zink	35	132,500	154,398
C-10	9/29/95	Carbon Adsorber	McGill	80	130,940	180,375
C-11	10/10-10/11/95	Carbon Adsorber	McGill	INA	123,590	123,590
C-12	10/12/95	Carbon Adsorber	McGill	80	200,100	262,872
C-13	11/3/95	Carbon Adsorber	John Zink	35	116,050	201,850
C-14	8/17/95	Carbon Adsorber	John Zink	35	220,200	227,700
C-15	5/31/95	Carbon Adsorber	John Zink	35	180,455	209,633
C-16	5/22/95	Carbon Adsorber	John Zink	35	132,789	132,789
C-17	5/23/95	Carbon Adsorber	John Zink	35	93,529	93,529
C-18	6/2/95	Carbon Adsorber	John Zink	35	61,939	175,456
C-19	6/20/95	Carbon Adsorber	John Zink	35	328,495	328,495
C-20	6/22/95	Carbon Adsorber	John Zink	35	267,598	301,424
C-21A	7/24/97	Carbon Adsorber	McGill	80	154,590	208,250
C-21B	7/24/97	Carbon Adsorber	McGill	80	146,492	155,092
C-21C	7/25/97	Carbon Adsorber	McGill	80	161,650	185,550
T-1	8/16/95	Thermal Oxidizer	John Zink	35	222,211	237,213
T-2	10/31/95	Thermal Oxidizer	John Zink	INA	724,581	724,581

TABLE 3-1. (Concluded)

API CODE	Sampling Date	Vapor Control Unit Type	Vapor Control Unit Manufacturer	VOC Compliance Limit (mg/l)	Accountable Gasoline Loaded (gal)	Total Product Loaded (gal)
T-3	9/13/95	Thermal Oxidizer	John Zink	10	308,100	340,300
T-4	9/22/95	Thermal Oxidizer	John Zink	35	205,396	305,396
T-5	10/27/95	Thermal Oxidizer	NAO	INA	27,572	27,572
T-6	5/1/96	Thermal Oxidizer	John Zink	10	175,850	209,850
T-7	6/19/96	Thermal Oxidizer	John Zink	INA	244,874	285,874
T-8	11/10/95	Thermal Oxidizer	John Zink	35	94,860	156,340
R-1	10/18/95	Refrigeration	Edwards	INA	235,794	235,794
R-2	10/17/95	Refrigeration/TO	Edwards/Zink	10	909,201	909,201

INA Indicates that information was not available in the data sets.

SELECTION OF DATA SET LOCATIONS

API member companies volunteered their bulk terminals for participation in this study. Terminals in the following 18 states participated: Arizona, California, Illinois, Indiana, Kentucky, Louisiana, Maryland, Massachusetts, Michigan, New Jersey, North Carolina, Ohio, Oregon, Pennsylvania, South Carolina, Texas, Virginia, and Wisconsin. Testing occurred between August 6, 1995 and July 26, 1997. In every case but two, the testing for selected HAPs was performed simultaneously with required VOC compliance testing.

EVALUATION PROCEDURES AND RESULTS

Each data set was assigned an overall data quality rating of A, B, C or D using the latest EPA guidance. This overall rating was based on a subjective evaluation of four separate criteria: 1) Source Operation, 2) Test Method and Sampling Procedures,

3) Sampling and Process Data, and 4) Analysis and Calculations. Each data set was assigned a rating (A through D) for each criterion. Two criteria—Test Method and Sampling Procedures, and Sampling and Process Data—were given more weight when the overall rating was assigned. Table 3-2 provides a summary of the overall quality ratings assigned to each data set as well as the quality ratings for each of the four criteria. The four criteria were evaluated as described below.

Source Operation ratings were assigned based on how well the source operation was documented and whether the source and control devices were operated within normal operating parameters.

The highest Source Operation rating assigned was a B due to the lack of documentation in all the reports on the operation of the vapor control system during the testing (e.g., operating temperature of the thermal oxidizer was not documented).

Test Method and Sampling Procedures ratings were assigned based on the accuracy of the test method and how well the field testing was documented. The highest Test Method and Sampling Procedures rating assigned was a B because the protocol failed to address proportional sampling and there was not sufficient field documentation in any of the reports on the HAP sampling (e.g., there was no documentation provided which indicated that HAP sampling was suspended when there was no product being loaded).

Sampling and Process Data ratings were assigned based on the variation in pollutant concentration between test run results. Since product loading varied significantly during the tests, run-by-run variations were expected. However, as a general rule, when the results of all three runs agreed within 50%, an A rating was assigned. When the individual test run results varied by more than 50% but less than an order of magnitude, a B or C rating was assigned. B ratings were assigned if there was a reasonable explanation of the variation, while C ratings were assigned when there was no reasonable explanation for the variation. When the individual test results varied by more than an order of magnitude, a C or D rating was assigned. Again, a C rating was assigned if an explanation was found, and a D rating was assigned when there was no reasonable explanation for the variation.

Analysis and Calculations ratings were assigned based on the level of documentation and quality of quality assurance (QA) data in the analytical reports and on how accountable product was calculated in the VOC compliance reports. The highest Analysis and Calculations rating assigned was a B because of the lack of traceable QA data in each of the analytical reports. A summary and discussion of the ratings assigned to each data set is presented in this section.

