

HEALTH AND
ENVIRONMENTAL
SCIENCES
AND
MANUFACTURING,
DISTRIBUTION AND
MARKETING
DEPARTMENTS

API PUBLICATION
NUMBER 4602

AUGUST 1994



American Petroleum Institute
1220 L Street, Northwest
Washington, D.C. 20005



Minimization, Handling, Treatment, and Disposal of Petroleum Products Terminal Wastewaters



AVA Documents
Document Sharing Hub



One of the most significant long-term trends affecting the future vitality of the petroleum industry is the public's concerns about the environment. Recognizing this trend, API member companies have developed a positive, forward looking strategy called STEP: Strategies for Today's Environmental Partnership. This program aims to address public concerns by improving our industry's environmental, health and safety performance; documenting performance improvements; and communicating them to the public. The foundation of STEP is the API Environmental Mission and Guiding Environmental Principles.

API ENVIRONMENTAL MISSION AND GUIDING ENVIRONMENTAL PRINCIPLES

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. The members recognize the importance of efficiently meeting society's needs and 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 these 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.

American Petroleum Institute
1220 L Street, Northwest
Washington, D.C. 20005



Karen Vaucrosson
Information Specialist
(202) 682-8319
(202) 682-8270 (FAX)

December 12, 1994

To: Recipients of API Pub No. 4602

API has recently been apprised by its contractor of errors made in preparing the report *Minimization, Handling, Treatment and Disposal of Petroleum Products Terminal Wastewaters*, API Publication 4602, published in August of 1994.

Enclosed, please find an errata sheet and several corrected pages. We apologize for the inconvenience.

Sincerely,

Karen Vaucrosson

Affected Publication: **API Publication Number 4602, Minimization, Handling, Treatment and Disposal of Petroleum Products Terminal Wastewaters, August 1994**

On page 1-1, paragraph 1, line 5, the word "to" has been omitted.

The text should read:

"Although wastewater generation at terminals is relatively minor, increasingly strict regulation of wastewater from even minor sources is making it more critical to understand and optimize..."

On page 4-16, Table 4-2, the word "napthenes" should be replaced by "naphthenes."

On page B-17, Figure B-8, the carbon drums are 165 lbs in size, not 500 lbs.

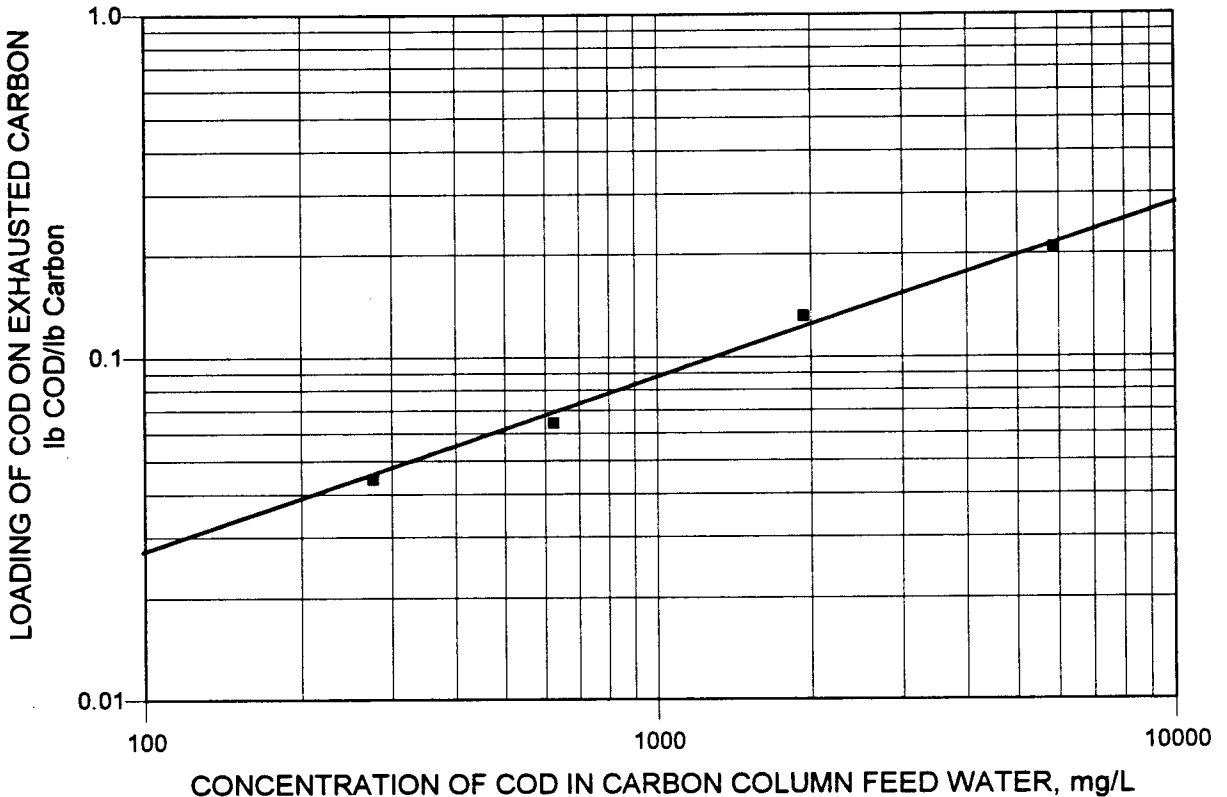
Pages 9-60, 9-62, 9-64, B-11, B-12 and B-13:

The calculations of activated carbon capacity based on pilot and full-scale testing were based on an erroneous value for the weight of carbon in two of the four studies. The erroneous values were based on 500 lb carbon drums. The corrected pages, based on 165 lb carbon drums, are attached. Please paste them into your document.

FIGURE 9-21

Granular Activated Carbon Column Capacity for COD Based on Exhaustion of Full-Scale and Pilot Scale Activated Carbon Columns

The data and graph on this figure were obtained from actual usage rates for granular activated carbon in columns or drums as determined in full-scale usage or pilot tests on marketing terminal wastewaters in the studies described in Appendix B. "Usage rate" is defined as the amount of carbon used before breakthrough of contaminants required changeout of the carbon. The table at the bottom shows the percent of feed COD in the effluent at the time of breakthrough. COD loading was calculated based on the average amount of COD removed from the feed water multiplied by the total volume of water passed through the carbon bed. Figure 9-22 shows similar data for TOC loading. Although the data are based on actual experience, they should be used with caution, since different wastewaters have different adsorption characteristics, and different modes of carbon usage can influence usage efficiency.



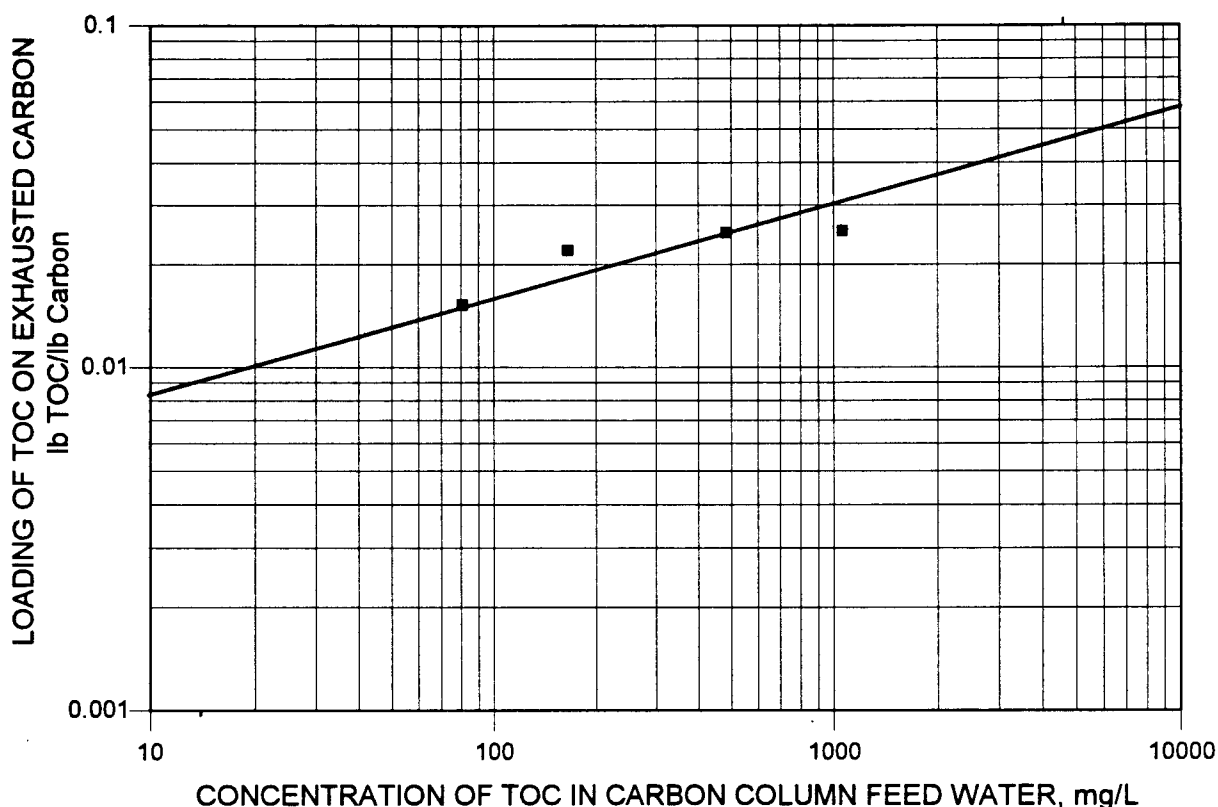
Linear regression equation for best-fit line shown is $LW = 2.0060 \times LC + 5.1353$, where LW is $\log_{10}$ of COD concentration in water (mg/L) and LC is $\log_{10}$ of COD loading on exhausted carbon (lb COD/lb carbon).

Water Being Treated	COD		% Effluent COD/Feed COD	
	Conc. in Water	Loading on Carbon, g/g	Initial	At Breakthrough
Trickling Filter / Activated Sludge Effluent	5962	0.206	31	71
RBC Effluent	616	0.06497	17	62
Untreated Wastewater	1931	0.125	21	51
RBC & SBR Effluents	263	0.04509	13	21

FIGURE 9-22

Granular Activated Carbon Column Capacity for TOC Based on Exhaustion of Full-Scale and Pilot Scale Activated Carbon Columns

The data and graph on this figure were obtained from actual usage rates for granular activated carbon in columns or drums as determined in full-scale usage or pilot tests on marketing terminal wastewaters in the studies described in Appendix B. "Usage rate" is defined as the amount of carbon used before breakthrough of contaminants required changeout of the carbon. The table at the bottom shows the percent of feed TOC in the effluent at the time of breakthrough. TOC loading was calculated based on the average amount of TOC removed from the feed water multiplied by the total volume of water passed through the carbon bed. Figure 9-21 shows similar data for COD loading. Although the data are based on actual experience, they should be used with caution, since different wastewaters have different adsorption characteristics, and different modes of carbon usage can influence usage efficiency.



Linear regression equation for best-fit line shown is $LW = 3.6238 \times LC + 8.5479$, where LW is $\log_{10}$ of TOC concentration in water (mg/L) and LC is $\log_{10}$ of TOC loading on exhausted carbon (lb TOC/lb carbon).

Water Being Treated	TOC		% Effluent TOC/Feed TOC	
	Conc. in Water	Loading on Carbon, g/g	Initial	At Breakthrough
Trickling Filter / Activated Sludge Effluent	1087	0.0252	22	57
RBC Effluent	163	0.02197	9	75
Untreated Wastewater	484	0.0246	24	59
RBC & SBR Effluents	80.8	0.0140	15	14

shows that when treating untreated terminal wastewater, the initial carbon effluent COD level was 21 percent of the feed level; for a typical terminal with 4000 mg/L COD, the best effluent which could be obtained with carbon (in this case) would be 840 mg/L COD. This factor must be taken into account when considering the use of carbon for treatment, and re-emphasizes the desirability of performing field tests before adopting this type (or any other type) of treatment.

9.10.3.3 Example of Carbon Usage Calculation

The following example is provided for purposes of estimating the success and cost of using carbon columns or drums for a given application. Before installing permanent equipment, it is strongly recommended to conduct field tests to confirm such estimations (one advantage of carbon drums is that they can be tried in the field without significant capital investment).

In the first example, it is assumed that a typical marketing terminal with 1000 gallons per week of wastewater with 4000 mg/L COD wishes to treat this water directly with granular activated carbon. The weekly quantity of COD is

$$1000 \text{ gal/week} \times 8.34 \text{ lb/gal} \times (4000 - 840) \times 10^{-6} = 26.35 \text{ lb COD/week}$$

From Figure 9-21, the effective capacity of carbon at a feed concentration of 4000 mg/L is

$$\log_{10}(\text{capacity}) = (\log_{10}(4000) - 5.1353)/2.0060 = -0.7643$$

$$\text{capacity} = 10^x = 0.1721 \text{ lb COD/lb carbon}$$

The weekly carbon usage will thus be

$$26.35 \text{ lb COD/week} / 0.1721 \text{ lb COD/lb carbon} = 153 \text{ lb carbon/week.}$$

At an assumed cost of \$1/lb for carbon, the annual carbon cost would be \$7956.

