

ENVIRONMENTAL IMPACT ASSESSMENT GUIDELINES  
FOR NEW SOURCE PETROLEUM REFINERIES

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ENVIRONMENTAL IMPACT ASSESSMENT GUIDELINES  
FOR NEW SOURCE PETROLEUM REFINERIES

DRAFT REPORT  
FOR  
REVIEW

U.S. Environmental Protection Agency  
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## INTRODUCTION

The Clean Water Act requires that EPA establish standards of performance for categories of new source industrial wastewater dischargers. Before the discharge of any pollutant to the navigable waters of the United States from a new source in an industrial category for which performance standards have been proposed, a new source National Pollutant Discharge Elimination System (NPDES) permit must be obtained from either EPA or the State (whichever is the administering authority for the State in which the discharge is proposed). The Clean Water Act also requires that the issuance of a permit by EPA for a new source discharge be subject to the National Environmental Policy Act (NEPA), which may require preparation of an Environmental Impact Statement (EIS) on the new source. The procedure established by EPA regulations (40 CFR 6 Subpart I) for applying NEPA to the issuance of new source NPDES permits may require preparation of an Environmental Impact Assessment (EIA) by the permit applicant. Each EIA is submitted to EPA and reviewed to determine if there are potentially significant effects on the quality of the human environment resulting from construction and operation of the new source. If there are, EPA publishes an EIS on the action of issuing the permit.

The purpose of these guidelines is to provide industry-specific guidance to EPA personnel responsible for determining the scope and content of EIA's and for reviewing them after submission to EPA. It is to serve as supplementary information to EPA's previously published document, Environmental Impact Assessment Guidelines for Selected New Source Industries, which includes the general format for an EIA and those impact assessment considerations common to all or most industries. Both that document and these guidelines should be used for development of an EIA for a new source petroleum refinery.

These guidelines provide the reader with an indication of the nature of the potential impacts on the environmental and the surrounding region from construction and operation of petroleum refineries. In this capacity, the volume is intended to assist EPA personnel in the identification of these impact areas that should be addressed in an EIA. In addition, the guidelines present (in Chapter I) a description of the industry, its principal processes, environmental problems, and recent trends in location, raw materials, processes, pollution control and the demand for industry output. This "Overview of the Industry" is included to familiarize EPA staff with existing conditions in the industry.

Although this document may be transmitted to an applicant for informational purposes, it should not be construed as representing the procedural requirements for obtaining an NPDES permit or as representing the applicant's total responsibilities relating to the new source EIS program. In addition, the content of an EIA for a specific new source applicant is determined by EPA in accordance with Section 6.908(b) of the Code of Federal Regulations and this document does not supersede any directive received by the applicant from EPA's official responsible for implementing that regulation.

The appendix is divided into six sections. Section I is the "Overview of the Industry," described above. Section II, "Impact Identification," discussed process-related wastes and the impacts that may occur during construction and operation of the facility. Section III, "Pollution Control," describes the technology for controlling environmental impacts. Section IV discusses other impacts that can be mitigated through design considerations and proper site and facility planning. Section V, "Evaluation of Alternatives," discusses the consideration and impact assessment of possible alternatives to the proposed action. Section VI, describes regulations other than pollution control that apply to the industry.

## I. OVERVIEW OF THE PETROLEUM REFINING INDUSTRY

Standard Industrial Classification (SIC) Code 2911 defines a petroleum refinery as a complex combination of interdependent operations engaged in the separation of crude oil by molecular cracking, molecular rebuilding, and solvent finishing to produce a varied list of intermediate and finished products including gasoline, jet fuel, fuel oil, lube oil, grease, asphalt, coke, wax, and others. About 120 companies are engaged in petroleum refining in the United States. As of January 1977 a total of 213 operating refineries existed with a daily production capacity of approximately 15.9 million barrels per calendar day (B/CD). Refineries vary in size according to production capacity and may range from 150 barrels to 445,000 B/CD. About one-third of U.S. refineries have a capacity of less than 10,000 barrels per day but these refineries represent in aggregate only 2.5% of the total capacity of the industry. Refineries with a rated daily capacity greater than 150,000 barrels, which represent about 9% of the total number of U.S. refineries, account for about 43% of the total industry capacity. Total annual employment for the industry numbers approximately 140,000 and total industry-wide sales for domestically consumed petroleum products were estimated to be \$30 billion in 1974. The State of Texas has the highest concentration of refineries, with a total of 40 facilities representing 16.2% of the national total. California has 34 refineries and Louisiana, Illinois, Kansas, Oklahoma, Pennsylvania, and Wyoming each have 10 or more. Refining capacity of individual states roughly parallels the number of facilities. About 58% of all U.S. refineries or a total of 158 refineries were constructed between the years 1944 and 1970.

### I.A. SUBCATEGORIZATION

The subcategorization of the petroleum refining industry for purposes of

establishing effluent limitations and new source performance standards is process oriented. Because all refinery wastes are almost equally amenable to treatment, separate subcategories were established on the basis of raw waste load characteristics as a function of process complexity. A description of the subcategorization scheme and a numerical distribution of petroleum refineries by subcategory (1976 data) are presented in Tables 1 and 2, respectively.

## I.B. PROCESSES

As an aid to developing a better understanding of the complexities of oil industry operations, this section describes the key components of various refinery processes and their capabilities. Simple process flow diagrams also are provided, particularly for use by those unfamiliar with the different levels of sophistication in refinery processes.

Although petroleum refineries are individually unique, they share a series of processes which generally perform three basic procedures:

- Separation of various components by boiling point  
(distillation, fractionation)
- Conversion of large molecules into smaller ones  
(cracking)
- Reconstruction of molecules (hydrogenation, alkylation).

Crude oil refining separates crude oil into gases, gasoline, kerosene, middle distillates (diesel fuel), fuel oil, and heavy bottoms. During separation, initial fractions seldom conform to product demand or qualitative requirements. Less desirable fractions are converted to saleable products by molecular splitting, uniting, or rearranging. Products then are treated to remove or

Table 1. Subcategorization of the petroleum refining industry.

<u>Subcategory</u>	<u>Basic Refinery Operations Included</u>
Topping	Topping and catalytic reforming whether or not the facility includes any other process in addition to topping and catalytic reforming. This subcategory is not applicable to facilities which include thermal processes (coking, vis-breaking, etc.) or catalytic cracking.
Cracking	Topping and cracking whether or not the facility includes any processes in addition to topping and cracking, unless specified in one of the subcategories listed below.
Petrochemical	Topping, cracking, and petrochemical operations <sup>1</sup> whether or not the facility includes any process in addition to topping, cracking, and petrochemical operations except lube oil manufacturing operations.
Lube	Topping, cracking, and lube oil manufacturing processes whether or not the facility includes any process in addition to topping, cracking, and lube oil manufacturing processes except petrochemical and integrated operations.
Integrated	Topping, cracking, lube oil manufacturing, and petrochemical operations whether or not the facility includes any processes in addition to topping, cracking, lube oil manufacturing, and petrochemical operations.

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1

The term "petrochemical operations" means the production of second generation petrochemicals, i.e., alcohols, ketones, cumene, styrene, etc., or first generation petrochemicals and isomerization products, i.e., BTX, olefins, cyclohexane, etc., when 15% or more of refinery production is as first generation petrochemicals and isomerization products. Owing to the diversity and complexity of the petrochemical processes and associated impacts, this subcategory will be the subject of a separate appendix. It is included here because it is an official subcategory of the petroleum refining industry.

Source: U.S. EPA. 1977. Interim final supplement for pretreatment to the development document for the petroleum refining industry. Existing point source category EPA 440/1-76/083A.

Table 2. Numerical distribution of petroleum refineries by subcategory  
(data from 1976).

<u>Subcategory</u>	<u>Indirect Dischargers</u>		<u>Total Industry</u>	
	<u>#</u>	<u>% of total</u>	<u>#</u>	<u>% of total</u>
A - Topping	10	38	96	38
B - Cracking	13	50	111	43
C - Petrochemical	2	8	19	7
D - Lube	0	0	22	9
E - Integrated	1	4	8	3

Sources: Contrell, Aileen. 1976. Annual refining survey. The Oil and Gas Journal, 29 March, pp. 125-152.

National Commission on Water Quality. 1975. Petroleum refining industry, technology and costs of wastewater control. Prepared by Engineering Science, Inc.

inhibit undesirable components. Lastly, refined base stocks, blended with each other and with various additives, are developed into useful products.

Crude oil capacity and process sophistication differ widely. Simple refineries perform crude separation and limited treating (Figure 1). Intermediate refineries use catalytic or thermal cracking, catalytic reforming, additional treating, and also manufacture heavy products, such as lube oils and asphalt (Figure 2). Complete large refineries include crude distillation, cracking, treating, gas processing, and manufacture of lube oils, asphalts, and waxes. Also included are catalytic reforming, alkylation, and isomerization, which are gasoline upgrading processes (Figure 3).

To make refinery operations easily comprehensible, the following process descriptions focus only on the production of fuels. Operations for the manufacture of lubricating oils, waxes, solvents, road oils, asphalt, petrochemicals, and other nonfuel products are omitted.

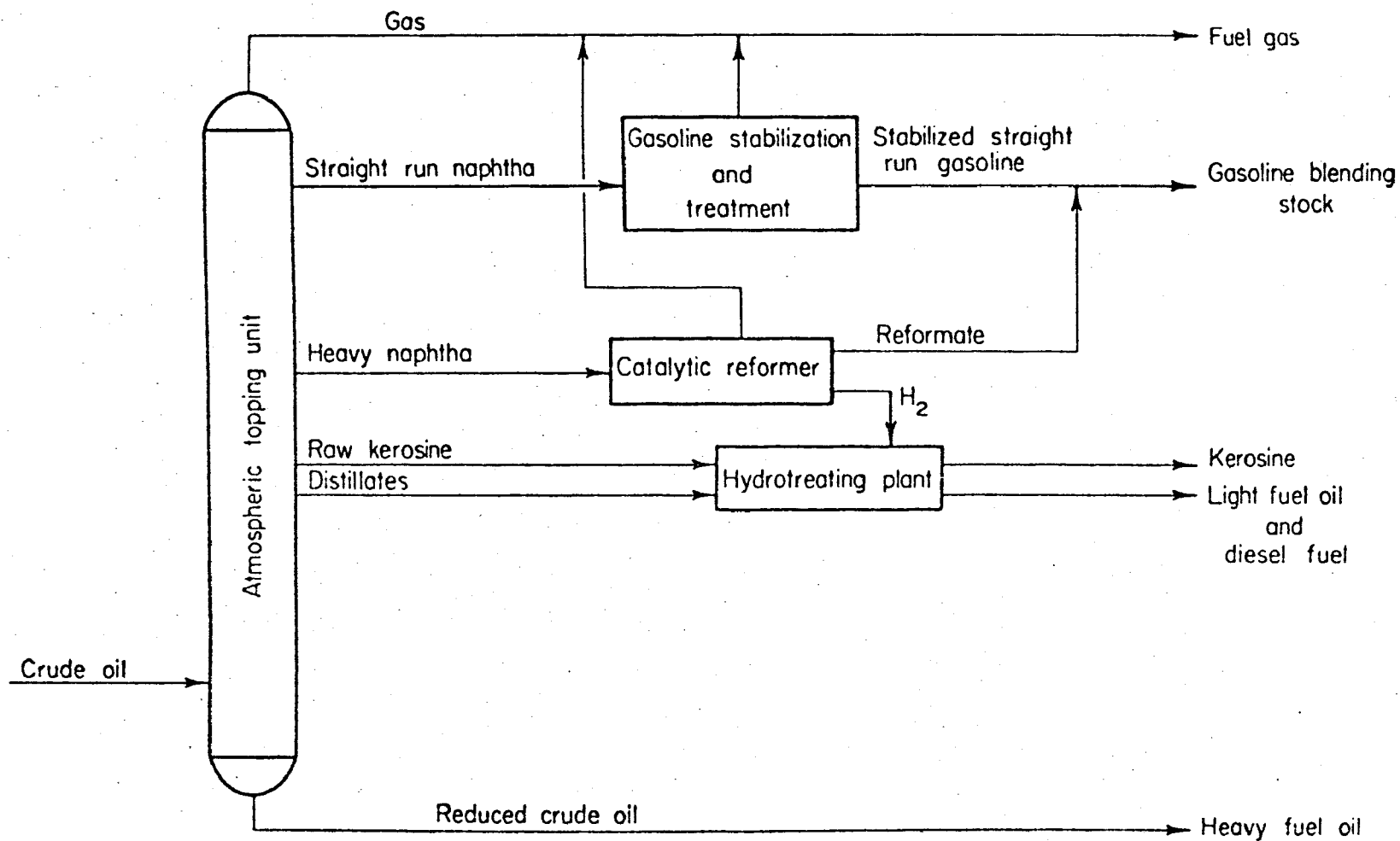
The basic unit processes for the manufacture of fuel products in the refinery industry usually include:<sup>1</sup>

- Crude distillation
- Catalytic reforming
- Catalytic cracking
- Catalytic hydrocracking
- Thermal cracking
- Hydrotreating

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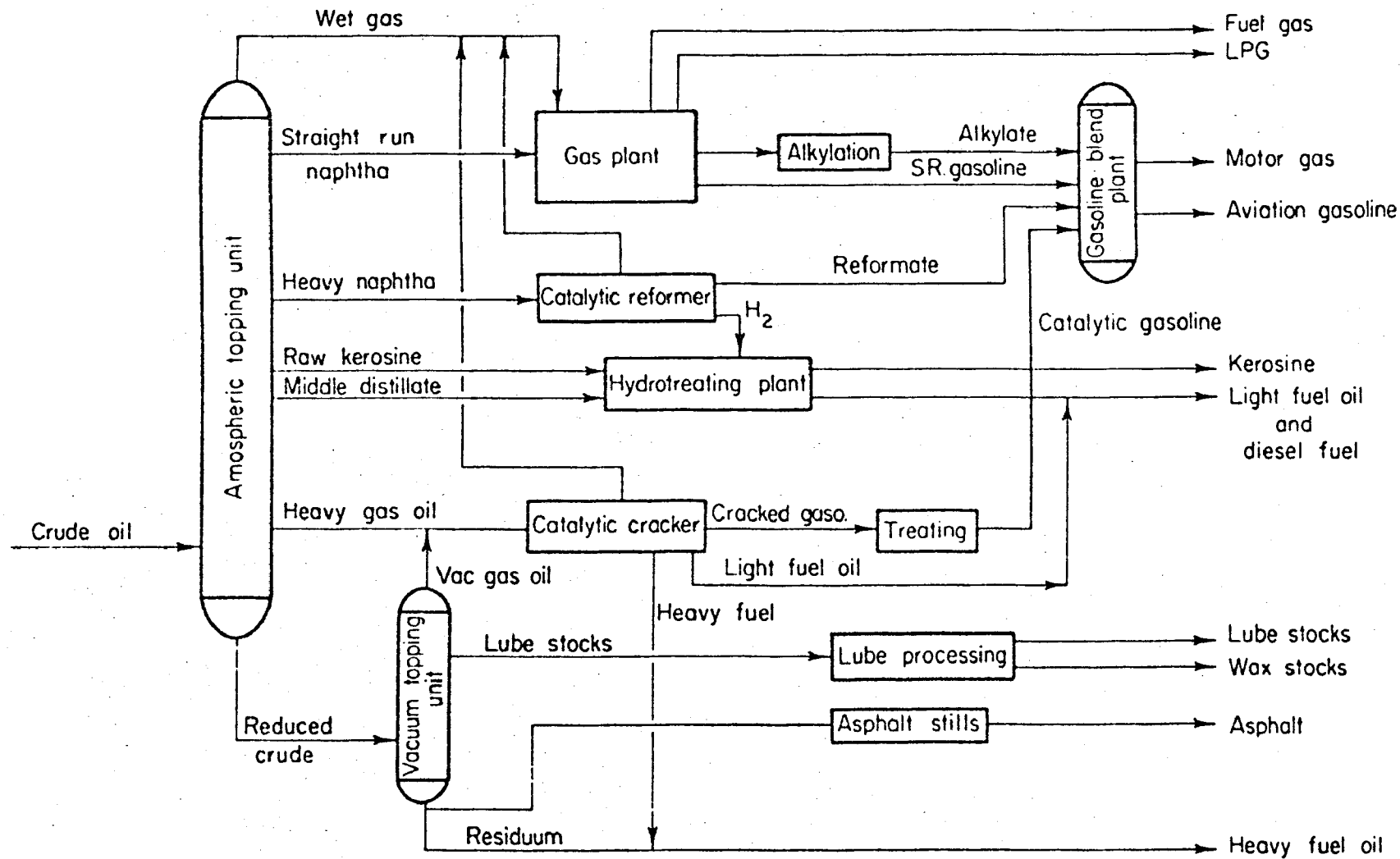
<sup>1</sup>Based on U.S. refinery practice; outside the U.S., the use of gasoline-creating processes, e.g., catalytic cracking, alkylation, and catalytic hydrocracking in refineries, is less common.





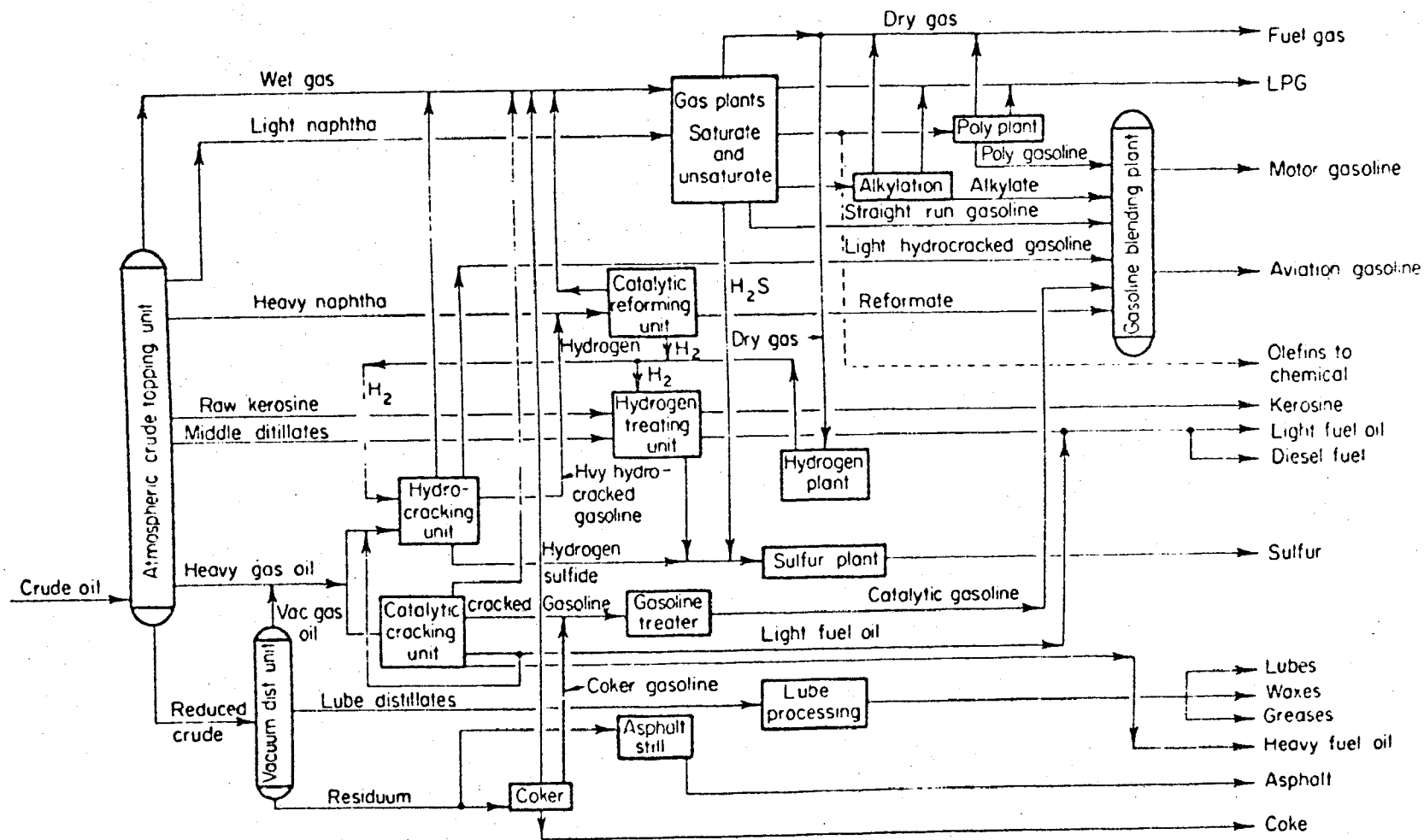
Source: U.S. EPA. 1972. Evaluation of waste waters from petroleum and coal processing. Office of Research and Monitoring. R2-72-001. Washington DC.