TABLE 3-2. SUMMARY OF DATA SET QUALITY RATINGS

API Code	Source Operation	Test Method and Sampling Procedures	Sampling and Process Data	Analysis and Calculations	Overall Rating	Used to Develop Factors
C-1	D	D	D	B	D	No
C-2	D	D	D	B	D	No
C-3	B	B	A	B	B	No
C-4	D	B	A	C	D	No
C-5	B	B	D	C	D	No
C-6	B	B	C	C	C	Yes
C-7	D	D	D	B	D	No
C-8	B	B	B	B	B	Yes
C-9	B	B	A	C	B	Yes
C-10	B	B	A	B	B	Yes
C-11	C	D	D	B	D	No
C-12	B	B	B	B	B	Yes
C-13	B	B	D	C	D	No
C-14	C	B	A	B	B	Yes
C-15	C	C	B	C	C	Yes
C-16	C	C	B	C	C	Yes
C-17	B	C	A	C	B	Yes
C-18	C	C	B	B	C	Yes
C-19	B	C	B	B	B	Yes
C-20	B	C	A	C	B	Yes
C-21A	B	B	B	C	B	Yes

TABLE 3-2. (Concluded)

API Code	Source Operation	Test Method and Sampling Procedures	Sampling and Process Data	Analysis and Calculations	Overall Rating	Used to Develop Factors
C-21B	B	B	B	C	B	Yes
C-21C	B	B	B	C	B	Yes
T-1	C	B	B	B	B	Yes
T-2	D	B	D	C	D	No
T-3	B	B	A	C	B	Yes
T-4	B	B	D	B	D	No
T-5	D	C	C	C	D	No
T-6	B	B	B	C	B	Yes
T-7	B	B	A	C	B	Yes
T-8	B	B	A	B	B	Yes
R-1	B	D	C	B	D	No
R-2	B	C	C	C	C	No

C-1: Reference C-1 is a source test performed on a carbon adsorption system at a bulk gasoline terminal on August 10, 1995. The test was given an overall rating of D. Source Operation was given a D rating because the process stopped operation after the first run. Test Method and Sampling Procedures was given a D rating because no test report or documentation on the sampling procedures was available. Sampling and Process Data was given a D rating because very little process data and no sampling data were available. Analysis and Calculations was given a B rating due to the lack of traceable QA data in the analytical report. Since this data set was given an overall D rating, it was not used in developing the average emission factors presented in Section 4.

C-2: Reference C-2 is a source test performed on a carbon adsorption system at a bulk gasoline terminal on August 14, 1995. The test was given an overall rating of D. Source Operation was given a D rating because no process operation or control system information was available. Test Method and Sampling Procedures was given a D rating

because no test report or documentation on the sampling procedures was available. Sampling and Process Data was given a D rating because no process or sampling data were available. Analysis and Calculations was given a B rating due to the lack of traceable QA data in the analytical report. Since this data set was given an overall D rating, it was not used in developing the average emission factors presented in Section 4.

C-3: Reference C-3 is a source test performed on a carbon adsorption system at a large barge loading terminal on September 6, 1995. The test was given an overall rating of B. Source Operation was given a B rating due to the lack of documentation on the operation of the carbon adsorber during the testing. Test Method and Sampling Procedures was given a B rating because of the lack of field documentation on the HAP sampling. Sampling and Process Data was given an A rating. Analysis and Calculations was given a B rating due to the lack of traceable QA data in the analytical report. Although this data set was given an overall B rating, it was not used in developing the average emission factors presented in Section 4 because the process was barge loading instead of cargo tank loading.

C-4: Reference C-4 is a source test performed on a carbon adsorption system at a bulk gasoline terminal on August 22, 1995. The test was given an overall rating of D. Source Operation was given a D rating due to the lack of documentation on the carbon adsorber and because of very low product loading during the testing. Test Method and Sampling Procedures was given a B rating because of the lack of field documentation on the HAP sampling. Sampling and Process Data was given an A rating. Analysis and Calculations was given a C rating because of the lack of traceable QA data in the analytical report and because of the way accountable product was calculated. Since this data set was given an overall D rating, it was not used in developing the average emission factors presented in Section 4.

C-5: Reference C-5 is a source test performed on a carbon adsorption system at a bulk gasoline terminal on August 30, 1995. The test was given an overall rating of D. Source Operation was given a B rating due to the lack of documentation on the carbon adsorber during the testing. Test Method and Sampling Procedures was given a B rating because of the lack of field documentation on the HAP sampling. Sampling and Process Data was given a D rating because, for no apparent reason, the run-to-run HAP concentrations varied by an order of magnitude. Analysis and Calculations was given a C rating because no detailed analytical report was available. Since this data set was given an overall D rating, it was not used in developing the average emission factors presented in Section 4.

C-6: Reference C-6 is a source test performed on a carbon adsorption system at a bulk gasoline terminal on September 1, 1995. The test was given an overall rating of C. Source Operation was given a B rating due to the lack of documentation on the carbon adsorber during the testing. Test Method and Sampling Procedures was given a B rating because of the lack of field documentation on the HAP sampling. Sampling and

Process Data was given a C rating because run-to-run HAP concentrations varied by an order of magnitude. The variation may be due in part to the load swings during the testing. Analysis and Calculations was given a C rating because of the lack of traceable QA data in the analytical report and because of the way accountable product was calculated. This data set was used in developing the average emission factors presented in Section 4.

C-7: Reference C-7 is a source test performed on a carbon adsorption system at a bulk gasoline terminal on September 15, 1995. The test was given an overall rating of D. Source Operation was given a D rating because no process operation or control device information was available. Test Method and Sampling Procedures was given a D rating because no test report or documentation on the sampling procedures was available. Sampling and Process Data was given a D rating because no process or sampling data were available. Analysis and Calculations was given a B rating due to the lack of traceable QA data in the analytical report. Since this data set was given an overall D rating, it was not used in developing the average emission factors presented in Section 4.

C-8: Reference C-8 is a source test performed on a carbon adsorption system at a bulk gasoline terminal on September 19, 1995. The test was given an overall rating of B. Source Operation was given a B rating because there was no documentation on the operation of the carbon adsorber during the testing. Test Method and Sampling Procedures was given a B rating because of the lack of field documentation on the HAP sampling. Sampling and Process Data was given a B rating because run-to-run HAP concentrations varied significantly. The variation may be due in part to the load swings during the testing. Analysis and Calculations was given a B rating because of the lack of traceable QA data in the analytical report. This data set was used in developing the average emission factors presented in Section 4.