In the next example, it is assumed that the terminal wishes to produce an effluent with no more than 200 mg/L COD, and that activated carbon alone can only achieve a COD level of 840 mg/L (see above). It is also assumed that biological treatment will achieve 80 percent COD removal, to produce a bioeffluent with 800 mg/L COD, and that carbon treatment of the bioeffluent can reduce this to 21 percent of the feed value (breakthrough value at the bottom of the table on Figure 9-21), for an effluent with 176 mg/L COD. The weekly quantity of COD in the carbon column feed water is

$$1000 \text{ gal/week} \times 8.34 \text{ lb/gal} \times (800 - 176) \times 10^{-6} = 5.204 \text{ lb COD/week}$$

From Figure 9-21, the effective capacity of carbon at a feed concentration of 800 mg/L is

$$\log_{10}(\text{capacity}) = (\log_{10}(800) - 5.1353)/2.006 = -1.1128$$

$$\text{capacity} = 10^x = 0.07713 \text{ lb COD/lb carbon}$$

The weekly carbon usage will thus be

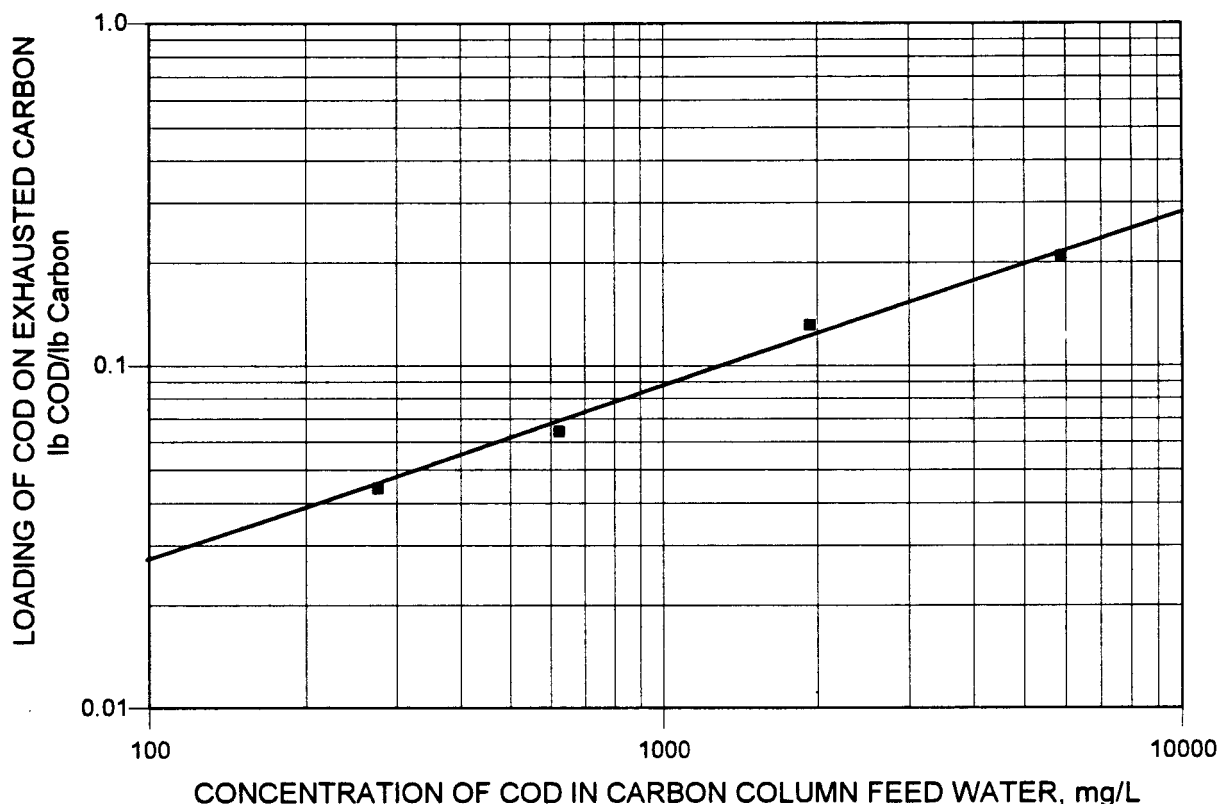
$$5.204 \text{ lb COD/week} / 0.07713 \text{ lb COD/lb carbon} = 67.5 \text{ lb carbon/week.}$$

At an assumed cost of \$1/lb for carbon, the annual carbon cost would be \$3510. Note that carbon usage for treating the bioeffluent is not much less than the cost of treating the raw wastewater. This is a consequence of the fact that carbon has lower capacity when exposed to lower contaminant concentrations (also, bioeffluent COD may be less adsorbable, e.g., more polar, than raw wastewater COD). The main reason for using biotreatment in this case is that effluent concentration will be reduced from 840 mg/L to 176 mg/L. Of course, this may be a very good reason in some cases.

FIGURE B-5

Granular Activated Carbon Column Capacity for COD Based on Exhaustion of Full-Scale and Pilot Scale Activated Carbon Columns

The data and graph on this figure were obtained from actual usage rates for granular activated carbon in columns or drums as determined in full-scale usage or pilot tests on marketing terminal wastewaters in the studies described in Appendix B. "Usage rate" is defined as the amount of carbon used before breakthrough of contaminants required changeout of the carbon. The table at the bottom shows the percent of feed COD in the effluent at the time of breakthrough. COD loading was calculated based on the average amount of COD removed from the feed water multiplied by the total volume of water passed through the carbon bed. Figure B-6 shows similar data for TOC loading. Although the data are based on actual experience, they should be used with caution, since different wastewaters have different adsorption characteristics, and different modes of carbon usage can influence usage efficiency.



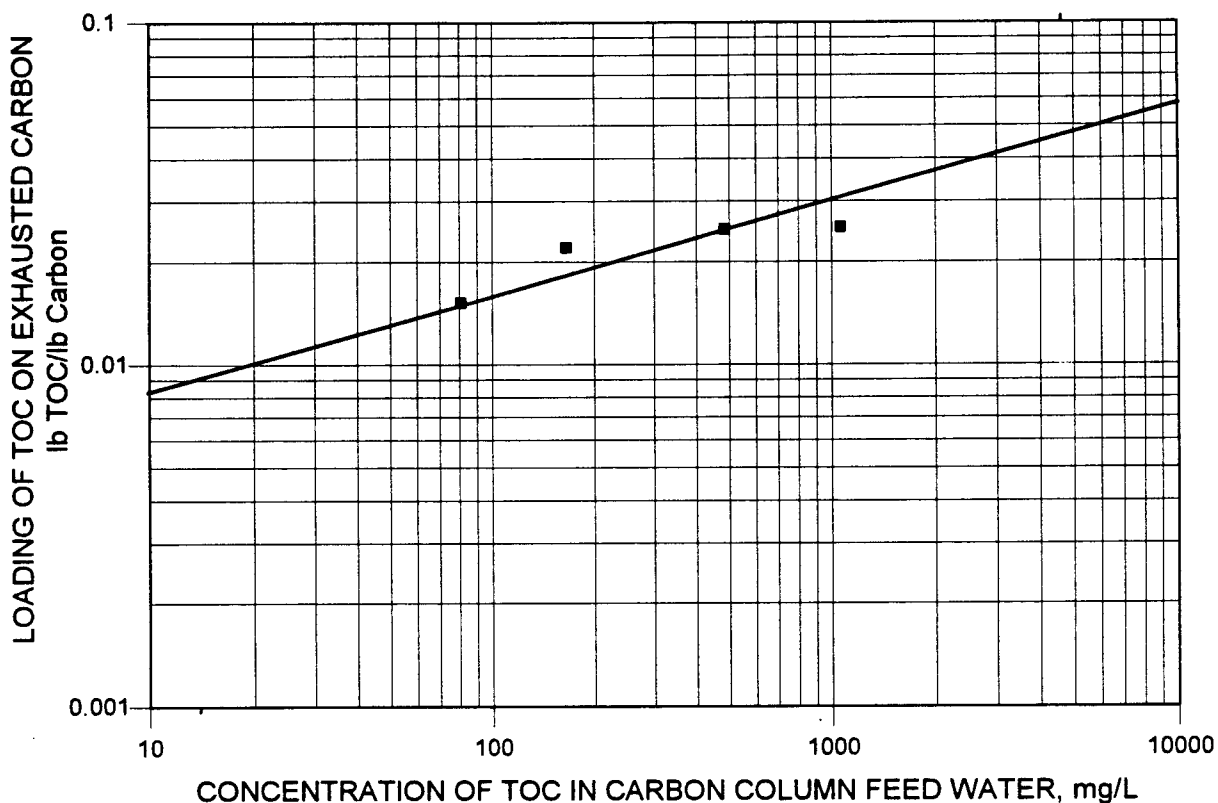
Linear regression equation for best-fit line shown is $LW = 2.0060 \times LC + 5.1353$, where LW is $\log_{10}$ of COD concentration in water (mg/L) and LC is $\log_{10}$ of COD loading on exhausted carbon (lb COD/lb carbon).

Water Being Treated	COD		% Effluent COD/Feed COD	
	Conc. in Water	Loading on Carbon, g/g	Initial	At Breakthrough
Trickling Filter / Activated Sludge Effluent	5962	0.206	31	71
RBC Effluent	616	0.06497	17	62
Untreated Wastewater	1931	0.125	21	51
RBC & SBR Effluents	263	0.04509	13	21

FIGURE B-6

Granular Activated Carbon Column Capacity for TOC Based on Exhaustion of Full-Scale and Pilot Scale Activated Carbon Columns

The data and graph on this figure were obtained from actual usage rates for granular activated carbon in columns or drums as determined in full-scale usage or pilot tests on marketing terminal wastewaters in the studies described in Appendix B. "Usage rate" is defined as the amount of carbon used before breakthrough of contaminants required changeout of the carbon. The table at the bottom shows the percent of feed TOC in the effluent at the time of breakthrough. TOC loading was calculated based on the average amount of TOC removed from the feed water multiplied by the total volume of water passed through the carbon bed. Figure B-5 shows similar data for COD loading. Although the data are based on actual experience, they should be used with caution, since different wastewaters have different adsorption characteristics, and different modes of carbon usage can influence usage efficiency.



Linear regression equation for best-fit line shown is $LW = 3.6238 \times LC + 8.5479$, where LW is $\log_{10}$ of TOC concentration in water (mg/L) and LC is $\log_{10}$ of TOC loading on exhausted carbon (lb TOC/lb carbon).

Water Being Treated	TOC		% Effluent TOC/Feed TOC	
	Conc. in Water	Loading on Carbon, g/g	Initial	At Breakthrough
Trickling Filter / Activated Sludge Effluent	1087	0.0252	22	57
RBC Effluent	163	0.02197	9	75
Untreated Wastewater	484	0.0246	24	59
RBC & SBR Effluents	80.8	0.0140	15	14

Minimization, Handling, Treatment, and Disposal of Petroleum Products Terminal Wastewaters

**Health and Environmental Sciences Department
and
Manufacturing, Distribution, and Marketing Department**

API PUBLICATION NUMBER 4602

PREPARED UNDER CONTRACT BY:

B.V. KLOCK TEXACO INC.
RESEARCH & DEVELOPMENT DEPARTMENT
ENVIRONMENTAL RESEARCH SECTION
PORT ARTHUR, TEXAS

AUGUST 1994

**American
Petroleum
Institute**



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.

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

Priscilla J. Young, Manufacturing, Distribution & Marketing Department

MEMBERS OF THE MARKETING TERMINAL EFFLUENT TASK FORCE

Robert R. Goodrich, *Chairman*, Exxon Research and Engineering Company
Dave Pierce, *Vice-Chairman*, Chevron Research and Technology

Jeff Baker, Conoco Inc.
Terrie Blackburn, Williams Pipeline
Sanjay Dhawan, Amoco Oil Co.
Don Hitchcock, Texaco Refining and Marketing
Nancy Kralik, Marathon Oil Co.
LeAnne Kunce, BP Oil
Al Schoen, Mobil Research & Development
Marilyn Shup, Sun Refining and Marketing
Paul Sun, Shell Development Co.
Carl Venzke, Citgo Petroleum

The author wishes to express his appreciation to his colleagues within Texaco's Marketing, Pipeline, and Research Departments and to members of the API Marketing Terminal Effluent Task Force, who provided much valuable input on operations and procedures in petroleum products terminals. Special thanks for their guidance and assistance are owed to Mr. Dave Pierce, to task force chairman Mr. Robert Goodrich, and to API's Ms. Priscilla Young.

ABSTRACT

This report is intended to be a basic guide and information resource for all wastewater operations at petroleum products terminals. It includes the regulatory framework for wastewater issues, a detailed description of the sources of terminal wastewater and associated contaminants, guidance on means for analyzing the wastewater situation at a terminal, on means for minimizing wastewater flow and contamination, on means for handling and disposing of wastewater, and on available methods for treating wastewater with various types of contaminants. The regulatory discussion focuses on the effects of wastewater and hazardous waste regulations on wastewater handling and treatment. This is followed by a description of petroleum products terminals operations and associated wastewater generation and typical contaminants. The remainder of the report covers methods for investigating and designing wastewater operations at terminals. First is an overview of wastewater handling, treatment, and disposal options. Means for characterization and minimization of terminal wastewater flow and contamination are covered. Last is an overview of wastewater treatment options for terminal wastewater. The types of treatment appropriate for removing various types of contaminants are listed, along with opportunities for source reduction of these contaminants. General factors for wastewater treatment are outlined and wastewater treatment methods applicable to the types of contaminants expected in petroleum products terminal wastewater are reviewed.

