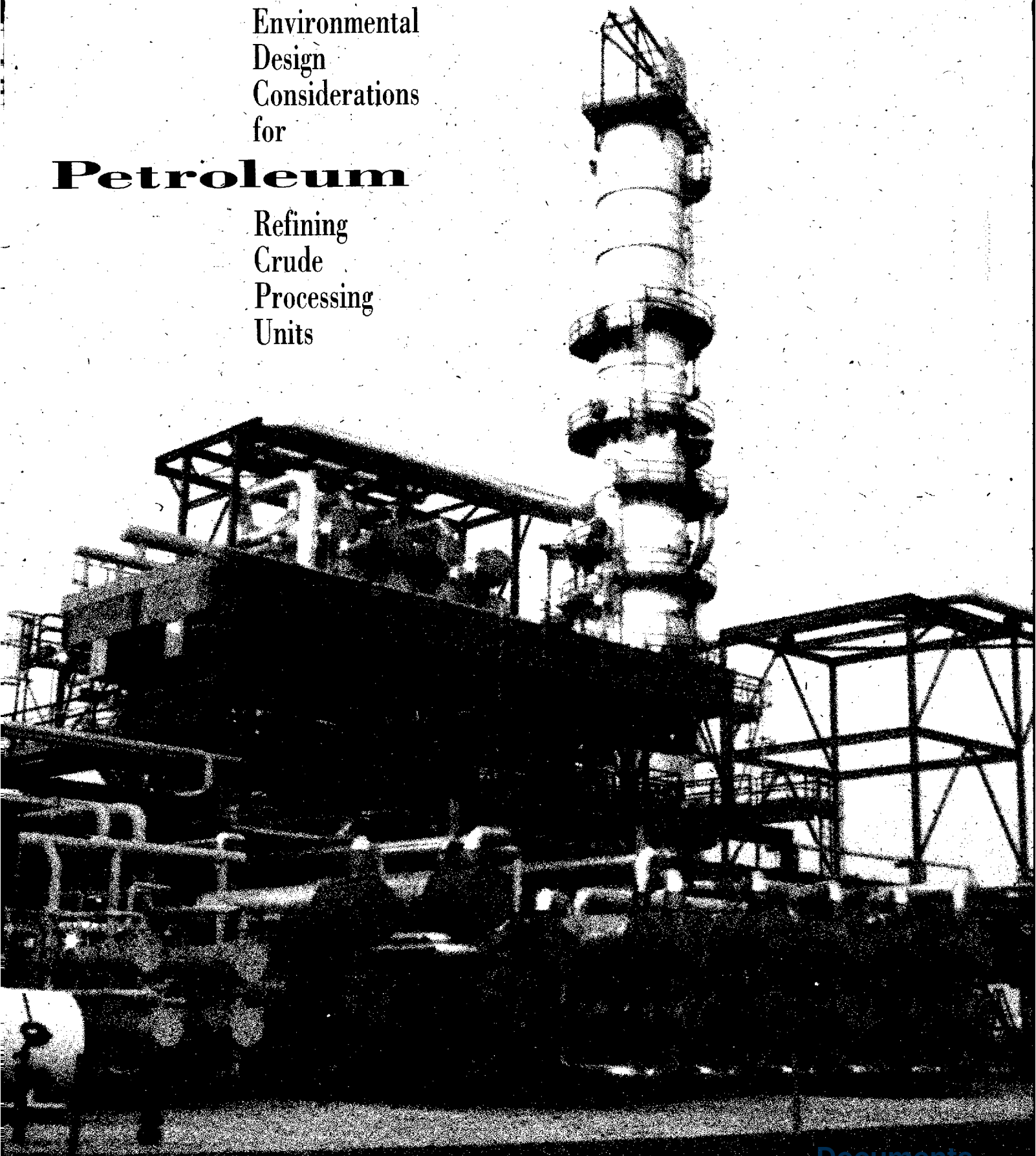


Environmental
Design
Considerations
for
Petroleum
Refining
Crude
Processing
Units



Environmental Design Considerations for Petroleum Refining Crude Processing Units

Health and Environmental Affairs Department

API PUBLICATION NUMBER 311
FEBRUARY 1993

PREPARED UNDER CONTRACT BY:
THE M.W. KELLOGG COMPANY
HOUSTON, TEXAS

**American
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AMERICAN PETROLEUM INSTITUTE

**ENVIRONMENTAL DESIGN CONSIDERATIONS FOR
PETROLEUM REFINING CRUDE PROCESSING UNITS**

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Section 1: EXECUTIVE SUMMARY

1.1 Basis of Study

The Pollution Prevention Task Force (PPTF) of the American Petroleum Institute (API) has developed the following working definition of pollution prevention:

"Pollution prevention is a multi-media concept that reduces or eliminates pollutant discharges to air, water, or land and includes the development of more environmentally acceptable products, changes in processes and practices, source reduction, beneficial use and environmentally sound recycling."

The PPTF and the API Committee on Refinery Environmental Control (CREC) recognize the importance of developing pollution prevention strategies for refineries. This study was initiated to investigate how the crude unit in a typical refinery could be designed to minimize multi-media environmental releases while still efficiently performing the traditional functions of a crude unit.

This report presents the findings of the study. The report is intended to serve as a reference for refinery designers during the preliminary design phase of building a new crude unit or revamping an existing crude unit.

A generic methodology for conducting pollution prevention studies on process units was developed and was then applied to the refinery crude unit (refer to Section 4). This methodology approached pollution prevention from two perspectives, or cases:

- Case 1 - The design of a model new crude unit.
- Case 2 - The revamp of a conventional existing crude unit, applying the principles learned in Case 1.

A typical ten-year-old U.S. Gulf Coast crude unit of 175,000 BPSD capacity was chosen to serve as the reference point or Base Case.

The technical contents of this report include: crude charge and product slates, process flow diagrams, major equipment lists, raw material use, water use, energy, equipment costs, and multi-media releases. These releases include: point source air emissions, fugitive air emissions, solid and hazardous waste production, and wastewater inventory.

The study investigated in detail these specific methods of pollution prevention:

- modification of vacuum tower to dry operation and reduced flash zone pressure to minimize cracking of feed;
- dry operation to reduce the quantity of sour condensate;
- use of vacuum pumps to replace all or part of the steam jet ejector system to provide the vacuum for the vacuum tower;
- use of reboiled sidestrippers on the atmospheric tower rather than open steam stripping to reduce the quantity of sour condensate;
- replacement of first generation low NO_x burners with new generation low NO_x burners in furnaces;
- use of catalytic and non-catalytic processes for the selective reduction of NO_x ;
- reuse of stripped sour water to replace clean process water as desalter water; and

- heat integration for maximum energy utilization (commonly referred to as pinch analysis).

1.2 Limitations of Study Results

Numerous pollution prevention concepts have been evaluated and reported in this study, but no optimum or "best" design is implied. This study was as comprehensive as time allowed, but doubtlessly there are other pollution prevention measures that have potential application to crude units. Each refiner will need to make an assessment of his refinery's requirements and then consider the ideas that best suit those needs. Corporate planning, engineering, regulatory, and operations personnel will be able to use the ideas and techniques reported in this study as an initial step toward a more thorough case-by-case evaluation of pollution prevention for the crude units at individual refineries.

1.3 Pollution Prevention Ideas for Model New Crude Unit

For a model new crude unit (Case 1), the following pollution prevention ideas may be considered in the design stage and are reported in Section 6:

- Apply pinch analysis to the crude preheat train heat integration (refer to Appendix I). Increase crude preheat temperature and minimize heat losses to air and cooling water.
- Increase crude distillation column pumparounds from two to four. Reboil sidestrippers with a heat transfer oil rather than by steam stripping.
- Lower vacuum column flash zone pressure from 35 to 20 mmHgabs. This will lower furnace fired duty and reduce cracking of the feed to lighter products and wet oil/recovered oil.

- Use a liquid ring vacuum pump in place of the third stage steam jet ejector on the vacuum tower overhead.
- Strip desalter brine for benzene removal before sending brine to wastewater treatment. Send recovered benzene to gasoline blending.
- Install new generation low NO_x burners. Use selective catalytic reduction (SCR) to reduce NO_x in furnace flue gas.
- Scrub furnace flue gas for removal of SO_x when firing high sulfur fuel oil.
- Optimize water reuse by application of sidestream softening to blowdown streams.
- Apply advanced process control to optimize energy utilization. Install analyzers to provide continuous pollutant monitoring.
- Employ specialized hardware and inspection & maintenance (I&M) to eliminate fugitive emissions of volatile organic compounds (VOC):
 - Select leakless or graphite packed valves.
 - Use sealless design pumps or pumps with double seals.
 - Minimize flanges and install sealing rings on leaking flanges.
 - Blind, plug, or cap open-ended vent and drain valves.