Figure 1. Processing plan for typical minimal refinery.



Source: U.S. EPA. 1972. Evaluation of waste waters from petroleum and coal processing. Office of Research and Monitoring. R2-72-001. Washington DC.

Figure 2. Processing plan for typical intermediate refinery.



Source: U.S. EPA. 1972. Evaluation of waste waters from petroleum and coal processing. Office of Research and Monitoring. R2-72-001. Washington DC.

Figure 3. Processing plan for typical complete refinery.

- Gas concentration
- Alkylation.

Petroleum refineries also use many auxiliary systems, e.g., treating units to purify both liquid and gas streams, waste management and pollution control systems, cooling water systems, units to recover hydrogen sulfide ( $H_2S$ ) from gas streams and to convert it into elemental sulfur or sulfuric acid, electric power support stations, steam-producing facilities, and provisions for storage and handling of crude oil and byproducts.

The descriptions of the major processes that follow focus on the relationships between and basic functions of the aforementioned process units.

#### I.B.1. Crude Oil Distillation

To minimize corrosion of refining equipment, a crude oil distillation unit generally is preceded by a desalter, which reduces the inorganic salt content of raw crudes. Salt concentrations vary widely (from nearly zero to several hundred pounds, expressed as  $NaCl/1,000$  bbl). The crude unit functions to separate the crude oil physically, by fractional distillation, into components of such boiling range that they can be processed appropriately in subsequent equipment to make specified products.

Although the boiling ranges of these components (or fractions) vary between refineries, a typical crude unit will resolve the crude into the following fractions:

- By distillation at atmospheric pressure
  - A light straight-run fraction, primarily consisting of  $C_5$  and  $C_6$  hydrocarbons but also containing  $C_4$  and lighter gaseous hydrocarbons dissolved in the crude
  - A naphtha fraction having a nominal boiling range of 93-204 C (200-400 F)
  - A light distillate with boiling range of 204-343 C (400-650 F)
- By vacuum flushing
  - Heavy gas oil having a boiling range of 343-566 C (650-1050 F)
  - A nondistillable residual pitch.

In the atmospheric pressure distillation section of the unit, the crude oil is heated to a temperature at which it is partially vaporized and then introduced near, but at some distance above, the bottom of a distillation column. This cylindrical vessel is equipped with numerous trays through which hydrocarbon vapors can pass in an upward direction. Each tray contains a layer of liquid through which the vapors can bubble and the liquid can flow continuously by gravity in a downward direction from one tray to the next one below. As the vapors pass upward through the succession of trays, they become lighter (lower in molecular weight and more volatile) and the liquid flowing downward becomes progressively heavier (higher in molecular weight and less volatile). The countercurrent action results in fractional distillation or separation of hydrocarbons based on their boiling points. A liquid can be withdrawn from any preselected tray as a net product, the lighter liquids, e.g., naphtha, from trays near the top of the column, and the heavier liquids, e.g., diesel oil, from the trays near the bottom. The boiling range of the net product

liquid depends on the tray from which it is taken. Vapors which contain the  $C_6$  and lighter hydrocarbons are withdrawn from the top of the column as a net product and a liquid stream with a temperature of about 343 C (650 F) is removed from the bottom of the crude distillation column.

This bottom liquid stream, called the atmospheric residue, is heated further and introduced into a vacuum column operated at an absolute pressure close to 50 mm Hg maintained by the use of steam ejectors. In this vacuum column, a flash separation is made to produce the heavy gas oil and the nondistillable pitch products previously described. Although the vacuum column contains certain internal hardware to minimize the entrainment of pitch in the rising vapors and to aid in heat transfer between vapor and liquid, it is more nearly a chamber in which vapor and liquid are separated by a single-stage flash than a fractional-distillation column.

The crude oil and atmospheric residue are brought to their desired temperatures in tubular heaters. Oil is pumped through the inside of the tubes contained in a refractory combustion chamber fired with oil or fuel gas in such manner that heat is transferred through the tube wall in part by convection from hot combustion gases and in part by radiation from the incandescent refractory surfaces.

The light straight-run gasoline fraction generally contains all hydrocarbons lighter than  $C_7$  in the crude and primarily consists of the native  $C_5$  and  $C_6$  families. This light fraction is stabilized to remove the  $C_4$  and lighter hydrocarbons which are routed to a central gas-concentration unit for further resolution. The stabilized  $C_5/C_6$  blend usually contains odorous mercaptans, which normally are treated for odor improvement before delivery to the refinery gasoline pool.

Of the components in modern gasoline pools, the light straight-run fraction has the lowest octane number<sup>2</sup> (antiknock rating). Its unleaded octane number, in a typical case, will be just under 70 and the unleaded octane number for the entire refinery pool (on a U.S. average basis) will be about 89. The light straight-run fraction has a good octane-number response to the additions of lead alkyls. Isomerization also can be used to improve its octane rating.

#### I.B.2. Catalytic Reforming

The chemical composition of the naphtha fraction, and therefore its octane number, varies with the crude source, but normally it will range from 40 to 50 octane. To become a suitable component for blending into finished gasoline pools, its octane number must be raised by changing its chemical composition. Most refineries accomplish this change by catalytic reforming.

Practically all naphtha feedstocks to catalytic reforming units are hydrotreated first to prolong the processing life of the reforming catalyst. An important byproduct of catalytic reforming is hydrogen, which is used in hydrotreating and whatever hydrocracking may be practiced in the refinery. At times, supplementary hydrogen is produced by the steam reforming of natural gas or light naphtha cuts.

#### I.B.3. Catalytic Cracking

The primary function of catalytic cracking is to convert into gasoline those fractions having boiling ranges higher than that of gasoline. An important secondary function is to create light olefins, such as propylene and butylenes, to be used as feedstocks for motor-fuel alkylation and petrochemical production.

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<sup>2</sup>In this description, Research Method octane numbers are used.

Isobutane, a necessary reactant for the alkylation process, also is an important product of catalytic cracking.

Although the principal feedstock is the gas oil separated from the crude by distillation, this feed often is supplemented with light distillates and with distillate fractions which result from thermal coking operations.

For practical reasons, the conversion of distillate feedstocks to lighter materials is not carried to completion. The remaining, uncracked distillates (cycle oils) are used as components for domestic heating fuels (generally after hydrotreating) and to blend with residual fractions to reduce their viscosity to make acceptable heavy fuel oil. In some refineries, cycle oils are hydrocracked to complete their conversion to gasoline.

Unleaded octane numbers are catalytically cracked gasolines which range in octane number from 89 to 93. After treatment for odor control, they are blended directly into the refinery gasoline pool.

#### I.B.4. Hydrocracking

In a sense, hydrocracking is complementary and supplementary to catalytic cracking because hydrocracking occurs over a catalyst in a hydrogen environment with heavy distillates and, in some cases, cycle oils which are impractical to convert completely in catalytic cracking units. The process also takes place at lower temperatures and higher pressures than fluid catalytic cracking. The primary product is gasoline or jet fuels and other light distillates. An important secondary product is isobutane.

Generally, the  $C_5/C_6$  fraction is blended into the gasoline pool and occasionally the heavier portion of the gasoline also is blended into the gasoline pool;



otherwise this portion may be reformed first, to improve its octane number. Figure 3 shows only heavy gas oil as a feedstock and the entire liquid product as gasoline is routed directly to the refinery gasoline pool even though the aforementioned options are performed widely in various combinations.

#### I.B.5. Thermal Cracking

The pitch, as produced by most vacuum-flashing units, is too viscous to be marketed as a heavy fuel oil without further treatment. In some refineries the pitch is processed further in a thermal cracking unit (visbreaking) under relatively mild conditions to reduce its viscosity sufficiently and additional viscosity reduction is obtained by blending in a required amount of catalytic cycle oil to produce marketable residual fuel oil.

In certain situations it is more economical to process the pitch in a thermal coking unit from which the main products are gasoline, distillates, and coke. The gasoline from a coking unit is handled as previously described. The coke can be used, after calcination, for electrode manufacture where it meets certain purity specifications but the coke is used principally as a metallurgical coke or as fuel. Distillates from thermal coking operations may be used as feedstock for catalytic cracking or the lighter distillates may be routed to the refinery distillate product pool after hydrotreatment.

A few refiners obtain additional feedstock for catalytic cracking or hydrocracking operations by solvent extraction of the vacuum pitch, usually with propane as the solvent. The extract is relatively free of organometallic compounds and highly condensed aromatic structured hydrocarbons. Thus, the extract is suitable for handling by catalytic units. Extracted pitch is processed subsequently in thermal units or converted to asphalts.

The small amount of thermal gasoline which is made as a byproduct is routed after treatment to the gasoline pool or to catalytic reforming through a hydrotreating unit because its octane number is relatively low.

#### I.B.6. Hydrotreating

As a processing tool, hydrotreating has numerous applications in a refinery, where its principal function is to purify and improve the quality of the feedstock. The process employs hydrogen and a catalyst. The use of hydrotreating for pretreating naphthas prior to catalytic reforming has been already mentioned.

Figure 3 shows hydrotreatment of the crude light distillate and the net catalytic cycle oil in a single block before being routed to the refinery light distillate pool. Occasionally the light distillate in the crude may be sufficiently low in sulfur content to bypass hydrotreating; however, usually part of the stream is hydrotreated to remove native sulfur compounds. Some refineries hydrotreat parts of their catalytic cracking feeds, particularly if they originate from thermal operations or if they are inordinately high in sulfur content.

Desulfurization also is an objective in the production of low sulfur residual fuel oils. Sulfur content of reduced crudes (>4%) can be reduced to about 1% by vacuum flashing, hydrodesulfurizing the overhead vacuum-distilled gas oil, and blending the gas oil of low sulfur content with the untreated pitch to obtain a reconstituted low sulfur fuel oil.

#### I.B.7. Gas Concentration

The gas concentration system (Figure 3) collects gaseous product streams from various processing units and physically separates the components to provide, usually, a  $C_3/C_4$  stream as a feedstock for alkylation and a  $C_2$  and lighter

stream that largely is used to supply process heat requirements for the refinery.

Hydrogen sulfide is removed from gas streams in which it occurs by selective absorption in liquid solutions (usually organic amines). The  $H_2S$  released from the rich solution is converted by further processing into elemental sulfur or  $H_2SO_4$ .

#### I.B.8. Alkylation

In motor fuel refineries the alkylation units produce a high quality paraffinic gasoline by the chemical combination of isobutane with propylene and/or butylenes. A small amount of pentenes also is alkylated. The alkylation is accomplished with the catalytic aid of hydrofluoric (HF) or sulfur acid ( $H_2SO_4$ ) to produce a gasoline with octane numbers that range from 93 to 95.

Propane and n-butane associated with the olefins in the feedstocks are withdrawn from alkylation units as byproducts. Part of the n-butane is routed to the gasoline pool to adjust the vapor pressure of the gasoline to a level which permits prompt and easy starting of engines. The remainder of the n-butane and the propane is available for liquified petroleum gas (LPG), a clean fuel that easily is distributed as bottled gas for heating purposes.

#### I.C. TRENDS

##### I.C.1. Locational Changes

U.S. refineries are concentrated largely in areas of major crude production (California, Texas, Louisiana, Oklahoma, and Kansas) and in major population areas (Illinois, Indiana, Ohio, Pennsylvania, Texas, and California) (US-EPA 1973). Projected geographic growth patterns of new refineries by Petroleum

Administration for Defense (PAD) Districts through 1981, shown in Table , indicate little change in this locational pattern.

The majority of 1977 growth was in PAD District III. Most of this growth occurred in Texas and Louisiana. The next largest growth was in PAD District V where California accounted for the largest increase in new and expanded capacity. Alaska, however, had one new and one expanded refinery. Texas and Louisiana continue to lead the growth trends through 1981. Outside those states a new 175,000 bbl/day facility in Portsmouth, Virginia, in 1980 and a 250,000 bbl/day refinery in Eastport, Maine, in 1981 are the largest planned capacity additions. Large new projects not reflected in Table 3 which are in early or uncertain stages of planning include (FEA 1977):

- 200,000 bbl/day at Baltimore, Maryland
- 250,000 bbl/day at Sanford, Maine
- 200,000 bbl/day at Oswego, New York
- 400,000 bbl/day at Sagbrook, Connecticut

PAD Districts are anachronisms relating to the old Petroleum Administration for Defense which ceased to exist many years ago. The districts are shown geographically in Figure 4. Figure 5 presents the concentrations of petroleum refinery operations by EPA regional office jurisdictions.

In short, the consensus among industry representatives is that little or no significant change is expected to occur in locational patterns unless substantial quantities of oil are discovered and produced offshore on the East Coast (Interview, Mr. Eugene Peer, Office of Oil and Gas, DOE, 18 April 1978).

#### I.C.2. Raw Materials

Crude oil is by far the most important raw material used by the refining industry.

Table 3. Projected geographical distribution  
of new, expanded, or reactivated U.S. refining capacity  
by PAD District (thousands of bbl/day, crude distillation).

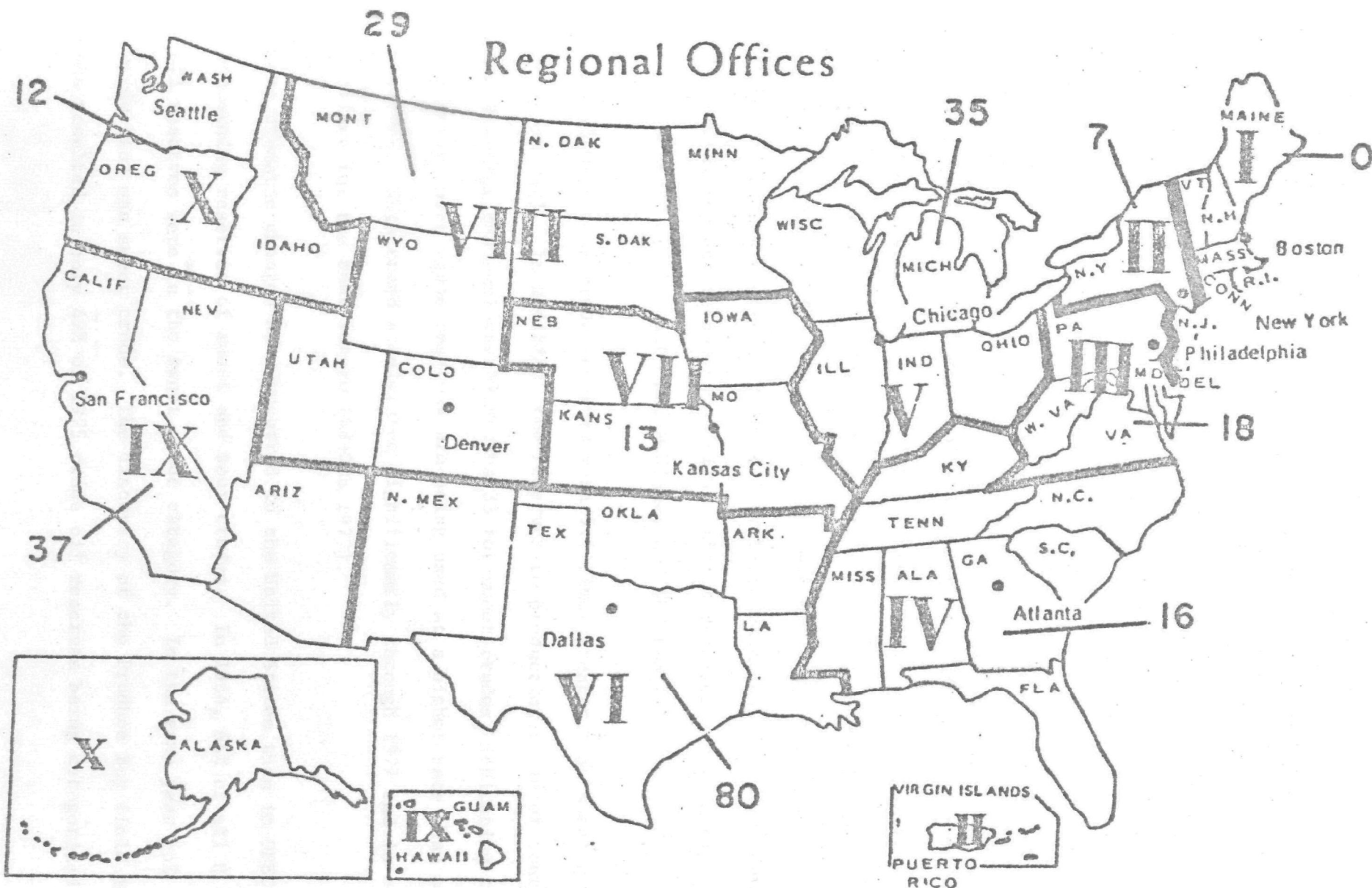
<u>Total New, Expanded, or Reactivated Capacity</u>	<u>1977</u>	<u>1978</u>	<u>1979</u>	<u>1980</u>	<u>1981</u>
PAD Region I	-	12.0	24.0	199.0	274.0
PAD Region II	2.5	36.0	101.0	61.0	52.0
PAD Region III	478.2	117.0	181.0	284.0	84.0
PAD Region IV	24.5	9.4	8.0	8.0	8.0
PAD Region V	84.1	41.0	32.0	32.0	32.0

Source: Peer, E. L., et al. 1977. Trends in refinery capacity and utilization.  
Federal Energy Administration, FEA/G-77/281. June.

Figure 4. Geographical locations  
of Petroleum Administration for Defense (PAD) Districts.



Source: Peer, E. L., et al. 1977. Trends in refinery capacity and utilization. Federal Energy Administration, FEA/G-77/281. June.



Source: U.S. EPA. 1976. Assessment of hazardous waste practices in the petroleum refining industry. Prepared by Jacobs Engineering Company. NTIS PB-259-097. Springfield VA.

Figure 5. Numbers of petroleum refineries within EPA regional jurisdictions (Arabic numbers indicate number of refineries in each region).

Natural gasoline, a liquid product of the natural gas industry, furnishes about 5% of refinery intakes. Butanes contribute about 1.5% of refinery intake. No other significant raw materials exist. As of 1976, about 73% of the industry's raw material was of domestic origin; 27% was imported. Recent statistics indicate that 1978 will mark the first time since 1970 that crude oil imports have dropped, permitting a temporary decrease in U.S. dependence on foreign sources. The volume of crude imports anticipated in 1978 is the combined result of slower growth in oil demand and increased domestic crude production (Oil and Gas Journal 1978). The composition of crude oil is becoming increasingly important because of its effects on air quality and industry economics. However, changes in the composition of crude oil supplies have shown a trend toward higher sulfur crudes. Table 4 presents examples of typical compositions of several representative crude oils. (For a detailed analysis of crude oils see McKinney, et al. 1966 and McKinney and Shelton 1967.)

In 1975 OPEC sour crude reserves were 5.5 times greater than sweet crudes (<.5% sulfur). In addition, the reserves to production ratio of sour crudes (>.5% sulfur content) was 49 versus 33 for sweet crudes, indicating that currently sweet crude reserves are being used at a higher rate than sour crude reserves. This trend accelerated significantly through 1977 and is expected to continue for the near future (US-DOE 1977).

More dramatic changes have occurred in the United States than in OPEC countries concerning reserves of sweet and sour crudes. In 1964, 64% of all U.S. crude oil reserves were in the sweet crude category. In the same year 66% of the production was sweet crude. The discovery of the Prudhoe Bay field in Alaska has resulted in only 42% of 1975 crude oil reserves being categorized as sweet.



Table 4. Examples of typical compositions of representative crude oils.

	Gravity °API	Sulfur Wt.%	Viscosity Saybolt, at 100°F, seconds	Carbon residuum Wt.%	Vol. %	Gasoline Anonaphtha Gravity °API	Vol. %	Kerosine Distillation Gravity °API
<u>California</u>								
Brea Olinoa	24.0	0.75	135	14.2	17.4	51.3	-	-
Elk Hills	22.8	0.68	135	4.6	11.1	49.9	-	-
Torrance	23.8	1.84	160	13.2	17.9	52.5	-	-
<u>Louisiana</u>								
Black Bay	30.0	0.27	57	6.3	15.2	54.2	5.5	42.1
Grand Isle	36.4	0.18	40	3.7	25.8	54.7	15.0	11.7
West Delta	27.0	0.33	92	5.7	9.5	50.9	4.7	40.0
<u>Oklahoma</u>								
Bradley	35.0	0.22	56	6.7	24.3	57.4	15.6	43.0
Golden Trend	42.1	0.11	39	2.7	34.6	62.9	17.1	42.8
Sho-Ven-Tu	29.1	1.36	87	10.1	21.2	59.5	4.3	42.8
<u>Texas</u>								
Conroe	37.0	0.10	36	4.9	32.8	48.8	-	-
East Texas	37.4	0.25	42	6.1	33.9	58.2	5.0	42.8
Walnut Bend	46.0	0.23	38	3.3	38.3	64.5	16.5	43.4
<u>Libya</u>	39.2	0.33	40	7.6	36.6	59.9	12.2	43.4
<u>Indonesia</u>	36.8	0.10	35	3.8	37.1	52.5	-	-
<u>Iran</u>	34.6	1.43	46	9.1	28.8	60.8	10.2	43.2
<u>Iraq</u>	36.6	1.93	42	14.6	35.5	63.7	9.8	44.5
<u>Saudi Arabia</u>	33.6	1.66	49	11.3	27.8	62.3	9.9	44.7
<u>Venezuela</u>	14.7	2.62	3,310	9.6	5.7	45.6	-	-

Source: McKinney, et al. 1966. Analyses of crude oils from 546 important oil fields in the United States. Prepared for US-DOI. Bureau of Mines Report of Investigations 6819. Available US-GPO, Washington, D.C.