CONDENSED TABLE OF CONTENTS

1	INTRODUCTION	
2	DEFINITIONS	
3	OVERVIEW OF REGULATORY REQUIREMENTS	
3.1	Overview	3-1
3.2	Wastewater Discharges: Federal Water Pollution Control Act of 1972 and Amendments and Safe Drinking Water Act of 1974	3-1
3.3	Hazardous Wastes: Resource Conservation and Recovery Act of 1976 and Amendments	3-10
4	TERMINAL OPERATIONS	
4.1	Introduction	4-1
4.2	Petroleum Products Distribution Network	4-1
4.3	Petroleum Products Terminals Functions	4-4
4.4	Products Terminal Distribution Facilities	4-5
4.5	Storage Facilities	4-6
4.6	Products Handled	4-13
4.7	Other Terminal Operations	4-18
4.8	Terminal Operations	4-20
4.9	Wastewater Sources	4-20
4.10	Impact of Terminal Wastewater on the Environment	4-27
4.11	Characteristic Contaminants in Petroleum Products Terminal Wastewater Streams	4-29
5.	DESIGN OF WASTEWATER HANDLING AND TREATMENT: OVERALL PERSPECTIVE	
5.1	Introduction	5-1
5.2	Disposal Options for Contaminated Water	5-1
5.3	Model System	5-4
5.4	Design Factors	5-7
5.5	Wastewater Handling and Treatment Investigation and Design Procedure	5-10
6.	SOURCE IDENTIFICATION	
6.1	Overview	6-1
6.2	Water System Process Flow Diagram	6-1
6.3	Supply Water System Map	6-1
6.4	Wastewater Sewer Diagram	6-1
6.5	Wastewater Flow Characterization	6-1
6.6	Wastewater Contaminants Characterization	6-7
6.7	Terminal Survey/Checklist Form	6-12
7.	SOURCE REDUCTION	
7.1	Introduction	7-1
7.2	Stormwater	7-1
7.3	Minimizing Contamination of Potentially Contaminated Stormwater	7-7
7.4	Minimizing Oil Discharge Contamination of Wastewater	7-9

7.5	Minimizing Oil/Water Emulsion Contamination.....	7-16
7.6	Use of Slop Oil Systems to Minimize Oil Discharges.....	7-19
7.7	Minimizing Tank Bottoms Water Accumulation.....	7-20
7.8	Minimizing Other Wastewater Sources.....	7-24
7.9	Overview of Source Reduction Measures.....	7-27
8.	WASTEWATER HANDLING DESIGN	
8.1	Introduction.....	8-1
8.2	Stormwater Handling in Terminals.....	8-1
8.3	Contaminant Load Equalization for Wastewater Treatment.....	8-10
8.4	Wastewater Conveyance.....	8-12
8.5	Design of Tank Bottoms Collection Systems.....	8-15
9.	WASTEWATER TREATMENT DESIGN	
9.1	Introduction.....	9-1
9.2	Selection of Treatment.....	9-1
9.3	Appropriate Treatments.....	9-2
9.4	General Wastewater Treatment Factors.....	9-7
9.5	Oil/Water Separation.....	9-14
9.6	Biological Wastewater Treatment.....	9-26
9.7	Coagulation.....	9-44
9.8	Filtration.....	9-45
9.9	Wastewater Gas Strippers.....	9-48
9.10	Activated Carbon Adsorption.....	9-55
9.11	pH Control.....	9-65
9.12	Oxidation.....	9-65
9.13	Ammonia Removal Techniques.....	9-68
9.14	Advanced Metals Removal Techniques.....	9-69
9.15	Biological Effluent Polishing.....	9-70

REFERENCES

APPENDIX A: PETROLEUM PRODUCTS TERMINAL WASTEWATER FACT SHEETS

APPENDIX B: SUMMARY OF TREATMENT RESULTS AT TERMINALS

B-1	Introduction.....	B-1
B-2	Overview of the Four Cases.....	B-1
B-3	Treatment Performance.....	B-9
B-4	Treatment System Design Guidelines.....	B-14

TABLES

4-1	Petroleum Products Boiling Points.....	4-16
4-2	Typical Gasoline Composition, Weight Percent.....	4-16
4-3	Petroleum Products Terminals Wastewater Sources and Likely Contaminants.....	4-21
4-4	Terminal Product Contact Water Concentrations.....	4-22



Documents

Document Sharing Hub

4-5	Comparison of Terminal Effluent With Other Discharges	4-28
4-6	Solubility of Petroleum Products' Components in Water.....	4-30
4-7	Octanol-Water Partition Coefficients for Common Contaminants	4-31
4-8	pH Levels of Common Solutions	4-33
4-9	Estimated Aquatic Chronic Toxicity Thresholds.....	4-37
5-1	Comparison of Disposal Options.....	5-2
6-1	Common Petroleum Industry Wastewater Analyses.....	6-13
		6-14
7-1	Stormwater Characteristics	7-2
9-1	Contaminants and Source Reduction Potentials.....	9-4
9-2	Contaminants and Appropriate Treatments	9-4
9-3	Typical Specific Gravities of Petroleum Products.....	9-15
9-4	Comparison of Biological Treatment Processes.....	9-38
9-5	Comparison of Secondary Treatments of Petroleum Products Terminals Wastewaters	9-40
9-6	Typical Sand Filter Operating Conditions.....	9-47
9-7	Henry's Law Constants at 20 C	9-49

APPENDIX B

B-1	Comparison of Secondary Treatments of Petroleum Products Terminals Wastewaters	B-9
B-2	Comparison of Activated Carbon Treatments of Bioeffluents	B-10
B-3	Biological Treatments Loading and Performance	B-15

FIGURES

3-1	RCRA Guide for Benzene-Containing Water	3-12
3-2	Tank Bottoms Water Handling Scenarios.....	3-15
4-1	Product distribution network	4-2
4-2	Tank Bottoms Construction.....	4-6
4-3	Tank Roofs.....	4-7
4-4	Floating Roof Seals.....	4-8
4-5	Floating Roof Drains	4-9
4-6	Tank Water Draw Sumps.....	4-10
4-7	Tank Level Gauging	4-10
4-8	Horizontal Tanks	4-11
4-9	Hydrocarbon Vapor Control	4-12
4-10	Petroleum Product Chemicals	4-15
4-11	Rack Slab Spill Containments	4-25

5-1	Optimized Terminal Water Minimization, Handling, and Treatment System.....	5-6
5-2	Outline of Wastewater Handling and Treatment Investigation	5-11
6-1	Example of Marketing Terminal Wastewater Process Flow Diagram	6-2
6-2	Example of Marketing Terminal General Arrangement Plan With Water Supply Lines and Wastewater Lines.....	6-3
6-3	Example of Marketing Terminal Water Flow Balance.....	6-5
6-4	Subsurface Sampler	6-9
6-5	Filling VOA Bottles	6-10
6-6	Sample Filtration	6-11
7 -1	Geographical Stormwater Segregation.....	7-3
7-2	Storm Segregation Procedure	7-5
7-3	Rack Canopy Rain Protection	7-6
7-4	Tank Basin Storm Drain	7-8
7-5	Pipeway Spill Berms	7-8
7-6	Tank Bottoms Sight Glass Connection.....	7-9
7-7	Tank Bottoms Sight Glass Piping.....	7-10
7-8	Tank Water Draw Product Entrainment Control	7-11
7-9	Control Valve Bypass and Isolation Loop	7-14
7-10	Facilitation of Pipe Drainage	7-15
7-11	Product Sample Piping.....	7-16
7-12	Tank Product Draw Water Entrainment Control	7-23
8-1	Flooded Tank Basin Access	8-6
8-2	Tank Water Draw Dry Well	8-7
8-3	Stormwater Storage in Excavated Tank Basin.....	8-7
8-4	Tank Draw Water Equalization Tank Design	8-13
9-1	Batch Processing	9-10
9-2	Batch Feed Tank Oil Skimming.....	9-11
9-3	API Oil/Water Separator.....	9-18
9-4	Downflow Parallel Plate Separator.....	9-23
9-5	Dissolved Air Flotation	9-25
9-6	Biological Treatment Clarifier	9-31
9-7	Cone-Bottom Clarifier	9-32
9-8	Aerated Lagoon.....	9-32
9-9	Activated Sludge Process.....	9-33
9-10	Sequencing Batch Reactor Time Sequence.....	9-34
9-11	Rotating Biological Contactor.....	9-35
9-12	Fluidized bed bioreactor.....	9-37
9-13	Pressure Sand Filter	9-46
9-14	Air Stripper	9-49
9-15	Recycle Air Stripper	9-52

9-16	Sparger Stripper	9-53
9-17	Activated Carbon Isotherm Example.....	9-56
9-18	Granular Activated Carbon Column Operation.....	9-57
9-19	Use of Granular Activated Carbon Drums.....	9-58
9-20	Powdered Activated Carbon Usage.....	9-59
9-21	Granular Activated Carbon Column Capacity for COD Based on Exhaustion of Full-Scale and Pilot Scale Activated Carbon Columns.....	9-60
9-22	Granular Activated Carbon Column Capacity for TOC Based on Exhaustion of Full-Scale and Pilot Scale Activated Carbon Columns.....	9-62
9-23	Ozone Generation and Use	9-66

APPENDIX B

B-1	Case 1: Treatment Summary from API 4581, "Evaluation of Technologies for the Treatment of Petroleum Marketing Terminal Wastewater"	B-2
B-2	Case 2: Treatment Summary from API 4582, "Comparative Evaluation of Biological Treatment of Petroleum Product Terminal Wastewater by the Sequencing Batch Reactor Process and the Rotating Biological Contactor Process"	B-4
B-3	Case 3: Treatment Summary from a Full-Scale Operation of a Trickling Filter - Activated Sludge - Activated Carbon - UV/Ozone Treatment of a Petroleum Products Terminal Tank Bottoms Wastewater.....	B-7
B-4	Case 4: Treatment Summary for Full-Scale Sequencing Batch Reactor Treatment of Marketing Terminal Tank Bottoms Water.....	B-8
B-5	Granular Activated Carbon Column Capacity for COD Based on Exhaustion of Full-Scale and Pilot Scale Activated Carbon Columns.....	B-12
B-6	Granular Activated Carbon Column Capacity for TOC Based on Exhaustion of Full-Scale and Pilot Scale Activated Carbon Columns.....	B-13
B-7	Case 1: Design and Operating Conditions for the API 4581 Pilot Study	B-16
B-8	Case 2: Design and Operating Conditions for the API 4582 Pilot Study	B-17
B-9	Case 3: Design and Operations of a Full-Scale Trickling Filter - Activated Sludge - Activated Carbon - UV/Ozone Treatment of a Petroleum Products Terminal Tank Bottoms Wastewater.....	B-18
B-10	Case 4: Design and Operations of a Full-Scale Sequencing Batch Reactor Treatment System on a Marketing Terminal Wastewater.....	B-19

PREFACE

The American Petroleum Institute (API), through its Marketing Terminal Effluent Task Force is conducting a multi-year program to evaluate and identify practical and environmentally sound technology options for handling and treating waters generated at petroleum product distribution terminals. The results of this program are intended to provide industry and regulatory agencies with sound technical information to make informed decisions on appropriate alternatives for individual terminal facilities.

This document provides comprehensive information to allow terminal engineers or operations staff to identify technology options for minimizing, handling, treating and disposing of water and wastewaters. The report covers typical terminal operations, an overview of regulatory requirements, wastewater source identification and reduction, onsite and offsite disposal options, wastewater treatment technologies and design. The information is a culmination of prior studies done by the API, as well as industry-supplied data and information from publicly available sources.

Prior work has shown that operations and wastewater characteristics at petroleum product distribution terminals can vary significantly, as do the regulatory requirements in different geographical jurisdictions. Hence, it is recommended that terminal operators or engineers carefully review the requirements for each facility prior to implementing control measures. This comprehensive compilation of information and treatment process options should greatly aid in these reviews.

The task force acknowledges and greatly appreciates the excellent efforts of Texaco's Port Arthur Research staff, in particular Dr. Byron Klock, for their extensive work in preparing this useful and comprehensive report. The work was a major multidisciplined effort covering many facets of terminal operations, specialized industry treatment technology and various fields of engineering, chemistry and aquatic toxicology.

R.R. Goodrich

On behalf of the Marketing and
Terminal Effluent Task Force

Chapter 1

INTRODUCTION

Petroleum products terminals are used with transportation operations to move products from their source in refineries down to the consumers. They are relatively simple facilities comprising product storage tanks, the means for connecting the tanks to transportation operations, and other supporting equipment. Although wastewater generation at terminals is relatively minor, increasingly strict regulation of wastewater from even minor sources is making it more critical to understand and optimize handling, treatment and disposal of terminal wastewater to ensure that effective treatment is accomplished at reasonable cost.

This report is intended to be a basic guide and information resource for all wastewater operations at petroleum products terminals. It includes the regulatory framework for wastewater issues, a detailed description of the sources of terminal wastewater and associated contaminants, and guidance on means for analyzing the wastewater situation at a terminal, on means for minimizing wastewater flow and contamination, on means for handling and disposing of wastewater, and on available methods for treating wastewater with various types of contaminants.

Chapter 3 is an overview of the regulatory framework for petroleum products terminal wastewater issues. Although not a substitute for detailed understanding of environmental regulatory law, it provides an outline of the issues most likely to be applicable to petroleum products terminals. Most of this chapter covers wastewater permits for discharge to public waters or municipal treatment plants, and provides guidance on the issues covered by these and on permit application and negotiation procedures. Since hazardous waste disposal regulations can potentially be applied to wastewater, guidance is provided on such regulations, and on the effects of these on wastewater handling, treatment, and disposal.

Chapter 4 describes petroleum products terminals operations and associated wastewater generation. The function of terminals in the transportation network, and the various types of terminals, are outlined. Terminal operations and products are discussed, along with the wastewater sources from these. The impact of a typical terminal wastewater on the environment is described to place this in context. Finally, the nature of typical contaminants in terminal wastewaters is discussed.

The remaining chapters are devoted to methods for investigating and designing wastewater operations at terminals.

Chapter 5 provides an overview of wastewater handling, treatment, and disposal options. Since the means utilized for final disposition of the wastewater strongly affects the required upstream operations, the choices of disposal options, with their advantages and disadvantages, are discussed first. This is followed by an outline of a model system, with optimized techniques for minimizing wastewater flow and contamination, and of treating the wastewater. Finally, the general factors to be considered in selecting wastewater designs are discussed.

Chapter 6 is a guide to characterization of terminal wastewater flow and contamination. The first section covers various means for measuring continuous and sporadic flows, while the second section describes wastewater sampling in some detail, and provides an overview of analytical techniques.

Chapter 7, on source reduction, is a technical guide to means for reducing the flow and contamination in terminal wastewaters. Stormwater segregation and minimization of contamination are described first. This is followed by detailed techniques on minimizing oil contamination of terminal wastewater, and minimizing flow of the principal contaminated water source, tank bottoms water. Finally, means for minimizing flow or contamination from other likely terminal wastewater sources are covered.

Chapter 8 provides information on various aspects of terminal wastewater handling design. The topics include routing and storage of various types of stormwater, contaminant load equalization, particularly for sporadic tank bottoms draws, and design of tank bottoms collection systems.

Chapter 9 is an overview of wastewater treatment options for terminal wastewater. It opens with a discussion of the effects of the means chosen for wastewater disposal on the likely needs for treatment, ranging from essentially no treatment to possibly very thorough treatment. Next, the types of treatment appropriate for removing various types of contaminants are listed, along with opportunities for source reduction of these contaminants. General factors for wastewater treatment are outlined, including the modes of treatment (continuous vs. periodic treatment, permanent vs. mobile installation). Finally, wastewater treatment methods applicable to the types of contaminants expected in petroleum products terminal wastewater are reviewed. This discussion is meant to provide an overview of available treatment methods, but not design guidelines, which must be obtained from more specialized and detailed sources.