C-9: Reference C-9 is a source test performed on a carbon adsorption system at a bulk gasoline terminal on September 21, 1995. The test was given an overall rating of B. Source Operation was given a B rating due to the lack of documentation on the operation of the carbon adsorber during the testing. Test Method and Sampling Procedures was given a B rating because of the lack of field documentation on the HAP sampling. Sampling and Process Data was given an A rating. Analysis and Calculations was given a C rating because of the lack of traceable QA data in the analytical report and because the Relative Percent Difference (RPD) of the duplicate analyses was greater than 30%. This data set was used in developing the average emission factors presented in Section 4.

C-10: Reference C-10 is a source test performed on a carbon adsorption system at a bulk gasoline terminal on September 29, 1995. The test was given an overall rating of B. Source Operation was given a B rating due to the lack of documentation on the operation of the carbon adsorber during the testing. Test Method and Sampling Procedures was given a B rating because of the lack of field documentation on the HAP sampling. Sampling and Process Data was given an A rating. Analysis and

Calculations was given a B rating due to the lack of traceable QA data in the analytical report. This data set was used in developing the average emission factors presented in Section 4.

C-11: Reference C-11 is a source test performed on a carbon adsorption system at a bulk gasoline terminal on October 10 and 11, 1995. The test was given an overall rating of D. Source Operation was given a C rating due to the lack of documentation on the carbon adsorber and because many truck tanks leaked vapors during the testing. Test Method and Sampling Procedures was given a D rating because sampling was not performed on the inlet to the carbon adsorber. Sampling and Process Data was given a D rating because for no apparent reason the run-to-run HAP concentrations varied by an order of magnitude. Analysis and Calculations was given a B rating due to the lack of traceable QA data in the analytical report. Since this data set was given an overall D rating, it was not used in developing the average emission factors presented in Section 4.

C-12: Reference C-12 is a source test performed on a carbon adsorption system at a bulk gasoline terminal on October 12, 1995. The test was given an overall rating of B. Source Operation was given a B rating due to the lack of documentation on the operation of the carbon adsorber during the testing. Test Method and Sampling Procedures was given a B rating because of the lack of field documentation on the HAP sampling. Sampling and Process Data was given a B rating because inlet HAP data were missing for run 3. The average inlet HAP data presented for C-12 are based on the average of runs 1 and 2. Analysis and Calculations was given a B rating because of the lack of traceable QA data in the analytical report. This data set was used in developing the average emission factors presented in Section 4.

C-13: Reference C-13 is a source test performed on a carbon adsorption system at a bulk gasoline terminal on November 3, 1995. The test was given an overall rating of D. Source Operation was given a B rating due to the lack of documentation on the operation of the carbon adsorber during the testing. Test Method and Sampling Procedures was given a B rating because of the lack of field documentation on the HAP sampling. Sampling and Process Data was given a D rating because for no apparent reason the run-to-run HAP concentrations varied by an order of magnitude. Analysis and Calculations was given a C rating due to the lack of traceable QA data in the analytical report and because the percent variation between duplicate analyses for some of the HAPs was greater than 30%. Since this data set was given an overall D rating, it was not used in developing the average emission factors presented in Section 4.

C-14: Reference C-14 is a source test performed on a carbon adsorption system at a bulk gasoline terminal on August 17, 1995. The test was given an overall rating of B. Source Operation was given a C rating due to the lack of documentation on the carbon adsorber and because of low product loading during the first run. Test Method and Sampling Procedures was given a B rating because of the lack of field documentation on the HAP sampling. Sampling and Process Data was given an A rating. Analysis

and Calculations was given a B rating due to the lack of traceable QA data in the analytical report. This data set was used in developing the average emission factors presented in Section 4.

C-15: Reference C-15 is a source test performed on a carbon adsorption system at a bulk gasoline terminal on May 31, 1995. The test was given an overall rating of C. Source Operation was given a C rating due to the lack of documentation on the carbon adsorber and because the vapor holding tank made it difficult to accurately apportion product to the individual runs. Test Method and Sampling Procedures was given a C rating because of the lack of field documentation on the HAP sampling. Sampling and Process Data was given a B rating because the run-to-run HAP concentration results varied more than 50% due to the use of a holding tank. Analysis and Calculations was given a C rating due to the lack of traceable QA data in the analytical report and a discrepancy with the accountable product loaded. This data set was used in developing the average emission factors presented in Section 4.

C-16: Reference C-16 is a source test performed on a carbon adsorption system at a bulk gasoline terminal on May 22, 1995. The test was given an overall rating of C. Source Operation was given a C rating due to the lack of documentation on the carbon adsorber and because of low product loading during the third run. Test Method and Sampling Procedures was given a C rating because of the lack of field documentation on the HAP sampling. Sampling and Process Data was given a B rating because the run-to-run HAP results varied by more than 50%. Analysis and Calculations was given a C rating due to the lack of traceable QA data in the analytical report and the MTBE duplicate analysis varied by more than 30%. This data set was used in developing the average emission factors presented in Section 4.

C-17: Reference C-17 is a source test performed on a carbon adsorption system at a bulk gasoline terminal on May 23, 1995. The test was given an overall rating of B. Source Operation was given a B rating due to the lack of documentation on the carbon adsorber. Test Method and Sampling Procedures was given a C rating because of the lack of field documentation on the HAP sampling. Sampling and Process Data was given an A rating. Analysis and Calculations was given a C rating due to the lack of traceable QA data in the analytical report, duplicate analyses varied by more than 30%, and the compliance report contained a minor mistake. This data set was used in developing the average emission factors presented in Section 4.

C-18: Reference C-18 is a source test performed on a carbon adsorption system at a bulk gasoline terminal on June 2, 1995. The test was given an overall rating of C. Source Operation was given a C rating due to the lack of documentation on the carbon adsorber and because about 25% of the potential gasoline vapor was not counted (current diesel loading with previous gasoline service). Test Method and Sampling Procedures was given a C rating because of the lack of field documentation on the HAP sampling. Sampling and Process Data was given a B rating because the results varied by more than 50% caused by variations in the product loading. Analysis and

Calculations was given a B rating due to the lack of traceable QA data in the analytical report. This data set was used in developing the average emission factors presented in Section 4.