In 1978, production in the U.S. is showing a significant increased percentage of sour crude. Another factor giving impetus to this shift will be improved sulfur recovery processes. In California this is reflected in more production of heavy, high sulfur crude oils.

Short of any unforeseen large discoveries, it is expected that the world's refineries will rely increasingly on sour crude supplies.

Despite the proportionately greater reserves and the production of sour crudes, the U.S. continues to rely heavily on sweet crude imports. During the period from 1969 through 1977, the percentage of crude oil imports that is sweet has ranged from a high of 66.95% (1972) to a low of 54.7% (1977). During the same period crude oil imports increased from 2.2 million barrels per day to 6.6 million barrels per day. Although the percentage of sweet crude has dropped, the actual volume of sweet crude imports is increasing each year (US-DOE 1977).

Recently the increased sweet crude imports have originated primarily in OPEC sources. During 1969, the U.S. imported only 5% of OPEC's sweet crude production; however, in 1976 the percentage increased to 37.5 and during the first quarter of 1977 it increased to 42%. By contrast, during the same 4-month period in 1977, the U.S. imported only 12.4% of OPEC's sour crude production (US-DOE 1977).

### I.C.3      Processes

As in most industries, trends in process change are likely to be closely tied to or motivated by pollution control requirements. This is true because few industrial processes can be altered significantly without introducing some

effect on waste generation. If a process change improves efficiency, cost-effectiveness, and does not adversely effect waste generation, it normally has high use potential. In contrast there must be significant tradeoffs in process change efficiency and economy to tolerate generation of additional or more complex wastes, since the treatment or control of these wastes would tend to offset other factors. Commonly, process change is effected because its improved efficiency and economy lie not in its own performance per se, but in reduced waste generation. Therefore trends in internal pollution control are addressed concomitantly with trends in process change. Trends in external pollution treatment, control, and disposal methods are discussed in Section I.C.4.

To assist in the projection of process trends a historical perspective of degrees of application or use of the various processes and subprocesses is meaningful. A comprehensive survey of every process in every refinery would be beyond the scope of this study; therefore, based on a review of the literature this analysis was done only for the major processes and subprocess alternatives. The percent use of these basic processes and major subprocesses by U.S. refineries is presented in Table 5.

The discussions of current and future process trends which follow are largely based on recent literature (U.S. EPA 1973; U.S. EPA 1976; FEA 1977; DOE 1977) and on conversations with key individuals knowledgeable of changes in the petroleum refining industry.

#### I.C.3.a. Storage and Transportation

- Crude oil and product storage

Many refineries already had installed equipment to minimize the release of hydrocarbons from crude and product storage areas to the atmosphere before

Table 5. Estimate percentage of petroleum refineries using various manufacturing processes.

Process	Percentage Use by Year					Technological Status <sup>1</sup>
	1950	1963	1967	1972	1977	
Crude oil desalting		100%	100%	100%	100%	
-Chemical desalting		5	2	0	0	O
-electrostatic desalting		95	97	100	100	T,N
Crude distillation	100%	100	100	100	100	
-Atmospheric fractionator	100	100	100	100	100	O,T,N
-Vacuum fractionator		60	64	70	75	O,T,N
-Vacuum flasher						
Thermal cracking	59	48	45	40	35	
-Thermal cracking		28	18	8	2	O
-Delayed coking		12	14	16	19	T,N
-Visbreaking		13	16	18	22	T,N
-Fluid coking		2	2	4	6	T,N
Catalytic cracking	25	51	56	60	65	
-Fluid catalytic cracking		39	45	50	60	T,N
-Thermoform catalytic cracking		13	12	10	6	O
-Houdrifiow		3	3	2	0	O
Hydrocracking	0	2	8	25	34	
-Isomax			4	11	15	N
-Unicracking			2	8	12	N
-H-G hydrocracking		0.3	0.8	3	3	N
-H-oil			0.4	1	1	N
Reforming		62	67	74	79	
-Platforming		37	40	44	47	O,T,N
-Catalytic reforming-Englehard		5	9	11	12	O,T
-Powerforming		1	2	3	3	T,N
-Ultraforming		6	6	7	8	T,N
Polymerization	25	42	33	26	7	
-Bulk acid polymerization						T,N
-Solid phosphoric acid condensation						T
						O
-Sulfuric acid polymerization						
-Thermal polymerization		1	0.4			O
Alkylation	10	38	47	54	62	
-Sulfuric acid alkylation		22	26	32	38	T,N
-HF alkylation		16	21	22	25	O,T,N
-DIP alkylation						N
-Thermal alkylation						O

Table 5. Estimate percentage of petroleum refineries  
using various manufacturing processes (continued).

	Percentage Use by Year					Technological Status <sup>1</sup>
	1950	1963	1967	1972	1977	
Isomerization		5%	7%	10%	15%	
-Isomerase		1	1.5	3	6	N
-Liquid-Phase Isomerization		2	3	4	5	N
-Butamer		1	1	2	2	N
-Penex		0.7	1	1	2	N
Solvent Refining		25	29	30	32	
-Furfural Refining		14	15	16	16	O,T,N
-Duo-Sol		2	3	3	3	T,N
-Phenol Extraction		10	10	11	11	O,T,N
-Udex		3	5	8	8	T,N
Dewaxing		11	11	11	11	
-Solvent Dewaxing (MEK)		8	8	9	9	O,T,N
-Propane Dewaxing		2	2	2	2	O,T
-Pressing and Sweating		1	1	0	0	O
Hydrotreating		47	56	70	80	
-Unifining		22	23	30	35	T,N
-Hydrofining		3	3	5	8	T,N
-Trickle Hydrodesulfurization		0.3	2	4	5	T,N
-Ultrafining		3	5	8	10	T,N
Deasphalting		20	23	25	27	
-Propane Deasphalting and Fractionation		15	18	20	21	O,T,N
-Solvent Decarbonizing		4	5	5	6	T,N
Drying and Sweetening		80	80	80	80	
-Copper Sweetening						O,T
-Doctor Sweetening						O
-Merox						N
-Girbotal						O,T,N
Wax Finishing		11	11	11	11	
-Wax Fractionation		10	9	6	5	O,T
-Wax Manufacturing, MIBX		1	1	1	1	O,T,
-Hydrotreating			1	4	5	N
Grease Manufacture		12	12	10	10	O,T,N
Lube Oil Finishing		19	19	20	20	
-Percolation Filtration		11	7	5	2	O,T
-Continuous Contract Filtration		6	7	7	7	O,T
-Hydrotreating		2	5	8	11	N

Table 5. Estimate percentage of petroleum refineries using various manufacturing processes (concluded).

	1950	Percentage Use by Year					Technological Status <sup>1</sup>
		1950	1963	1967	1972	1977	
Hydrogen Manufacture			2	8	25	34	
-Hydrogen Partial Oxidation			1	3	10	12	N
-Hydrogen, Steam Reforming			1	5	15	22	
Total No. of Refineries		346	293	261	236	211	

<sup>1</sup> O = Older - Refineries which use relatively inefficient and/or obsolescent processes and subprocesses

T = Typical - Refineries which use those processes and subprocesses that are most common today

N = Newer - Refineries which use all or most of the advanced processes and subprocesses available

Source: US-DOJ. 1967. The cost of clean water. Volume III Industrial Waste Profile No. 5: Petroleum Refining. Prepared for FWPCA. Available from US-GPO, Washington, DC.

the storage regulations discussed in Section I.D.2 were promulgated. Doubtless some motivation was provided by Rule 66 of the Los Angeles Air Pollution Control District, which regulates photochemical oxidants and other state and local regulations patterned after Rule 66. Refineries also were motivated by the economics of product loss versus vapor recovery.

Storage regulations now require the use of alternative technologies--floating-roof covers, pressurized tanks, and/or connections to vapor recovery systems--so the trend in this direction should accelerate. Although floating-roof covers can add to the wastewater flow from storage tanks, strict refinery specifications on the characteristics of crude oil supplies will minimize wastewater from modern crude storage facilities. A factor which will tend to reduce quantities of wastewater from finished product storage is the trend toward increased use of dehydration or drying processes ahead of produce finishing (US-EPA 1973).

- Crude oil and product transportation

The trend in tanker use for shipping intermediate and final products is to larger and larger vessels which arrive at the refinery in ballast and must discharge wastewaters from up to 30% of their capacity. If the discharge is sent directly to the wastewater treatment system, a shock load could result. Thus, the use of larger ballast water storage tanks or holding ponds will be necessary to control the flow into the treatment system. The discharge of ballast wastewater directly into ocean or estuarine areas without treatment is expected to be eliminated completely (US-EPA 1973).

#### I.C.3.b. Crude Oil Desalting

The current trend is toward increased use of electrostatic desalting and less use of chemical processes to remove inorganic salts and suspended solids from crude oil prior to fractionation. In the future, chemical methods are expected to be used only as a supplement where the crude has a high salt content. A two-stage electrical desalting process is expected to be used as "dirtier" crude feedstocks are processed. The growth in capacity of desalting units will be proportionate to the growth in crude oil capacity.

#### I.C.3.c Crude Oil Fractionation

The trend is toward large and more complex combinations of atmospheric and vacuum towers with more individual sidestream products. New refineries also can be expected to install surface condensers to significantly reduce wastewater loads from vacuum operations.

#### I.C.3.d. Cracking Operations

- Thermal cracking

Regular thermal cracking, which was an important process before the development of catalytic cracking, is being phased out. Visbreaking and coking units are still installed, but at a slower rate than before, because of product sulfur restrictions. Whereas the current trends are toward dirtier crudes with higher sulfur content, hydrocracking, and propane deasphalting are expected to receive more attention to recover saleable products with low sulfur content from the residuum.

- Catalytic cracking



Recycle rates have been declining since 1968 and the trend is expected to continue because of the development of higher activity catalysts (molecular sieve catalysts, instead of high surface area silica-alumina catalysts). Large fluidized catalytic cracking processes, in which the finely-powered catalyst is handled as a fluid, largely have replaced the fixed-bed and moving-bed processes, that use a beaded or pelleted catalyst.

- Hydrocracking

This process continues to be an efficient, low to moderate temperature, catalytic method for conversion of refractory middle boiling or heavy feed-stock into high-octane gasoline, reformer charger stock, jet fuel and/or high grade fuel oil. Hydrocracking still possesses considerable flexibility (relative to catalytic cracking) in adjusting operations to meet changing product demands. At one time, hydrocracking was a rapidly growing refinery process; however, its growth rate is now stable (about 1.5 percent/year) because of high investment costs and the large quantities of expensive hydrogen that are required for operation. Primary catalysts which currently are used in hydrocracking include tungsten sulfide-silica alumina, and nickel-silica alumina.

#### I.C.3.e. Hydrocarbon Rebuilding

- Polymerization

This process currently is used by only a small number of refineries because the product octane is not sufficiently higher than that of the basic gasoline blending stocks to significantly upgrade the overall motor fuel pool. Also alkylation yields per unit of olefin feed are much better than polymerization yields. Consequently, the current polymerization downtrend is expected to

continue. The primary catalysts used include copper pyrophosphate and phosphoric acid.

- Alkylation

Alkylation is the reaction of an isoparaffin, usually iso-butane and an olefin (propylene, butylene, etc.), in the presence of a catalyst to produce a high octane alkylate, which is one of the most important components of automotive fuels. Sulfuric acid is the most widely used catalyst, although hydrofluoric acid and aluminum chloride also are used. Alkylation process capacity is expected to increase (after a slow decline) in response to the demand for high octane low lead, gasoline.

#### I.C.3.f. Hydrocarbon Rearrangements

- Isomerization

This is a molecular rearrangement process which is similar to reforming. The charge stocks generally are lighter and more specific (normal butane, pentane, and hexane). The catalysts currently used are aluminum chloride, antimony chloride, bauxite, cobalt molybdate, hydrochloric acid, and silica-alumina. The desired products are isobutane for alkylation feed-stocks and high octane isomers for the original feed materials for motor fuel. Reforming capacity in the U.S. currently is expanding at about the same rate as total crude capacity. This growth rate should continue to increase as the demand for motor fuel grows.

- Reforming

This is another process of molecular rearrangement to convert low-octane feedstocks to high octane gasoline blending stock, or to produce aromatics

for petrochemical uses. Multireactor, fixed-bed, catalytic processes have almost completely replaced the older thermal process. There are many variations, but the essential difference is the composition of the catalyst involved. The types of catalyst commonly used in this process are alumina, cobalt molybdate and oxide, molybdenum, platinum, and silica-alumina. No significant changes are expected.

#### I.C.3.g. Solvent Refining

The major contact solvent processes include solvent deasphalting, solvent dewaxing, lube oil solvent refining, aromatic extraction, and butadiene extraction. Generally solvent extraction capacities are expected to increase slowly as quality requirements for all refinery products become more stringent, as the demand for the lube oils grows, and as the petrochemical industry continues to require increased quantities of aromatics.

#### I.C.3.h. Hydrotreating

This process removes sulfur compounds, odor, color, gum-forming materials, and other impurities from a variety of petroleum fractions by catalytic action in the presence of hydrogen. The principal hydrotreating subprocesses now being used include (1) pretreatment of catalytic reformer feedstock, (2) naphtha desulfurization, (3) lube oil polishing, (4) pretreatment of catalytic cracking feedstock, (5) heavy gas-oil and residual desulfurization, and (6) naphtha saturation. In most subprocesses, the feedstock is mixed with hydrogen, heated, and charged to the catalytic reactor. The reactor products are cooled, and the hydrogen, impurities, and high grade product are separated. Hydrotreating was first used primarily on lighter feedstocks, however, with more operating experience and improved catalysts, hydrotreating has been

applied to heavier fractions such as lube oils and waxes. It has been one of the most rapidly growing refinery processes. It should continue to increase at a greater rate than crude capacity because the process can be applied to most sour feedstocks, it is flexible, and it also eliminates contaminants of concern to the refining industry from an operating standpoint and to the general public from an aesthetic standpoint. Among the catalysts most commonly used in hydrotreating are alumina, cobalt molybdate, nickel sulfide platinum, silica alumina, and tungsten nickel sulfide.

#### I.C.3.i. Grease Manufacturing

This process begins with preparation of a soap base from an alkali earth hydroxide and a fatty acid. This solution then is mixed with oil and special additives to form the various lubricating greases. The major equipment at present consists of an oil circulation heater, a high-dispersion contractor, a scraper kettle, and a grease polisher. Because of developments in sealed grease fittings and longer lasting greases, grease production generally is expected to decline.

#### I.C.3.j. Product Finishing

- Drying and sweetening

Drying is a process concerned primarily with removal of sulfur compounds, water, and other impurities from gasoline, kerosene, jet fuels, domestic heating oils, and other middle distillate products. "Sweetening" is the removal from these products of hydrogen sulfide, mercaptans, and elemental sulfur, which impart a foul odor and/or decrease the tetraethyl lead susceptibility of gasoline: the major sweetening operations now in use are oxidation

of hydrogen sulfide to disulfides, removal of mercaptans, and destruction and removal of all sulfur compounds, including elemental sulfur. Drying currently is accomplished by salt filters or adsorptive clay beds. Electric fields are sometimes used to facilitate separation of product from treating solution.

Air quality regulatory agencies are expected to increase their efforts to control emissions of sulfur. Therefore restrictions which govern sulfur contents in fuels are expected to become stricter. This will generate a trend toward replacement of the sweetening processes by hydrotreating (desulfurization), because hydrotreating removes most sulfur compounds and not just hydrogen sulfide, mercaptans, and elemental sulfur. Nevertheless, efficacy and economics will ensure the use of sweetening processes for certain feedstocks, excepting those processes which produce high waste loads.

- Lube oil finishing

This process is used in further refinement of solvent-refined and dewaxed lube oil stocks. Historically it has involved clay or acid treatment to remove color-reforming and other undesirable materials. The two methods most widely used by industry are: (1) continuous contact filtration in which an oil-clay slurry is heated and the oil removed by vacuum filtration; and (2) percolation filtration, in which the oil is filtered through clay beds. Percolation also involves naphtha washing and kiln-burning of spent clay to remove carbon deposits and other impurities. It is expected that acid and clay treatment of lube oils eventually will be replaced by hydrotreating techniques. Acid treatment already has been significantly reduced.

- Blending and packaging

Blending is the final step in the production of finished petroleum products to meet quality specifications and market demands. The largest volume operation is the blending of various gasoline stocks, including alkylates and other high-octane components, with anti-knock such as tetraethyl lead, anti-rust, anti-icing, and other additives. Diesel fuels, lube oils, waxes, and asphalts are other refinery products which normally require blending of various components and/or of additives. Packaging at refineries generally is highly automated and restricted to high volume, consumer-oriented products such as motor oils.

It is expected that there will be increased use of automated proportioning facilities for the blending of products with a trend toward contracting out of packaging of lower-volume products that are less suitable to highly-automated operation.

#### I.C.3.k. Auxiliary Activities

- Hydrogen manufacture

Past and present growth in hydrotreating and hydrocracking processes will result in a continued demand by new refineries for hydrogen, to a level beyond that obtained as a byproduct of reforming and other refinery processes. The demand for hydrogen as a feedstock for the manufacture of ammonia and methanol also is expected to continue. Currently the most widely used subprocess steam reforming, in which desulfurized refinery gases are converted to hydrogen, carbon monoxide, and carbon dioxide in a catalytic reaction; this generally requires the use of an additional shift converter to convert carbon monoxide to carbon dioxide. No significant changes are expected.

#### I.C.4 Pollution Control

Because of crude supply limitations, new refinery capacity will be designed to process higher sulfur crudes which means a corresponding increase in desulfurization capacity. The increased use of sour (higher sulfur) crude feedstock from outside the U.S. will require changes in processing equipment, in-plant wastewater control, and treatment operations. There are refineries that consume sweet crude stock, but do not employ strippers to remove minimal amounts of ammonia and hydrogen sulfide from their wastewaters. Increases in sour crude processing within these refineries, will require sour water strippers to be used prior to discharge of the wastewaters to biological wastewater treatment facilities. Generally, more highly sophisticated pollution control techniques will continue to replace older techniques. These techniques include use of incinerators to destroy trace organic discharges, use of reactor exhausts as furnace air to reduce gaseous organic discharges, improved treatment of sour heavy bottoms, more effective control of emissions of sour gases, and increased emphasis on wastewater reuse/recirculation techniques such as:

- The use of catalytic cracker accumulator wastewaters rich in  $H_2S$  (sour waters) for makeup to crude desalters
- The use of blowdown condensate from high-pressure boilers for makeup to low-pressure boilers
- The reuse of waters that have been treated for closed cooling systems, fire mains, and everyday washing operations
- Stormwater use for routine water applications
- Blowdown waters from cooling towers for use as water seals on high-temperature pumps

- The recirculation of steam condensate
- The recycling of cooling waters

Good maintenance practices can effectively reduce waste streams. More emphasis is being placed on:

- The recovery of oil spills and hydrocarbons with vacuum trucks to reduce emissions and water effluents
- Reduction of leaks and accidents through preventive maintenance
- The separation of hazardous wastes, concentrated wastes, and other process wastes from general effluents for more effective treatment
- The diking of process unit areas to control and treat spills, oily stormwater runoff, or periodic washes
- The reduction of shock pollutant loads on treatment facilities through the periodic flushing of process sewers to prevent contaminant build-up
- Specialized programs for handling hazardous wastes, sludges, washwaters, and other effluents
- Systems to minimize wastes from monitoring stations
- Personnel awareness that the waste treatment is initiated at the process unit.