- Route relief valves to flare and add rupture disks.
- Pipe compressor seal vents back to process and vent compressor distance pieces to refinery flare.
- Install a maintenance drain-out (MDO) system to eliminate open discharges from drains.
- Totally close-loop all samplers.

1.4 Pollution Prevention Ideas for Revamp of Conventional Crude Unit

For the revamp of an existing conventional crude unit (Case 2), the following pollution prevention ideas may be considered and are reported in Section 7:

- Apply pinch analysis to the crude preheat train heat integration. Increase crude preheat temperature and minimize heat losses to air and cooling water. Keep equipment and piping relocation to a manageable minimum.
- Reboil the atmospheric column sidestrippers (except for high boiling point Atmospheric Gas Oil) with heat transfer oil rather than by steam stripping. Install two new sidestrippers and modify one existing sidestripper.
- Lower vacuum column flash zone pressure from 35 to 20 mmHgabs. Use liquid ring vacuum pump in place of the third stage steam jet ejector on the vacuum tower overhead. Add parallel ejectors to the first and second stages.
- Strip desalter brine for benzene removal.

- Retrofit new generation low NO_x burners and install SCR units for post-combustion NO_x reduction.
- Scrub flue gas for removal of SO_x when firing high sulfur fuel oil in heaters.
- Optimize water reuse by application of sidestream softening to blowdown streams.
- Apply advanced process control to optimize energy utilization. Install analyzers to provide continuous pollutant monitoring.
- Employ specialized hardware and I&M to reduce fugitive emissions of VOC:
 - Improve I&M program (leak definition, monitoring frequency, and repair response time).
 - Selectively retrofit leakless or graphite packed valves.
 - Selectively retrofit sealless design pumps or pumps with double seals.
 - Minimize flanges and install sealing rings on leaking flanges.
 - Blind, plug, or cap open-ended vent and drain valves.
 - Route relief valves to flare and/or add rupture disks.

- Pipe compressor seal vents back to process and vent compressor distance pieces to refinery flare.
- Install a MDO system to eliminate open discharges from drains.
- Totally close-loop all samplers.

1.5 Summary of Findings

Air emissions, wastewater effluents, solid wastes, energy consumption, and costs are summarized in Table 1.1. Figures 1.1 through 1.4 give graphical representations of air emissions, wastewater loads, and solid waste generation.

The findings of this pollution prevention study on refinery crude units are summarized below:

- A generic systematic methodology for conducting pollution prevention studies on process units can be applied to the crude unit in a typical refinery.
- There is a correlation between energy efficiency and environmental effectiveness: the more efficient the crude unit, the less it pollutes.
- The total energy usage in the crude unit can be reduced by improving heat integration in the crude preheat train through pinch analysis.
- Reductions in wastewater generation can be achieved by energy reduction and stream recycling.

- Reductions in solid and hazardous wastes can be achieved by water recycling and preventing the mixing of hazardous and non-hazardous waste streams. If the heaters burn high sulfur fuel, limestone scrubbing for SO_x reduction will generate non-hazardous sludge.
- NO_x emissions can be reduced by new generation low NO_x burners, SCR units, and Flue Gas Recirculation (FGR).
- The total annual benzene quantity (TAB) in wastewater can be reduced by steam stripping.
- Fugitive emissions from piping components can be reduced by hardware improvements and stringent inspection & maintenance programs.

TABLE 1.1: SUMMARY OF FINDINGS
MULTI-MEDIA RELEASES FROM 175,000 BPSD CRUDE UNIT

HEATERS FIRING FUEL GAS

	AIR EMISSIONS, TON/YR				WASTE WATER, GPM	SOLID WASTE, TONS/DAY		HAZARDOUS		NON-HAZARDOUS		ENERGY		CAPITAL COST \$MM
	NO _x	CO	VOC	TSP	SO _x			HAZARDOUS	NON-HAZARDOUS	HAZARDOUS	NON-HAZARDOUS	MMBTU/ HR	KW	
BASE CASE (Conventional Crude Unit)	415	185	183	23	3.3	584		6.3	0			948	2,670	128.7
CASE 1 (Model New Crude Unit)	164	152	5.6	19	2.7	339		0.5	2.7			786	3,153	164.3
Reductions (Base Case - Case 1)	251	33	177	4	0.6	245		5.8	-2.7			162	-483	-35.6
CASE 2 (Revamp of Conventional Crude Unit)	170	168	12	21	3.0	342		0.5	3.7			864.5	3,033	28.7
Reductions (Base Case - Case 2)	245	17	171	2	0.3	242		5.8	-3.7			83.5	-363	n/a

CRUDE HEATER FIRING 1 wt% SULFUR FUEL OIL

	AIR EMISSIONS, TON/YR				WASTE WATER, GPM	SOLID WASTE, TONS/ DAY		HAZARDOUS		NON-HAZARDOUS		ENERGY		CAPITAL COST \$MM
	NO _x	CO	VOC	TSP	SO _x			HAZARDOUS	NON-HAZARDOUS	HAZARDOUS	NON-HAZARDOUS	MMBTU/ HR	KW	
BASE CASE (Conventional Crude Unit)	597	171	190	187	2,105	584		6.3	0			948	2,670	128.7
CASE 1 (Model New Crude Unit)	172	142	11	134	149	339		0.5	12.5			786	3,310	169.8
Reductions (Base Case - Case 1)	425	29	179	53	1,956	245		5.8	-12.5			162	-640	-41.1
CASE 2 (Revamp of Conventional Crude Unit)	179	156	18	157	176	342		0.5	15.3			864.5	3,190	34.7
Reductions (Base Case - Case 2)	418	15	172	30	1,929	242		5.8	-15.3			83.5	-520	n/a

FIGURE 1.1 AIR EMISSIONS FROM 175,000 BPSD CRUDE UNIT (HEATERS FIRING FUEL GAS)