C-19: Reference C-19 is a source test performed on a carbon adsorption system at a bulk gasoline terminal on June 20, 1995. The test was given an overall rating of B. Source Operation was given a B rating due to the lack of documentation on the carbon adsorber. Test Method and Sampling Procedures was given a C rating because of the lack of field documentation on the HAP sampling and the lack of inlet 5-minute VOC readings. Sampling and Process Data was given a B rating due to inability to compare run by run data. Analysis and Calculations was given a B rating due to the lack of traceable QA data in the analytical report. This data set was used in developing the average emission factors presented in Section 4.

C-20: Reference C-20 is a source test performed on a carbon adsorption system at a bulk gasoline terminal on June 22, 1995. The test was given an overall rating of B. Source Operation was given a B rating due to the lack of documentation on the carbon adsorber. Test Method and Sampling Procedures was given a C rating because of the lack of field documentation on the HAP sampling. Sampling and Process Data was given an A rating. Analysis and Calculations was given a C rating due to the lack of traceable QA data in the analytical report and the way accountable product was calculated. This data set was used in developing the average emission factors presented in Section 4.

C-21A, C-21B, C-21C: References C-21A, C-21B, and C-21C are three separate source tests performed on a carbon adsorption system at a bulk gasoline terminal on July 24 and 25, 1997. Each of the three source tests was performed at a different vapor load condition on the carbon adsorber. The vapor load to the carbon adsorber was varied by controlling the amount of vapor exiting the vapor holding tank. Each test was given an overall rating of B. Source Operation was given a B rating due to the lack of documentation on the carbon adsorber. Test Method and Sampling Procedures was given a B rating because the HAP sampling protocol failed to address proportional sampling. Sampling and Process Data was given a B rating because of the difficulty in comparing run-by-run results due to the large product loading variations. Analysis and Calculations was given a C rating due to the lack of traceable QA data in the analytical report and the way accountable product was calculated due to the vapor holding tank. This data set was used in developing the average emission factors presented in Section 4.

T-1: Reference T-1 is a source test performed on a thermal oxidizer at a bulk gasoline terminal on August 16, 1995. The test was given an overall rating of B. Source Operation was given a C rating due to the lack of documentation on the thermal oxidizer and because of the significant swing in VOC loading from the holding bladder during the testing. Test Method and Sampling Procedures was given a B rating because of the lack of field documentation on the HAP sampling. Sampling and Process Data

was given a B rating because it was difficult to compare run-to-run results due to load swings from the holding bladder. Analysis and Calculations was given a B rating due to the lack of traceable QA data in the analytical report. This data set was used in developing the average emission factors presented in Section 4.

T-2: Reference T-2 is a source test performed on a refrigeration system in series with a thermal oxidizer at a bulk gasoline terminal on October 31, 1995. This test was given an overall rating of D. Source Operation was given a D rating because the process was operated differently for each of the three test runs. Test Method and Sampling Procedures was given a B rating because of the lack of field documentation on the HAP sampling. Sampling and Process Data was given a D rating because only one test run per condition was available. Analysis and Calculations was given a C rating due to the lack of traceable QA data in the analytical report and because the RPDs between duplicate analyses for some of the HAPs were greater than 30%. Since this data set was given an overall D rating and because two different control devices in series were used, it was not used in developing the average emission factors presented in Section 4.

T-3: Reference T-3 is a source test performed on a thermal oxidizer at a bulk gasoline terminal on September 13, 1995. The test was given an overall rating of B. Source Operation was given a B rating due to the lack of documentation on the thermal oxidizer during the testing. Test Method and Sampling Procedures was given a B rating because of the lack of field documentation on the HAP sampling. Sampling and Process Data was given an A rating. Analysis and Calculations was given a C rating due to the lack of traceable QA data in the analytical report and because the percent variation between duplicate analyses for some of the HAPs was greater than 30%. This data set was used in developing the average emission factors presented in Section 4.

T-4: Reference T-4 is a source test performed on a thermal oxidizer at a bulk gasoline terminal on September 22, 1995. The test was given an overall rating of D. Source Operation was given a B rating due to the lack of documentation on the thermal oxidizer during the testing. Test Method and Sampling Procedures was given a B rating because of the lack of field documentation on the HAP sampling. Sampling and Process Data was given a D rating because for no apparent reason HAP concentrations and control efficiencies varied by an order of magnitude from the other data sets. Analysis and Calculations was given a B rating due to the lack of traceable QA data in the analytical report. Since this data set was given an overall D rating, it was not used in developing the average emission factors presented in Section 4.

T-5: Reference T-5 is a source test performed on a thermal oxidizer at a bulk gasoline terminal on October 27, 1995. The test was given an overall rating of D. Source Operation was given a D rating because of the very low product loading during the testing. Test Method and Sampling Procedures was given a C rating because of the lack of field documentation on the HAP sampling and because the sampling protocol on the outlet was modified. Sampling and Process Data was given a C rating because no inlet flow rate data were available for run 1. The average inlet data presented for T-5

are based on the average of runs 2 and 3. The variation may be due in part to the load swings during the testing. Analysis and Calculations was given a C rating due to the lack of traceable QA data in the analytical report and because the RPDs between duplicate analyses for some of the HAPs were greater than 30%. Since this data set was given an overall D rating, it was not used in developing the average emission factors presented in Section 4.

T-6: Reference T-6 is a source test performed on a thermal oxidizer at a bulk gasoline terminal on May 1, 1996. The test was given an overall rating of B. Source Operation was given a B rating due to the lack of documentation on the thermal oxidizer during the testing. Test Method and Sampling Procedures was given a B rating because of the lack of field documentation on the HAP sampling. Sampling and Process Data was given a B rating because run-to-run HAP concentrations varied significantly. The variation may be due in part to the load swings during the testing. Analysis and Calculations was given a C rating because a detailed analytical report was not available. This data set was used in developing the average emission factors presented in Section 4.