Appendix A is a set of blank forms on terminal wastewater, to be used as a tool in developing information on the wastewater situation at a given terminal.

Appendix B provides summaries of treatment results from use of pilot or full-scale treatment in actual installations to serve as a guide to the effectiveness and practicality of various types of treatment.

Chapter 2

DEFINITIONS

The following terms are used throughout the report, and may not be familiar to those persons who do not normally deal with petroleum products terminals or wastewater. In addition to the following, definitions of specialized terms are given throughout the report at the point where they are used.

Ballast Water	Water placed in empty ships and barges to stabilize their motion while under way.
Barrel	In the petroleum industry, a unit of volumetric measure equal to 42 gallons. Abbreviated <i>bbl</i> .
Bioassay	A test of water quality which directly measures the degree of adverse effects on living aquatic organisms.
BTEX	Benzene, Toluene, Ethylbenzene, Xylenes, simple aromatic compounds comprising benzene, methyl benzene (toluene), ethylbenzene, and three dimethyl benzenes (xylenes), commonly found as high-octane components of gasoline.
CFR	Code of Federal Regulations, the US federal law code. Environmental regulations are contained in section 40 CFR.
CWA	Clean Water Act, the Federal law designed to protect the quality of public waters.
DIPE	Di Iso Propyl Ether, a high-octane petrochemical used as a gasoline supplement to enhance octane and reduce vehicle emissions. Formula: $(\text{CH}_3)_2\text{HC}-\text{O}-\text{CH}(\text{CH}_3)_2$
Downstream	That portion of the petroleum industry involving crude oil refining, products distribution, and products marketing.
EPA	Environmental Protection Agency, the Federal agency which administers Federal environmental laws by developing and enforcing environmental regulations.
Hazardous Waste	A term defined in RCRA to mean solid waste which either fails tests for hazardousness (<i>characteristic</i> hazardous waste) or is defined by its method of generation as being hazardous (<i>listed</i> hazardous waste).

LEL & UEL	Lower Explosive Limit & Upper Explosive Limit, measures (as percent of fuel vapor) of the ability of a fuel-air mixture to explode when exposed to an ignition source. At fuel percentages below the LEL, the mixture is too <i>lean</i> to explode (not enough fuel to sustain combustion). At fuel percentages above the UEL, the mixture is too <i>rich</i> to explode (not enough oxygen to sustain combustion). The atmosphere in most petroleum products storage vessels is above the UEL.
Midstream	That portion of the petroleum industry involving crude oil transport from producing operations to refining operations.
M	In the petroleum industry, a numerical prefix meaning a thousand (equivalent to the metric system prefix <i>kilo</i>).
MM	In the petroleum industry, a numerical prefix meaning a million.
MTBE	Methyl Tertiary Butyl Ether, a high-octane petrochemical used as a gasoline supplement to enhance octane and reduce vehicle emissions. Formula: $\text{CH}_3\text{-O-C}(\text{CH}_3)_3$
NPDES	National Pollutant Discharge Elimination System, the Federal regulations controlling the treatment and disposal of wastewaters discharged to public waters.
Oil	In wastewater terminology, used to mean oil & grease or TPH.
Oil & Grease	A water quality test which measures the amount of material extractable into a solvent (usually Freon) by weighing the residue left by evaporating the solvent. Sometimes abbreviated O&G.
pH	A measure of the acid - base balance in water, with pH 1 being extremely acidic, pH 7 being neutral, and pH 14 being extremely alkaline. By definition, the negative base ten logarithm of the activity (approximately equal to the gram-molar concentration) of hydrogen ions.
POTW	Publicly Owned Treatment Works, municipal wastewater treatment plants which normally treat domestic sewage along with some commercial and industrial wastewater. Most POTWs employ settling and biological wastewater treatment.
RCRA	Resources Conservation and Recovery Act, the Federal law which regulates the generation, handling, treatment, and disposal of solid and hazardous wastes.

SDWA	Safe Drinking Water Act, the Federal law controlling activities which affect the quality of drinking water sources.
Sludge	Generally, solid or semi-solid material which separates by settling from wastewater.
Solid Waste	A term defined in RCRA to mean discarded material other than air emissions and wastewater discharges.
TAME	Tertiary Amyl Methyl Ether, a high-octane petrochemical used as a gasoline supplement to enhance octane and reduce vehicle emissions. Formula: $\text{CH}_3\text{-O-C(CH}_3)_2\text{CH}_2\text{CH}_3$
Tank	Most commonly, a vertical cylindrical vessel used for storing petroleum products, with bottom and sides made from steel plates, and usually with a fixed or floating metal roof. Storage capacities range from 500 to 300,000 barrels.
Tank Bottoms	The material, usually a mixture of water and solids, which collects at the bottom of petroleum product storage tanks. Sometimes used to mean tank bottoms water.
Tank Bottoms Water	Water which collects at the bottom of petroleum product storage tanks and is periodically removed.
Terminal	A facility used to store petroleum products along the distribution chain from the petroleum refinery to the final consumer.
Toxicity	Adverse effects (lethality, growth suppression, reduced fecundity) on aquatic organisms.
TPH	Total Petroleum Hydrocarbons, a water quality test similar to oil & grease, but limited to petroleum-derived hydrocarbons by excluding other extractable materials such as sulfur and polar organic compounds.
Truck Wash Water	Water, usually containing detergent, soil particles, and some oil, produced by the washing of petroleum product tanker trucks. Similar in nature to car wash water.
Upstream	That portion of the petroleum industry involving exploration for and production of crude oil.

Chapter 3

OVERVIEW OF REGULATORY REQUIREMENTS

3.1 Overview

This section contains a general description of environmental legislation and resulting regulations that relate to effluent (wastewater) discharges from petroleum products terminals. The writeup is arranged by areas, with each area defined by the primary federal legislation for that area.

This discussion is not intended to address all regulatory requirements related to petroleum product terminals, but to provide pertinent information on some of the most important issues related to wastewater treatment plants and effluent discharges. Due to the complexity of the regulations, petroleum product terminals should obtain guidance from environmental regulatory specialists when dealing with specific permitting or compliance issues.

3.2 Wastewater Discharges: Federal Water Pollution Control Act of 1972 and Amendments and Safe Drinking Water Act of 1974

The Federal Water Pollution Control Act of 1972, also known as the Clean Water Act (CWA), provides the EPA with the authority to regulate the direct or indirect discharge of wastewater to waters of the United States. Indirect discharges are those which reach the receiving waters after treatment in a municipal sanitary sewage treatment plant, called a “publicly owned treatment works”, or POTW, in the regulations. Direct discharges are those which are sent directly from the commercial or industrial facility to the receiving water without further treatment. Direct wastewater discharges are regulated under the National Pollutant Discharge Elimination System (NPDES) in accordance with Section 402 of the CWA. Indirect wastewater discharges are regulated in accordance with Section 307(b) of the CWA.

3.2.1 NPDES PERMITS

In general, any direct discharge of pollutants to waters of the United States from a point source requires an NPDES permit. “Waters of the United States” is interpreted very broadly to mean virtually any surface waters not solely on private property; even dry stream beds or drainage ditches are included. However, groundwater is *not* included, so if the water is sent to a well, or into a french drain, percolation pond, evaporation pond, or infiltration gallery, then an NPDES permit is probably not needed. A number of court cases have addressed the question of whether discharges to groundwater with a close connection to surface water may require an NPDES permit. The prevailing view appears to be that a permit is not needed, but the issue has not been completely resolved nationally. Also, for discharges to ground, another type of wastewater permit may be required by the Safe Drinking Water Act or local regulations. Also, note that an NPDES permit allows water which would otherwise be classified as hazardous waste to be exempted (see below).

3.2.1.1 Point Source

A “point source” is any discharge to public waters resulting from collection and conveyance of wastewater, by means including pipes, sewers, ditches, channels, and so forth. A nonpoint source is water which leaves the property by running off the land (e.g., down a hillside) in sheet flow, i.e., not collected or channeled. In general, if the water is collected before discharge, the discharge becomes a point source. As noted, any point source discharge containing pollutants as defined in the CWA (except stormwaters, in some cases) sent directly to public waters must have an NPDES permit. If the facility has more than one point source, each source must be permitted (although all the sources at a facility are usually covered by a single NPDES permit). Point sources are referred to as *Outfalls* and are assigned unique numbers. Each outfall may have different parameters to be monitored and controlled, and different levels of control.

3.2.1.2 Permit Application

An NPDES permit is an official document which specifies the legal conditions for discharging wastewater. It is obtained by filing a permit application with the proper authority (see below), using special forms. The usual application contains a facility description, the volumes and characteristics of all point source wastewaters, and the type of treatment being applied (or planned to be applied) to the wastewater. An application must be filed at least 180 days before the first discharge occurs, or 180 days before the expiration of an existing permit. It is essential to make the application as complete and accurate as possible. The wastewater flow and contaminant levels need to be accurately described, since these are often used as the basis for the permit limits.

3.2.1.3 Legal Status of Permits

Obtaining a permit usually requires knowledge of correct procedures as applied to each location (many states and municipalities have requirements which differ considerably from federal requirements); obtaining expert help, either within the company or from outside consultants, is recommended. Severe civil and criminal penalties can be assessed for violating the Clean Water Act, even if the violation was not intentional. If the proposed permit contains provisions which cannot be met by the facility (for instance, if effluent standards are stricter than can be achieved by the facility treatment system), then the permit should not be accepted; once the permit *is* accepted, all violations become subject to the penalties noted.

3.2.1.4 Permitting Authority

The authority to issue NPDES permits is ultimately controlled by the EPA. However, the EPA can, and has in most cases, given this permitting authority to the individual states. In states not so authorized, both EPA and state discharge permits may be required. States can also delegate permit writing for federal or state permits to local agencies. At each level (state and local) downwards, *more stringent* limits can be applied; on the other hand, more lenient low-level standards do *not* override stricter upper level standards.

3.2.1.5 EPA Guidelines

EPA has established detailed national permitting guidelines for various industrial categories such as petroleum refineries and chemical plants. At this time, no such national guidelines are available for petroleum products terminals, probably because of the relatively small impact such facilities have on the environment. Because of this lack of national guidelines, NPDES permit limits for terminals

are set by EPA regional offices, or by states, localities, or other local agencies. This leads to considerable variety in the types and stringency of permits issued across the country. Another source of variation is the change of permit requirements with time: older permits are usually less complex and less stringent. The following provides a general indication of the types of permit requirements which can be expected.

3.2.1.6 Effluent Contaminant Parameters

Effluent limitations (concentrations, mass emissions, and other) imposed under NPDES permit programs can include, but are not limited to, any of the following parameters (see 4.11.3 for a more complete discussion of the parameters):

Conventional parameters are those contaminants which are typically found in sewage or stormwater runoff. These parameters have an adverse effect on the receiving water, but also are indicators of the quality of wastewater treatment which produced the effluent. EPA defines the list of conventional parameters, which currently includes BOD₅, oil & grease, TSS, and pH.

Priority pollutants are those identified by EPA as being worthy of special attention due to a combination of their toxicity and their likelihood of being found in industrial and municipal effluents. Most priority pollutants would not be expected to be found in petroleum products terminal wastewater. Some which are found include benzene, toluene, ethylbenzene, and some of the heavy metals such as copper and zinc.

Nonconventional parameters are regulated parameters commonly found in some commercial or industrial discharges, but not included in the conventional or priority pollutant categories. Nonconventional parameters include COD, ammonia, and phenolic compounds, and several other parameters.

Toxicity limits are based on bioassay tests on the effluent, rather than chemical analyses. In a bioassay, living aquatic organisms of various types are exposed to the effluent at various dilutions for set time periods, and the responses such as lethality (death), growth (weight increase), and reproduction (number of descendants) are measured. Generally, the limits for acute toxicity (typically measuring short-term lethal effects) are expressed in terms of the concentration or dilution of the effluent (in terms of percent) which is lethal to half of the test organisms. This is called the median lethal concentration (LC₅₀). Chronic toxicity (typically measuring longer term lethal or sublethal effects such as growth) is typically expressed as the maximum effluent concentration which is seen to have no effect on the organisms, the no observed effect concentration (NOEC). Toxicity limits are becoming favored by regulatory authorities since they provide a broad-based indication of the adverse effects, or lack thereof, of the effluent on the receiving water.

3.2.2 BASES FOR PERMITS

There are a variety of bases which Federal, state, and local agencies use to set permit limits, or to establish the guidelines which are used to set permit limits. These include technology bases, receiving water quality bases, and bases other than these.

3.2.2.1 Technology Basis for Permits

The technology basis provides limits which are supposed to reflect the capabilities of treatment technologies. Examples include the oil and grease levels to be expected from oil/water separators, suspended solids levels to be expected from clarifiers, and BOD levels to be expected from biological treatment systems. Clearly, such limits must make assumptions as to the quality of the water fed to the treatment: the oil separability, the solids settleability, and the biodegradability of the biofeed water components. Permittees are not required to use the technologies assumed in the development of standards, so long as the technology used provides equally good treatment.

Technology-based limits must consider the cost and economic achievability of the treatment. The degree to which the permit writer must consider the costs varies according to the contaminant and the situation (e.g., whether the facility is existing or new), and is beyond the scope of this document. However, under current laws, cost *must* be considered to some degree. Often, EPA considers the cost on the basis of the dollars per pound of contaminant removed, and relates this cost to costs of existing treatment already being practiced within the same or other industries. Appropriate cost levels for some petroleum product terminal wastewater treatments have not yet been established; hence, the reasonableness of costs for such treatments may be subject to negotiation.

3.2.2.2 Receiving Water Quality Basis for Permits

The supposed overall goal of wastewater regulations is the restoration of the receiving water to certain quality standards. One such standard is “fishable”, meaning that aquatic life of various types is protected; another standard is “swimmable”, meaning that human health will not be endangered by exposure to the water. The problem faced by regulators is setting effluent quality standards for all dischargers to a receiving water which will enable the receiving water to meet its quality standards. A general approach is the setting of allocations for various parameters to each discharger, such that when each discharger meets its allocation, the total contaminant load on the receiving water will, when the receiving water flow and assimilative capacity (ability to remove contaminants by natural processes in the water) are taken into account, result in the water meeting the standards. Clearly, except for small streams with few dischargers, this can be a complex task. In order to simplify the task, many regulatory bodies will establish general effluent standards which, when met, will approximately result in the desired receiving water quality. In many areas, receiving waters (streams, rivers, lakes, estuaries, bays) are assigned to various classes, with each class having its own set of quality standards.