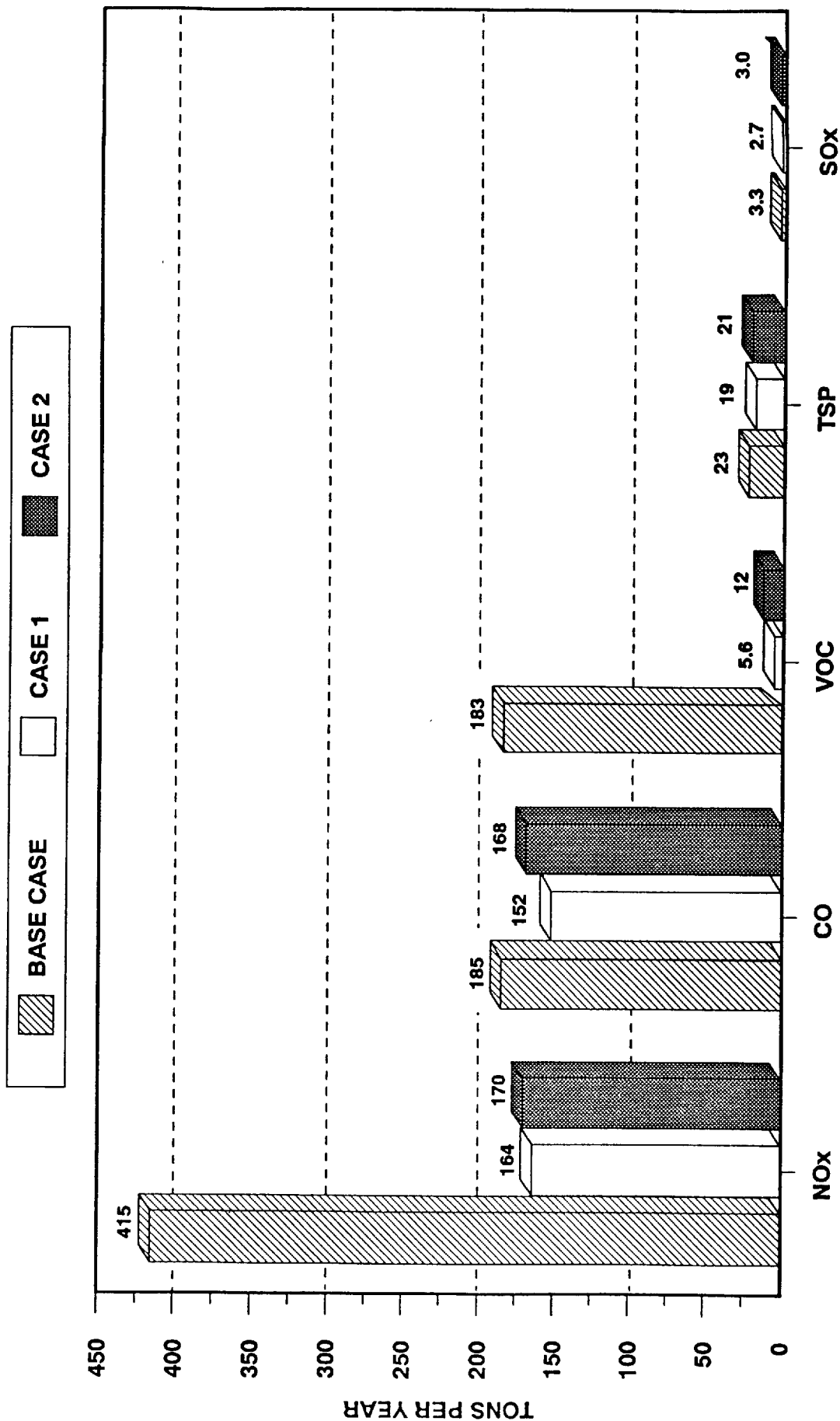


FIGURE 1.2
AIR EMISSIONS
FROM 175,000 BPSD CRUDE UNIT
(ATMOSPHERIC CRUDE HEATER FIRING 1 WT% SULFUR FUEL OIL)