T-7: Reference T-7 is a source test performed on a thermal oxidizer at a bulk gasoline terminal on June 19, 1996. The test was given an overall rating of B. Source Operation was given a B rating due to the lack of documentation on the thermal oxidizer during the testing. Test Method and Sampling Procedures was given a B rating because of the lack of field documentation on the HAP sampling. Sampling and Process Data was given an A rating. Analysis and Calculations was given a C rating due to the lack of traceable QA data in the analytical report and because the percent variations between duplicate analyses for some of the HAPs was greater than 30%. This data set was used in developing the average emission factors presented in Section 4.

T-8: Reference T-8 is a source test performed on a thermal oxidizer at a bulk gasoline terminal on November 10, 1995. The test was given an overall rating of B. Source Operation was given a B rating due to the lack of documentation on the thermal oxidizer during the testing. Test Method and Sampling Procedures was given a B rating because of the lack of field documentation on the HAP sampling. Sampling and Process Data was given an A rating. Analysis and Calculations was given a B rating due to the lack of traceable QA data in the analytical report. This data set was used in developing the average emission factors presented in Section 4.

R-1: Reference R-1 is a source test performed on a refrigeration system at a bulk gasoline terminal on October 18, 1995. The test was given an overall rating of D. Source Operation was given a B rating due to the lack of documentation on the thermal oxidizer during the testing. Test Method and Sampling Procedures was given a D rating because sampling was not performed on the inlet to the refrigeration unit. Sampling and Process Data was given a C rating because for no apparent reason the run-to-run HAP concentrations varied significantly. Analysis and Calculations was

given a B rating due to the lack of traceable QA data in the analytical report. Since this data set was given an overall D rating, it was not used in developing the average emission factors presented in Section 4.

R-2: Reference R-2 is a source test performed on a refrigeration system in series with a thermal oxidizer at a bulk gasoline terminal on October 17, 1995. The test was given an overall rating of C. Source Operation was given a B rating due to the lack of documentation on the thermal oxidizer during the 6 hour HAP test. Test Method and Sampling Procedures was given a C rating because of the lack of field documentation and because the HAP sampling appears to have continued after the rest of the sampling was completed. Sampling and Process Data was given a C rating because for no apparent reason the run-to-run HAP concentrations varied significantly. Analysis and Calculations was given a C rating due to the lack of traceable QA data in the analytical report and because the RPDs between duplicate analyses for some of the HAPs were greater than 30%. This data set was not used in developing the average emission factors presented in Section 4 because the process utilized two different control devices in series instead of one control device.

SECTION 4

EMISSION TEST RESULTS

This section summarizes the results of the emission testing and presents control efficiencies for VOCs and HAPs. The tests included in the analysis are shown in Table 4-1. Fifteen carbon adsorption units (CAU) and five thermal oxidizers (TO) were included in this evaluation. As discussed in Section 3, thirteen tests were eliminated from this evaluation.

The data included in this study were taken from VOC compliance test reports and data collected concurrently with the compliance tests following the Volatile Organic Hazardous Air Pollutant (VOHAP) test protocol. This protocol is provided in Appendix A.

The results for each of the 20 tests included in this evaluation are presented in Appendix B. The test data summarized in this appendix include (1) volume of products loaded, (2) vapor inlet and outlet volumes, and (3) inlet and outlet gas concentrations of VOCs and HAPs. For completeness, Appendix C contains the emission test results for the tests that were not included in the analysis.

Analysis of Non-Detects

Many of the analytical results for individual HAP concentrations yielded values that were below the minimum detection limit (MDL) of the test method used (i.e., non-detects). The minimum detection limit is defined as the minimum concentration of a substance that can be measured and reported with 99% confidence that the value is above zero. For this study the minimum detection limit for all the HAPs except methanol was 10 parts per million by volume (ppmv) at the inlet and 0.2 ppmv at the outlet. For methanol, the MDL was 100 ppmv at the inlet and 2.0 ppmv at the outlet.

Methanol and 1,3-butadiene were never detected at the inlets or the outlets. Cumene and naphthalene were detected in a few cases at the inlets but never detected at the outlets. Consequently, these four compounds were excluded from any further analysis and control efficiencies and emission factors are presented only for the remaining eight HAPs of those listed in Table 2-1.

TABLE 4-1. RATINGS SUMMARY OF DATA SETS USED TO DEVELOP FACTORS

API Code	Source Operation	Test Method and Sampling Procedures	Sampling and Process Data	Analysis and Calculation	Overall Rating
C-6	B	B	C	C	C
C-8	B	B	B	B	B
C-9	B	B	A	C	B
C-10	B	B	A	B	B
C-12	B	B	B	B	B
C-14	C	B	A	B	B
C-15	C	C	B	C	C
C-16	C	C	B	C	C
C-17	B	C	A	C	B
C-18	C	C	B	B	C
C-19	B	C	B	B	B
C-20	B	C	A	C	B
C-21A	B	B	B	C	B
C-21B	B	B	B	C	B
C-21C	B	B	B	C	B
T-1	C	B	B	B	B
T-3	B	B	A	C	B
T-6	B	B	B	C	B
T-7	B	B	A	C	B
T-8	B	B	A	B	B

Of the remaining eight HAPs, very few non-detects were reported on the inlet samples. For the outlet samples, however, a large number of non-detects were reported. These non-detects were treated as follows: Three samples were collected at each location. If non-detects were reported for a given HAP in all three samples, a concentration value of zero was used in the calculations. If concentrations for one or two of the samples were reported above the MDL, concentrations equal to one half of the MDL were used for the non-detects.