In setting standards based on receiving water quality, regulators do not consider the cost of the treatments required to achieve the standards (unlike the technology-based limits discussed above). This fact leads to the possibility of standards being set which cannot be economically met by dischargers, and makes it critical that the standards be set on the basis of sound scientific principles.

A special type of receiving water quality standards are toxicity standards. These standards are generally divided into *acute* and *chronic* toxicity standards. Acute standards are short-term (generally 48 or 96 hours) lethality standards, typically expressed as LC₅₀. The function of these standards is avoidance of adverse effects in the immediate vicinity of the effluent discharge. To

determine the allowed dilution for the effluent standard, the concentration of the effluent in the mixing zone is calculated based on the effluent flow, the stream flow, the size of the mixing zone, and the degree of mixing. In some cases, there is no mixing zone, if, for example, the effluent discharge is the sole source of water in the stream. Chronic standards are long-term standards, intended to provide full protection to aquatic life after the effluent is completely mixed with the receiving water. The effects can thus be calculated by dividing the effluent flow by the receiving water flow, and comparing this with the bioassay dilution which shows no adverse effects of the effluent.

One type of biological standard which is being considered is the bioconcentration standard, which is based on the fact that certain materials accumulate in living organisms over the life of the organism, and also are passed up the food chain as the organisms are eaten by other organisms. These standards are generally stricter than the normal bioassay standards, since levels of contaminants which do not show any effects in a bioassay test can result in significant accumulation for relatively long-lived organisms, and can, via the food chain, affect organisms not used in the bioassay tests (an example is pesticides which accumulate in fish bodies, and affect the birds which eat the fish). It should be noted that not all contaminants are subject to bioconcentration, since this requires that (1) the contaminant be ingested by the organism, (2) the contaminant must be stored, and accumulate, in the organism's tissues, (3) the stored contaminant must not be significantly metabolized, and (4) the organism must be eaten by another organism which itself will store and not metabolize the contaminant.

Yet another type of biological standard receiving regulatory attention is bioassays of *sediment*, which refers to material from an effluent which is deposited on the receiving water bottom as insoluble particles. Clearly, such materials must be either insoluble in the effluent, or precipitated from the effluent in the receiving water. The reason such materials are separately regulated from water-soluble toxins is that high levels can build up on the receiving water bottom over time, and potentially result in adverse effects on the organisms (*benthic* organisms) which live in the sediment, and on aquatic animals which feed on these. Contaminated sediments regulation presents complex issues, such as the likelihood of material depositing from the effluent (which is affected strongly by the receiving water velocity and turbulence), the possibility of a given sediment being contaminated because of upstream dischargers, and the long-term nature (sediments accumulate over decades) of the problem.

3.2.2.3 Bases for Permits Other Than Receiving Water Quality or Technology

Although EPA can generally trace its effluent standards back to statutory requirements that they be based on treatment technology or protection of receiving water, other regulatory bodies may not be required to meet such requirements. In many cases, as a result, standards appear to be issued arbitrarily, with no sound basis. Some limits, for example, are set equivalent to the analytical limit of detection for the contaminant; besides being without scientific foundation, these are usually moving targets, since analytical techniques are being constantly improved. In other cases, limits are set equal to drinking water quality, even though the water in question (e.g., brackish or saline water) may never be used for drinking water. Sometimes, limits are set which ignore the assimilative capacity of the receiving water. Ammonia, for example, is toxic to fish at elevated concentrations, but is also readily removed from water by being taken up as a nutrient by algae and

other aquatic plants. Likewise, almost all organic materials are subject, however slowly, to biodegradation by the multitude of bacteria and other micro-organisms which are found in the natural environment (the only surviving ancient organic materials are those which come from environments which are too anaerobic [e.g., coal and oil] or too dry to sustain biological activity). A related issue is *bioavailability*, meaning the extent to which the contaminant is able to exert adverse effects. Heavy metals are quite toxic *as the free ions*; but in fact, most aquatic heavy metals are in a chemical form (precipitated or chelated) which renders them much less harmful to aquatic life. In fairness to the regulatory community, it should be pointed out that determination of the effects of effluents is a highly complex issue, and requires a great deal of scientific information which is not currently available. Under these circumstances, development of discharge standards will necessarily involve some degree of arbitrariness. It is not improper, however, to examine proposed permit limits for their bases and to discuss these with regulatory personnel.

3.2.2.4 Mass Emission Limits vs. Concentration Limits

Outside of the mixing zone (water volume in which effluent mixes with receiving water), the only emission standards which make sense for protecting the environment are mass emission limits (e.g., pounds/day), since it is the quantity of a contaminant, not its emitted concentration, which exerts effects on the downstream receiving water. Despite this, many non-EPA limits are concentration limits, not mass emission limits. One reason for this is simplicity, since it is easy to set single concentration limits for all dischargers, but more difficult to determine the proper mass limits, which depend on the size of the facility, and the flow and assimilative capacity of the specific receiving water. In addition, it is easier to determine compliance with concentration limits by collecting a sample and analyzing it. To determine compliance with mass emission limits, the effluent flow must also be taken into account.

The greatest disadvantage of concentration limits is that they strongly inhibit flow reduction as an ingredient of pollution prevention. As discussed below (5.4.4), flow reduction is generally to be encouraged as a means for achieving more cost-effective treatment (since equipment is smaller) and achieving more thorough treatment (since it is generally easier to remove concentrated contaminants than dilute contaminants). However, when flow is reduced, concentrations generally increase (although not necessarily proportionally), and thus flow reduction jeopardizes compliance with concentration limits. If a facility is considering flow reduction, and has concentration limits in its permit, it should carefully consider the effects of the flow reduction on permit compliance.

3.2.3 PERMIT APPLICATION AND NEGOTIATION PROCEDURES

Obtaining an NPDES permit is a multi-step process, initiated by the original application, followed by issuance by the regulatory authority of a draft permit, then by negotiation of the permit provisions, and finally by acceptance of the revised permit by the discharger and the regulatory authority. The process is generally quite lengthy, and more than a year can be required for obtaining the final permit.

Factors to consider in making the permit application include:

- Current operations should be accurately described. It is particularly important to accurately characterize the facility wastewater with regard to concentrations and mass emissions of those contaminants listed on the application form, even though this may be difficult for a terminal with infrequent discharges of diverse wastes (see 8.3). *The temptation to report lower than realistic levels of contaminants should be resisted, since these reported levels are often used as one basis for setting standards* (“if you can do that well now, you can do that well forever”).
- In general, the permitting process is so onerous and time-consuming that it is very desirable to minimize the chances that the permit will have to be renegotiated before it expires. For this reason, anticipated changes in facility operations over the duration of the permit should be described, and the impact of these changes on wastewater quality should be estimated as accurately as possible. As an example, the facility may be planning to begin handling oxygenated fuel components, which would be expected to increase the amount of soluble organic matter in the wastewater, and which may justify obtaining higher limits for such material. In general, any change such as the above or an expansion which will lead to increased emissions is better covered in the original permitting than in renegotiation.
- Most permit applications require specification of the treatment technology. To avoid being locked in to what may turn out to be inappropriate treatment, it may be desirable to specify a range of possible treatments, and to state that the type and degree of treatment needed to meet the final permit requirements will be utilized. As described at length in latter sections of this report, the type of water handling and treatment which is appropriate for each facility varies widely from terminal to terminal, and is best determined by careful examination of the situation at each facility, not by regulatory fiat. *Unless required by statute, imposition of the type of water handling and treatment in the permit should be strongly resisted. Allowing such specification may result in inadequate treatment, in treatment which is not cost-effective, and in a water handling and treatment system which cannot be adjusted to meet changing conditions.*

As noted above, expert assistance, including experienced environmental legal assistance, should be obtained in the permit negotiation process from technology and regulatory specialists in that area. Some factors and procedures to consider in the negotiation process include:

- If not stated in the draft permit, the statutory basis for all permit conditions should be requested, and the statutes and regulations should be examined for agreement with the permit conditions. Most draft permits, including those which limit toxic parameters, are required by law (see 40 CFR §124.8 and §124.56) to include a fact sheet which explains the basis for each limit. Specific justification on the fact sheet for each permit condition should be requested if it is not already present.

- Any specialized terms in the permit should be defined; if they are not, definition should be requested. Any limitations based on chemical or biological analysis should have the exact method of analysis specified by reference.
- Sampling and reporting requirements should be examined for agreement with terminal operations. For a facility which discharges its wastewater sporadically, frequent sampling will not be meaningful or cost-effective. Reporting schedules need to allow sufficient time for results to be obtained from (frequently overloaded) analytical laboratories.
- Although not a sure method, it may help to provide technical evidence on the unsoundness of certain proposed limitations. It is inappropriate, for example, to set permit limits which require the treated effluent to have lower levels of certain constituents than would be found by the receiving water in its natural state. Examples would include salinity or conductivity limitations on discharge to saline water, or turbidity limitations on discharges to muddy streams. (Note that this argument does *not* apply to manmade pollution, since regulators can legitimately achieve restoration of water quality by requiring discharges to be better than the receiving water).

Likewise, permit writers should be asked to justify the environmental benefits of discharge standards, particularly those which appear to be extremely restrictive. As supporting data for this type of approach, the published toxicity and water quality criteria data for the contaminants in question should be collected and compared with the discharge standards.

- Some draft permits contain concentration regulations at the limit of detection of the specified analytical method. As those who are familiar with analyses know, it is quite common to receive false positive results (i.e., the contaminant is shown as being present when it is actually absent) at the detection limits. For this reason, limits should not be specified as being below the *quantitation limit*, which is a statistically validated value which can be accepted with confidence.
- To ensure fairness, copies of recent discharge permits from similar facilities in the region should be obtained (as public records) and examined. If it appears that there has been unequal treatment for similar circumstances, this should be protested.
- Regulatory personnel are commonly overworked (as indicated by the length of time required to obtain a permit), and permitting may thus be expedited by making their job easier. Some steps in this direction include:
 - Establish and maintain a good working relationship with the regulatory personnel handling the permit application.
 - Explain facility operations clearly, since some regulators, particularly those newly hired, are not familiar with these.

- Whenever draft permit provisions are questioned, provide as much technical information as possible to justify the change.
- Provide useful information to support any proposed changes. For example, calculate appropriate mass emissions when these are sought in place of concentration limits.
- When replying to a draft permit, supply a redlined or marked-up copy of their document instead of just a summary of proposed changes. This is easier for the permit writers to deal with.

3.2.4 DISCHARGES TO PUBLICLY OWNED TREATMENT WORKS

Publicly owned treatment works (POTWs) is the regulatory term for municipal wastewater treatment plants, used mostly for treatment of domestic sanitary wastes, but also used for treating commercial and industrial wastewaters within the territory served by the POTW. Many petroleum products terminals discharge to POTWs, whose pretreatment regulations are generally less stringent than NPDES limits for discharge to public waters since the POTW's treatment plant takes over the main function of removing contaminants from the discharger's wastewater. POTWs generally have pretreatment standards for non-domestic wastes, based on regulations imposed by EPA (see 40 CFR §403) and state standards, and on locally-developed standards. POTWs are widely divergent in the nature and degree of their limitations, but commonly found restrictions include:

- Bans on discharge of flammable material (to protect sewers and the treatment plant).
- Bans of discharge of settleable solids (to keep sewer lines open).
- Bans, or limitations, on discharge of storm water (to keep treatment works from being hydraulically overloaded).
- Bans of materials which "interfere with or pass through" the treatment works. "Interfere with" means to chemically or physically harm the treatment system, and "pass through" means to not be removed by the treatment.
- Limits on specific materials, such as BOD₅, phenols, lead, and BTEX.

In addition to restrictions on discharges, POTWs also generally impose treatment charges of various types, including the following:

- Connection charges for making sewer hookups.
- Charges based on the amount of water discharged.
- Charges on the amount or concentration of discharged contaminants of various types, including BOD, oil & grease, phenols, and others.

Also, it may be necessary to pay for installation of a sewer line from the facility to the nearest sewer main. In some cases, major dischargers are asked to partly pay for construction of a new treatment plant.

3.2.5 DISCHARGES TO GROUND: THE SAFE DRINKING WATER ACT

Under the Safe Drinking Water Act, drywells or septic systems used to place non-sanitary (non-sewage type) waste into the ground are classified as Class V wells. Individual permits are not normally needed for such wells, but inventory information must be submitted to the regulators (see 40 CFR §144.24, §144.26, and §144.25). To legally operate Class V wells, the water disposed of must not have the potential for causing groundwater beneath the well to become unfit for drinking if the groundwater is or is likely to be used for that purpose. Further details can be found in Section 2.1 of API Recommended Practice 1633, "Handling Water Discharges from Automotive Service Facilities Located at Petroleum Marketing Operations".

3.3 Hazardous Wastes: Resource Conservation and Recovery Act of 1976 and Amendments

Were it not for benzene, most wastewaters from petroleum products terminals would not be potentially classified as hazardous wastes under the Resource Conservation and Recovery Act of 1976 (commonly known as RCRA). However, in 1990, regulations were issued (40 CFR §261.24) which made any *solid waste* containing more than 0.5 mg/L extractable benzene under conditions of the Toxicity Characteristics Leaching Procedure (TCLP) a hazardous waste. Under this procedure, *water* which contains more than 0.5 mg/L dissolved benzene is potentially a hazardous waste. Typically, tank bottoms water from gasoline tanks, and from other sources in a petroleum products terminal, will contain more than 0.5 mg/L benzene, which raises RCRA TCLP issues on its handling and disposal.

In the following discussion, the generally understood implications of RCRA regulations are presented. However, RCRA is a very complex law with severe penalties, and expert regulatory and legal advice should be obtained before taking action on hazardous waste issues. Also, it is important to note that the following discussion *only* applies to the federal EPA rules on solid and hazardous wastes. Since some states and localities have their own definitions and regulations, which may be stricter or broader than the federal rules, and which apply *in addition to* the federal rules, legal advice should be sought on those regulations as well.