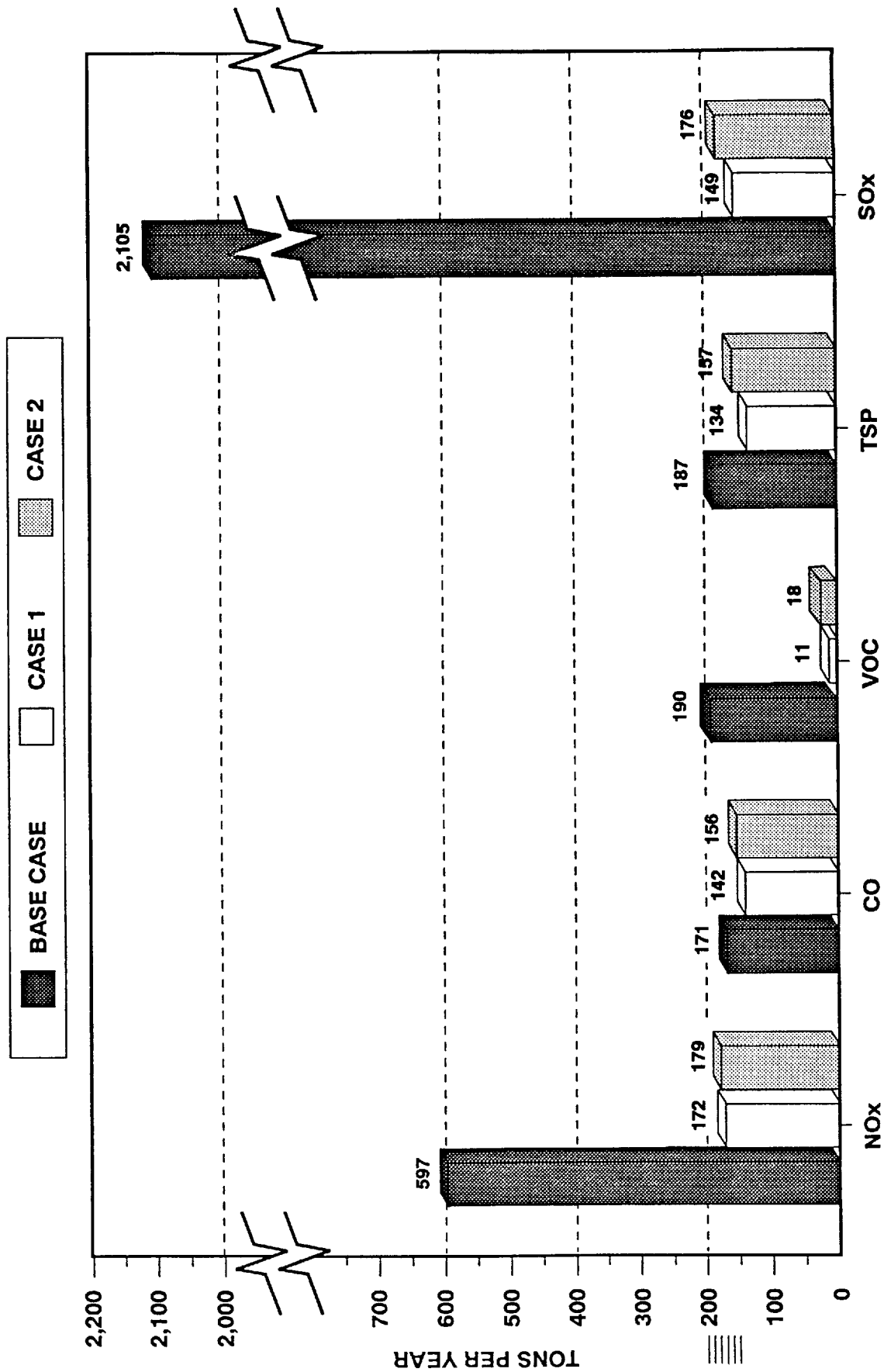


FIGURE 1.3
WASTE WATER LOADS
FROM 175,000 BPSD CRUDE UNIT

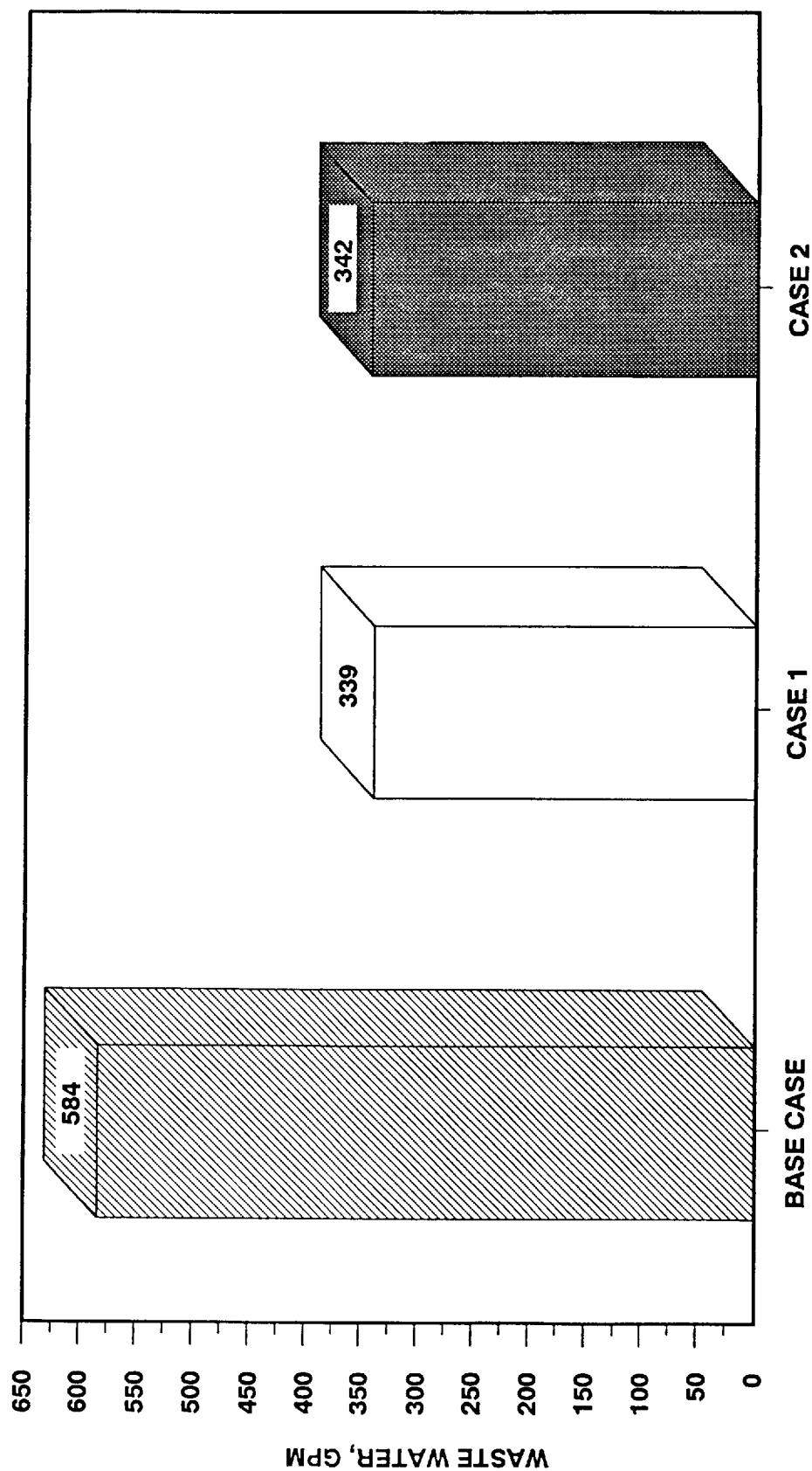
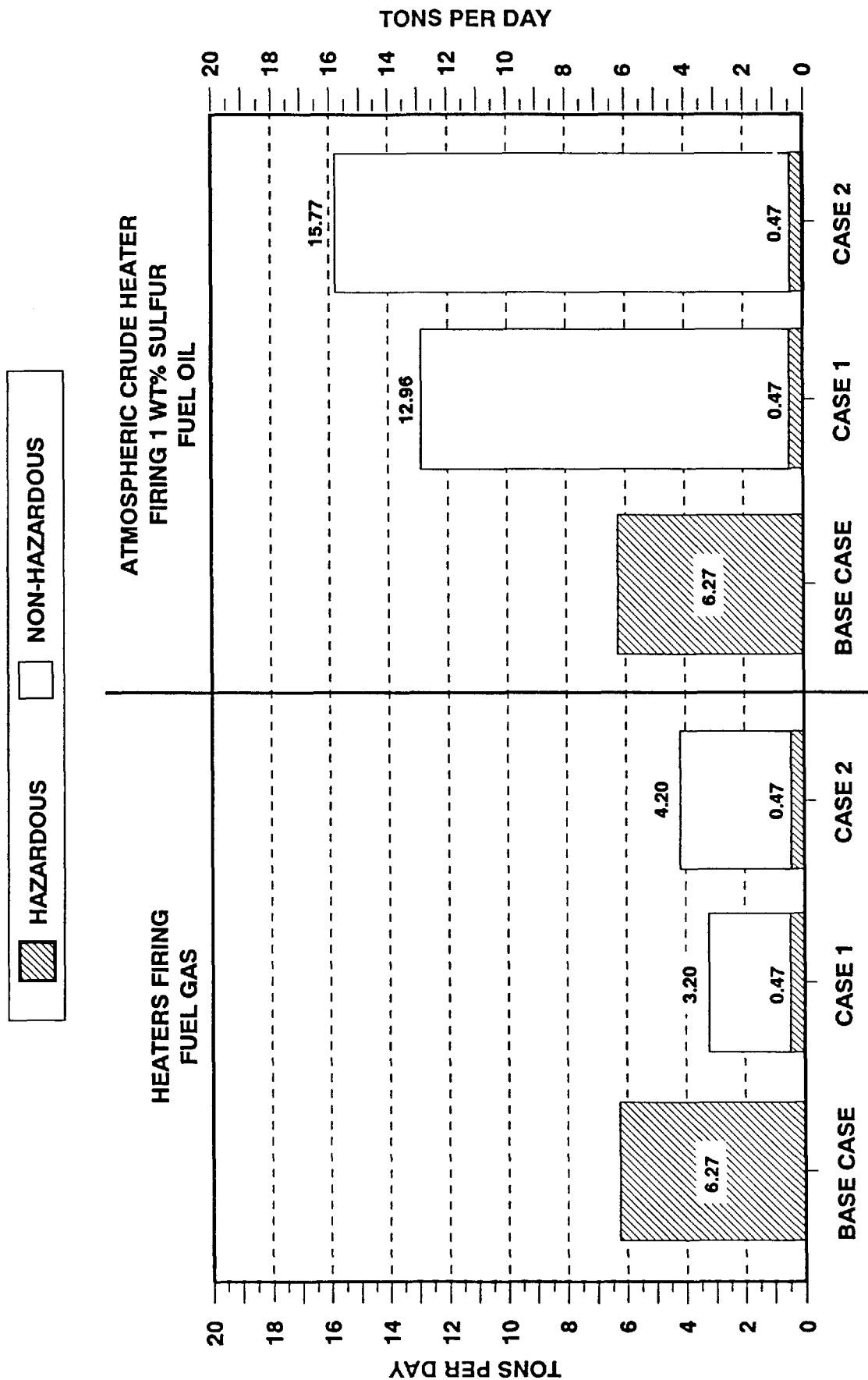


FIGURE 1.4
SOLID WASTE GENERATION
FROM 175,000 BPSD CRUDE UNIT



Section 2: INTRODUCTION

2.1 Background

API has developed the following working definition of pollution prevention:

"Pollution prevention is a multi-media concept that reduces or eliminates pollutant discharges to air, water, or land and includes the development of more environmentally acceptable products, changes in processes and practices, source reduction, beneficial use and environmentally sound recycling."

The API definition of pollution prevention does not include end-of-the-pipe treatment. With this definition serving as the theme, the API Pollution Prevention/CREC Workgroup initiated this pollution prevention study on crude units.

2.2 Statement of Objective

The objective of this study was to investigate how the crude unit in a "typical" refinery could minimize multi-media releases while still efficiently performing the traditional functions of a crude unit. Consistent with good engineering practice, both pollution prevention and end-of-the-pipe treatment approaches were considered.

2.3 Study Plan

This study viewed pollution prevention from two perspectives:

- from the point of view of designing a model new crude unit (referred to as Case 1); and
- from the point of view of revamping a conventional existing crude unit (referred to as Case 2).

To serve as a reference point or Base Case, a typical ten-year-old U.S. Gulf Coast crude unit of 175,000 BPSD feed rate was chosen.

2.4 Usefulness of Results

The primary result of this study is a technical assessment of alternative pollution prevention concepts applicable to a refinery crude unit and how these concepts could be incorporated into a new or revamp crude unit. A secondary product of the study is the methodology that was developed for the systematic analysis of pollution prevention. This methodology is applicable to the evaluation of other refinery processes and to individual pollution prevention projects.

Some caveats apply to this study. This study should not be regarded as a recommendation for the process design of a crude unit. Only one type of crude and one set of product specifications were considered in this study. This does not form an adequate design basis for a process study. Multiple crude feedstocks and a range of product specifications would normally be considered in the design of a crude unit.

2.5 Limitations of Study Results

No optimum or "best" design is to be implied from this study. Numerous pollution prevention concepts have been evaluated and reported in this study. Other pollution prevention measures have potential application to crude units. Each refiner will need to make an assessment of requirements and utilize the ideas and concepts that best fit the needs of the individual refinery and situation. Corporate planning, engineering, regulatory, and operations personnel will be able to use the ideas and techniques developed by this study as an initial step toward a more thorough case-by-case evaluation of pollution prevention at individual refineries.

There is considerable difference between a conceptual study and the actual implementation of pollution prevention systems. For many of the ideas that appear to be promising for an individual refinery, it may be necessary to conduct laboratory studies or field demonstrations before implementing the project.

Laboratory studies are useful to verify the technical feasibility of the proposed design and operating changes, to confirm that the process will still produce products that meet customer requirements, to develop a basis for investment estimates, and to identify safety and logistic concerns prior to field implementation. Plant field demonstrations prove the technology on a larger scale.

2.6 Physical Boundaries and Study Limits

The scope and content of this study was limited to the crude unit and subject to the boundaries and exclusions explained below:

2.6.1 The study addressed equipment and processes Inside Battery Limits (ISBL) of the crude unit, including:

- crude oil desalter
- crude oil preheat exchangers
- atmospheric distillation tower and its heater
- vacuum-producing equipment
- vacuum distillation tower and its heater.