Actual process modifications often reduce waste streams significantly while returning a recovery value. Technology changes that reduce pollution may not be as cost effective during process cycles, but may prove to be highly beneficial when waste treatment costs have been reduced. Depending on the feasibility and suitability of a particular project, such process technology changes are expected to include:



- Catalyst switching to one of longer life and greater activity reducing regeneration rates
- Reduction in cooling water usage through the implementation of air-fin coolers
- Reduction in spent caustic and sulfides loadings by including hydrocracking and hydrotreating processes
- Inclusion of process control instrumentation to employ emergency shut-downs or control upset conditions.
- Minimization of filter solids, water washes, and spent caustics and acids through the optimization of drying, sweetening, and finishing processes.

Concerning wastewater streams, the trend is toward higher removal of organics and residual solids. The removal of heavy metals from catalyst systems and specific toxic organics also is being stressed. Front end treatment systems to remove heavy metals and organics (i.e., precipitation, ion exchange, phenol removal by solvent extraction), settling and filtration techniques to remove suspended solids and physical systems to remove specific organics are now becoming common practice.

Table 6 presents historical trends (1950 to 1977) in the use of various waste water treatment methods by oil refineries.

#### I.C.5. Environmental Impact

Federal and State regulations for water and air pollutants (Clean Water and Air Act Amendments of 1977) and solid waste generation and disposal (Toxic Substances Control Act; Resource Conservation and Recovery Act) have resulted in improvements in the technological design and efficiency of pollution control

Table 6. Estimated percentage of petroleum refineries using various wastewater treatment processes.

Processes and Subprocess	1950	1963	1967	1972	1977
API Separators	40%	50%	60%	70%	80%
Earthen Basin Separators	60	50	40	30	20
Evaporation	0-1	0-1	1	1-2	2-5
Air Flotation	0-1	10	15	18	20
Neutralization (total wastewater)	0-1	0-1	0-1	0-1	0-1
Chemical Coagulation and Precipitation	1-5	1-5	5-10	10-15	10-15
Activated Sludge	0	5	10	40	55
Aerated Lagoons	0	5	10	25	30
Trickling Filters	1-2	7	10	10	10
Oxidation Ponds	10	25	25	25	20
Activated Carbon	0	0.5	0.5	3	5
Ozonation	0	1	1	3	5
Ballast Water Treatment (Physical)	9	9	8	5	5
Ballast Water Treatment (Chemical)	1	1	2	5	5
Slop Oil-Vacuum Filtration	0	5	7	12	15
Slop Oil-Centrifugation	0	2	3	10	15
Slop Oil-Separation	100	93	90	80	70
Sour Water-Stream Stripping					
Flue Gas Strippers	60	70	85	90	90
Natural Gas					
Sour Water-Air Oxidation	0	3	3-5	7	10
Sour Water-Vaporization	1	1-2	1	0	0
Sour Water-Incineration <sup>a</sup>	35-40	40	50	30	20
Neutralization of Spent Caustics					
Flue gas	20	30	35	20	20
Spent acid (including springing and stripping)	15	25	30	25	20
Oxidation	0	3	5	5	5
Incineration <sup>a</sup>	25	40	50	20	15

<sup>a</sup>Incineration includes flaring, boiler furnaces, and separate incinerators used only in conjunction with stripping and vaporization.

Source: US-DOI. 1967. The cost of clean water, Volume III, Industrial Waste Profiles no. 5 - petroleum refining. FWPCA, Washington, DC.

methods. More attention is being given to the siting of major new industrial facilities in recognition of the increased emphasis on State, regional, and local land use planning. Also, owing to the ratification of the National Environmental Policy Act and other non-regulatory legislation, government decision making is more exposed to public scrutiny and to a more objective, complete environmental review process. Thus, refineries which have become operational since the early 1970's generally can be expected to have less waste stream-related impacts than those built a decade or two ago. Although this trend is expected to continue the projected growth of small refineries (<10,000 B/CD) because of incentives provided in Federal entitlement programs, and increased overall industrial activity, more consideration will be given to the assessment of cumulative and secondary impacts from siting new refinery facilities.

#### I.D. MARKETS AND DEMANDS<sup>3</sup>

##### I.D.1. Refinery Capacity

During the period from 1 January 1960 to 1 January 1977, U.S. refinery operation capacity increased about 7.0 million barrels per calendar day (9.5 million B/CD to 16.5 million B/CD). This increase represents an average compounded growth rate of about 3.5 percent per year; however, this growth has not been equal in all PAD districts. The highest growth during this period occurred in PAD district III, whereas the lowest occurred in PAD district I (see Figure 4 for the geographical distribution of PAD districts) (FEA 1977a, 1977b). Future trends show total operable capacity to rise to:

- 17.0 million B/CD in 1978

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<sup>3</sup> This draft discussion will be revised and expanded to reflect a new longer range forecast to 1990, recently projected by DOE. The new data will be included in the final report. Growth projections also will be made by PAD districts.

- 17.3 million B/CD in 1979
- 17.6 million B/CD in 1980
- 18.2 million B/CD in 1981
- 18.6 million B/CD in 1982

and actual crude runs through 1981 are estimated (by Bureau of Mines) to be about 90 percent of the above total operable capacities, or 15.3 million B/CD in 1978; 15.5 million B/CD in 1979; 15.8 million B/CD in 1980; and 16.4 million B/CD in 1981.

Discrepancies do exist, however, among authorities for crude capacity projections. For example, Oil and Gas Journal figures (Lange 1978) for crude runs during 1977 and 1978 are lower than those determined by the Bureau of Mines and the Office of Oil and Gas (FEA 1977a) as indicated below:

	1977 (million B/D)	1978 (million B/D)
O & G Journal	14.6	14.9
BM/OOG	14.9	15.4

Under the President's proposed National Energy Plan (NEP), the petroleum product demand is expected to rise only slightly, but U.S. refinery output is expected to increase at a greater rate owing to a decline in product imports forced by a sharp decrease in residual fuel oil demand. Nevertheless, the required increase in refinery output is less than that capacity currently planned. Capacity additions are expected to total 2.1 million barrels per day between 1977 and 1982. Even if some of the projects scheduled to come on stream between 1977 and 1982 fail to materialize, the addition of as little as 1.0 million barrels per day is expected to meet future demand (1985) at reasonable upper limits of refinery utilization. Because there probably will be some growth in petroleum product demand between 1985 and 1990, some added

capacity beyond the 1.0 million barrels per day would be needed during that period.

One very significant impact of the President's NEP is the substantial reduction in residual fuel oil demand which drops from 3.5 million barrels per day in the base case to 2.0 million barrels per day under the program.

Whereas U.S. refineries in the 50 States already are capable of producing 2.0 million barrels per day of residual fuel oil, it would appear that all export refineries in the Bahamas/Caribbean area would be shut down. In reality, some of these U.S.-owned Caribbean refineries probably would continue operations while U.S. refineries would tend to minimize residual fuel oil production to the extent possible, while still maintaining operations to produce other necessary products.

The base case, for petroleum product demand which represents anticipated 1985 and 1990 demand without the President's program was also developed. The requirement for new refinery capacity would be 3.6 million barrels per day by 1985 for the base case as compared with 1.9 million barrels per day of planned "firm" projects (FEA 1977b).

#### I.D.2. Incentives

Currently the primary incentive to refine domestically (as opposed to abroad) is the Federal entitlements program. A secondary incentive is the import fee system which has been active since April 1973. Under the entitlements program, because of price controls, the average refiner pays less for his crude oil than other countries pay for foreign crude oil. This large advantage endangered U.S.-owned refinery operations in the Bahamas and Caribbean with the result that partial entitlements were given to residual fuel oil importers.

With the application of the crude equalization tax under the NEP, the advantage offered by the entitlements system will disappear, and leave import fees as the last significant element to encourage domestic refining.

Other factors for consideration include increased investment tax credits and accelerated depreciation on new facilities or modification to existing facilities. The NEP also will affect refinery operations through the user's tax which is to be paid on liquid fuels burned in the refinery. Current technology does not permit the burning of coal in process furnaces. If the cost of the tax can be passed through or exceptions granted, it will not affect refineries. According to the NEP Macro Economic Effects, one-third of the crude oil equalization tax will have to be absorbed by refineries which may nullify the protection of the product import fee.

#### I.D.3. Changes in Refinery Configuration

Although the general trend has been toward fewer, but larger refineries this trend appears to be reversing. The capacities of the 256 refineries operating as of 1 January 1976, ranged from 32 m<sup>3</sup>/day (200 B/D) to 69,000 m<sup>3</sup>/day (434,000 B/D). Refineries unit capacities over 15,900 m<sup>3</sup>/day (100,000 B/D) represented only 11.5% of total refineries in 1967, but accounted for 48% of the refining capacity. By 1972, 16.6% of all refineries exceeded this size and represented 58% of total capacity. However, more recent information indicates that most new refinery construction utilizing fluid catalytic cracking units will range from 25,000 to 50,000 B/D (US-EPA 1976).

Although larger refineries are able to take advantage of continuous processing units, the number of small refineries (under 10,000 B/D), both new and reactivated, is increasing. In part, this is because of the small refiner

bias in the Federal entitlements program which provides special allocations of petroleum feedstocks to small refineries at a substantial price advantage (FEA 1977). In point of fact, the smaller the refiner, the greater dollar per barrel advantage. For example, a refinery with 80,000 B/D capacity receives only one-tenth of the benefits of a 10,000 B/D facility (Peer and Marsik 1977).

Most of the small refineries being built or planned are of simple design that often consists only of crude distillation towers and storage tanks; therefore, they are less able to respond to changing market demands or to produce more sophisticated products (FEA 1977a).

In contrast, the larger refineries have instituted improvements in technology which have resulted in more sophisticated processing techniques such as fluid-bed catalytic cracking instead of static-bed catalytic cracking, catalytic reforming, and advanced hydrotreating.

Trends in the construction of larger petroleum refineries will be dictated primarily by market demand. This effect was evidenced by the considerable buildup during the 1960's in processes which provided higher octane gasoline. Recently, although there has been a significant reduction in the octane numbers required, the necessity to achieve specific octanes without the addition of lead again has modified petroleum processing. Moreover, the market for low sulfur fuel oil has generated the construction of desulfurization facilities.

The rate of refinery expansion or construction will be influenced by the relative contribution of oil-derived products to the total energy demand. The share supplied by oil is projected to drop from 46% in 1975 to 42% in 1990 (Denman 1978).

Other factors that are expected to influence refinery configurations include:

- Uncertainty created by unstable government programs
- Threat of legislation to force divestiture by refineries of production and marketing
- Cost and composition of crude oils
- Inflation rates
- Construction costs, pollution control regulations, and equipment costs
- Environmental restrictions and opposition.

The above summary discussion represents an overview. A detailed analysis of markets and demands for the petroleum refining industry is outside the scope of these guidelines. For the reviewer who seeks more detailed analyses of this subject see: FEA 1977a; FEA 1977b; DOE 1977.



## I.E.        SIGNIFICANT ENVIRONMENTAL PROBLEMS

### I.E.1.    Location

Petroleum refinery operations generally are large installations which can occupy considerable acreage. Naturally the areal extent varies with the capacity of the refinery and the extent of ancillary support facilities planned. Most refinery facilities are located either in rural areas or on the periphery of an urban center in the oil producing regions. Because the siting of new source petroleum refineries can involve a significant change in land use, particularly in rural areas, direct and indirect social and ecological impacts may occur. Direct impacts are primarily a function of the type and size of the facility proposed, the composition of the crude oil to be refined, and characteristics of the site (e.g., wetlands versus upland). The extent and significance of secondary or indirect impacts such as induced growth, infrastructure changes, and demographic changes depends largely on the local economy, existing infrastructure, numbers and characteristics of construction workers (e.g., local or nonlocal, size of worker's family) and other related factors. Long term secondary impacts are seldom significant unless the refinery, because of its size, processing methods, and location, employs a sufficient number of workers to result in spin-off developments (commercial, industrial, and residential). A discussion of secondary impact assessment is contained in the existing EPA document, Environmental Impact Assessment Guidelines for Selected New Source Industries, pages III-11-12.

### I.E.2.    Raw Materials

The most significant environmental problems associated with raw materials result from the transport, handling, and storage of the crude oil (oil

exploration, development and production activities are not included in this report). Also the composition and nature of the feedstock is of particular consequence with respect to potential environmental impacts.

During handling, transportation and storage of crude oil and products, residues can impact waste streams through spills and leaks, tank-cleaning operations, and ballast waters from tankers, which in turn, can affect environmental quality. Oil, finished product, water and other residues on storage tank bottoms (i.e., product, intermediate, and crude storage tanks) are potential sources of wastewaters. Filters and filter media also can contribute to waste streams.

Relative to crude oil constituents, sulfur and sulfur compounds constitute the most significant contaminants in crude oil fractions. Oxygen compounds, nitrogen compounds and metal compounds of vanadium, nickel, iron, calcium, manganese, aluminum, copper, sodium, potassium, arsenic, and zinc are other foreign materials which was present treating problems and potential environmental degradation. Of the metals, vanadium, nickel and iron are the most significant because they shorten the life of hydrodesulfurization catalysts.

The sulfur content of crude oils appears to be related to the density of the crude oil which in turn depends on the distribution of hydrocarbon types in the crude oil.

Further, the sulfur content of crude oil is not distributed uniformly throughout the boiling range of the oil, but is progressively concentrated in the higher boiling fractions. The types of sulfur compounds present in crude oils also vary. Over one hundred sulfur compounds have been identified through analyses of only three crude oils (Rall, et al. 1962). During the

past three or four years, however, increasingly severe environmental restrictions have been placed on sulfur recovery units themselves (Claus process) in terms of emission controls, therefore, the severity of potential environmental impacts should be controllable to an extent.

### I.E.3. Process Wastes<sup>4</sup>

Figure 6 shows basic oil refinery operations and the general character of their respective wastes; the diagram includes operations typical of a complete refinery (i.e., a refinery that manufactures motor fuels, burning oils, lubricating oils and greases, waxes, asphalts and speciality products).

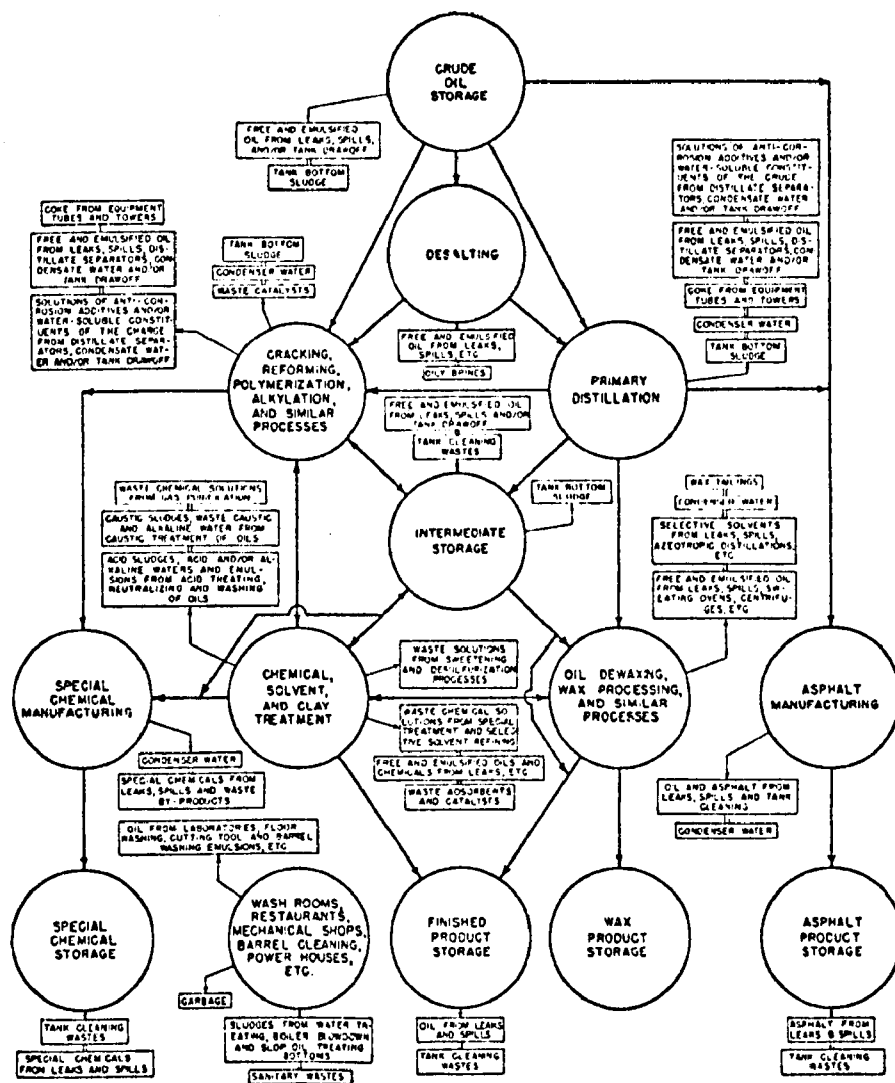
Because a multiplicity of potential pollutants may be generated from a complete refinery operation, for these guidelines, they have been categorized generally as follows:

- Free oil
- Emulsified oil
- Condensate waters
- Acid wastes
- Waste caustics
- Alkaline waters
- Special chemicals
- Waste gases
- Sludges and other solids
- Clean cooling water
- Sanitary wastes

The various wastes that may pollute the environment usually originate in small quantities from a large number of sources which are distributed widely throughout the refinery. The sources and characteristics of the various types of wastes that have potential to significantly effect the environment are described below:

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<sup>4</sup>This summary discussion is based largely on the following more detailed source documents: US-EPA 1976; 1967 Ind. Waste Treatment, US-EPA 1973.



Source: Rudolfs, W. Ed. 1953. Industrial Wastes: Their Disposal and Treatment. Reinhold Publishing Corporation. New York, N.Y.

Figure 6. Typical wastes produced in a complete petroleum refinery.

#### I.E.3.a. Free Oil

Depending on the efficiency of pollution control measures used, large complete refineries may be expected to have varying amounts of their crude oil charge escape to the sewers in the form of free oil. In large refineries this oil originates in small quantities from numerous sources such as individual sampling taps, pump gland leaks, valve and pipeline leaks, losses and spills at times of unit shutdown and equipment repair, accidental spills and overflows, tank bottom drawoffs and other miscellaneous sources.

The presence of light ends creates a potential explosion hazard in the sewers. For this reason precaution should be taken in the design of the sewerage system to adequately trap all sewer inlets.

Oil exists in the wastewater in two fractions:

- Suspended fraction (small droplets, small solids-oil agglomerates, oil in water emulsion)
- Floating fraction (water in oil emulsion or free oil)

In practically all cases gravity differential oil-water separates are provided to recover floating oil and to treat the waste. In the process of separating oil from water, oil rises to the surface, sediment settles to the bottom and relatively small concentrations of oil and suspended solids pass through the separator. Some solid matter rises to the surface with the oil and some oil settles to the bottom with the solids. It also should be noted that gravity differential oil-water separators cannot remove oil in the form of oil in water emulsions or in the form of oil-suspended solids agglomerates with specific gravities approximately that of the water.

I.E.3.b.      Emulsions of Oil

The presence of oil that cannot be separated from waste waters by conventional gravity differential means can significantly impact the environment, however, it also is of considerable economic importance to the refiner because of the loss of valuable product and the need for costly facilities to treat the effluent from his oil recovery separators.

An oil in water emulsion has turbidity as its chief characteristic and usually has a milky or pearly-gray appearance. This type of emulsion is not removed in the gravity type oil separator, and when it is discharged into a large stream or body of water, it usually breaks as a result of dilution and the oil rises to the surface of the water.

Emulsions also may be formed in the sewerage system as a result of intimate contact between oil, water, and emulsifying agents or may originate directly as process byproducts.

The occurrence of coke, clay, sanitary sewage, water treating plant sludges and other flocculent and fibrous solids appears to increase the concentration of nonseparable oil. The presence of tars, asphalts, petroleum sludges, soaps and numerous solvent and treating chemicals also increases the nonseparable oil content of waste waters. The pumping of wastewater is especially conducive to the formation of emulsions.

The direct formation of emulsions may result from the chemical treatment of lubricating oils, waxes and burning oils, from distillate separators, from barometric condensers, tank drawoffs, desalting operations, pump gland leakage, special chemical manufacturing, acid sludge recovery processing, wax

deoiling, barrel and truck washing, machine shops and other sources.

I.E.3.c.      Condensate Waters

Condensate waters, as referred to herein, originate from distillate separators, running tanks and barometric condensers. It has been reported (Teague 1950) that condensate waters from distillate separators may contain one or more of such compounds as organic and inorganic sulfides, normal or acid sulfites and sulfates, sulfonic acids and their salts, mercaptans, amines, amides, quinalines and pyridines, naphthenic acids, phenols, etc. They also may contain chemicals used for corrosion prevention such as ammonia, caustic soda, calcium hydroxide, etc. Not all these substances will be found in a specific wastewater at the same time. Waste of this type also may contain suspended matter such as coke, iron sulfide, silica, metallic oxides, soaps, emulsions, sulfonic and naphthenic acids, insoluble mercaptides and other suspended solids (Teague 1950).