3.3.1 DEFINITIONS

The following discussion uses certain specialized terms, which are summarized as follows (the references should be consulted for details):

Product recovery means that the petroleum product is being separated from the water, is removed from the process as a separate stream, and is reclaimed for its original use. The recycled material is not a solid waste as long as it fits the following regulatory definitions:

In 40CFR §261.2 (e)(1), the regulations state, "Materials are not solid wastes when they can be shown to be recycled by being: (i) Used or reused as ingredients in an industrial process to make a

product, provided the materials are not being reclaimed; or (ii) Used or reused as effective substitutes for commercial products; or (iii) Returned to the original process from which they are generated, without first being reclaimed. The material must be returned as a substitute for raw material feedstock, and the process must use raw materials as principal feedstocks.”

Wastewater treatment system tanks are stationary devices constructed primarily of non-earthen materials which are part of a system discharging to an NPDES discharge or a POTW (40 CFR §260.10). This has been interpreted by EPA to require that the tanks be designed to be water tight, and to be self-supporting without earthen support when filled to capacity.

90-day storage tanks are tanks and containers (see 40CFR §262.34) designed and operated to prevent migration of wastes out of the tank, and capable of detecting and containing any released materials (40 CFR §264.190 - §264.199). Most tanks will meet these requirements by being double-walled, by being placed in an impermeable vault, or by being surrounded by an impermeable membrane. The CFR reference should be consulted to determine other requirements for design and operation of secondary containment tanks.

RCRA Part B TSD permits are full-blown RCRA permits for treating, storing, and disposing of (TSD) hazardous wastes (40 CFR §264). TSD permits are very difficult, expensive, and time-consuming to obtain, and difficult and expensive to operate under. Almost always, obtaining TSD permits is not an attractive option for petroleum products terminals, so equipment and procedures for handling hazardous wastes must be arranged to avoid the necessity of obtaining these permits.

RCRA generator numbers are EPA-assigned identification numbers for all generators of hazardous wastes (40 CFR §262). In addition to obtaining the number, the generator is responsible for proper on-site storage of the waste, proper manifesting and transportation of the waste off-site, and proper final disposal of the waste by the recipient.

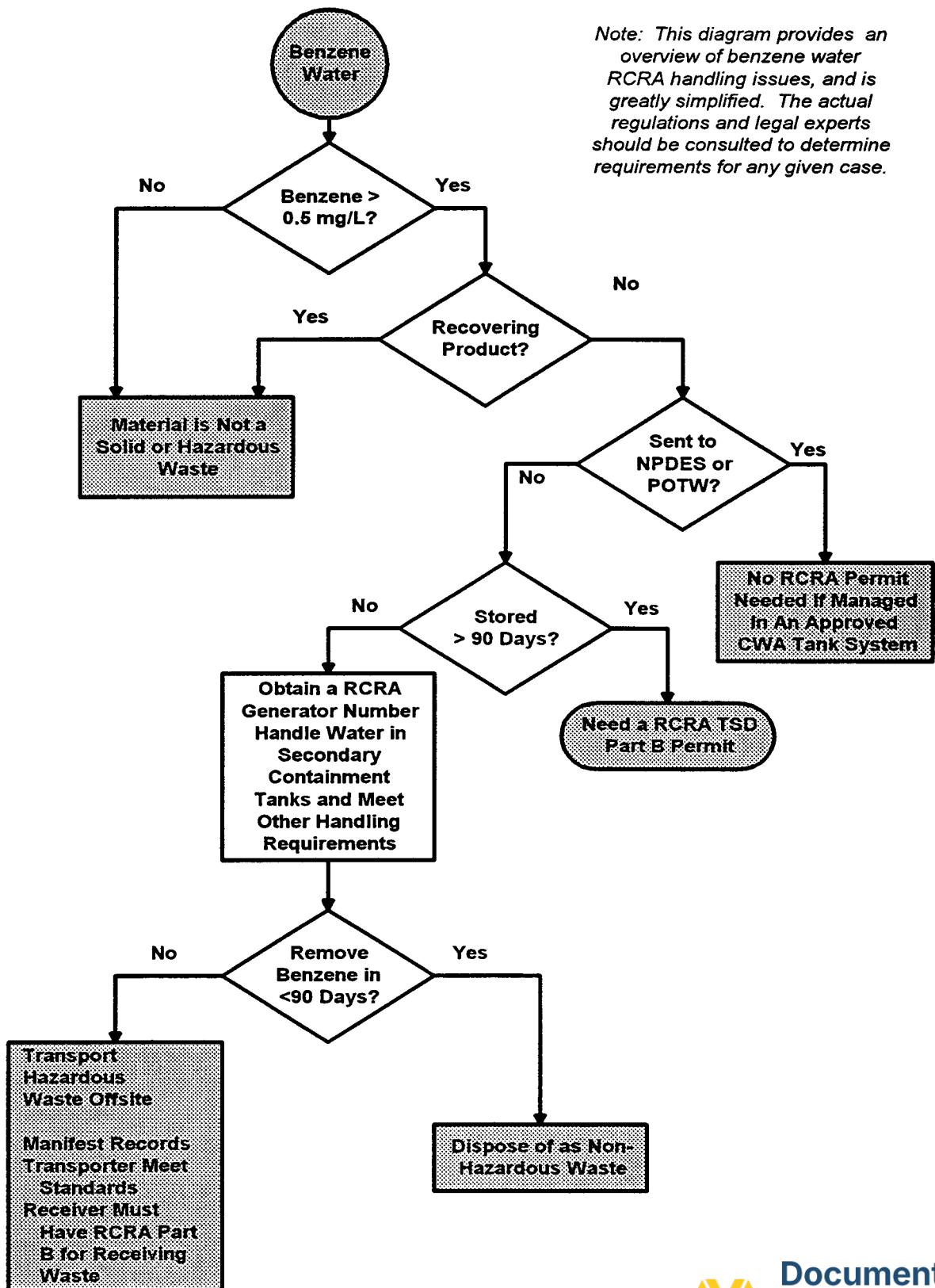
3.3.2 WASTEWATER HANDLING OPTIONS UNDER RCRA

3.3.2.1 Benzene-Contaminated Wastewater

The options for handling, treating, and disposing of benzene-contaminated water are outlined graphically in Figure 3-1. Some of the specific questions which arise in this process, and summary answers, are given below. Please note, however, that many of these determinations are case-specific. It is recommended that appropriate authorities be consulted before managing any potentially hazardous wastes.

- If the wastewater is classified as a hazardous waste, at what point in its processing is this classification applied? *Wastewater is generated as a solid, and potentially hazardous, waste only after it is discarded from a product recovery operation such as a product recovery tank or an oil/water separator. Upstream of that point (i.e., in product tankage or product recovery processing), it is not yet a regulated waste (40 CFR §261.2(e)(1)(i)-(iii)).*

**FIGURE 3-1
RCRA GUIDE FOR BENZENE-CONTAINING WATER**



- How long can the wastewater which is potentially hazardous be stored without RCRA involvement, and what must be done if the water is stored longer than that? *Generally, once wastewater is generated, either it can be sent to a permitted NPDES discharge or POTW without a time limit on storage, or it cannot be stored or processed for more than 90 days without obtaining a RCRA TSD permit (40 CFR §262.34).*
- What types of handling and treatment allow the wastewater to be exempted from RCRA regulation? *If the wastewater is stored and handled in tanks, and sent to a permitted NPDES discharge or hard-piped to a POTW, it is not subject to RCRA regulations (40 CFR §261.4(a)(2)).*
- If the wastewater is discharged under an NPDES permit, or is sent to a POTW with an NPDES permit, are there any RCRA concerns for the internal handling of the wastewater upstream of this discharge? *Only that the water be handled in tanks and hard piped (no earthen ditches or ponds upstream of treatment) to the treatment system, outfall, or municipal sewer.*
- If the wastewater is shipped offsite as a hazardous waste, what permitting and record keeping are required for generating and transporting the material? *The facility must obtain a RCRA generator number, must keep records on the waste generation, must store the waste in tanks with secondary containment, must use an approved hazardous waste transporter, must manifest each waste shipment, and must ensure that the final destination for the waste is a RCRA TSD facility permitted to receive, store, treat, and dispose of such wastes (40 CFR 262).*
- If the water is shipped offsite as a hazardous waste, what permitting is required by the receiving facility? *The facility must have a RCRA TSD permit which specifies that wastes of the type being shipped will be received and processed (40 CFR §262.20(b)), or, less commonly, has an NPDES permit which states that RCRA hazardous wastes will be accepted.*
- If the water is shipped offsite as a hazardous waste to another company, are there any potential liabilities for the terminal (and its owner) if this disposal is done improperly? *Yes, the waste generator retains legal liability for the waste for all time. If disposal of the waste in question, or other wastes, is done improperly, then the generator could be held liable for whatever penalties are imposed on the disposal facility and its customers.*
- Under what conditions can benzene be removed from wastewater without RCRA regulation? *The need for a RCRA permit can be avoided by disposing of the treated wastewater to an NPDES discharge or to a POTW, provided any storage and treatment at the facility is done in tanks, not impoundments (40 CFR §261.4(a)(2) and 40 CFR §264.1(g)(6)). If the wastewater is transported offsite as non-*

hazardous waste, the hazardous constituent (benzene) can be removed without a permit so long as the storage and treatment are done within 90 days, and the material is handled in tanks with secondary containment and other technical requirements are met (40CFR §264.190 - §264.199).

Figure 3-2 shows various wastewater handling flow schematics and their RCRA implications.

3.3.2.2 Benzene-Containing Products Mixed With Water

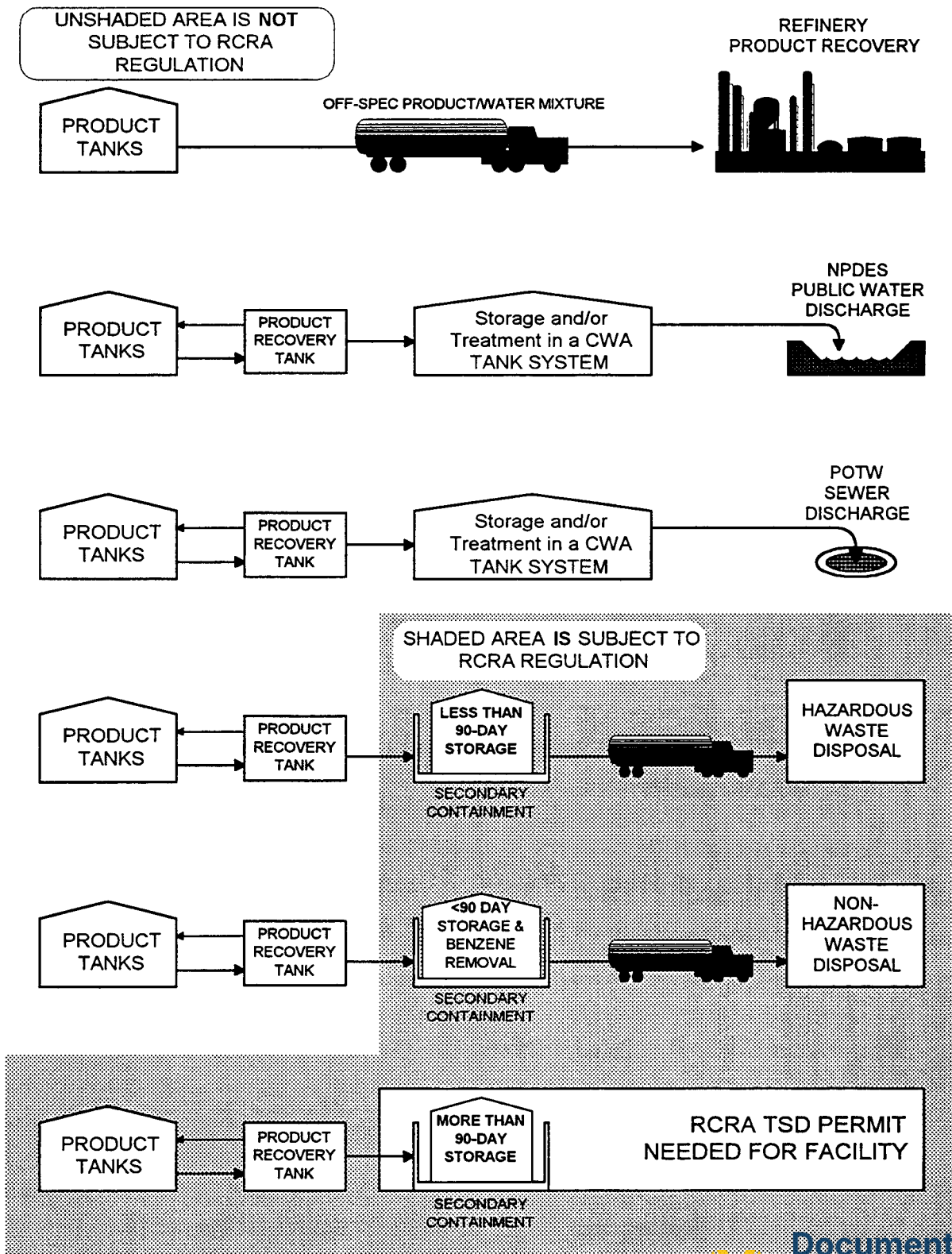
It is important to note that RCRA regulations are *environmental* regulations, and apply only to *wastes*, not to *products*. There are, clearly, a very large number of materials, manmade and natural, which would be classified as hazardous wastes if the hazardousness standards were inappropriately applied to them. RCRA, however, was designed to protect the environment from hazardous materials; materials which are not released to the environment (by disposal or discharge) are not covered. As one aspect of this, petroleum products are not subject to RCRA regulation while being manufactured, transported, or used; if disposed of or discharged (which is very rare, since all petroleum products have value), RCRA (or other environmental) regulation would apply.