2.6.2 A single sour crude feedstock was chosen: Light Arabian Crude.

2.6.3 Compression of overhead vapors from the atmospheric tower was accomplished within the battery limits.

2.6.4 The stabilizer was not within the study scope.

2.6.5 Unstabilized naphtha was routed to the battery limits for further processing.

2.6.6 The study investigated in detail the following methods of pollution prevention:

- modification of vacuum tower to dry operation and reduced flash zone pressure to minimize cracking of feed;
- dry operation to reduce the quantity of sour condensate;
- use of vacuum pumps to replace all or part of the steam jet ejector system used to create the vacuum for the vacuum tower;
- use of reboiled side strippers on the atmospheric tower rather than open steam stripping to reduce the quantity of sour condensate;
- replacement of conventional burners with low NO_x burners in furnaces;
- use of catalytic and non-catalytic processes for the selective reduction of NO_x;
- reuse of stripped sour water to replace clean steam condensate as desalter water; and
- heat integration for maximum energy utilization.

Other methods for pollution prevention were subsequently added or substituted for the ones mentioned above as the study evolved.

2.7 Future Studies

During the execution of this study, several areas were identified as worthy of further analysis in a future study:

- Analysis of interfaces with other refinery process units for downstream impacts
- Evaluation of alternate crude and product slates

- Sensitivity analysis of other engineering and financial parameters
- Evaluation of cooling tower system

2.8 Overview of This Report

Section 1 Executive Summary

This section summarizes the findings of the study.

Section 2 Introduction

This section previews the contents of this report and explains the basis for the study.

Section 3 Regulatory Issues

This section discusses the environmental regulations currently driving refineries and their influence on pollution prevention.

Section 4 Methodology

This section describes a generic methodology for conducting pollution prevention studies and how this methodology was applied to the pollution prevention study for crude oil units.

Section 5 Conventional Crude Unit (Base Case)

This section presents the results of a process and environmental audit of a conventional existing crude unit, referred to as the Base Case.

Section 6 Model New Crude Unit (Case 1)

This section describes a conceptual design for a model new crude unit which incorporates practicable pollution prevention ideas. The Model New Crude Unit is referred to as Case 1.

Section 7 Revamp of Conventional Crude Unit (Case 2)

This section describes how the Base Case crude unit can be revamped to incorporate pollution prevention ideas. The revamp of the conventional crude unit is referred to as Case 2.

Appendices A through M contain the collected information referenced in the text of the report.

Section 3: REGULATORY ISSUES

3.1 General Issues

Environmental regulatory compliance for today's petroleum refinery is an ever-increasing economic, technical, and operational challenge. Some of the most important environmental statutes that apply to U.S. refineries are:

- The Clean Air Act (CAA)
- The Clean Water Act (CWA)
- The Resource Conservation and Recovery Act (RCRA)
- The Superfund Amendments and Reauthorization Act (SARA)
- The Pollution Prevention Act of 1990 (PPA)

Several of these statutes that have been enacted or amended in the recent past contain various components of pollution prevention. Moreover, the Clinton administration has indicated that pollution prevention will continue to be a priority of the Environmental Protection Agency in its future activities.

In addition to traditional regulatory initiatives, pollution prevention (and energy efficiency) have also become the focus of many non-regulatory initiatives such as the 33/50 Program and the Green Lights Program. A common element of these programs seeks to engage facilities and individual companies in determining their own levels of participation in such programs and in finding the most cost-efficient method of attaining broad environmental goals set by the Agency.

Other voluntary efforts by industry trade associations (e.g., Responsible Care and STEP), independent organizations (GEMI), and company programs (e.g., SMART and WOW) are yet another method of instilling the pollution prevention principles into industry operations.

The result of the coupling of the traditional regulatory compliance activities and the numerous voluntary initiatives result in a very complex system and a close linkage between normal daily production operations and those systems installed to eliminate, separate, purify, recycle, and reuse

refinery streams that might have otherwise become wastes. Additionally, refiners and the operators of individual process units within the refinery are becoming responsible for the wastes their units generate and the resulting costs and liabilities incurred for treatment and disposal of generated wastes. This new aspect of responsibility for waste generation at the unit operation level add a new indicator of refining production efficiency. In addition to barrels of product per barrel of feed crude to pounds of waste generated per barrel of crude feed.

Refiners have demonstrated a historic capability to modify operations and maintenance attitudes and procedures to meet process, safety and environmental requirements. As these capabilities continue to evolve, new process design tools coupled with the arrival of proven and economic technologies will allow the industry to continue its efforts in achieving and sometimes exceeding environmental regulations. This chapter describes components of the various environmental regulations that may apply to petroleum refining operations.

3.2 Air Emissions

3.2.1 Federal Programs

Air emissions from refineries are regulated by the state and the federal government. State air programs are administered by a state department of environmental quality, commission, board, or similar agency. State agencies may adopt more stringent emission standards than federal standards.

The federal program is administered by the United States Environmental Protection Agency (EPA) and authorized states under the CAA. The EPA has promulgated several emission standards and programs which affect new and existing refineries, including:

- New Source Performance Standards (NSPS)
- National Emission Standards For Hazardous Air Pollutants (NESHAP)
- Prevention of Significant Deterioration of Air Quality (PSD)
- Best Available Control Technology (BACT)
- Lowest Achievable Emission Rate (LAER)

NSPSs which can apply to the crude unit (ignoring for this analysis the offsite and utility support systems for the crude unit) and include:

- 40 CFR Part 60 Subpart A - General Provisions
- 40 CFR Part 60 Subpart J - Standards of Performance for Petroleum Refineries
- 40 CFR Part 60 Subpart GGG - Standards of Performance for Equipment Leaks of VOC in Petroleum Refineries
- 40 CFR Part 60 Subpart QQQ - Standards of Performance for VOC Emissions from Petroleum Refinery Wastewater Systems

NESHAPs which can apply to the crude unit include:

- 40 CFR Part 61 Subpart A - General Provisions
- 40 CFR Part 61 Subpart J - National Emission Standard for Equipment Leaks (Fugitive Emission Sources) Benzene
- 40 CFR Part 61 Subpart FF - National Emission Standard for Benzene Waste Operations
- 40 CFR Part 61 Subpart V - National Emission Standard for Equipment Leaks (Fugitive Emission Sources)

The PSD program requires existing refineries that make major modifications to air emission sources to apply BACT. In non-attainment areas (areas which exceed the national ambient air quality standard for an air pollutant), refineries are subject to LAER controls, which is a technology standard more stringent than BACT.

The Clean Air Act regulates both point source (stack) emissions and fugitive emissions. The species and quantity of both point source and fugitive emissions are also included in calculations and modeling for air permit applications. Stack and fugitive emissions are also regulated under PSD.

The NESHAP and NSPS rules are interrelated in that both regulate air emissions from process effluents and wastewater. For example, NSPS regulations (40 CFR 60 Subpart QQQ) regulate the air emissions of VOCs from new and modified wastewater treatment equipment and sewers. NESHAP standards (40 CFR 61 Subpart FF) regulate chemicals such as benzene in waste and wastewaters.

3.2.2 The Clean Air Act Amendments

The Clean Air Act Amendments (CAAA) of 1990 expanded the EPA's enforcement powers and added or revised restrictions on the air emissions containing toxic chemicals, stratospheric ozone-depleting chemicals, acid rain related oxides of nitrogen (NO_x) and sulfur (SO_x), and gases considered to cause global warming (CO_2). With respect to hazardous air pollutants, amended Section 112 requires EPA to develop technology-based standards for 189 chemicals for certain source categories (e.g., refineries and marketing facilities). Emissions reductions of up to 90 percent will be required depending on the category of chemicals and the total annual emissions from the plant. Such standards are to be based on what can be achieved by Maximum Achievable Control Technology (MACT).

Once emissions of hazardous air pollutants have been controlled with MACT, EPA will assess remaining risks and may require that additional controls be implemented.

Emissions limits for VOCs will have a significant impact on wastewater treatment systems. Because widely used emissions control technologies involve transfer of the contaminant to an aqueous medium (e.g., scrubbing), either the contaminant must be recovered and reused in the plant processes or it must be treated prior to discharge. Recovery and reuse qualifies under the EPA's source reduction definition, while treatment prior to discharge does not.

3.3 Wastewater Treatment And Discharges

3.3.1 Clean Water Act

Wastewater discharges from refineries are regulated by the state and the federal government.

State programs are administered by a state department of environmental quality, water commission, or similar agency.

The federal program is administered by the EPA under the authority of the Clean Water Act (CWA). Under the CWA, discharges to U.S. waters must have a permit. Permits must contain technology-based limits and where necessary, water quality limits.

Technology-based limits include:

- Best Practicable Control Technology Currently Available (BPT)
- Best Available Technology Economically Achievable (BAT)
- Best Conventional Pollutant Control Technology (BCT)
- New Source Performance Standards (NSPS)

Discharges who discharge publicly-owned treatment works must comply with general pretreatment regulation, and where applicable, categorical:

- Pretreatment Standards for Existing Sources (PSES), and
- Pretreatment Standards for New Sources (PSNS).