Calculation of Control Efficiencies

Control efficiencies were calculated for total VOC and for each of the individual HAPs for each of the tests conducted. The control efficiencies were based on the measured masses of each HAP during the tests. For each 2-hour run, and for each HAP, the total masses at the inlet and outlet of the control device were calculated as follows:

$$\text{mass}_i = \frac{(\text{HAP concentration}_i)(\text{MW}_i)(\text{Volume})}{24.06}$$

where:

mass _i	= total mass of HAP _i over 2-hour run (mg)
HAP concentration _i	= concentration of HAP _i measured in a sample (ppmv)
MW _i	= molecular weight of HAP _i in g/g-mole (see Table 3-2)
Volume	= total volume of vapor/air mixture over 2-hour run (m ³)
24.06	= mole volume at standard cond., 68°F, 29.92"Hg (l/g-mole)

For data sets with no metered inlet volumes, the volumes were calculated using the outlet-to-inlet ratio of the measured VOC concentrations from the compliance test, as follows:

$$\text{Volume}_{\text{inlet}} = \text{Volume}_{\text{outlet}} \frac{1 - (\text{VOC}_{\text{out}}/10^6)}{1 - (\text{VOC}_{\text{inlet}}/10^6)}$$

where:

Volume _{inlet}	= inlet volume (cubic meters)
Volume _{out}	= outlet metered volume (cubic meters)
VOC _{out}	= VOC concentration at outlet (ppmv)
VOC _{inlet}	= VOC concentration at inlet (ppmv)

From the data described above, an inlet and an outlet 6-hour total mass in milligrams was calculated for each HAP by adding the three 2-hour run totals together.

The HAP control efficiency for each control device was calculated based on the total mass of each HAP measured simultaneously at the inlet (uncontrolled) and outlet (controlled). The HAP control efficiencies were calculated as follows:

$$CE\%_i = \frac{\text{inlet mass}_i - \text{outlet mass}_i}{\text{inlet mass}_i} \times 100$$

where:

$CE\%_i$ = control efficiency for HAP_i (%)

inlet mass_i = total mass of HAP_i from inlet runs (mg)

outlet mass_i = total mass of HAP_i from outlet runs (mg)

The control efficiencies for total HAPs were calculated by determining the total inlet HAP mass and the total outlet HAP mass and then using the equation above. Tables 4-2 and 4-3 present the HAP control efficiencies for carbon adsorber units (CAUs) and thermal oxidizers (TOs). Note that Table 4-2 contains the control efficiencies for each individual test (averaged over the entire 6-hour test) while Table 4-3 summarizes these results and shows the average and range of control efficiencies for each HAP. Control efficiencies for all the test results are listed in Appendices B and C.

Discussion of Control Efficiency Results

Figure 4-1 shows the total HAP control efficiencies and VOC control efficiencies as a function of the controlled VOC emissions (taken from the compliance test) for the carbon adsorption units. Note that a relatively broad range of values is observed for the VOC control efficiencies (from 87.44% to 99.94%) and a smaller range is seen for the total HAP control efficiencies (from 98.77% to 100.0%). These results indicate that carbon absorption units tend to control HAP emissions at a constant level, independent of the control efficiency for VOCs.

Figure 4-2 shows the total HAP control efficiencies and VOC control efficiencies as a function of controlled VOC emissions for the thermal oxidizers. Note that while a smaller range of controlled VOC emissions was included in the study for thermal oxidizers, a comparison of the control efficiencies reveals that the range of VOC removal efficiencies (99.00% to 99.77%) is similar to that for the total HAPs (99.42% to 99.97%)

TABLE 4-2. CONTROL EFFICIENCY SUMMARY

Test	MTBE	Benzene	Toluene	Ethylbenzene	o,m-Xylene	p-Xylene	Hexane	Iso-Octane	Total HAP	Total HAP w/o MTBE	Total VOC
C-6	99.99	99.95	99.62	98.54	97.98	97.69	99.97	99.84	99.85	99.80	99.90
C-8	100.00	100.00	99.99	100.00	99.95	99.88	100.00	100.00	100.00	100.00	99.94
C-9	100.00	99.99	99.98	100.00	99.96	99.93	99.99	99.98	99.99	99.98	99.77
C-10	NA	100.00	100.00	100.00	100.00	100.00	100.00	99.99	100.00	100.00	98.63
C-12	100.00	99.98	99.97	100.00	99.91	100.00	99.98	99.91	99.97	99.97	99.77
C-14	98.65	99.86	99.91	99.84	99.81	99.73	99.00	97.51	98.77	99.02	98.44
C-15	99.78	99.99	99.96	99.86	99.83	99.80	99.97	99.97	99.94	99.96	95.68
C-16	99.99	99.97	99.85	99.57	99.55	99.44	99.99	99.99	99.93	99.92	97.57
C-17	100.00	100.00	99.99	100.00	99.95	100.00	100.00	100.00	100.00	100.00	98.48
C-18	99.88	99.96	99.88	99.64	99.59	99.39	99.95	99.75	99.85	99.84	95.47
C-19	99.99	99.96	99.97	99.85	99.85	99.88	99.95	99.96	99.98	99.96	99.83
C-20	99.58	99.89	99.86	99.87	99.87	99.81	99.90	99.46	99.73	99.81	99.90
C-21A	99.61	100.00	99.99	99.62	99.54	99.73	99.93	99.58	99.71	99.83	96.25
C-21B	99.17	99.99	99.99	99.42	99.28	99.73	99.85	99.40	99.45	99.73	92.52
C-21C	98.49	99.99	99.98	98.70	98.21	99.27	99.75	99.05	98.99	99.57	87.44

TABLE 4-2. (Concluded)

Test	MTBE	Benzene	Toluene	Ethyl- benzene	o,m- Xylene	p-Xylene	Hexane	Iso- Octane	Total HAP	Total HAP w/o MTBE	Total VOC
T-1	99.96	100.00	100.00	100.00	100.00	100.00	100.00	100.00	99.97	100.00	99.77
T-3	NA	99.16	99.08	100.00	100.00	100.00	99.56	99.41	99.42	99.42	99.50
T-6	NA	100.00	96.42	100.00	100.00	100.00	100.00	100.00	99.45	99.45	99.45
T-7	99.63	100.00	98.82	100.00	96.06	100.00	99.57	99.39	99.53	99.32	99.66
T-8	NA	100.00	100.00	100.00	100.00	100.00	98.29	100.00	99.44	99.44	99.00