The most likely point of confusion is when a mixed stream of petroleum products and water is being handled. As described in 4.9.1, water is often found in contact with petroleum products, and is transported along with them. The fact that water (an unwanted material) accompanies product does not make the mixture of the two a waste, even though the water phase will ultimately be disposed of as a waste. The RCRA regulations handle this situation by defining the point of waste generation as being *the point just beyond the step in which product is separated* (this same point is covered in 3.3.2.1, above). To re-state this point, *mixtures of product and water, even if mostly water, can be classified as product, so long as there is legitimate recycling of product from the mixture.*

In the petroleum industry, it is very common to re-process products which do not meet specifications for their use; the term for these is off-spec products. These off-spec products often contain water. Refineries commonly send mixtures of products recovered from process vessels or wastewater (slop oil) back through crude oil distillation. Pipeline terminals often take cuts of materials at the interface between different products and send it back to refineries for reprocessing. In the case of petroleum products marketing terminals, off-spec products from the service stations served by the terminal are often received back by the terminal, and mixtures of products from the terminals, sometimes mixed with water, are often sent back to a refinery for reprocessing. So long as the receiving facility (the terminal or the refinery, respectively) accepts the mixture for recovery of useful product, the mixture is not classified as a hazardous waste for purposes of generation, transportation, storage, or processing, even though benzene levels in the mixture exceed the RCRA TCLP standards.

FIGURE 3-2

TANK BOTTOMS WATER HANDLING SCENARIOS



3.3.2.3 Other Hazardous Wastewater Constituents

Although benzene is found in most petroleum products terminal wastewater since it is a normal component of gasoline, there are also other contaminants which could be present in tank bottoms water, and which would cause the water to potentially be a hazardous waste at the following concentrations:

Contaminant	Limit, mg/L	Reason for Listing
Arsenic	5.0	Found in crude oils, water-soluble
o-Cresol	200	Made in refining, water-soluble
m-Cresol	200	Made in refining, water-soluble
p-Cresol	200	Made in refining, water-soluble
Cresols	200	Made in refining, water-soluble
Lead	5.0	Used as a gasoline additive
Selenium	1.0	Found in crude oils, water-soluble

Wastewater which contains these contaminants at levels in excess of the limit will have the same hazardous waste restrictions as wastewater contaminated with benzene. However, handling may be different, in that benzene is easily removed by stripping (see 9.9), but the above contaminants cannot be so removed. The various cresols can be removed by various treatments (cresols are highly biodegradable, for instance), and lead can usually be removed by filtration, but arsenic and selenium can be quite difficult to remove (9.14).

3.3.3 NON-AQUEOUS HAZARDOUS WASTES

In addition to the issue of benzene-contaminated wastewater, there are also other hazardous wastes which might be generated in a petroleum products terminal, which will be solid wastes with the following characteristics:

- **Ignitability.** If the waste is ignitable (flash point less than 140 F) under the RCRA test conditions, then it will be hazardous. Some product-contaminated sludges may fall in this category.
- **Reactivity.** If the waste contains sufficient cyanide or sulfide to release more than the regulated amount of hydrogen cyanide or hydrogen sulfide when acidified, it will be hazardous. It is unlikely that petroleum products terminals will normally generate reactive wastes from normal operations. However, since anaerobic biological activity converts sulfate to sulfide (by sulfate-reducing bacteria), it is possible that alkaline tank bottoms water stored for long periods might accumulate enough sulfide to fail the reactivity standard.
- **Corrosivity.** If the pH of the waste is less than 2.0, or more than 12.5, it will be classified as corrosive. Such wastes should be rare in petroleum products terminals.
- **Leachability.** If more than regulated amounts of any or several chemical constituents are leached from the waste when it is subjected to specified leaching

tests, it is hazardous. The regulated materials include toxic heavy metals and selected organic constituents. Possible materials which would fail this test are tank bottom sludges and wastewater treatment sludges. More than likely, these sludges will pass the test, since heavy metals are not common in petroleum products terminals, and most of the regulated organic compounds are not expected to be in terminal products or wastes. However, if wastes are derived from leaded product storage tanks, or from removal of lead-based paints (e.g., spent blasting sand), then the lead leachability test could be failed for that waste. Also, as noted above, benzene is one of the regulated materials, and may appear in solid wastes at excessive levels as well as in wastewater (the wastewater disposal exclusions do not apply to non-aqueous wastes).

Chapter 4

TERMINAL OPERATIONS

4.1 Introduction

Petroleum products terminals are collection and distribution points along the complex distribution network which connects the refineries which manufacture the products and the service stations and other destinations which serve end users. This network is shown schematically on Figure 4-1.

Along this network, products are transported by various means, including pipelines, tanker ships, barges, rail cars, and tank trucks. The terminals are distinguished from other parts of the network by having tank capacity to store products, and by having equipment for connecting the tanks to the transportation system. Similar distribution networks exist for crude petroleum, and for petrochemical products; this report, however, is restricted to petroleum products distribution, and to the petroleum products portion of the (not uncommon) combined operations.

Unlike those parts of the petroleum industry further upstream such as producing and refining operations, the distribution network is characterized by *batch*, not *continuous*, transfers. Batches of products are collected from refineries, sent as discrete batches through the transportation system, and finally sold as batches to the end users. Much of the work in the distribution network is spent on accounting for the location, quantity, and quality of the product batches.

4.2 Petroleum Products Distribution Network

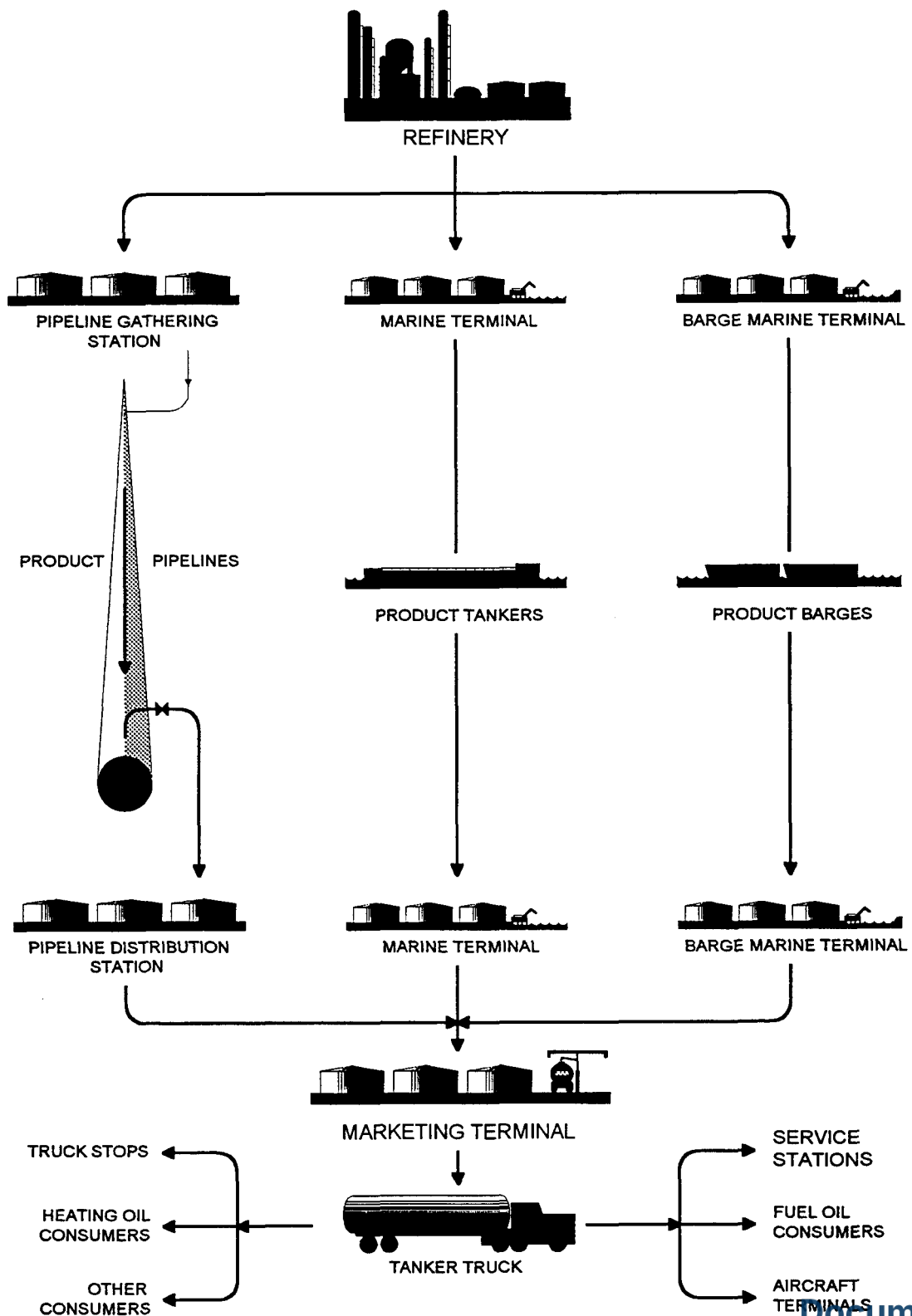
Although not part of this report, the other elements in the petroleum products distribution network are intimately connected to the terminal facilities, and so are described briefly below.

4.2.1 POINTS OF ORIGIN

All petroleum products are manufactured in petroleum refineries. Most of the refineries which supply the U.S. market are domestic, although the amount of overseas refining for U.S. markets is increasing as crude supplies shift overseas and U.S. environmental regulations on refineries become stricter. Overseas refineries deliver their products by tanker ship to marine terminals, described below. Domestic refineries connect to the transportation network in various ways. In some, direct loading of tanker ships and barges is done. In others, the products are sent into the pipeline system through originating pipeline stations, described below. Many refineries operate (or are directly linked to) a marketing terminal which serves the retail area in the vicinity of the refinery; except for small refineries, this is a minor destination for the plant's products.

FIGURE 4-1 PETROLEUM PRODUCTS DISTRIBUTION NETWORK

Distribution shown is typical. Many combinations and variations exist.



4.2.2 TRANSPORTATION

4.2.2.1 Pipelines

Pipelines of various sizes and capacities provide a great nationwide arterial system for products distribution, and handle far more volume of products than any other means of transportation. At the heart of the pipeline system are the high-volume transcontinental pipelines, which pump products over long distances at high pressure through large diameter pipes. In addition, many other smaller pipelines are used to feed into or out of the transcontinental lines, and to connect other parts of the distribution network. Pipeline operations comprise the lines themselves, pumping operations to move products into the pipeline and to boost pressure along the line, and valving systems for splitting products out of the pipeline at various points.

Products move through pipelines as discrete batches. By various means (including gauging of supply and receiving tanks, flow metering, and quality checks), the identity of the material moving through the line at a given point is precisely determined to ensure the integrity of the batch (i.e., to avoid *commingling* of the various product batches sent through the same line).

4.2.2.2 Water Transport

Tanker ships are self-powered vessels used for marine (including Great Lakes) transport to coastal locations, and to those inland river ports which serve deep-draft vessels. Barges are towed shallow-draft vessels used mostly for inland water transport on rivers, canals, and lakes. In both, the vessels are divided into sealed compartments for carrying various products. When empty, vessels ride high, and are subject to pitching and rolling; for this reason, empty vessels are commonly filled with ballast water, taken on near the point of vessel product delivery (often from the water body at the vessel location) and discharged near the point of the vessel loading (often at the facility supplying the products). Unless the vessel has dedicated compartments for ballast water, the ballasting operation may make ballast water contaminated with the products previously in the compartment.

4.2.2.3 Rail Transport

Although used extensively for relatively low-volume products such as chemicals and lubricants, rail cars are not a major part of the petroleum products distribution network. Rail transport is done in tanker cars of about 20,000 to 40,000 gallons capacity.

4.2.2.4 Tank Trucks

Tank trucks, in sizes ranging from 5000 to 12,000 gallons, though little used for long-distance transport, are essentially the only means employed for the final leg of the products journey to the retail (service station and truck stop) outlets and other final points. Bulkheads within the tank trailer enable transport of several different products together.

4.2.3 FINAL PRODUCT DESTINATIONS

The final destinations are the points at which the users of the petroleum products receive the products. Since the products are mostly used as transportation fuels, the largest-volume users are vehicles.

4.2.3.1 Service Stations and Truck Stops

Service stations supply cars and trucks with various grades of gasoline and with diesel fuel. Products are normally received by tanker truck from marketing terminals, and stored in underground or aboveground tanks which supply the fuel pumps. In some cases, off-specification products (including product/water mixtures) collect in the underground tanks, and are transported back to the marketing terminal for reprocessing. Truck stops are essentially large service stations which supply diesel fuel to commercial trucks, mostly tractor-trailers.

4.2.3.2 Other Fuel Users

Gasoline and diesel fuel are also supplied in bulk to industrial and commercial operations of various types. Railroads are supplied with diesel fuel, agricultural operations with gasoline and diesel fuel for farm machinery engines, and truck and car fleets of various types are supplied with gasoline and diesel fuel. Home heating oil trucked to homes and other facilities by local distributors. Heavy oil fuels are supplied to power plants, asphalt plants, and to ships.

4.3 Petroleum Products Terminals Functions

As noted above, there are various types of terminals along the distribution network which serve the basic functions of collecting, storing, and distributing products. These can be characterized by their functions, as described below.

4.3.1 PIPELINE ORIGINATING STATIONS

Pipeline originating stations serve as collection points for one or several refineries, or for other products suppliers. They collect products (often through gathering pipelines) over time in tanks at relatively slow rate, and send them at high rate into the main pipeline system. Batch delivery volumes are large compared to those in marketing terminals. Operations include control room coordinating of valve switching and tank transfers, field operation and inspection of equipment, maintenance of equipment, product batch accounting, and management of these functions.

4.3.2 PIPELINE DISTRIBUTION STATIONS

Pipeline distribution or breakout stations are the inverse of the originating stations: products are taken at high rate from the main pipelines into tanks, and sent out at relatively slow rates to downstream points. Operations are similar to those of originating stations.

4.3.3 MARKETING TERMINALS

Marketing terminals, which are the majority of petroleum products terminals, receive bulk transportation fuels by various means, including pipelines and water transport, and distribute them to retail outlets (service stations and truck stops) by tanker truck. In addition to tank operations, truck loading rack operations are the main functions of these terminals. Many marketing terminals coordinate retail operations for the area served by their products. Marketing terminals may also supply home heating oil (similar to diesel) by tank truck to users, either as a sole product or in conjunction with transportation fuels, and may distribute aircraft fuel to airports or airbases by tanker truck.