I.E.3.d.      Acid Wastes

Sulfuric acid is used extensively in the petroleum industry both as a treating agent and a catalyst. Other acids and acid salts also used as catalysts include hydrofluoric acid, phosphoric acid, aluminum chloride and zinc chloride. Acid bearing wastes originate from the acid treatment of gasoline, white oils, lubricating oils and waxes; from the handling of acid sludges and the recovery or manufacture of acid; from the alkylation of motor fuel stocks; from the use of acidic catalysts; and from special chemical manufacturing. The wastes occur as rinse waters, scrubber discharges, spent catalyst, sludges, condensate waters, and miscellaneous discharges resulting from sampling procedures, leaks and spills and shutdowns.

#### I.E.3.e. Waste Caustics

Waste caustics as referred to herein originate from the caustic washing of light oils to remove mercaptans, hydrogen sulfide, and other acidic materials that occur naturally in crude oil or any of its fractions or may be produced by a variety of processing methods.

The quantity of waste caustic produced will vary greatly depending on the characteristics of the crude and the methods of processing.

The constituents of waste caustics responsible for their potent pollution characteristics include mercaptans, thiophenol, thiocresols, phenols, cresols, disulfides, alkylsulfides, the sodium salts of any one of a number of saturated mono acids, naphthenic acids or sulfonic acids and other materials (Weston 1944).

#### I.E.3.f. Alkaline Waters

Alkaline waters, as differentiated from alkaline condensate waters and waste caustics, may originate from the washings of neutralized acid treated oils, the washings of caustic treated oils, the dehydration of treated light oils, the aqueous tank bottoms of stored caustic treated and washed gasolines, vessel and tower washings at times of shutdowns and miscellaneous sources.

#### I.E.3.g. Special Chemicals

This category of wastes includes the special solvents and extraction solutions utilized in selective solvent refining, gas purification, light oil treating, etc. Such special chemicals utilized in petroleum processing may include phenol, creosols, furfural, salts of isobutyric acid, nitrobenzene, acetone,



methyl ethyl ketone, B.B. dichlorethyl ether, ethylene dichloride, benzol, tannin, fatty acids, diethanol amine, methanol, toluol sodium hypochlorite, tri-sodium phosphate, lead sulfide, copper chloride and others. These special chemicals may create serious waste control problems. The water soluble organics, for example, can add tremendously to the oxygen demand characteristics of the plant wastes if allowed to discharge into the sewers. Others listed are emulsifying agents and would adversely affect separator operation if allowed to mix with other refinery wastes. Frequently, the value of these materials is sufficient to justify the use of collection and recovery systems. Drainage from leaks, spills, pumps, valves, sampling, routine maintenance activities, etc., often is recovered to keep losses to a minimum.

#### I.E.3.h. Waste Gases

The waste gases from petroleum refining are stack gases from furnances and reactors, hydrogen sulfide and sulfur dioxide. Except that stack gases may be used in waste treatment processes or may be scrubbed with water for solids removal they do not enter into water pollution control problems.

The acid gases (hydrogen sulfide and sulfur dioxide), however, may cause water pollution control problems. Hydrogen sulfide as produced from the distillation of crude and other processing is a contaminant to other refinery gases (i.e., methane, ethane, etc.). The removal of hydrogen sulfide from liquid and gaseous hydrocarbon stream creates wastewaters of highly obnoxious characteristics. These wastes were discussed briefly in section I.E.3.e.

#### Waste Caustics.

Sulfur dioxide is produced from stack gases, sulfuric acid concentrators, liquid sulfur dioxide refining units and sulfuric acid treating units. Normally sulfur dioxide wastes are discharged to the atmosphere. However, not infrequently atmospheric pollution problems must be corrected and the corrective measures may create water pollution problems. The utilization of sulfur dioxide for the recovery of sulfur offers the best long term solution to the problem of pollution abatement. In addition to the formation of  $\text{SO}_2$  during the combustion of sulfur-containing liquid refinery fuels,  $\text{NO}_x$  formation can be enhanced if those fuels also contain nitrogen compounds. This  $\text{NO}_x$ , as well as the small amount of  $\text{SO}_3$  formed from sulfur compounds in the fuel, tend to be the principal cause of stack plumes from refinery furnances.

Carbon monoxide and particulate emissions also occur, however, they largely are confined to flue gases from catalytic cracker regenerators and fluid cokers (unless coal or coke are used as fuel).

#### I.E.3.i. Sludges and Solids

Sludges may accumulate at the bottom of various crude or product storage tanks; as the result of various treatment processes; at the bottom of cooling towers and as the result of process and wastewater treatment.

Solids may include coke, waste catalysts, filtering clays, slag, tank bottoms, etc.

Disposal of sludges and solids to the plant sewers is highly objectionable because of the effect of solids on oil separation.

Tank bottom sludges vary greatly in their characteristics, e.g., from an easily pumpable fluid to a set solid. In general these wastes may be treated for oil recovery or burned as fuel. Sometimes for the purpose of tank cleaning it is advantageous to flush these materials from the tanks using water. In some cases water flushing will create emulsions and suspensions that will produce unsatisfactory waste water effluents. The use of water flushing should be avoided as much as possible.

One of the major sources of sludge of high pollutional characteristics is the acid treatment of refinery stocks (See Section I.E.3.d. Acid Wastes).

Sludge accumulating at the bottom of cooling towers generally is adaptable to disposal as fill. However, the removal of the sludge from the tower basin and the transfer of the material to the point of final disposal can pose numerous problems.

Sludge from the clarification of water for process use create the same type of problem as that of cooling tower sludge.

Sludge from the softening of water may be utilized, in some cases, for the neutralization of acidulous waters or as a coagulant aide in wastewater treatment.

#### I.E.3.j.        Cooling Water

Cooling water makes up nearly the entire volume of wastewater from petroleum refining operations. Because these wastes may become oil-contaminated, owing to equipment failure, it is necessary to provide oil separation facilities to prevent accidental pollution. Consequently, uncontaminated cooling water generally is turned into a common oil carrying sewerage system. However,

when wastewater quality standards necessitate additional treatment the separate collection and disposal of cooling waters which are subject to periodic pollution has been undertaken at some refineries. The size of effluent treatment facilities has been reduced substantially by reducing the quantity of wastewater through the use of recirculating cooling systems. The use of dirty water cooling tower systems and the elimination of barometric condensers and jet vacuum pumps have also served to keep sizes of treatment facilities at a minimum.

#### I.E.3.k. Sanitary Wastes

Sanitary wastes offer minimal opportunity for waste utilization. The wastes may be discharged to refinery or municipal sewerage systems or to separate sewerage and disposal facilities. Generally, discharge to refinery sewerage systems is not in agreement with good public health practice and may interfere with efficient oil separation. If adequate pretreatment methods are employed the impacts associated with these wastes usually are insignificant.

#### I.E.4. Pollution Control

Pollution control measures on waste streams can effectively reduce adverse impacts that result when control is absent; however, the same control measures can create other kinds of impacts. The equipment used to control various waste streams in oil refining facilities also can generate solid and liquid residual wastes which must be treated and disposed of properly. For example, pollution control processes to remove acid components in the gas stream ( $H_2S$ ) may leave sulfur-based compounds in the exhaust gases. Waste treatment measures for aqueous streams likewise may not be adequate to treat all of the complex organic compounds which are discharged from a petroleum

refinery. Therefore, all proposed pollution abatement devices should be well-designed, well-operated, and properly maintained to minimize other pollutant impacts which may result from unnecessary residual waste products.

#### I.F. REGULATIONS

Federal water pollution regulations are covered primarily by the Standards of Performance for New Sources (SPNS) for the petroleum refining point source category, in Section 40 CFR 419. Control is through the NPDES permit process. Administration and enforcement rest either with US-EPA or with those States with approved NPDES permit programs.

Air pollution control standards are enumerated by Federal New Source Performance Standards (NSPS) as described in 40 CFR Parts 50 and 60 and by State and local air pollution regulations. Usually control is through the State regulatory function of licensing the construction of the oil refinery.

Other applicable pollution control regulations include the Federal Resource Conservation and Recovery Act of 1976 and the various state regulations regarding disposal of solid wastes.

##### I.F.1. Water Pollution Standards of Performance

The effluents of new or expanded petroleum refineries are subject to standards of performance for new sources (SPNS) and pretreatment standards for new sources established under Public Law 92-500, the Federal Water Pollution Control Act, as amended. These standards have been subjected to court challenge, but currently are in effect. The regulations govern conventional pollutants, as they are termed in Section 304(a)(4) of the Clean Water Act of 1977 (P.L. 95-217), and others as follows:

- BOD<sub>5</sub>
- TSS
- COD
- Oil and grease
- Phenolic compounds
- Ammonia as N
- Sulfide
- Total chromium
- Hexavalent chromium
- pH

Additional SPNS and pretreatment standards for toxic pollutants applicable to the subcategories of this industry also are being developed. These are required for a specific list of substances by the Consent Decree resulting from the recent litigation, Natural Resources Defense Council, Inc., et al. v. Russell E. Train (Civil Action No. 2153-73 U.S. District Court for the District of Columbia) and from the Clean Water Act of 1977. The list appended to the Decree and referenced in the Act, includes a number of exotic organics and heavy metals of potential concern to refiners. The toxic SPNS and pretreatment standards will be effective immediately upon promulgation.

EPA may revise the list from time to time, adding substances to it and removing others. Thus, after determining the toxic effluents already subject to standards, new source NPDES applicants should obtain the latest version of the list in order to identify other types of effluents which will become the subject of toxic SPNS and pretreatment standards.

The SPNS applicable to the five subcategories of refineries are complex. The subcategories are further broken down by the use of two factors based on size of plant (1000 barrels of feedstock) and process configuration. The product of these two factors is a number by which a specified base SPNS value for each waste parameter for each of the five subcategories is multiplied to obtain a value for a specific plant. Plant size is broken down into seven ranges, giving seven size factors. The process factor is broken down into 22 increments, each of which produces a different process factor. An example of the application of the factors was promulgated (40 CFR, Part 419, Subpart D (d)(3)) and is shown in Table 7 for a refinery in the lube subcategory. The SPNS for the five subcategories topping, cracking, petrochemical, lube, and integrated are shown in Table 8.

From review of effluent limitations that reflect the best available treatment economically achievable (BATEA), which were remanded by the courts, EPA is expected to eliminate the size factor and simplify the regulations. Similar action on the NSPS also can be expected.

The pretreatment standards for new source petroleum refineries are nearly identical to the SPNS for each subcategory as presented in Table 8 provided that:

- The SPNS value will be reduced correspondingly when the publicly-owned treatment works receiving the discharge is committed in its NPDES permit to remove a specified percentage of an incompatible pollutant
- The following wastes are not introduced into the publicly-owned treatment works:

Table 7. Example of the application of the size and process configuration factors.

Calculation of the Process Configuration

<u>Process category</u>	<u>Processes included</u>	<u>Weighting factor</u>
Crude	Atm. crude distillation. Vacuum crude distillation. Desalting.	1
Cracking and coking	Fluid cat. cracking. Vis-breaking. Thermal cracking. Moving bed cat. cracking. Hydrocracking. Fluid coking. Delayed coking.	6
Lube	Less than 12% of the feedstock throughput	13
Asphalt	Asphalt production. Asphalt oxidation. Asphalt emulsifying.	12

EXAMPLE.--Lube refinery 125,000 bbl per stream day throughout

<u>Process</u>	<u>Capacity (1,000 bbl per stream day)</u>	<u>Capacity relative to throughput</u>	<u>Weighting factor</u>	<u>Processing configuration</u>
Crude:				
Atm	125	1		
Vacuum	60	.48		
Desalting	125	1		
Total		2.48	X	1 = 2.48
Cracking-FCC	41	.328		
Hydrocracking	20	.160		
Total		.488	X	6 = 2.93
Lubes	5.3	.042		
	4.0	.032		
	4.9	.039		
Total		.113	X	13 = 1.47
Asphalt	4.0	0.032	X	12 = .38
Refinery process configuration				= 7.26

NOTES: Process factor = 0.88

Size factor = 0.93

To calculate the limits for each parameter, multiply the applicable limit by both the process factor and size factor. The limits for the lube subcategory are as follows:



Table 7. Example of the application of the size and process configuration factors (Concluded).

<u>Effluent characteristics</u>	<u>Effluent limitations</u> <u>kg/1000 m<sup>3</sup> (1b/1000 bbl) of feedstock</u>	
	<u>Maximum for any one day</u>	<u>Average of daily values for thirty consecutive days shall not exceed</u>
BOD <sub>5</sub>	50.6 (17.9)	25.8 (9.1)
TTS <sub>1</sub>	35.6 (12.5)	22.7 (8.0)
COD <sub>1</sub>	360 (127)	187 (66)
Oil and grease	16.2 (5.7)	8.5 (3.0)
Phenolic compounds	.38 (.133)	.184 (.065)
Ammonia as N	23.4 (8.3)	1056 (3.8)
Sulfide	.33 (.118)	.10 (.053)
Total chromium	.77 (2.73)	.45 (.160)
Hexavalent chromium	.068 (.024)	.030 (.011)
pH	Within the range 6.0 to 9.0	

BOD<sub>5</sub> limit (max. for any one day) = 17.9 X 0.88 X 0.93 = 14.6 lb/1000 bbl of feedstock.

Table 8. Standards of performance for new sources  
applicable to the five subcategories of references

<u>TOPPING SUBCATEGORY</u>	<u>Effluent Limitations</u>			
	<u>kg/1000 m<sup>3</sup> (1b/1000 bbl) of feedstock</u>		<u>Average of daily values for 30 consecutive days shall not exceed</u>	
	<u>Maximum for any one day</u>			
BOD <sub>5</sub>	11.8	(4.2)	6.3	(2.2)
TSS	8.3	(3.0)	4.9	(1.9)
COD <sup>1</sup>	61	(21.7)	32	(11.2)
Oil and grease	3.6	(1.3)	1.9	(.70)
Phenolic compounds	.088	(.031)	.043	(.016)
Ammonia as N	2.8	(1.0)	1.3	(.45)
Sulfide	.078	(.027)	.035	(.012)
Total chromium	.18	(.064)	.105	(.037)
Hexavalent chromium	.015	(.0052)	.0068	(.0025)
pH	Within the range 6.0 to 9.0			

<sup>1</sup> In any case in which the applicant can demonstrate that the chloride ion concentration in the effluent exceeds 1,000 mg/l (1,000 ppm), the Regional Administrator may substitute TOC as a parameter in lieu of COD. Effluent limitations for TOC shall be based on effluent data from the plant correlating TOC to BOD<sub>5</sub>.

If in the judgment of the Regional Administrator, adequate correlation data are not available, the effluent limitations for TOC shall be established at a ratio of 2.2 to 1 to the applicable effluent limitations on BOD<sub>5</sub>.

Table 8. Standards of performance for new sources applicable to the five subcategories of references (Continued).

<u>Size factor.</u>	
1,000 bbl of feedstock per stream day:	<u>Size factor</u>
Less than 24.9 -----	1.02
25.0 to 49.9 -----	1.06
50.0 to 74.9 -----	1.16
75.0 to 99.9 -----	1.26
100.0 to 124.9 -----	1.38
125.0 to 149.9 -----	1.50
150.0 or greater -----	1.57

<u>Process factor.</u>	
<u>Process Configuration</u>	<u>Process factor</u>
Less than 24.9 -----	0.62
2.5 to 3.49 -----	0.67
3.5 to 4.49 -----	0.80
4.5 to 5.49 -----	0.95
5.5 to 5.99 -----	1.07
6.0 to 6.49 -----	1.17
6.5 to 6.99 -----	1.27
7.0 to 7.49 -----	1.39
7.5 to 7.99 -----	1.51
8.0 to 8.49 -----	1.64
8.5 to 8.99 -----	1.79
9.0 to 9.49 -----	1.95
9.5 to 9.99 -----	2.12
10.0 to 10.49 -----	2.31
10.5 to 10.99 -----	2.51
11.0 to 11.49 -----	2.73
11.5 to 11.99 -----	2.98
12.0 to 12.49 -----	3.24
12.5 to 12.99 -----	3.53
13.0 to 13.49 -----	3.84
13.5 to 13.99 -----	4.18
14.0 or greater -----	4.36

(a) Runoff

The allocation allowed for storm runoff flow, as kg/cu m (lb/Mgal), shall be based solely on that storm flow (process area runoff) which is treated in the main treatment system. All additional storm runoff (from tankfields and non-process areas), that has been segregated from the main waste stream for discharge, shall not exceed a concentration of 35mg/l of TOC or 15 mb/l of oil and grease when discharged. The following allocations for runoff are in addition to the process discharge allowed by the above limitations:

Table 8. Standards of performance for new sources applicable to the five subcategories of references (Continued).

(a) Runoff continued

	Effluent Limitations			
	kg/1000 m <sup>3</sup> (lb/1000 gal) of flow			
	<u>Maximum for any one day</u>		<u>Average of daily values for 30 consecutive days shall not exceed</u>	
BOD <sub>5</sub>	0.048	(0.40)	0.026	(.01)
TSS	.033	(.27)	.021	(.17)
COD <sup>1</sup>	.37	(3.1)	.19	(1.6)
Oil and grease	.015	(.126)	.0080	(.067)
pH	Within the range 6.0 to 9.0			

(b) Ballast

The allocation allowed for ballast water flow, as kg/cu m (lb/M gal), shall be based on those ballast waters treated at the refinery. The following allocations are in addition to the process and runoff limitations:

	Effluent Limitations			
	kg/1000 m <sup>3</sup> (lb/1000 gal) of flow			
	<u>Maximum for any one day</u>		<u>Average of daily values for 30 consecutive days shall not exceed</u>	
BOD <sub>5</sub>	0.048	(.40)	0.026	(.21)
TSS	.033	(.27)	.021	(.17)
COD <sup>1</sup>	.47	(3.9)	.24	(2.0)
Oil and grease	.15	(.126)	.008	(.067)
pH	Within the range 6.0 to 9.0			

(c) Cooling water

Once through cooling water may be discharged with a total organic carbon concentration not to exceed 5 mg/l.

Note: The above provisions relating to runoff, ballast, and once through cooling water also are applicable to the cracking, petrochemical, lube, integrated subcategories.

Table 8. Standards of performance for new sources applicable to the five subcategories of references (Continued)

<u>CRACKING SUBCATEGORY</u>	Effluent Limitations kg/1000 m <sup>3</sup> (1b/1000 bbl) of feedstock			
	<u>Maximum for any one day</u>		<u>Average of daily values for 30 consecutive days shall not exceed</u>	
BOD <sub>5</sub>	16.3	(5.8)	8.7	(3.1)
TSS	11.3	(4.0)	7.2	(2.5)
COD <sub>1</sub>	118	(41.5)	61	(21.0)
Oil and grease	4.8	(1.7)	2.6	(.93)
Phenolic compounds	.119	(.042)	.058	(.020)
Ammonia as N	18.8	(6.6)	8.6	(3.0)
Sulfide	.105	(.037)	.048	(0.17)
Total chromium	.24	(.084)	.14	(.049)
Hexavalent chromium	.020	(.0072)	.0088	(.0032)
pH	Within the range 6.0 to 9.0			

Size Factor.

1,000 bbl of feedstock per stream day:	<u>Size factor</u>
Less than 24.9 -----	0.91
25.0 to 49.9 -----	0.95
50.0 to 74.9 -----	1.04
75.0 to 99.9 -----	1.13
100.0 to 124.9 -----	1.23
125.0 to 149.9 -----	1.35
150.0 or greater -----	1.41

Process Factor.

<u>Process configuration:</u>	<u>Process factor</u>
Less than 24.9 -----	0.58
2.5 to 3.49 -----	0.63
3.5 to 4.49 -----	0.74
4.5 to 5.49 -----	0.88
5.5 to 5.99 -----	1.00
6.0 to 6.49 -----	1.09
6.5 to 6.99 -----	1.19
7.0 to 7.49 -----	1.29
7.5 to 7.99 -----	1.41
8.0 to 8.49 -----	1.53
8.5 to 8.99 -----	1.67
9.0 to 9.49 -----	1.82
9.5 or greater -----	1.89

Table 8. Standards of performance for new sources applicable to the five subcategories of references (Continued).

PETROCHEMICAL SUBCATEGORY

Effluent Limitations

kg/1000 m<sup>3</sup> (1b/1000 bbl) of feedstock

	<u>Maximum for any one day</u>		<u>Average of daily values for 30 consecutive days shall not exceed</u>	
BOD <sub>5</sub>	21.8	(7.7)	11.6	(4.1)
TSS	14.9	(5.2)	9.5	(3.3)
COD <sup>1</sup>	133	(47.0)	69	(24.0)
Oil and grease	6.6	(2.4)	3.5	(1.3)
Phenolic compounds	.158	(.056)	.077	(.027)
Ammonia as N	23.4	(8.3)	10.7	(3.8)
Sulfide	.140	(.050)	.063	(.022)
Total chromium	.32	(.116)	.19	(.068)
Hexavalent chromium	.025	(.0096)	.012	(.0044)
pH	Within the range 6.0 to 9.0			

Size factor.