TABLE 4-3. HAP CONTROL EFFICIENCIES FOR VAPOR CONTROL UNITS AT GASOLINE LOADING RACKS

HAP Compound	Carbon Adsorbers			Thermal Oxidizers		
	Average CE %	Min. CE %	Max. CE %	Average CE %	Min. CE %	Max. CE %
MTBE	99.65	98.49	100.0	99.79	99.63	99.96
Benzene	99.97	99.86	100.0	99.83	99.16	100.0
Toluene	99.93	99.62	100.0	98.86	96.42	100.0
Ethylbenzene	99.66	98.54	100.0	100.0	100.0	100.0
m,p-Xylene	99.55	97.98	100.0	99.21	96.06	100.0
o-Xylene	99.61	97.69	100.0	100.0	100.0	100.0
Xylene Average	99.58	na	na	99.60	na	na
Hexane	99.88	99.00	100.0	99.48	98.29	100.0
Isooctane	99.62	97.51	100.0	99.76	99.39	100.0
Total HAP	99.74	98.77	100.0	99.56	99.42	99.97
Total HAP w/o MTBE	99.82	99.02	100.0	99.52	99.32	100.0
Average HAP CE %	99.73	98.59	100.0	99.61	98.62	100.0
Total VOC	97.30	87.44	99.94	99.47	99.00	99.77