4.3.4 AIRPORT TERMINALS

Airport terminals are service stations for aircraft. Generally located at major airports, they provide bulk storage for aviation gasoline and jet fuel, and distribute these to the aircraft in fueler trucks or through a pipeline and hydrant system.

4.3.5 MARINE TERMINALS

Marine terminals receive products in large-volume batches from tanker ships at high rate into tankage, and send them out at lower rates to downstream points. The terminals may also supply fuels (diesel and bunker fuels) for vessels.

4.4 Products Terminal Distribution Facilities

Two of the main functions of terminals are receipt of products and delivery of products. The equipment for these two functions are similar. Products are received from and delivered to pipelines, ships, barges, rail tank cars, and tank trucks.

4.4.1 PIPELINE TRANSFERS

Terminals are generally at the end of pipelines, and so take products directly out of, and place products directly into, the pipeline via pipe networks equipped with valves and pumps. Terminals that employ spur pipelines obtain products by taking cuts out of the product batches passing by in the main trunk line.

4.4.2 SHIP AND BARGE TRANSFERS

Products are transferred into tanker ship and barge compartments with high-volume pumps and hoses, which are connected to the vessel's fill nozzles. Ships generally have their own pumps for transferring products through hoses to shore.

4.4.3 TANK TRUCK TRANSFERS

Tank truck transfers are done in systems called *racks*. Since the majority of truck transfers are those into trucks, the general term is *loading racks*. Loading racks are similar in layout to service station fuel bays, with pump islands between the truck bays, and overhead canopies for rain protection. They are equipped with filling hoses or pipes which are connected directly to the truck tank. Two methods of loading are used: top loading or bottom loading, depending on the location of the truck tank fill nozzle. Products are metered into the tanks, and vapors displaced by the products are generally taken from the tanks into vapor treatment or vapor balancing systems (see 4.9.7). Loading racks normally have concrete floors, which are sloped to drain into a spill containment system to ensure that accidental spills will not run off onto the surrounding ground.

4.4.4 RAIL TANK CAR TRANSFERS

Rail tank car transfers are somewhat similar to truck transfers. Rail cars are generally top loaded. Compared to pipeline product deliveries, rail car products generally do not contain significant amounts of entrained water.

4.5 Storage Facilities

4.5.1 VERTICAL TANKS

The standard storage vessel for bulk petroleum products (in volumes from 1000 to several hundred thousand barrels) in terminals is the vertical cylindrical tank. These tanks are essentially cylinders (*shells*) made of joined curved steel plates, with steel bottoms and various styles of roofs. The joints in modern tanks are welded, but older riveted tanks are still in service. The tank shells are supported on foundations, usually concrete rings, but other types of support such as piers are also used.

4.5.1.1 Tank Bottoms

The bottoms of tanks are made of joined steel plates, and have three shapes, as shown on Figure 4-2. Cone-bottom tanks have the low point in the center, crowned tanks are high in the center, and low around the perimeter, and flat-bottom tanks have nominally straight and level bottoms.

4.5.1.2 Tank Roofs

All petroleum products tanks for transportation fuels in terminals have roofs, which serve to prevent product losses, preserve product purity, reduce fire hazards, and control air pollution. In addition, the roofs greatly reduce the amount of rainwater which would otherwise enter the tank, jeopardize product quality, and have to be drained as contaminated water.

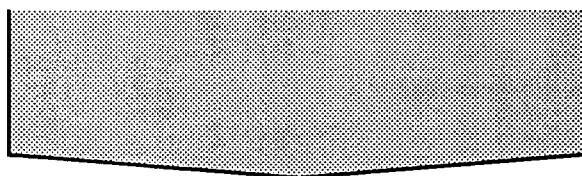
4.5.1.3 Fixed Roofs

The main distinction between tank roofs is between fixed roofs (also called *cone roofs*) and floating roofs. Fixed roofs (Figure 4-3a), as the name implies, are steel covers permanently attached to the top of the tank shell. These types of roofs convert the tank into a closed vessel, with the following consequences:

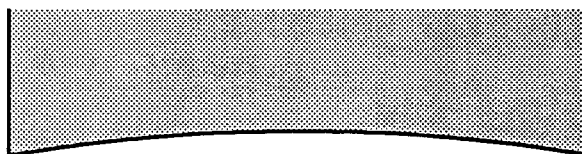
- Entry of rain water will not occur except through leaks
- When product is withdrawn from the tank, air must be allowed in to prevent creating a vacuum in the vapor space, and collapsing the tank

FIGURE 4-2

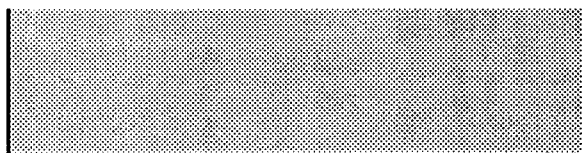
TANK BOTTOM CONSTRUCTION



CONE BOTTOM



CROWN BOTTOM

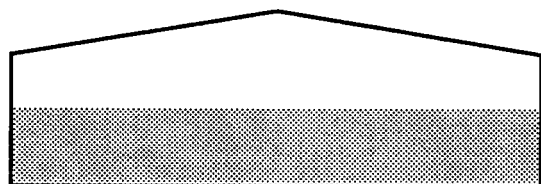


FLAT BOTTOM

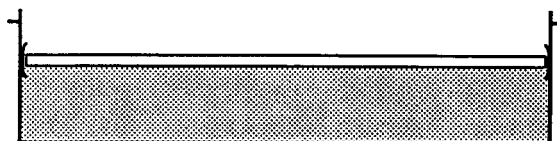
- When product is placed in the tank, air must be released to prevent developing pressure in the tank, and rupturing it.

FIGURE 4-3

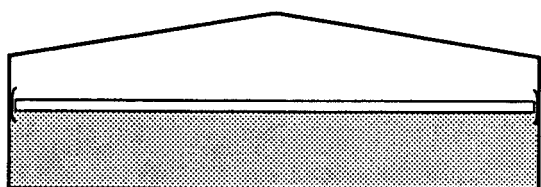
TANK ROOFS



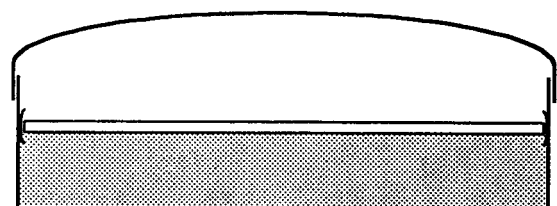
(A) FIXED OR CONE ROOF



(B) OPEN-TOP FLOATING ROOF



(C) COVERED FLOATER



(D) GEODESIC DOME

4.5.1.4 Floating Roofs

Floating tank roofs (Figure 4-3b) come in several styles, but typically are disks, several inches smaller in diameter than the inner tank shell diameter, made of steel or aluminum plates. The connection between the roof and the tank shell is made with *floating roof seals*, which are described below. The flotation is accomplished in various ways, but typically is achieved with pontoons, which are closed air-filled chambers attached to the bottom of the roof, or by double-deck roofs, which are essentially hollow roofs filled with air. Tanks fitted only with floating roofs are commonly called *open-top floaters*. Floating roofs ride up and down with the product level, with the following consequences:

- Rain water can enter the tank by hitting the inner tank shell, running down to the seal, and partially penetrating the seal to enter the tank.
- Most of the rain entering the tank shell will be collected on the floating roof. This rainwater is drained through a tank drain, as described below.
- Product withdrawal and placement are accommodated by the movements of the floating roof, so there is no need for venting air in or out of the tank, and no need for treating vent air.

4.5.1.5 Dual Roofs

In some tanks, both types of roof are used together, as shown in Figure 4-3c. Some tanks originally fitted with floating roofs have fixed roofs added later, which are called *covered floaters*.

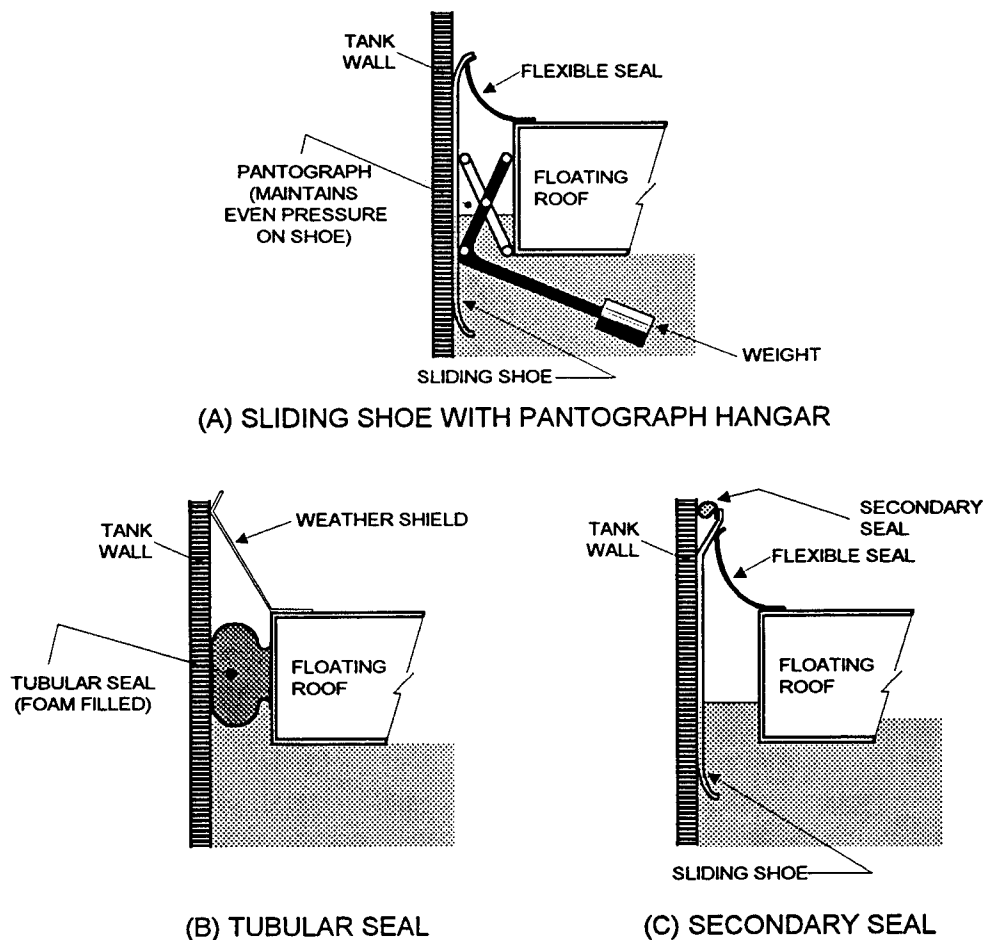
Some tanks originally built with fixed roofs have floating roofs added later. Both these, and tanks originally built with two roofs, are called *internal floaters*. Although obviously more expensive, the dual-roof tanks have the mutual advantages of their roofs:

- Rain water is kept out of the tank.
- The need for further controlling air emissions is eliminated (the fixed roof is vented to atmosphere without controls).

A relatively new type of tank roof is the geodesic dome (Figure 4-3d), a lightweight metal roof which is usually placed over tanks equipped with open floating roofs. In addition to their method of construction being different from cone roofs, these roofs are generally not tightly sealed to the tank shell. Advantages for such roofs are similar to those of the covered floaters.

FIGURE 4-4

FLOATING ROOF SEALS



4.5.1.6 Floating Roof Seals

The seals placed between the tank shell and the floating roof have a challenging job: to maintain a tight seal between the roof and shell, and still allow free vertical movement of the roof. As shown on Figure 4-4, this is accomplished with two basic approaches.

Figure 4-4a shows the conventional, or sliding shoe, type of seal. In this type, the sealing surface is a metal cylinder (the shoe) which is kept pressed against the tank shell by mechanical means (the pantographic device is shown). The gap between the shoe and the roof is sealed with a flexible vapor-tight fabric.

Figure 4-4b shows the tubular type of seal, in which a tube inflated by air, liquid, or elastomeric foam is attached to the roof, and maintains a seal with the shell by pressing against it. Tubular seals are generally equipped with sheet metal weather shields, to protect the tube and help keep rainwater out of the seal area.

Both of the above types of seals are known as *primary seals*. Mostly as an air emissions control measure, many tanks are also equipped with *secondary seals*, shown on Figure 4-4c. The secondary seal is located above the primary seal, and supplements its action. As noted above, floating roof seals help prevent rainwater entry into the tank, but cannot completely eliminate it, since a seal which is capable of moving can also allow some liquid passage. Maintaining seals in good condition, and using secondary seals, can help to reduce rainwater intrusion.

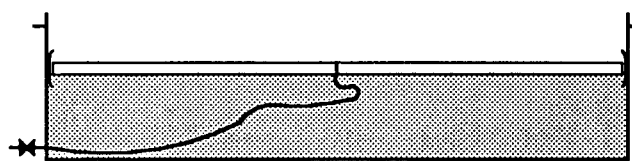
Details on floating roof seals can be found in (REA Staff), Chapter 28.

4.5.1.7 Floating Tank Roof Drains

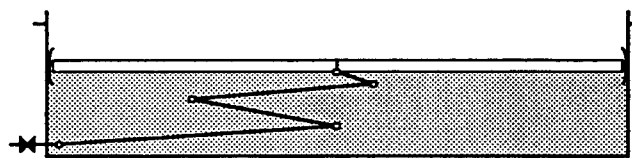
The rainwater which falls on a floating roof must be drained to prevent the roof from sinking. This can be handled by a direct drain (essentially, a hole in the roof) into the tank, but while this will not greatly harm the main functions of the roof, it will clearly eliminate the function of keeping water out of the tank. For this reason, most floating roofs are equipped with an internal drain, as shown on Figure 4-5. The internal drain is a jointed pipe, or a flexible hose, which connects the low point of the roof (usually the center) to a nozzle through the bottom of the tank. Potential problems with roof drain lines are leaks: if the top connection leaks, then water can still enter the tank; if the line itself leaks, then product could be released through the drain nozzle.

FIGURE 4-5

FLOATING ROOF DRAINS



ROOF DRAIN THROUGH HOSE



ROOF DRAIN THROUGH JOINTED PIPE