The effluent limitations corresponding to each control strategy can be found in the Code of Federal Regulations, Title 40 - Protection of Environment, Chapter I - Environmental Protection Agency, Subchapter N - Effluent Guidelines and Standards, Part 419 - Petroleum Refining Point Source Category.

Under 1987 amendments to the Clean Water Act, the EPA required all states to set standards limiting toxic chemical concentrations in aqueous discharges from Publicly Owned Treatment Works (POTWs) and NPDES discharges within their state by early 1992. This ruling now involves 105 chemicals and will include additional chemicals as time passes. Many states have not set these standards and will be subject to EPA enforcement.

Water quality-based permit limits must be met regardless of cost and feasibility and are based on water quality standards which states are to establish and revise periodically. State agencies may adopt more stringent wastewater discharge limits than the federal limits. Some states have set their own surface water quality standards and have recently adopted new limits for toxic chemicals. Recently, EPA promulgated water quality standards applicable in states that had failed to update their own (57 FR 60848; December 22, 1992).

3.4 RCRA Hazardous Waste

The 1984 Hazardous and Solid Waste Amendments to RCRA required EPA to define limitations to "wastes" intended for land disposal. This limitation was established for "listed" or "characteristic" hazardous wastes. One important ramification of these regulations is the change that will be required in the wastewater treatment facilities that receive waste streams now classified as hazardous wastes. For example, under current classification procedures, refinery wastewater containing 0.5 ppm benzene is characteristically hazardous. Surface impoundments "that manage wastes meeting the RCRA definition of hazardous" will have to meet the requirements of RCRA permitted facilities, including double liners, leachate collection systems, VOC control measures, and groundwater monitoring systems. Existing hazardous waste impoundments that manage wastes RCRA definition of hazardous must be retrofitted by March 29, 1994.

Another important environmental regulation promulgated by the EPA on November 2, 1990 and enacted on May 2, 1991 is the Refinery Primary Sludge Listing. This listing defines most sludges (designated F037 and F038) generated by refinery process wastewater systems as hazardous wastes. These separation operations include any portion of the process wastewater treatment system that generates sludges from the physical or chemical separation of oil, water, and solids. These operations are now designated as hazardous waste treatment facilities. These hazardous waste treatment facilities may require re-permitting under RCRA and must comply with Minimum Technical Standards by November 2, 1994, or cease generating any such sludges by that date.

3.5 The Pollution Prevention Act

The Pollution Prevention Act of 1990 (PPA) expanded the required SARA Title III Form R reporting to include reporting on the methods being used to reduce waste generation at the site, the amounts reduced for each type of waste and chemical, and the efforts underway to reduce wastes further. It is expected that this publicly available information will be reviewed closely by a number of special interest groups that are involved in public hearings and permitting activities for refiners. It is also expected that those companies who have achieved their predicted or promised waste reduction goals will be allowed greater ease of environmental permitting and new plant sitings.

3.5.1 Chemical Release Reporting

The purpose of the PPA is to establish a national policy to reduce or eliminate the generation of waste at the source, whenever feasible. The PPA directs the EPA to initiate an extensive program of information collection, technology transfer, and financial assistance to the states to implement this policy and to promote source reduction techniques.

Reporting data that must be included in each annual SARA III Form R are as follows:

- Annual quantities of each toxic chemical entering waste streams prior to off-site recycling, treatment, or disposal. This includes the percent change from the previous year and estimates for the next two years.
- Annual quantities of each chemical recycled on-site and off-site, the recycling processes used, the percentage change from the previous year, and estimates for the next two years.
- Annual quantities of each chemical treated on-site or off-site and the percent change from the previous year.

- Annual quantities of each chemical released to the environment due to catastrophic events, remediation of wastes on site, or any other event not associated with routine operations.
- Source reduction practices used for each chemical at the facility and the techniques used to identify additional opportunities for source reduction.
- The ratio of overall facility production to that of the previous year.

3.5.2 The Toxics Release Inventory

The Toxics Release Inventory (TRI) is an annual report required by Section 313 of the 1986 Emergency Planning and Community Right-To-Know Act (EPCRA), otherwise known as Title III of SARA. These regulations require that all manufacturing and production facilities employing more than 10 people full time must provide annual emissions estimates for over 300 chemicals and 20 chemical categories used for any purpose in amounts exceeding certain threshold limits. Emissions estimates for routine and accidental releases must be provided for each chemical and chemical group on separate forms (Form R) with estimates for release to the air, water, and land. These laws are based on the premise that the community and citizens near these facilities have a right to know about the use, storage, and emissions of toxic chemicals.

This act has three main purposes:

- To inform the public and the government about possible chemical hazards to their community,
- To provide for planning in the case of chemical accidents, and
- To provide the public with a compiled and categorized annual inventory of releases and transfers of toxic chemicals - The Toxic Release Inventory.

For the reporting years 1987 through 1990, the TRI forms included an optional section for companies to report activities that reduced the generation of toxic chemical wastes. This section was expanded and made mandatory by the Pollution Prevention Act of 1990.

3.5.3 Uses For TRI Data

It is expected that this publicly available information will be reviewed closely by a number of special interest groups that are involved in public hearings and permitting activities for chemical producers and manufacturers.

The federal government has already used TRI data to form new environmental legislation such as the Clean Air Act Amendments of 1990. The EPA has also used TRI data for the implementation of existing programs involving permitting, inspection, enforcement targeting, compliance reviews, risk screening, and pollution prevention monitoring.

State governments are using TRI data in their permitting and pollution prevention programs. These uses involve:

- Development of permit requirements for facility discharges to air and water (NPDES and POTW permits).
- Determination of whether additional chemicals should be included in permit applications.
- Determination of whether additional control measures should be required.
- Targeting facilities with the greatest potential for waste reduction.
- Identification of facilities in need of state technical assistance in their waste reduction programs.

Users use of TRI data include public interest groups, citizen groups and universities. These groups analyze and report data for geographic areas, industries, or selected release media. One of the beneficial side-effects of good waste reduction performance is an improved public image for the facility or plant involved. This usually leads to an improved public perception and potential acceptance of their products as being produced in an environmentally responsible manner.

3.6 New Economic Justification For Waste Reduction

Economic considerations used to justify implementation of projects or systems that reduce hazardous waste and solid waste generation should include more than those traditionally used for plant process modifications or new installations. This is because waste reduction systems will have an ever increasing affect on the entire plant or facility in terms of:

- The type of waste generated,
- The amount of waste generated,
- Where in the plant it was generated, and
- The effects the waste will have on downstream operations.

These "whole plant" economic considerations should include the following at a minimum:

- The predicted future costs for handling, treating, transporting, and disposal of wastes generated,
- Positive effects on other unit operations within the plant such as reducing wastewater treatment and emissions control requirements,
- Increases in production yields that may result from installation of reclamation and reuse systems,

- The effects on company-wide waste reduction goals if planned waste reduction goals are not achieved at each plant,
- The effects of reducing the amount of process wastewater requiring treatment because of water reuse within the plant,
- The avoided costs of complying with new and restrictive wastewater treatment and pre-treatment standards,
- The avoided future costs of hazardous waste cleanup and long-term liability for feed water treatment sludges and other solid wastes that may become reclassified as hazardous wastes,
- The reduction in the long-term liability associated with hazardous waste generation and disposal,
- The reduced need for installation of future air emission control systems (i.e. MACT systems),
- Reduced CAAA emission fees and state taxes,
- Reduced costs associated with future monitoring and permitting of air emissions such as risk assessment and toxicology studies,
- Reduced costs associated with reducing VOC emissions from wastewater treatment systems.

Section 4: METHODOLOGY

4.1 Introduction

This section discusses a generic systematic methodology for conducting pollution prevention studies and how this methodology was applied to the pollution prevention study for crude oil units.

4.2 Generic Methodology for Pollution Prevention Studies

4.2.1 Logic Flow Chart

A logic flow diagram which describes a generic methodology for conducting pollution prevention studies is included as Figure 4.1.

4.2.2 Project Execution Strategy

A pollution prevention project begins in the same way that a process study would begin. The goals, objectives, scope, deliverables, and key issues of the study are captured in a project execution strategy.