1,000 bbl of feedstock per stream day:	<u>Size factor</u>
Less than 24.9 -----	0.73
25.0 to 49.9 -----	0.76
50.0 to 74.9 -----	0.83
75.0 to 99.9 -----	0.91
100.0 to 149.9 -----	1.08
150.0 or greater -----	1.13

Process factor.

<u>Process configuration:</u>	<u>Process factor</u>
Less than 4.49 -----	0.73
4.5 to 5.49 -----	0.80
5.5 to 5.99 -----	0.91
6.0 to 6.49 -----	0.99
6.5 to 6.99 -----	1.08
7.0 to 7.49 -----	1.07
7.5 to 7.99 -----	1.28
8.0 to 8.49 -----	1.39
8.5 to 8.99 -----	1.51
9.0 to 9.49 -----	1.65
9.5 or greater -----	1.72

Table 8. Standards of performance for new sources applicable to the five subcategories of references (Continued.)

LUBE SUBCATEGORY

Effluent Limitations  
kg/1000 m<sup>3</sup> (lb/1000 bbl) of feedstock

	<u>Maximum for any one day</u>		<u>Average of daily values for 30 consecutive days shall not exceed</u>	
BOD <sub>5</sub>	34.6	(12.2)	18.4	(6.5)
TSS	23.4	(8.3)	14.9	(5.3)
COD <sup>1</sup>	245.0	(87.0)	126.0	(45.0)
Oil and grease	10.5	(3.8)	5.6	(2.0)
Phenolic compounds	.25	(.088)	.12	(.043)
Ammonia as N	23.4	(8.3)	10.7	(3.8)
Sulfide	.220	(.078)	.10	(.035)
Total chromium	.52	(.180)	.31	(.105)
Hexavalent chromium	.046	(.022)	.021	(.0072)
pH	Within the range 6.0 to 9.0			

Size factor.

1,000 bbl of feestock per stream day:

Size  
factor

Less than 49.9 -----	0.71
50.0 to 74.9 -----	0.74
75.0 to 99.9 -----	0.81
100.0 to 124.9 -----	0.88
125.0 to 149.9 -----	0.97
150.0 to 174.9 -----	1.05
175.0 to 199.9 -----	1.14
200.0 or greater -----	1.19

Process factor

Process configuration:

Process  
factor

Less than 6.49 -----	0.81
6.5 to 7.49 -----	0.88
7.5 to 7.99 -----	1.00
8.0 to 8.49 -----	1.09
8.5 to 8.99 -----	1.19
9.0 to 9.49 -----	1.29
9.5 to 9.99 -----	1.41
10.0 to 10.49 -----	1.53
10.5 to 10.99 -----	1.67
11.0 to 11.49 -----	1.82
11.5 to 11.99 -----	1.98
12.0 to 12.49 -----	2.15
12.5 to 12.99 -----	2.34
13.0 or greater -----	2.44

Table 8. Standards of performance for newsources applicable to the five subcategories of references (Concluded).

<u>INTEGRATED SUBCATEGORY</u>	<u>Effluent Limitations</u>			
	<u>kg/1000 m<sup>3</sup> (1b/1000 bbl) of feedstock</u>		<u>Average of daily values for 30 consecutive days shall not exceed</u>	
	<u>Maximum for any one day</u>			
BOD <sub>5</sub>	41.6	(14.7)	22.1	(7.8)
TSS	28.1	(9.9)	17.9	(6.3)
COD <sup>1</sup>	295	(104.0)	152	(54.0)
Oil and grease	12.6	(4.5)	6.7	(2.4)
Phenolic compounds	.30	(.105)	.14	(.051)
Ammonia as N	23.4	(8.3)	10.7	(3.8)
Sulfide	.26	(.093)	.12	(0.42)
Total chromium	.64	(.220)	.37	(.13)
Hexavalent	.052	(.019)	.024	(.0084)
pH	Within the range 6.0 to 9.0			

Size factor.

1,000 bbl of feedstock per stream day:	<u>Size factor</u>
Less than 124.9 -----	0.73
125.0 to 149.9 -----	0.76
150.0 to 174.9 -----	0.83
175.0 to 199.9 -----	0.91
200.0 to 224.9 -----	0.99
225 or greater -----	1.04

Process factor.

<u>Process configuration:</u>	<u>Process factor</u>
Less than 6.49 -----	0.75
6.5 to 7.49 -----	0.82
7.5 to 7.99 -----	0.92
8.0 to 8.49 -----	1.00
8.5 to 8.99 -----	1.10
9.0 to 9.49 -----	1.20
9.5 to 9.99 -----	1.30
10.0 to 10.49 -----	1.42
10.5 to 10.99 -----	1.54
11.0 to 11.49 -----	1.68
11.5 to 11.99 -----	1.83
12.0 to 12.49 -----	1.99
12.5 to 12.99 -----	2.17
13.0 or greater -----	2.26



- wastes that create a fire or explosion hazard
- wastes that will cause corrosive structural damage to treatment works, but in no case wastes with a pH lower than 5.0, unless the works is designated to accommodate such wastes
- solid or viscous wastes in amounts that would cause obstruction to the flow in sewers or other interference with the proper operation of the publicly owned treatment works
- wastes at a flow rate and/or pollutant discharge rate that is excessive over relatively short time periods so that there is a treatment process upset and subsequent loss of treatment efficiency

These prohibitions are taken from the more general pretreatment standards set forth in 40 CFR Part 128 which are applicable as amended by the specific pretreatment standards for each point source category.

NPDES permits also impose special conditions beyond the effluent limitations stipulated, such as schedules of compliance and treatment standards. Once refineries are constructed in conformance with all applicable standards of performance, however, they are relieved by Section 306(d) of P.L. 92-500 from meeting any more stringent standards of performance for 10 years or during the period of depreciation or amortization, whichever ends first. This guarantee does not extend to toxic standards adopted under Section 207(a), which can be added to the refinery's NPDES permit when they are promulgated.

Many States have qualified, as permitted by Public Law 92-500, to administer their own NPDES permit programs. The major difference in obtaining an NPDES

permit through approved State programs vis-a-vis the Federal NPDES permit system is that the FWPCA Amendments of 1972 do not extend the NEPA environmental impact review requirements to State programs. As of April 1976, however, 26 States had enacted NEPA-type legislation and others plan to do so. Thus it is likely that new refineries or major expansions of existing refineries will come under increased environmental review in the future. Because the scope of the implementing regulations varies considerably, current information on prevailing requirements should be obtained early in the planning process from permitting authorities in the appropriate jurisdiction.

#### I.F.2 Air Pollution Performance Standards

Air pollution regulations specify both the amount of various pollutants that can be emitted from a source and standards for pollution of ambient air. The paragraphs which follow discuss these regulations.

New source performance standards (NSPS) applicable to several sources of air pollution from petroleum refineries are promulgated in 40 CFR 60, subpart J and K. Subpart J imposes emission limitations on fluid catalytic cracking unit catalyst regenerators, fuel gas combustion devices, and all Claus sulfur recovery plants (except recovery plants of 20 long tons per day or less) associated with a small refinery. Subpart J regulates the storage of petroleum, condensate, and finished or intermediate products (with the exception of most fuel oils) in order to control hydrocarbon emissions.

The storage NSPS only apply to storage vessels of greater than 151,412 liters (40,000 gal.) except:

- Pressure vessels designed to operate in excess of 6.8kg (15 lb) per  $\text{cm}^2$  ( $\text{in}^2$ ) gauge without emissions except under emergency conditions;
- Subsurface caverns or reservoirs; or
- Underground tanks if the total volume added to and taken from a tank annually does not exceed twice the volume of the tank.

In contrast to other NSPS, the standards for storage vessels do not place specific limitations on hydrocarbon emissions, and instead require the installation and use of specified equipment. A floating roof, vapor recovery system, or equivalent is required for storage vessels when the true vapor pressure of the liquid stored is equal to or greater than 78 mm Hg (1.5 psia) but not greater than 570 mm Hg (11.1 psia). A vapor recovery system or equivalent is required when the vapor pressure exceeds the latter value. Some gasolines and gasoline feedstocks, for example, would fall in this category. The applicant should not that any device capable of providing comparable hydrocarbon emission control that may be substituted for the specified device. These regulations currently are undergoing review to determine whether or not revisions are needed.

The sulfur dioxide NSPS for fuel gas combustion systems in refineries limits  $\text{SO}_2$  emissions to the atmosphere by specifying that the fuel gas combusted shall contain no more than 230 milligrams per dry standard cubic meter (mg/dscm) (0.10 grain per dry standard cubic foot) (gr/dscf) of hydrogen sulfide. Compliance with the standard also will be permitted by effectively removing  $\text{SO}_2$  from the stack gases instead of removing  $\text{H}_2\text{S}$  from the fuel gas. Fuel gas is defined as any gas produced by a process unit and combusted except process upset gas.

SO<sub>2</sub> standards applicable to Claus sulfur recovery plants, which process gases produced within a petroleum refinery regardless of whether the plant is physically located within the refinery, are as follows:

- 0.025% by volume of sulfur dioxide at 0% oxygen on a dry basis if emissions are controlled by an oxidation control system, or a reduction control system followed by incineration; or
- 0.030% by volume of reduced sulfur compounds and 0.0010% by volume of hydrogen sulfide calculated as sulfur dioxide at 0% oxygen on a dry basis if emissions are controlled by a reduction control system not followed by incineration.

Particulate matter emitted from fluid catalytic cracking unit catalyst regenerators is limited to 1.0 kilogram (kg)/1000 kg (1.0 lb/1000 lb) of coke burnoff. When the gases from the regenerator pass through an incinerator or waste heat boiler in which oil or coal is burned as an auxiliary fuel, this limitation may be exceeded except that the incremental rate of emissions may not exceed 43.0 gram (g)/MS (0.10 lb/million Btu) of heat input attributable to the auxiliary fuel.

The opacity of catalyst regenerator gases is limited to less than 30% except for six minutes in any one hour or when greater opacity is due to the presence of uncombined water. The opacity standard is a backup means to ensure that control equipment always is maintained and operated properly. The NSPS limit on the CO content of the regenerator emission is 0.050% by volume.

Screening studies preliminary to establishing NSPS are being completed on vacuum distillation and other miscellaneous sources (e.g., leaks) in refineries. Projections on future NSPS action on these sources currently are not available.

The above NSPS for air applicable to new source refineries have undergone several revisions, which indicates that these regulations are far from static. Applicants, therefore, should determine the most recent status of the various air regulations, early in the planning process.

Applicants also should be current on the status of national emission standards for hazardous air pollutants (NESHAP) promulgated under Section 112 of the Clean Air Act. To date only five materials have been declared as hazardous pollutants: asbestos, beryllium, mercury, polyvinyl chloride, and benzene. EPA is examining other substances for possible inclusion in this classification. Also, although present standards only apply to specific processes which generate concentrated emissions of these pollutants, EPA is emphasizing control of trace toxic emissions.

The effects of the national ambient air quality standards (NAAQS) on construction or expansion of refinery capacity also should be ascertained. Although standards of this type are nonenforceable goals for acceptable air quality, they may exert a strong influence on the siting of new facilities. The primary and secondary standards designed to protect public health and welfare respectively are shown in Table 9. NAAQS for sulfur dioxide and particulates assume an especial importance in both pristine areas where the air quality is cleaner than the levels of these standards and in areas where the standards are being exceeded.

In 1974, the Environmental Protection Agency (EPA) issued regulations for the prevention of significant deterioration of air quality (PDS) under the 1970 version of the Clean Air Act (Public Law 90-604). These regulations established a plan for protecting areas that possess air quality which is

Table 9 Applicable Federal ambient air quality standards \*\*

Emission	Standard*	
	Primary	Secondary
Sulfur dioxide	80 $\mu\text{g}/\text{m}^3$ annual arithmetic mean	1,300 $\mu\text{g}/\text{m}^3$ maximum 3-hour concentration
	365 $\mu\text{g}/\text{m}^3$ maximum 24-hour concentration	
Particulate matter	75 $\mu\text{g}/\text{m}^3$ annual geometric mean	150 $\mu\text{g}/\text{m}^3$ maximum 24-hour concentration
	260 $\mu\text{g}/\text{m}^3$ maximum 24-hour concentration	60 $\mu\text{g}/\text{m}^3$ annual geometric mean as guide in assessing implementation plants
Nitrogen dioxide**	100 $\mu\text{g}/\text{m}^3$ annual arithmetic mean	100 $\mu\text{g}/\text{m}^3$ annual arithmetic mean
Photochemical oxidants	160 $\mu\text{g}/\text{m}^3$ (0.08 ppm) maximum 1-hour concentration	160 $\mu\text{g}/\text{m}^3$ (0.08 ppm) maximum 1-hour concentration
Carbon monoxide	10 $\text{mg}/\text{m}^3$ (9 ppm) maximum 8-hour concentration	10 $\text{mg}/\text{m}^3$ (9 ppm) maximum 8-hour concentration
	40 $\text{mg}/\text{m}^3$ (35 ppm) maximum 1-hour concentration	40 $\text{mg}/\text{m}^3$ (35 ppm) maximum 1-hour concentration

\*For any standard other than annual, the maximum allowable concentration may be exceeded for the prescribed period once each year.

\*\*Within one year after the date of the enactment of the Clean Air Act Amendments of 1977 (PL 95-95), the US-EPA Administrator shall promulgate a national primary ambient air quality standard for  $\text{NO}_2$  concentrations over a period of not more than 3 hours unless, based on the criteria issued under Section 108(c), he finds that there is no significant evidence that such a standard for such a period is requisite to protect public health.

cleaner than the National Ambient Air Quality Standards (NAAQS). Under EPA's regulatory plan, clean air areas of the Nation could be designated as one of three "Classes." The plan permitted specified numerical "increments" of air pollution increases from major stationary sources for each class, up to a level considered to be "significant" for that area. Class I provided extraordinary protection for air quality deterioration and permitted only minor increases in air pollution levels. Under this concept, virtually any increase in air pollution in the above pristine areas would be considered significant. Class II increments permitted increases in air pollution levels such as would usually accompany well-controlled growth. Class III increments permitted increases in air pollution levels up to the NAAQS.

Sections 160-169 were added to the Act by the Clean Air Act Amendments of 1977. These amendments adopt the basic concept of the above administratively developed procedure of allowing incremental increases in air pollutants by class. Through these amendments, Congress also provided a mechanism to apply a practical adverse impact test which did not exist in the EPA regulations.

The PSD requirements of 1974 applied only to two pollutants: total suspended particulates (TSP) and sulfur dioxide (SO<sub>2</sub>) (See Table 10 ). However, Section 166 requires EPA to promulgate PSD regulations by 7 August 1980 addressing nitrogen oxides, hydrocarbons, carbon monoxide, and photochemical oxidants utilizing increments or other effective control strategies. For these additional pollutants, States may adopt non-increment control strategies which, if taken as a whole, accomplish the purposes of PSD policy set forth in Section 160.

Whereas the earlier EPA regulatory process had not resulted in the Class I designation of any Federal lands, the 1977 Amendments designated certain

Table 10. Nondeterioration increments for particulate matter  
and for SO<sub>2</sub> by area air quality classifications

Pollutant*	Class I ( $\mu\text{g}/\text{m}^3$ )	Class II ( $\mu\text{g}/\text{m}^3$ )	Class III ( $\mu\text{g}/\text{m}^3$ )	Class I' increment ( $\mu\text{g}/\text{m}^3$ )
Particulate matter:				
Annual geometric mean	5	19	37	19
24-hour maximum	10	37	75	37
Sulfur dioxide:				
Annual arithmetic mean	2	20	40	20
24-hour maximum	5**	91	182	91
3-hour maximum	25**	512	700	325

\*Other pollutants for which PSD regulations will be promulgated are to include hydrocarbons, carbon monoxide, photochemical oxidants, and nitrogen oxides.

\*\*A variance may be allowed to exceed each of these increments on 18 days per year, subject to limiting 24-hour increments of  $36 \mu\text{g}/\text{m}^3$  for low terrain and  $62 \mu\text{g}/\text{m}^3$  for high terrain and 3-hour increments of  $130 \mu\text{g}/\text{m}^3$  for low terrain and  $221 \mu\text{g}/\text{m}^3$  for high terrain. To obtain such a variance both State and Federal approval is required.

Source: Public Law 95-95. 1977. Clean Air Act Amendments of 1977, Part C, Subpart 1, Section 163 (Passed August 1977).



Federal lands Class I. All international parks, national memorial parks and national parks exceeding 6,000 acres, are designated Class I. These 158 areas may not be redesignated to another class through State or administrative action. The remaining areas of the county are initially designated Class II. Within this Class II category, certain national primitive areas, national wild and scenic rivers, national wildlife refuges, national seashores and lakeshores, and new national park and wilderness areas which are established after 7 August 1977, if over 10,000 acres in size are Class II "floor areas" and are ineligible for redesignation to Class III.

Although the earlier EPA regulatory process allowed redesignation by the Federal land manager, the 1977 amendments place the general redesignation responsibility with the States. The Federal land manager only has an advisory role in the redesignation process, and may recommend redesignation to the appropriate State or to Congress.

In order for Congress to redesignate areas, proposed legislation would be introduced. Once proposed, this would probably follow the normal legislative process of committee hearings, floor debate, and action. In order for a State to redesignate areas, the detailed process outlined in Section 164(b) would be followed. This would include an analysis of the health, environmental, economic, social, and energy effects of the proposed redesignation to be followed by a public hearing.

Class I status provides protection to areas by requiring any new major emitting facility (generally a large point source of air pollution--see Section 169(1) for definition) in the vicinity to be built in such a way and place as to insure no adverse impact on the Class I air quality related values.

The permit may be issued if the Class I increment will not be exceeded, unless the Federal land manager demonstrates to the satisfaction of the State that the facility will have an adverse impact on the Class I air quality related values.

The permit must be denied if the Class I increment will be exceeded, unless the applicant receives certification from the Federal land manager that the facility will not adversely affect Class I air quality related values.

The permit may be issued even though the Class I increment will be exceeded (Up to the Class I' increment -- see table 10).

### I.F.3 Land Disposal of Wastes

The disposal of hazardous and non-hazardous wastes on land will be regulated under the Federal Resource Conservation and Recovery Act of 1976 (RCRA) (P.L. 94-580), either by EPA or by a State with an approved state program. EPA is in the process of drafting regulations to implement the various provisions of the Act, including guidelines and minimum requirements for state programs.

Disposal of non-hazardous wastes on land will require the use of sanitary landfills because disposal sites classified as open dumps are prohibited. A site can be classified as a sanitary landfill only if disposal of wastes at the site would pose no reasonable probability of adverse effects on health or the environment.

Criteria for classifying sites were proposed by EPA in the Federal Register on 6 February 1978. Before designing an on-site disposal area for non-hazardous wastes or contracting with another party for disposal, all applicants should ascertain that status of the criteria and be guided by the

minimum standards imposed. Applicants also should keep in mind that states are free to establish more stringent state or site-specific (situational) standards or criteria and should determine the location, design, construction, operation, maintenance, and performance standards currently applicable to specific sites.

Disposal of wastes deemed to be hazardous under Subtitle C of RCRA will be a much more complex procedure for refinery operators. A number of refining wastes will qualify as hazardous as discussed in Section II-D and will be subject to standards applicable to generators, transportors, treators, storers, and disposers of hazardous wastes.

As a future generator of hazardous wastes -- API separator and other sludges, leaded tank bottoms, and slop oil emulsion among many others -- the applicant will be required to notify EPA of the location and general description of any proposed hazardous waste-generating activities and indicate those wastes identified by EPA to be hazardous.

Hazardous waste standards which apply to generators (to be promulgated soon) will further require the applicant-generator to:

- Maintain records that identify the quantities of hazardous wastes generated, the constituents which are significant in quantity or in potential harm to human health or the environment, and the disposition of such wastes;
- Label containers used for the storage, transport, or disposal of hazardous waste in a manner which will accurately identify the waste;
- Use appropriate containers;

- Furnish information on the general chemical composition of the waste to persons transporting, treating, storing, and disposing of such wastes;
- Use of manifest system to ensure that all hazardous waste generated is designated for treatment, storage, or disposal facilities (other than on-site facilities) for which a permit has been issued.

The applicant also may qualify as a transporter, treater, storer, or disposer of hazardous wastes depending upon the practices in which he plans to engage and then may become subject to the standards established for those activities. They will be similar to, or a follow-up to, the generator standards. To determine which standards are applicable to his operations, the applicant should understand that EPA considers incineration to be a treatment process rather than a disposal practice.