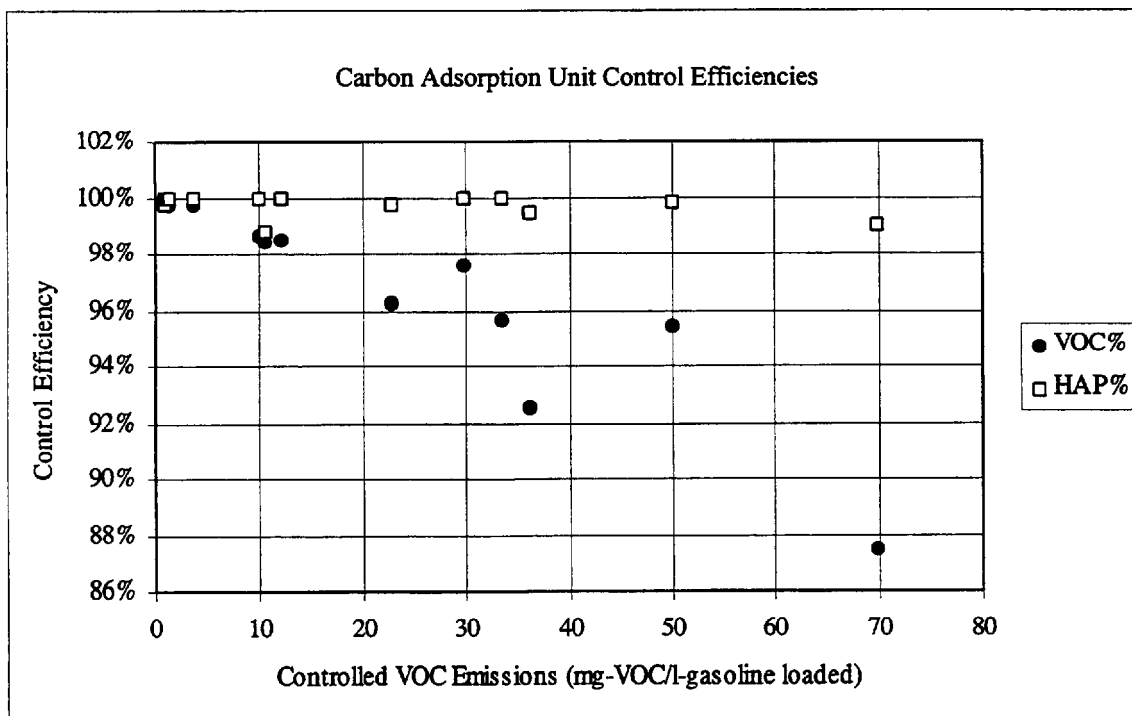


FIGURE 4-1. CARBON ADSORBER UNIT CONTROL EFFICIENCIES

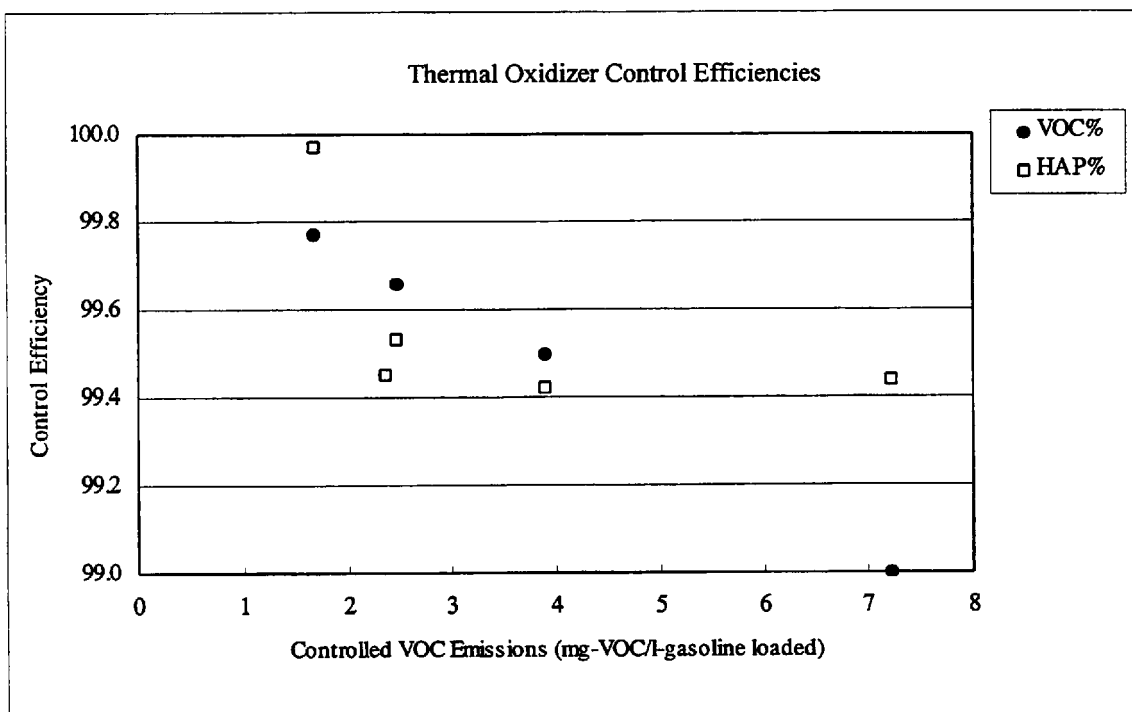


FIGURE 4-2. THERMAL OXIDIZER CONTROL EFFICIENCIES

SECTION 5

EXAMPLE EMISSION FACTOR CALCULATIONS

The control efficiency data collected can be used to derive emission factors for HAPs that allow HAP emission estimation based on volume of gasoline loaded at a facility. The emission factors are presented here as example calculations because it is possible that the user may choose to apply site-specific values for some of the parameters listed below. Although the example calculations listed below are given only for the carbon adsorption units, this approach may be applied to develop emission factors for thermal oxidizers as well. A discussion of parameters that may influence the emission factors is included at the end of this section.

Example Emission Factors

Controlled emission factors for HAPs may be calculated as follows:

$$EF_{HAP_i} = (EF_{VOC})(HAP \text{ to } VOC\%_i) \left(1 - \frac{CE\%_i}{100} \right)$$

where:

- EF_{HAP_i} = controlled emission factor for HAP_i (mg- HAP_i /l-gasoline loaded)
- EF_{VOC} = uncontrolled emission factor for VOC (mg-VOC/l-gasoline loaded)
- $HAP \text{ to } VOC\%_i$ = weight percent of HAP_i in uncontrolled gasoline vapor,
- $CE\%_i$ = control efficiency of HAP_i (percent) (from Table 4-3)

The first two terms in this expression represent the mass of a HAP that is fed to the control unit per liter of gasoline loaded. The last term accounts for the fraction of the vapor stream that is not controlled. Note that the overall efficiency of the treatment unit (with respect to VOCs) is not included in this expression. This is consistent with the finding that the HAP control efficiencies are independent of the VOC control efficiency.

Values for the uncontrolled emission factor for VOC (EF_{VOC}) and speciation of HAPs in uncontrolled gasoline vapors will vary with different gasolines. It is possible that some locations may have site-specific information on these values. For these sample calculations, values for these variables are taken from USEPA guidance. The uncontrolled VOC emission factors are available in AP-42 Table 5.2-5 and are presented in Table 5-1. The individual HAP content values of uncontrolled VOC

emissions (HAP to VOC%) are taken from the EPA publication *Gasoline Distribution Industry (Stage I) - Background Information for Proposed Standards* (EPA-453/R-94-002a) and are presented below in Table 5-2.

The vapor control unit HAP control efficiencies, CE%, were developed in this study and are presented in Table 4-3. Note that since speciation data for the different xylene isomers are not provided in the EPA guidance, control efficiencies for m,p-xylene and o-xylene are averaged for the derivation of a mixed xylene emission factor.

EFs were calculated for carbon adsorption units at loading operations with submerged loading using dedicated normal service and vapor balance service. Tables 5-3 and 5-4 present the EFs for dedicated normal service and vapor balance service, respectively.

Use of Emission Factors

The EFs from Table 5-3 or 5-4 may be used to estimate the emissions of specific HAP compounds as follows:

$$E_{\text{HAP}_i} = V_T \times EF_{\text{HAP}_i}$$

where:

E_{HAP_i} = controlled emissions (mg/time period) for HAP_i

EF_{HAP_i} = emission factor (mg/liter) for HAP_i

V_T = volume of gasoline transferred (liter/time period)

HAP Emission Estimates - Comparison to Previous Approach

In the past, methods used to predict HAP emissions did not consider the fact that carbon adsorption units preferentially remove HAPs compared to total VOC. The results of this study indicate that HAP removal efficiencies average over 99% and will often be greater than VOC removal efficiencies. The impact of these different assumptions is best demonstrated through the evaluation of emissions from an example facility. Consider a gasoline bulk distribution terminal that annually loads 500,000,000 gallons of oxygenated gasoline using dedicated normal service. Also assume this facility controls emissions with a carbon adsorption unit that has a VOC emission limit of 80 mg-VOC/l gasoline transferred.

Previously, HAP emissions estimates assumed the carbon adsorption unit has equivalent HAP and VOC removal efficiencies. To determine HAP emissions, first the total VOC emission rate is calculated and then this value is multiplied by the HAP-to-VOC content of the uncontrolled vapor stream (as listed in Table 5-2).

TABLE 5-1. UNCONTROLLED VOC EMISSION FACTORS FOR TANK TRUCKS

Loading Operation	Emission Factor, mg-VOC/l-transferred gasoline
Submerged loading	
Dedicated normal service	590
Vapor balance service	980

Source: AP-42 Table 5.2-5

TABLE 5-2. UNCONTROLLED GASOLINE VAPOR HAP-TO-VOC CONTENT

	HAP-to-VOC WEIGHT % BY TYPE OF GASOLINE			
HAP	Normal	Reformulated	Oxygenated	Reformulated & Oxygenated
MTBE	0.0	8.7	11.9	11.9
Benzene	0.9	0.4	0.7	0.4
Toluene	1.3	1.1	1.1	1.1
Ethylbenzene	0.1	0.1	0.1	0.1
Xylenes	0.5	0.4	0.4	0.4
Hexane	1.6	1.4	1.4	1.4
Isooctane ^a	0.8	0.7	0.7	0.7
Total HAP ^b	na	12.9	16.3	16.0
Total HAP w/o MTBE ^b	4.8	na	na	na

^a 2,2,4 Trimethylpentane

^b The total HAP ratios shown are not simply sums of the individual HAPs but are the average of the total HAPs and therefore may not be equal to the sum of the individual averages.

Source: Gasoline Distribution Industry (Stage I) - Background Information for Proposed Standards (EPA-453/R-94-002a)