A pollution prevention study must have a reference point, or base case. The project execution strategy will define the conventional process unit, or base case, against which the proposed pollution prevention measures will be evaluated. Once the base case is selected, the relevant process data, environmental data, and equipment specifications will be collected for subsequent comparative analyses in the pollution prevention study.

4.2.3 Idea Generation and Selection - The Creative Process

Brainstorming is a team problem-solving technique which is particularly effective in generating ideas for pollution prevention studies. A team of process and environmental specialists are invited to participate. The brainstorming session provides a creative and uninhibited atmosphere where ideas can be proposed without dwelling on details. Details are left to be fleshed out in the subsequent steps of the study. A literature search can be performed ahead of the brainstorming session to kick off the flow of ideas.

Following the creative storm of ideas, the candidate ideas are sorted by engineering system and the environmental medium being impacted. Some ideas may fit more than one category. The categories of engineering systems in order of priority are:

- Source Reduction: Process Modifications
- Source Reduction: Process Optimization
- Source Treatment
- Waste Segregation
- End-of-Pipe Treatment
- Fugitive Emission Management
- Containment
- Other

The categories of environmental media are:

- Air
- Wastewater
- Solid Waste
- Hazardous Waste

The ideas are then qualitatively rated for their anticipated environmental benefits and cost impacts using three simple grades:

- High
- Medium
- Low

It is now possible to identify those ideas which have the potential to yield the greatest return on investment; i.e., a high environmental benefit at relatively low cost. These ideas receive priority. A second list of medium benefit-to-cost ideas can also be prepared. All ideas are captured for future consideration and evaluation.

4.2.4 Evaluation of Ideas

The next step is to analyze how the pollution prevention ideas can be applied to a model new process unit (Case 1) and to a revamp of a conventional process unit (Case 2). Since the model new process unit begins as a blank sheet of paper, any idea can be considered. The revamp unit must necessarily consider technical and physical constraints. Not every good idea can be practically retrofitted to an existing unit.

Process Flow Diagrams (PFDs) are then developed to incorporate the pollution prevention ideas selected for Case 1 and Case 2. The resulting process operations are confirmed by computer simulations. Heat and material balances are prepared. Heat integration (pinch analysis) is performed to optimize the process. At the same time the process design is proceeding, the air emissions, wastewater loads, and solid and hazardous wastes can be quantified.

A list of equipment can be generated from the PFDs. Process engineers will size the equipment, set design conditions, and specify performance requirements. The cost estimate can now be prepared. Cost estimating specialists will price the new equipment for Case 1 and estimate the cost of modifying the existing equipment for Case 2. The target accuracy of the cost estimate is $\pm 35\%$.

A cost/benefit analysis is then developed from the results of the cost estimate and the anticipated process/environmental benefits. If a particular pollution prevention idea results in energy conservation or marketable product, the payback period can be calculated. If a particular idea results in reduction of a waste without a compensating recovery credit, the cost/benefit of the idea can be calculated in terms of cost per ton of pollutant controlled.

The final step in this methodology is to assemble the findings of the pollution prevention study into a report. The final report compares the model new process unit and the revamp conventional process unit to the base case. The final report concludes the study but does not represent the end of the pollution prevention process. Pollution prevention is not a static once-through process; it is a dynamic iterative cycle of regularly reevaluating systems to reduce pollution.

4.3 Pollution Prevention Methodology Applied to Crude Units

4.3.1 Project Execution Strategy

After award of this contract, API and Kellogg jointly prepared a project execution strategy. The project execution strategy established the project goals and objectives, scope of work, deliverables, budget, schedule, and work processes. The project execution strategy also defined the conventional crude unit, or base case. Refer to Section 2 of this report for further discussion.

4.3.2 Idea Generation and Selection

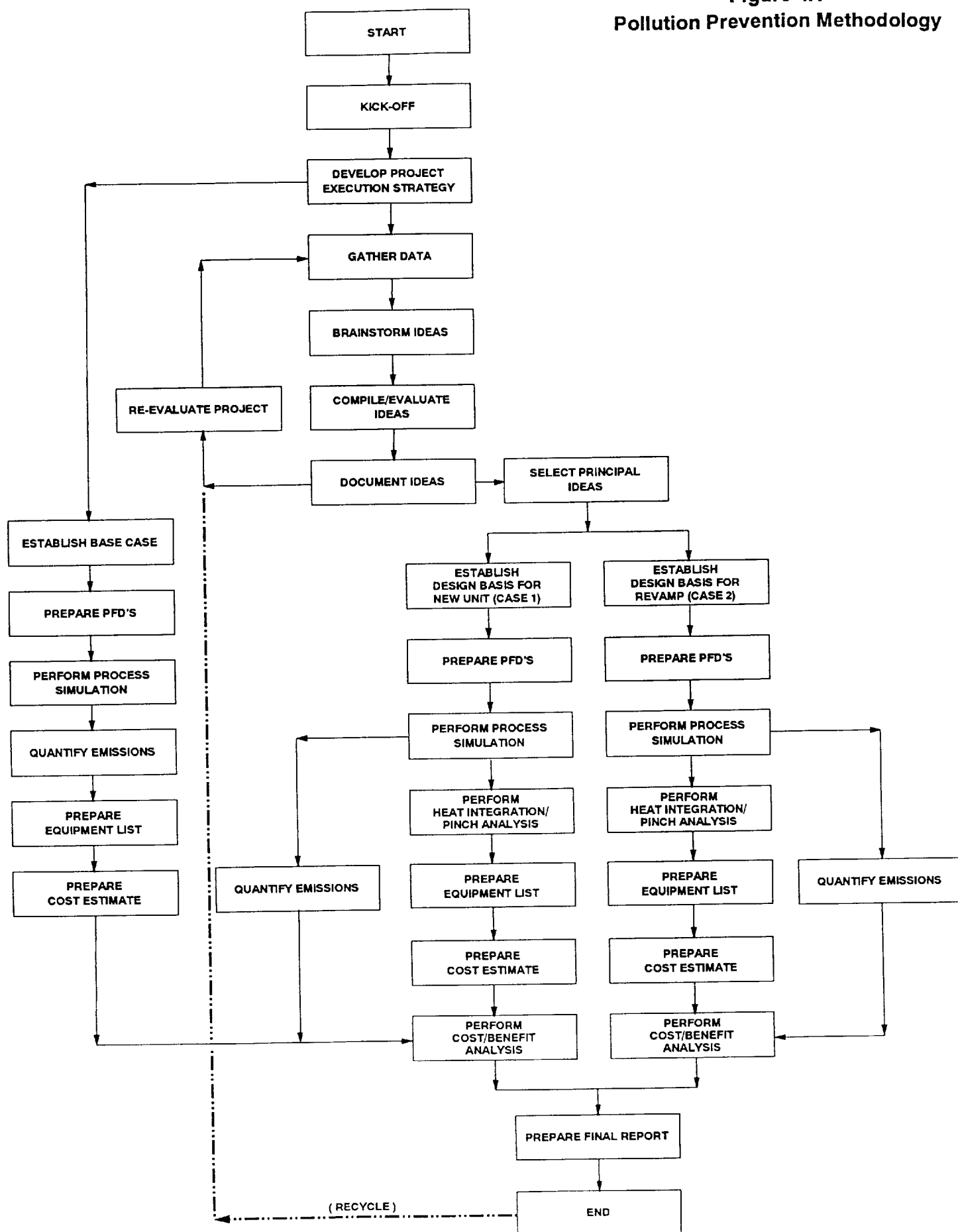
A literature search was performed and input from API committee members was solicited. Several brainstorming sessions were conducted with senior process refinery engineers, environmental engineers, and technical managers. The brainstorming sessions produced 116 pollution prevention ideas with potential application to crude units. The candidate ideas are presented in Appendix A, classified according to engineering system and environmental medium, and qualitatively rated for environmental benefits and cost impacts. Of the 116 ideas, a short list of 39 ideas were selected for further study based on qualitative cost/benefit analyses. These ideas are denoted with an asterisk in the listing in Appendix A.

4.3.3 Evaluation of Ideas

The ideas selected were examined for feasibility of application to Case 1 and Case 2. Ideas were struck if they were not commercially proven (i.e., if the idea was derived from an emerging technology or if it was not commercially available). A further constraint was imposed on Case 2: only ideas which could be implemented during a scheduled turnaround period were considered. In-house engineering expertise was used to evaluate ideas which fit these criteria.