It also is important to be aware that disposal of hazardous wastes on-site requires a permit under Section 3005 of RCRA. To obtain such a permit, the disposal site must conform to the standards applicable to public or commercial sites, required by Section 3004 of RCRA. Draft regulations (published in Federal Register on 1 February 1978) indicate that it is very unlikely that EPA will approve any state program that does not require a permit or license.

Because none of the regulations to implement RCRA have been promulgated, the permit applicant should determine their status and applicability early in the planning stages.

## II. IMPACT IDENTIFICATION

A variety of impacts may result from waste streams generated by typical petroleum refinery operations. These process operations were described in some detail in Section I.B and I.C. The sections that follow outline the major waste streams (water, air, solid waste), pollutant sources, pollutant loads and the potential environmental impacts that should be addressed in the EIA for a new source oil refinery.

### II.A. PROCESS WASTES (EFFLUENTS)

In general refineries are substantial dischargers of wastewaters. Further, these wastewaters generally have high concentrations of tars, oils and dissolved organics. Frequently a large fraction of the dissolved organics are not readily biodegradable. Spent catalysts, containing large amounts of heavy metals may create serious problems for waste treatment systems and the environment. A substantial number of chemicals which may be found in refinery effluents such as styrene, benzene, anthracene and phenol are believed to be toxic. Therefore, it is necessary for the permit applicant to include factual data for at least the following:

- All effluent streams (sources, quantities, flow composition)
- Frequency and duration of wasteflows and variations in composition
- Potential toxic chemicals
- Biological/chemical characteristics of all receiving waters and their use patterns

#### II.A.1. Sources and Quantities of Process-Related Wastes

The permit applicant should identify all sources of process wastes, preferably

by means of a schematic or flow diagram. The checklist that follows indicates the major process operations and the associated wastewater streams that should receive a careful, systematic analysis in the EIA.

- Crude Desalting
  - Desalter wastewater
- Crude Oil Fractionation
  - Wastewater from overhead accumulators
  - Oil sampling lines
  - Barometric condensers
- Cracking
  - Overhead accumulator wastewater (thermal cracking)
  - Wastewaters from steam strippers and overhead accumulators on fractionators (catalytic)
- Hydrocarbon Rebuilding
  - Wastewater from polymerization process
  - Alkylation wastewater streams resulting from the neutralization of hydrocarbon streams leaving the sulfuric acid alkylation reactor
  - Wastewater from overhead accumulator
  - Wastewaters from hydrofluoric acid alkylation rerun-unit
- Hydrocarbon Rearrangements
  - Wastewater from overhead accumulator
- Solvent Refining
  - Fractionation tower bottoms
- Hydrotreating
  - Wastewater from hydrotreatment unit

- Grease Manufacturing
  - Wastewater from grease manufacturing unit
- Asphalt Production
  - Wastewater from asphalt-blowing operations
- Product Finishing
  - Wastewater from drying and sweetening ( $H_2S$  removal) process
  - Lubricating oil finishing wastes (acid-bearing wastes, rinse waters, sludges and discharges resulting from acid treatment of lubricating oils)
  - Wastewaters from blending and finishing operations
  - Washing of railroad tank cars or tankers prior to loading
  - Tetraethyl and tetramethyl lead additives. These anti-knock compounds are extremely toxic and can gain entrance to wastewaters via two avenues: (1) TEL and TML are separated from other compounds by a steam distillation and purification process. Water is then contaminated by the condensing steam; (2) TEL and TML are present in tank bottom sludges and contaminate waters through washings and other maintenance.
- Auxiliary Activities
  - Process wastes from hydrogen manufacture
  - Utilities functions (steam and cooling water systems)
  - Blowdowns from closed-loop recirculating systems

Table 11 presents a qualitative matrix showing the relative contributions of pollutants from various refinery operations.

Table 11. Qualitative evaluation of wastewater flow  
and characteristics by fundamental refinery processes

Fundamental Processes	Flow	BOD	COD	Phenol	Sulfide	Oil	Emulsified Oil	pH	Temp.	Ammonia	Chlorides	Acidity	Alkalinity	Susp. Solids
Crude Oil and Product Storage	XX	X	XXX	--	--	XXX	XX	0	0	0		0		XX
Crude Oil Desalting	XX	XX	XX	X	XXX	X	XXX	X	XXX	XX	XXX	0	X	XXX
Crude Oil Distillation	XXX	X	X	XX	XXX	XX	XXX	X	XX	XXX	X	0	X	X
Thermal Cracking	X	X	X	X	X	X	--	XX	XX	X	X	0	XX	X
Catalytic Cracking	XXX	XX	XX	XXX	XXX	X	X	XXX	XX	XXX	X	0	XXX	X
Hydrocracking	X	--	--	--	XX	--	--	--	XX	--	--	--	--	--
Reforming	X	0	0	X	X	X	0	0	X	X	0	0	0	0
Polymerization	X	X	X	0	X	X	0	X	X	X	X	X	0	X
Alkylation	XX	X	X	0	XX	X	0	XX	X	X	XX	XX	0	XX
Isomerization	X	--	--	--	--	--	--	--	--	--	--	--	--	--
Solvent Refining	X	--	X	X	0	--	X	X	0	--		0	X	--
Dewaxing	X	XXX	XXX	X	0	X	0	--	--	--	--	--	--	--
Hydrotreating	X	X	X	--	XX		0	XX	--	0	0	0	X	0
Drying and Sweetening	XXX	XXX	X	XX	0	0	X	XX	0	X	0	X	X	XX

#### Legend

XXX - Major contribution  
XX - Moderate contribution  
X - Minor contribution  
0 - No Problem  
-- - No data

Source: US-DOI. 1967. The cost of clean water. Volume III, Industrial Waste Profile No. 5: Petroleum Refining.  
FWPCA Publication No. I.W.P.-5. Available from US-GPO. Washington, DC.



The estimated wastewater pollutant loadings and volumes per unit for the major refinery processes are present in Table 12. Also the table makes a distinction between process technologies (old, typical, new) and the waste loads that can be expected from each.

#### II.A.2. Sources and Quantities of Wastewater from Transportation Activities

One of the most unpredictable sources of wastewaters from oil refineries are those associated with the transportation of feedstock and product to and from refineries. Although some of the discharges are associated with the accidental spillage from transport lines and tanker washings, the major concern is associated with tanker accidents and the spillage from a major tanker breakup.

The applicant must consider several key factors to predict the occurrence of and impact from tanker accidents. These include:

- Characteristics of the waterways to and from the unloading location (e.g., narrow passageways with frequent fog and inclement weather conditions, high tides and severe wave action will necessarily have a higher incidence of accidents)
- Nature of the navigational controls and guides available in harbors and passages
- The sophistication and availability of cleanup equipment
- Environmental sensitivity and value of ecosystems within the transport corridor
- Historical record of occurrences of tanker accidents under similar conditions

To assess adequately the potential impacts from an accidental oil spill, one approach could be to develop and evaluate a range of scenarios involving

Table 12. Estimated waste loadings and volumes per unit of fundamental process throughput for older, typical, and newer process technologies

Fundamental Process	Older Technology				Typical Technology				Newer Technology			
	Flow (gal/bbl)	BOD (lb/bbl)	Phenol (lb/bbl)	Mercaptans &Sulfides (lb/bbl)	Flow (gal/bbl)	BOD (lb/bbl)	Phenol (lb/bbl)	Mercaptans &Sulfides (lb/bbl)	Flow (gal/bbl)	BOD (lb/bbl)	Phenol (lb/bbl)	Mercaptans &Sulfides (lb/bbl)
Crude Oil and Product Storage	4	0.001	-	-	4	0.001	-	-	4	0.001	-	-
Crude Desalting	2	0.002	0.20	0.002	2	0.002	0.10	0.002	2	0.002	0.05	0.002
Crude Fractionation	100	0.020	3.0	0.001	50	0.0002	1.0	0.001	10	0.0002	1.0	0.001
Thermal Cracking	66	0.001	7.0	0.002	2	0.001	0.2	0.001	1.5	0.001	0.2	0.001
Catalytic Cracking	85	0.062	50.0	0.03	30	0.010	20	0.003	5	0.010	5	0.003
Hydrocracking	not in this technology				not in this technology				5	-	-	-
Reforming	9	tr	0.7	tr	6	tr	0.7	0.001	6	tr	0.7	0.001
Polymerization	300	0.003	1.4	0.22	140	0.003	0.4	0.010	not in this technology			
Alkylation	173	0.001	0.1	0.005	60	0.001	0.1	0.010	20	0.001	0.1	0.020
Isomerization	not in this technology				not in this technology				-	-	-	-
Solvent Refining	8	-	3	tr	8	-	3	tr	8	-	3	tr
Dewaxing	247	0.52	2	tr	23	0.50	1.5	tr	20	0.25	1.5	tr
Hydrotreating	1	0.002	0.6	0.007	1	0.002	0.01	0.002	8	0.002	0.01	0.002
Deasphalting	-	-	-	-	-	-	-	-	-	-	-	-
Drying and Sweetening	100	0.10	10	-	40	0.05	10	-	40	0.05	10	-
Wax Finishing	-	-	-	-	-	-	-	-	-	-	-	-
Grease Manufacture	-	-	-	-	-	-	-	-	-	-	-	-
Lube Oil Finishing	-	-	-	-	-	-	-	-	-	-	-	-
Hydrogen Manufacture	not in this technology				not in this technology				-	-	-	-
Blending and Packaging	-	-	-	-	-	-	-	-	-	-	-	-

- Data not available for reasonable estimate.  
tr = trace

Source: US-DOE. 1967. The cost of clean water. Volume III, Industrial Waste Profile No. 5: Petroleum Refining. FWPCA Publication No. I.W.P.-5.  
Available from US-GPO, Washington, DC.

potential tanker accidents of various magnitudes in high probability areas. From this, a projection of ecological consequences could be made for purposes of inclusion in the EIA. Table 13 presents a generalized summary of the types and magnitude of tanker accidents throughout the world. It gives an indication of the types and sizes of accidents that historically have been most frequent and significant.

## II.B. PROCESS WASTES (AIR EMISSIONS)

Sources of air emissions and air pollutants differ considerably among refineries which largely is a function of:

- Size of refinery
- Type of crude oil feedstock
- Product mix (which dictates the type and complexity of processes employed)
- Pollution control measures

Because of the wide variations possible in the above factors, new refineries normally must be assessed on an individual basis. There are, however, certain types of emissions which must be addressed in an emission assessment of any refinery, and there are certain major sources of emissions which must be evaluated if they are part of the refinery's process scheme.

Specifically the EIA should identify, describe (quantitatively), and evaluate all such refinery air emissions. Interim heat releases, start-up, shut-down, safety valve releases, leaks and any other potential sources of emissions should be documented in the EIA. Major sources of air waste streams from a petroleum refinery include:

Table 13. Types and magnitude of tanker casualties worldwide.

<u>Type of Casualty</u>	<u>Percent of Polluting Incidents</u>	<u>Percent of Pollution Resulting</u>
Structural Failures	19	49
Groundings	26	29
Collisions	31	8
Explosions	6	8
Rammings	8	1
Fires	7	1
Breakdowns and Other	2	4

<u>Range-Barrels</u>	<u>Percent of Incidents</u>	<u>Percent of Total Oil Released</u>
1 to 1,000	63.47	5.75
1,001 to 3,500	22.37	11.29
3,501 to 20,000	10.05	16.07
20,001 to 100,000	3.65	37.74
> 100,000	0.46	39.15

Source: US-EPA. 1975. Environmental impact assessment guidelines for selected new source industries. Office of Federal Activities, Washington, DC.

- Storage tanks
- Catalyst regeneration units
- Pipeline valves and flanges
- Pressure relief valves
- Pumps and compressors
- Compressor engines
- Acid treating
- Wastewater separators and process drains
- Cooling towers
- Loading facilities
- Blowdown systems
- Pipeline blind-flange changing
- Boilers and process heaters
- Vacuum jets
- Sampling
- Air blowing

The principal types of air pollutants from various emission sources are shown in Table 14.

#### II.C. PROCESS WASTES (SOLID WASTES)

Typical solid wastes generated at a refinery include process sludges, spent catalysts, waste materials and various sediments. The applicant should identify all solid waste streams and provide a flow diagram which quantitatively and qualitatively describes their characteristics.

Refinery solids wastes are grouped into three general categories:

- Process solids
- Effluent treatment solids
- General wastes (scrap materials, etc.)

Table 15 presents sources, descriptions, and characteristics of various categories of solid wastes generated from refinery operations. Table 16 lists the range of factors that can affect the composition and quantity of solid waste streams. Such factors should be considered by a new source applicant

Table 14. Major air pollutants emitted from various refinery sources.

<u>Pollutant</u>	
Oxides of Sulfur	Boilers, process heaters, catalytic cracking unit regenerators, treating units, H <sub>2</sub> S flares, decoking operations
Hydrocarbons	Loading facilities, turnarounds, sampling, storage tanks, wastewater separators, blow-down systems, catalyst regenerators, pumps, valves, blind changing, cooling towers, vacuum jets, barometric condensers, air-blowing, high pressure equipment handling volatile hydrocarbons, process heaters, boilers, compressor engines
Oxides of Nitrogen	Process heaters, boilers, compressor engines, catalyst regenerators, flares
Particulate Matter	Catalyst regenerators, boilers, process heaters, decoking operations, incinerators
Aldehydes	Catalyst regenerators
Ammonia	Catalyst regenerators
Odors	Treating units (air-blowing, steam-blowing), drains, tanks vents, barometric condenser sumps, wastewater separators
Carbon Monoxide	Catalyst regeneration, decoking, compressor engines, incinerators

Source: US-DHEW. 1960. Atmospheric emissions from petroleum refineries. Public Health Service Publication No. 763, Washington, DC.

Table 15. Categorization of representative solid wastes from various petroleum refining sources.

Waste Category	Waste Sources	Waste Description	Waste Characteristic
Process Solids	Crude oil storage, desalter	Basic sediment and water	Iron rust, iron sulfides, clay, sand, water oil
	Catalytic cracking	Catalyst fines	Inert solids, catalyst particles, carbon
	Coker	Coker fines	Carbon particles, hydrocarbons
	Alkylation	Spent sludges	Calcium flouride, bauxite, aluminum chloride
	Lube oil treatment	Spent clay sludges, press dumps	Clay, acid sludges, oil
	Drying and sweetening	Copper sweetening residues	Copper compounds, sulfides, hydrocarbons
	Storage tanks	Tank bottoms (crude, leaded, non-leaded)	Oil, water, solids
	Slop oil treatment	Precoat vacuum filter sludges	Oil, diatomaceous earth, solids
Effluent Treatment Solids	API separator	Separator sludge	Oil, sand and various process solids
	Chemical treatment	Flocculant aided precipitates	Aluminum or ferric hydroxides, calcium carbonate
	Air flotation	Scums or froth	Oil, solids, flocculants(if used)
	Biological treatment	Waste sludges	Water, biological solids, inerts
General Waste	Water treatment plant	Water treatment sludges	Calcium carbonate, alumina, ferric oxide, silica
	Office	Waste paper	Paper, cardboard
	Cafeteria	Food wastes (garbage)	Putrescible matter, paper
	Shipping and receiving	Packaging materials, strapping pallets, cartons, returned products, cans, drums	Paper, wood, some metal, wire
	Boiler plant	Ashes, dust	Inert solids
	Laboratory	Used samples, bottles, cans	Glass, metals, waste products
	Plant expansion	Construction and demolition	Dirt, building materials, insulation, scrap metal
	Maintenance	General refuse	Insulation, dirt, scrapped materials-valves, hoses, pipe

Source: US-EPA. 1975. Environmental impact assessment guidelines for selected new source industries. Office of Federal Activities, Washington, DC.

Table 16. Factors affecting the composition and quantity of specific solid waste streams.

<u>Solid Waste</u>	<u>Potential Factors</u>
Crude tank bottoms	Type of crude Treatment given to crude prior to storage Slop oil processing method Refinery size Mixing, if any Storage time Degree, if any, of sludge emulsion breaking
Leaded tank bottoms	Type and quantity of chemical additives Plant and tank metallurgy Type of product treatment used Type of processes used in producing gasoline and/or other products Refinery size
Non-leaded tank bottoms	Type and quantity of chemical additives Plant and tank metallurgy Type of product treatment used Type of processes used in producing gasoline and/or other products Refinery size
API separator sludge	Composition and quantity of process wastewater Composition and quantity of spills and leaks Composition and quantities blowdowns Refinery housekeeping Refinery size and age Segregation of refinery sewers
Neutralized HF alkylation sludge	Composition of fresh HF acid Composition of lime Feedstock composition Process operating conditions HF alkylation process metallurgy Size of HF alkylation unit
Spent filter clays	Type and number of clay treatment processes used Type and number of products treated Composition and quantity of products treated Type and amount of clay used Refinery size
Once-through cooling water sludge	Composition and quantity of raw water Cooling system metallurgy Size and nature of process leaks Refinery size and complexity



Table 16. Factors affecting the composition and quantity of specific solid waste streams (continued).

<u>Solid Waste</u>	<u>Potential Factors</u>
DAF float	Same factors as API separator sludge plus: Residence time Amount and time of flocculating chemical used Efficiency of API separator
Slop oil emulsions solids	Composition and quantity of individual oil spills and oil leakage. Composition of wastewater emulsions Nature of emulsion breaking treatment and degree of success Refinery size and complexity Quantity of oil in wastewater and degree of removal
Spent lime from boiler feedwater treatment	Composition of raw water Degree of hardness removed Type of treatment (hot or cold) Refinery size Boiler blowdown rates Percent condensate recovered and returned to boilers
Cooling tower sludge	Make-up water composition Type of chemical treatments employed Metallurgy of cooling water system Nature of contaminants introduced by process leaks Blowdown rate Make-up water rate Quantity of treatment chemicals used
Exchanger bundle cleaning sludge	Composition of shell and tubeside fluids Equipment metallurgy Effectiveness of desalter Refinery size and complexity Effectiveness of corrosion inhibitor systems
Waste bio-sludge	Composition and quantity of wastewater treated Type of biological treatment Efficiency of prior treatment units Operating conditions and practice Dewatering and/or treatment
Stormwater silt	Plant housekeeping Amount of rain Amount of refinery area paved Segregation of surface drainage

Table 16. Factors affecting the composition and quantity of specific solid waste streams (concluded).

<u>Solid Waste</u>	<u>Potential Factors</u>
FCC catalyst fines	Catalyst composition Oil composition Type of process Process operating conditions (temperature, percent conversion, recycle feed rate) Catalyst make-up rate Process metallurgy Oil feed rate Number of cyclones Use of precipitators Use of elutriators
Coke fines	Oil composition Type of process Operating condition (temperature, pressure, time) Process metallurgy Method of coke removal Method of handling and shipping Number of cyclone stages Oil feed rate

Source: US-EPA. 1976. Assessment of hazardous waste practices in the petroleum refining industry. Prepared by Jacobs Engineering Company. NTIS Publication PB-259 097, Washington, DC.

in designing control measures for solid waste generation and disposal.

Many solids may contain significant amounts of leachable heavy metals and organics which could contaminate the environment if not treated and disposed of properly. Therefore, to evaluate the potential impacts from solid wastes, the applicant should provide at least the following information in the EIA:

- Source and quantity of solid wastes generated
- Composition of solid wastes generated (quantitative)
- Composition of possible hazardous leachates from solid wastes (quantitative)
- Proposed measures to handle and dispose of solid wastes and the ecological sensitivity of all proposed deposition areas

To summarize impact sources of a refinery operation, Table 17 presents a consolidation of pollutants by source. Pollutants are listed per 1,000 barrels of crude oil processed. In this manner total emissions and effluents quantities can be approximated (although often the existing data base was unsuitable for projecting certain pollutant levels).

#### II.D. TOXICITY AND POTENTIAL FOR ENVIRONMENTAL DAMAGE FROM SELECTED POLLUTANTS

##### II.D.1. Human Health Impacts

Airborne and waterborne emissions from petroleum refineries may contain substances which could seriously affect human health. Both heavy metals and a variety of complex hydrocarbons are emitted from refinery operations. The following paragraphs describe briefly the major health-related effects of selected pollutants.

Table 17. Summary of pollutant sources and projected pollutant concentrations.