Three sets of PFDs were developed: Base Case, Case 1, and Case 2 (refer to Appendices B, C, and D). The PFDs provided the basis for the material balance, computer simulation (Appendix H), pinch analysis (Appendix I), inventory of emissions and effluents (Sections 5.5, 6.5, and 7.5), equipment lists (Appendices E, F, and G), cost estimates (Sections 5.6, 6.6, and 7.6) and cost/benefit analyses (Sections 6.8 and 7.8).

Figure 4.1
Pollution Prevention Methodology



Section 5: CONVENTIONAL CRUDE UNIT (BASE CASE)

5.1 Introduction

The refinery unit selected for this study is a typical U.S. Gulf Coast crude and vacuum unit that was designed in the early 1980's, with a 175,000 BPSD capacity.

5.2 Design Basis

A representative crude, Light Arabian Crude of 34.50 API gravity, was selected as the single feedstock for process evaluation of all cases. Establishing an identical feedstock for the three cases allows for a unified analysis of the results.

The following items establish the process boundaries of the crude unit for this study:

- Utilities were assumed to be available from the refinery in adequate supply for maintaining reliable operation of the crude unit. Utilities include: electric power, fuel gas, cooling water, steam, instrument air, and plant air.
- Crude feed was assumed to be pumped from tankage at battery limits. Products were assumed to be sent to tankage or to adjacent units for further processing. In the latter case, product cool-down between units was not considered.
- Tanks for feed and intermediate products were not included in this study.
- Atmospheric crude tower overhead non-condensables were assumed to be compressed, cooled and sent to battery limits. Overhead liquid product was assumed to be sent to battery limits as unstabilized gasoline.
- Vacuum tower overhead jet system was included in this study. Non-condensable overhead vapor was assumed to be compressed and sent to amine treating for H₂S removal.

The crude unit will produce the slate of products shown in Table 5.1.

Steam side-stripping is employed to adjust front end boiling range for each side product. Stripped products have the following degree of fractionation:

<u>Stripped Product</u>	<u>Fractionation</u>
Overhead/Naphtha	+150 °F Gap
Naphtha/Kerosene	+ 60 °F Gap
Kerosene/HDF	+ 30 °F Gap
HDF/AGO	-500 °F Overlap

The product slate chosen is typical for this crude. Additional product stream characteristics are provided in Appendix H.

5.3 Process Description

The process flow diagrams for the Base Case are included in Appendix B (Dwg. Nos. P-7001-D, P-7002-D, and P-7003-D).

5.3.1 Crude Preheat Train

Crude charge is pumped from storage into the suction of the crude charge Pump, J-101. Stripped water from an offsite sour water stripper tower bottoms is mixed with the crude charge to provide an initial wash. This step minimizes the fouling of process lines and exchanger tubes due to salt or sludge deposition. The washed crude is then preheated in a series of process-to-process heat exchangers to an appropriate temperature for desalting.

The heated crude is fed to the two-stage desalter, where a dispersed mixture of water in the crude is formed, and water removal is effected by exposing the mixture to an electric field. Brine effluent from the second-stage desalter, F-102, is used to wash the incoming raw crude in the first-stage desalter F-101. The brine effluent from F-101 is cooled down by heat exchange with the fresh water, as well as cooling water, prior to discharging to the refinery Wastewater

Treatment Plant (WWTP). Desalted crude, which contains less than one pound of salt per thousand barrels, is pumped by the Desalted Crude Charge Pump, J-102, to a second series of process-to-process exchangers. The desalted crude temperature is elevated to 440 °F at the inlet of the atmospheric crude heater.

5.3.2 Crude Distillation

After preheating, the crude is fed to the Atmospheric Tower Feed Heater B-101, where it is heated to the desired temperature for feeding to Tower E-101. This heater is provided with air preheat and low NO_x burners. The design basis calls for taking the 670 °F TBP cut point material as atmospheric residue. The resulting flash zone temperature requirements for light Arabian crude is 668 °F, with a design overflash of 4 vol% on crude.

The atmospheric tower contains forty valve trays. Two pumparounds remove heat from the tower at the Heavy Distillate Fuel and Naphtha Product draws. At these pumparound locations, liquid is withdrawn from the tower, pumped through heat exchangers, and then returned to the tower two trays above the draw tray. Side-products are withdrawn from the crude tower, steam-stripped in sidestrippers, and then pumped to battery limits after heat exchange.

Atmospheric tower overhead is first cooled against the crude charge for optimum heat recovery then further cooled and condensed with cooling water in C-102. The partially condensed overhead vapors enter the overhead accumulator drum F-103, where uncondensed vapor, hydrocarbon liquid and free water are separated. Vapors are directed to the steam-driven atmospheric overhead compressor, X-101, where they are compressed and directed to the fuel gas system outside of battery limits. The hydrocarbon liquid is split into a reflux stream, which is directed to the tower, and a distillate product, which is sent to battery limits as unstabilized gasoline. Sour water is taken from a boot and sent to battery limits for treatment.

The atmospheric tower bottoms stream is pumped through the Vacuum Heater, B-102, to the Vacuum Tower. The vacuum heater is also equipped with an air preheat system and low NO_x burners.

5.3.2 Vacuum Distillation

The Vacuum Tower, E-108, is a packed column, operating at 35 mmHgabs in the flash zone, with no stripping steam. In order to obtain a 1025 °F + TBP cut point for the vacuum residue, a flash zone temperature of 750 °F is required. The tower is packed with a combination of stainless steel grid and rings. There is a product and pumparound draw for HVGO and LVGO. HVGO is pumped through a spray header over the grid in the wash oil zone. Wash oil from this section is withdrawn from a chimney draw tray and recycled through the vacuum heater by the Vacuum Tower Recycle Pump, J-122. A mesh pad is located above the wash oil section to eliminate entrainment to the HVGO section.

HVGO side-draw is withdrawn from a total-draw, chimney tray on level control. This stream is cooled against the crude charge and split into two streams: one is directed back to the tower as pumparound, and the other is further cooled before sending to storage as HVGO product.

LVGO side-draw is also withdrawn from a total-draw, chimney tray. After cooling, a pumparound stream is returned to the tower through the spray header above the packed bed. LVGO product is sent to storage outside battery limits.

Vacuum is created by a three-stage, steam jet ejector system. The ejectors, along with their surface condensers, are located on an elevated platform to provide a barometric leg into the Vacuum Tower Overhead Drum, F-108. Motive steam for the jets is nominal 150 psig steam. The overhead drum is maintained at 2 psig.

Sour water is separated from condensed hydrocarbon liquid and pumped to battery limits by Vacuum Condensate Pump, J-118. Recovered oil is skimmed by internal baffles and pumped by J-119 to recovered oil storage. These streams are sometimes sent to the crude desalters. Non-condensable vapors from the overhead drum flow to Vacuum Seal Drum, F-109, then to the Vacuum Off Gas Compressor X-102. The vapors are compressed and sent to the battery limits after passing through Vacuum Tower Off-Gas Knockout Drum, F-111. Any water condensate removed in this drum is drained to an oily water sewer.

5.3.4 Pollution Sources

5.3.4.1 Air Emissions

The two fired heaters, B-101 and B-102, represent the major sources of air emissions in the crude unit. Pollutant emission rates depend to a great extent on the type of fuel consumed. For this study, it was assumed that the two heaters are provided with both fuel oil and fuel gas burners. To examine the effect of fuel selection upon the pollutant emission rates, the following two fuel cases were considered:

- **Fuel Gas Case:** One hundred percent (100%) fuel gas (equivalent to pipeline grade natural gas) firing in all heaters. The fuel gas was assumed to contain 0.25 grains H_2S /100 scf.
- **Fuel Oil Case:** Fuel oil firing in the Atmospheric Crude Heater (B-101), and fuel gas firing in all other heaters. Fuel oils with different levels of sulfur were considered: 0.2, 1.0, and 3.34 wt% sulfur.

High-sulfur fuel is produced as the vacuum tower bottoms stream. Low-sulfur fuel oils were included to reflect their commercial availability.

Furnace selection was based on a minimum heater efficiency of 93%. All furnaces in the Base Case were assumed to be equipped with first generation low NO_x burners generating 0.1 lb- NO_x /MMBTU for fuel gas firing and 0.2 lb- NO_x /MMBTU for fuel oil firing.

5.3.4.2 Liquid Effluents

Aqueous effluents from the crude unit include condensed stripping steam, condensed motive steam from the jet ejectors, and the desalter effluent.

5.3.5 Waste Minimization Practices

The Base Case crude unit utilizes low- NO_x burners in fired heaters and offsite boilers. Two stage desalting is employed for salt removal from the raw crude. Sour water, collected from both the