<u>Source of Pollutant</u>	<u>Pollutant Levels kg/1000 bbl.(lbs./1000 bbl.).</u>						
	<u>BOD</u>	<u>COD</u>	<u>Particulates</u>	<u>NOx</u>	<u>SOx</u>	<u>Hydrocarbons</u>	<u>Solids</u>
<u>Transport</u>							
Crude or product	-	-	-	-	-	-	-
Pipeline	-	-	.86(1.9)	24.94(55)	1.81(40)	2.50(5.5)	-
Tankers	-	-	.18(04)	17.27(38)	2.63(5.8)	.09(0.2)	-
Supertankers	-	-	.19(.042)	17.27(38)	2.63(5.8)	.09(0.2)	-
Barges	-	-	15.42(34)	10.90(24)	11.79(26)	7.26(16)	-
Tank Trucks	-	-	3.17(7)	95.26(210)	6.80(15)	9.53(21)	-
Tank Cars	-	-	6.35(14)	19.50(43)	16.78(37)	13.15(29)	-
<u>Processing</u>							
Crude desalting	.45	-	0(0)	0(0)	0(0)	0(0)	0(0)
Crude fractionation	.09(0.2)	2.27(5)	1.04(2.3)	12.25(27)	.045(0.1)	15.42(34)	-
Cracking	6.8(15)	8.16(18)	7.71(17)	46.27(102)	136.08(300)	19.96(44)	21.77(48)
Hydrocarbon rebuilding	5.4(12)	64.41(142)	3.17(7)	50.80(112)	.045(0.1)	34.92(Ti)	-
Hydrocarbon rearrangement	-	18.14(40)	2.27(5)	65.32(144)	.023(0.05)	15.72(34)	-
Solvent refining	-	-	-	-	-	40.82(90)	-
Hydrotreating	43.1(95)	45.36(100)	2.27(5)	22.68(50)	-	54.43(120)	-
Grease manufacturing	-	-	-	-	-	10.43(23)	-
Asphalt production	-	14.51(32)	2.72(6)	31.75(70)	.090(0.2)	15.88(35)	-
<u>Storage</u>							
Crude	.45(1)	-	0	0	0	28.12(62)	-
Product	-	-	-	-	-	9.53(21)	-

Source: US-EPA. 1974. Environmental impacts, efficiency and cost of energy supply and end use. Volume 1  
Final Report. Prepared by Hittman Associates, Washington, DC.

II.D.1.a. Carcinogens. During various refinery operations a worker may be exposed to such suspected carcinogens as arsenic, benzene, cadmium, chromium, cobalt, lead, vanadium, and certain organics. These and other trace metals along with their potential health problems are presented in Table 18; references to detailed research studies also are provided.

II.D.1.b. Sulfur Dioxide, Hydrogen Sulfide, and Mercaptans. The impact of high concentrations of sulfur dioxide and sulfates (especially in the presence of particulates), has been well documented (US-EPA 1970). Normally emissions of sulfur dioxide from petroleum refineries would not produce concentrations that would exceed national ambient air quality standards. However, even SO<sub>2</sub> levels below national ambient air quality standards may produce some adverse impacts upon sensitive receptors. The formation of sulfates at very low concentrations of sulfur dioxide may produce significant eye and respiratory problems (Science Applications, Inc. 1975) as well as damage to vegetation and to certain materials (metal surfaces).

Likewise hydrogen sulfide is strongly irritating to the respiratory organs. At high concentrations (1,000 mg/m<sup>3</sup>), hydrogen sulfide is extremely toxic and may paralyze the brain center that controls respiratory movements (Cavanaugh 1975).

II.D.1.c. Nitrogen Compounds. Nitrogen oxides are pulmonary irritants and may impair the ability of the lungs to clear inhaled infectious organisms. Exposure to nitrogen dioxide also can be corrosive to the mucous lining of the lungs. At high concentrations, it may cause pulmonary edema and even death, while chronic exposure may produce emphysema, polycythemia, and leukocytosis. Further, nitrogen oxides have been shown to contribute to the formation of photochemical smog (US-EPA 1971).

Table 18. Possible health problems associated with trace metals

<u>Metal or metal compounds</u>	<u>Health problems</u>	<u>Reference</u>
Aluminum, arsenic, cadmium, cobalt, copper, iron, lead, and zinc oxides	Enzymatic inference Fume fever	(Waldbott 1973)
Nickel	Nasal cancers	(Potts 1965) (Gilman and Ruckerbauer 1963)
Cadmium	Prostate cancer Enzymatic interference	(Kipling and Waterhouse 1967)
Chromium and compounds	Carcinogenesis	(Hueper 1961)
Arsenic	Cancer of the skin Poisoning	(Wickstrom 1972) (Lee and Fraumeni 1969)
Cobalt	Carcinogenesis	(Gilman and Ruckerbauer 1963)
Lead and compounds	Nasal cancers Kidney damage	(Zawirsica and Medras 1968) (Zollinger 1953)
Mercury and compounds	Mutagenic and teratogenic effects	(D'Itri 1972)
Vanadium	Inhibition of lipid formation; eye and respiratory irritant; carcinogenic	(Stokinger 1963)
Zinc	Gastrointestinal irritation	

II.D.1.d. Hydrocarbons. Apart from their potential carcinogenic activity, hydrocarbons play a vital role in the formation of photochemical smog (US-EPA 1971).

II.B.1.e. Carbon Monoxide. The toxicity of carbon monoxide is associated with its reactions with hemoproteins. Generally one can anticipate that there will be no increase of ambient concentrations of CO beyond national ambient air standards as a result of refinery emissions.

II.D.1.f. Ammonia. Ammonia is a highly irritating gas with a strong, pungent odor. It forms ammonium hydroxide when it comes in contact with the moisture of the throat and bronchi. Ammonium hydroxide is caustic, but it is not a threat to human health. Extremely high concentrations, however, (1,700-4,500 mg/m<sup>3</sup>) can produce pulmonary edema (Waldbott 1973).

II.D.1.g. Trace Metals. Among the possible health problems associated with trace metals are those shown in Table 18. The appropriate references should be reviewed by the permit applicant to ascertain the significance of the impact as associated with trace metal emissions from the proposed petroleum refining facility.

To adequately evaluate potential impacts to human health, the applicant should include at least the following information in the EIA:

- Analysis of crude oil to be used in the refining process
- Projection of emissions of potentially toxic substances (volumes, frequencies, and duration)
- Analysis of sensitive receptors (by use of isopleths or other suitable technique)

- Projection of ground level maximum concentrations of potentially hazardous substances
- Description of proposed measures to avoid or reduce potential adverse effects from toxic materials.

#### II.D.2. Biological Impacts

The biological environment also may be affected by certain pollutants especially heavy metals which are toxic to many terrestrial and aquatic organisms, both complex and simple.

The potential impacts on terrestrial and aquatic biota may be categorized by the following waste streams and pollutants:

- Air pollutants - emissions of heavy metals, sulfur compounds, particulates, and hydrocarbons
- Wastewater discharges - water pollutants such as heavy metals and toxic organics from process wastes, leachate from solid waste residues.
- Solid wastes - stockpiling and disposal of process sludges and other solid wastes (spent catalysts, sediments)

At a minimum the following factors should be described in the EIA to assess adequately the extent and significance of impacts to biological resources:

- Discharges and sinks for specific toxic materials such as heavy metals and organics (include information on volume, duration, and time of discharges)
- Characteristics of the aquatic and terrestrial biota of the impact area (species composition, diversity, abundance, densities, importance values)



- Determination of tolerance or sensitivity thresholds for selected species of plants and animals in the impact area
- Proposed measures to avoid or reduce adverse impacts to biological communities.

## II.E. OTHER IMPACTS

### II.E.1. Raw Materials Extraction and Transportation

The EIA should include examination of the extraction, transportation, and handling of crude oil raw materials as part of the refining impact assessment.

The proposed refinery complex also may include integral support or ancillary facilities as deepwater ports, submerged pipelines, marine terminals, overland pipelines, bulk storage areas, and loading areas.

When appropriate, such facilities should be fully described and analyzed in the EIA.

By way of guidance, the degree of detail given to impact evaluations for these facilities could be directly proportional to the degree to which such facilities are directly owned, operated, or supported by the proposed refinery. In cases where the proposed refinery will construct its own marine facility, or deepwater port, for example, the impact investigation would be tantamount to that for the refinery itself. This would apply to cases where a substantial part of the deepwater port or marine facility would be leased to other industry. If, however, the port facilities are being expanded to meet the new refinery demands by some independent or non-affiliated party, the degree of detail might be different. In short, the permit applicant should consult with EPA officials as to the required information and detail.

Because the impact assessment information developed in this guidance document has focused principally on the oil refinery proper, we refer the applicant to the existing EPA document, Environmental Impact Assessment Guidelines for Selected New Source Industries: Appendix B (US-EPA 1975) for guidance on ancillary facilities and their associated impacts.

#### II.E.2. Site Preparation and Refinery Construction

The environmental effects of site preparation and construction of new oil refinery facilities are common to most major land disturbing activities. Although erosion, dust, noise, vehicular traffic and emissions, and some loss of wildlife habitats are expected, the applicant has a number of mitigative measures available by which adverse impacts can be reduced. At present, however, neither the quantities of the various pollutants resulting from site preparation and construction nor their effects on the integrity of aquatic and terrestrial ecosystems has been studied sufficiently to permit broad generalizations. Therefore in addition to the impact assessment framework provided in the EPA document, Environmental Impact Assessment Guidelines for Selected New Source Industries, a suggested checklist of important study items is presented in Table 19 for further guidance to the applicant. The basic components of site preparation and plant construction outlined in the table include preconstruction, site work, permanent facilities, and ancillary facilities. At this time only potentially significant areas of impact are presented in the checklist, but a system of importance values should be assigned to the checklist items after sufficient quantitative data have been acquired at an individual site or for a region. The permit applicant also should tailor all proposed conservation practices to the specific site(s) being considered in order to account for and to protect certain site-specific

Table 19. Outline of potential environmental impacts and relevant pollutants resulting from site preparation and construction practices.

Construction practice	Potential environmental impacts	Primary pollutants
1. Preconstruction		
a. Site inventory	Short term and nominal	Dust, noise, sediment
(1) Vehicular traffic	Dust, sediment, tree injury	
(2) Test pits	Tree root injury, sediment	
b. Environmental monitoring	Negligible if properly done	Visual
c. Temporary controls	Short term and nominal	Sediment spoil, nutrients, solid waste
(1) Sedimentation ponds	Vegetation destroyed, water quality improved	
(2) Dikes and berms	Vegetation destroyed, water quality improved	
(3) Vegetation	Fertilizers in excess	
(4) Dust control	Negligible if properly done	
2. Site Work		
a. Clearing and demolition	Short term	Dust, sediment, noise solid wastes, wood wastes
(1) Clearing	Decreased area of protective tree, shrub, ground covers; stripping of topsoil; increased soil erosion, sedimentation, stormwater runoff; increased stream water temperatures; modification of stream banks and channels, water quality	
(2) Demolition	Increased dust, noise, solid wastes	
b. Temporary facilities	Long term	Gases, odors, fumes particulates, dust, deicing chemicals, noise, petroleum products, wastewater, solid wastes, aerosols, pesticides
(1) Shops and storage sheds	Increased surface areas impervious to water infiltration, increased water runoff, petroleum products	
(2) Access roads and parking lots	Increased surface areas impervious to water infiltration, increased water runoff, generation of dust on unpaved areas	

(continued on next page)

Table 19. Outline of potential environmental impacts and relevant pollutants resulting from site preparation and construction practices (Continued).

Construction practice	Potential environmental impacts	Primary pollutants
(3) Utility trenches and backfills	Increased visual impacts, soil erosion, sedimentation for short periods	
(4) Sanitary facilities	Increased visual impacts, solid wastes	
(5) Fences	Barriers to animal migration	
(6) Laydown areas	Visual impacts, increased runoff	
(7) Concrete batch plant	Increased visual impacts; disposal of wastewater, increased dust and noise	
(8) Temporary and permanent pest control (termites, weeds, insects)	Nondegradable or slowly degradable pesticides are accumulated by plants and animals, then passed up the food chain to man. Degradable pesticides having short biological half-lives are preferred for use	
c. Earthwork	Long term	Dust, noise, sediment,
(1) Excavation	Stripping, soil stockpiling,	debris, wood wastes,
(2) Grading	and site grading; increased	solid wastes, pesticides,
(3) Trenching	erosion, sedimentation, and	particulates,
(4) Soil treatment	runoff; soil compaction; increased in-soil levels of potentially hazardous materials; side effects on living plants and animals, and the incorporation of decomposition products into food chains, water quality	bituminous products, soil conditioner chemicals
d. Site drainage	Long term	Sediment
(1) Foundation drainage	Decreased volume of underground water for short and long time periods, increased stream flow volumes and velocities, downstream damages, water quality	
(2) Dewatering		
(3) Well points		
(4) Stream channel relocation		
e. Landscaping		Nutrients, pesticides
(1) Temporary seeding	Decreased soil erosion and overland flow of stormwater,	
(2) Permanent seeding and sodding	stabilization of exposed cut and fill slopes, increased water infiltration and underground storage of water, minimized visual impacts	

(continued on next page)

Table 19. Outline of potential environmental impacts and relevant pollutants resulting from site preparation and construction practices (Continued).

Construction practice	Potential environmental impacts	Primary pollutants
3. Permanent facilities		
a. Petroleum refinery and heavy traffic areas	Long term	Sediment, dust, noise, particulates
(1) Parking lots	Stormwater runoff, petroleum products	
(2) Marine terminal	Visual impacts, sediment, runoff	
b. Other buildings	Long term	Solid wastes
(1) Warehouses	Impervious surfaces, stormwater runoff, solid wastes, spillages	
(2) Sanitary waste treatment	Odors, discharges, bacteria, viruses	
c. Possible ancillary facilities	Long term	Sediment, trace elements, noise, caustic chemical wastes, spoil, flocculants, particulates, fumes, solid wastes, nutrients.
(1) Intake and discharge channel	Shoreline changes, bottom topography changes, fish migration, benthic fauna changes	
(2) Water supply and treatment	Waste discharges, water quality	
(3) Stormwater drainage	Sediment, water quality	
(4) Wastewater treatment	Sediment, water quality	
(5) Dams and impoundments	Dredging, shoreline erosion	
(6) Breakwaters, jetties, etc.	Circulation patterns in the waterway	
(7) Fuel handling equipment	Spillages, fire, and visual impacts	
(8) Waste storage areas	Visual impacts, waste discharges	
(9) Overland or underground pipelines, bulk storage areas, loading areas	Sediment runoff and erosion, landscape alteration, waste discharges, visual impacts	
(10) Conveying systems (cranes, hoists, chutes)	Visual impacts	
(11) Cooling lakes and ponds	Conversion of terrestrial and free flowing stream environment to a lake environment (land use trade-offs); hydrological changes, habitat changes, sedimentation, water quality	

(continued on next page)

Table 19. Outline of potential environmental impacts and relevant pollutants resulting from site preparation and construction practices (Concluded).

Construction practice	Potential environmental impacts	Primary pollutants
(12) Solid waste handling equipment (incinerators, trash compactors)	Noise, visual impacts	Particulates, dust, solid wastes
d. Security fencing	Long term	Sediments, wood wastes
(1) Access road	Increased runoff	
(2) Fencing	Barriers to animal movements	

Source: Modified from Hittman Associates, Inc. 1974. General environmental guidelines for evaluating and reporting the effects of nuclear power plant site preparation, plant and transmission facility construction. Modified from: Atomic Industrial Forum, Inc. Washington, DC.

features that warrant special attention (e.g., critical habitats of imperiled species, archaeological/historical sites, high quality streams, wetlands, or other sensitive areas on the site). All mitigating conservation measures which are proposed to avoid or reduce adverse impacts from preparation of the site and construction activities should be described in the EIA.

#### II.F. MODELING OF IMPACTS

The ability to forecast environmental impacts accurately often is improved by the use of mathematical modeling of the dispersion and dissipation of air and water pollutants as well as the effects of storm runoff.

Two of the most widely used and accepted models are:

- DOSAG (and its modifications)
- The QUAL series of models developed by the Texas Water Development Board and modified by Water Resources Engineers, Inc.

Some of the parameters that these models simulate are:

- Dissolved oxygen
- BOD
- Temperature
- pH
- Solids

In addition, there are many available water quality models that were developed in association with NPDES activity and the need for optimization of waste load schemes for an entire river basin.

There also are available mathematical models that may be used for air pollution studies and solid waste management optimization:

- For short term dispersion modeling of point sources, EPA's PTMAX, PTDIS, and PTMTP models may be employed.
- For modeling of long term concentrations over larger areas, the EPA's Climatological Dispersion Model, AQDM and CRSTER, may be used for point and area sources.

In general, the use of mathematical models is indicated when arithmetic calculations are too repetitious or too complex. Their use also simplifies analysis of systems with intricate interaction of variables. Models thus offer a convenient way of describing the behavior of environmental systems, but their use and applicability should be determined on a case by case basis. (For a more detailed discussion of modeling techniques see section II.E., Modeling of Impacts, in Guidelines for the preparation of an environmental impact assessment report for new source fossil-fueled steam electric generating station, US-EPA, to be published in 1978).



### III. POLLUTION CONTROL

#### III.A. STANDARDS OF PERFORMANCE TECHNOLOGY: IN-PROCESS CONTROLS - WATER, AIR, SOLID WASTES

There are a number of pollution control measures which can be taken to effectively reduce refinery waste streams and their associated impacts. Many of these steps also will reduce operation and capital costs and/or increase production. The EIA should contain a discussion of the applicability of these steps to the particular installation. Discussions of pollution control should consider reduction of effluents and emissions at the source (design planning, etc.). Further, reuse and recycling options should be investigated and may include:

- Use of catalytic cracker accumulator wastewaters rich in  $H_2S$  for makeup to crude desalters
- Use of blowdown condensate from high pressure boilers for makeup to low pressure boilers
- Reuse of waters that have been treated for closed cooling systems, fire mains and everyday washing operations
- Stormwater use for routine water applicators
- Blowdown waters from cooling towers for use as water seals on high temperature pumps
- Recirculation of steam condensate
- Recycling of cooling waters

Effective maintenance measures also can reduce waste streams. The applicant should describe all proposed maintenance activities in the EIA. They may include:

- Recovery of oil spills and hydrocarbons with vacuum trucks to reduce emission and water effluents
- Reduction of leaks and accidents through preventive maintenance (pump seals, valve stems, etc.)
- Separation of hazardous wastes, concentrated wastes, and other process wastes from general effluents from more effective treatment
- Diking of process unit areas to control and treat spills, oily stormwater runoff, or periodic washes
- Reduction of shock pollution loads on treatment facilities through the periodic flushing of process sewers of prevent contaminant buildup
- Development of a specialized program for handling hazardous wastes, sludges, washwaters and other effluents
- Development of a system to minimize wastes from monitoring stations
- Improvement of personnel awareness that waste treatment is initiated at the process unit.

Actual process changes often can reduce pollution significantly while returning a value through recovery. Technology changes that reduce pollution may not be as cost-effective during process cycles, but may prove to be highly beneficial when waste treatment costs have been reduced. Depending on the feasibility and suitability of a particular project, such process technology changes may include:

- Catalyst switching to a longlife catalyst with greater activity to reduce regeneration frequency

- Replacement of barometric condensers (direct-contact condensers) with surface condensers (indirect-contact condensers) or air-fin coolers

#### III.A.1. Cooling System

A description of the cooling system is necessary including possible alternatives, i.e., nonevaporative devices. The evaporating cooling systems include spray ponds, mechanical-draft cooling towers, atmospheric cooling towers, and natural-draft cooling towers. Treated wastewater should be considered for makeup purposes. The cooling water blowdown composition is dependent on the composition of the original water used, the operation methods, and cooling water treatment. Chromates, zinc, polyphosphates, dust, microorganisms and other corrosion inhibitors are constituents of the cooling treatment wastewaters. A discussion of alternate treatment methods, process operations and piping materials also should be discussed. Dry cooling systems of air-fins to dissipate the undesired heat directly to the atmosphere should be discussed.

#### III.A.2. In-Process Physical/Chemical Pretreatment

The applicant should discuss the following important pretreatment steps in the EIA:

- Flow equalization neutralization of spent acid and spent caustic wastewaters
- Oil separators and slop oil recovery systems
- Clarifiers to separate sediments using chemical coagulations as needed

### III.B. STANDARDS OF PERFORMANCE TECHNOLOGY: END-OF-PROCESS CONTROL (WATER STREAMS)

Table 6 (page 41) identifies and estimates the various wastewater treatment processes used by petroleum refineries. It illustrates the impact of the recent environmental considerations on the increased usage of wastewater pollution control devices.

Depending on refinery location, refinery plant size, the refining process (degree of crude finishing), and wastewater characteristics, the wastewater treatment facilities are designed based on the processes in Table 6. Table 12 (presented earlier in Section II.A.) shows wastewater characteristics and quantities for the various petroleum unit operation.

The EIA should demonstrate that the applicant has given adequate attention to implementation of new technology for abatement of water pollution. The EIA should include an understandable, but complete description of the proposed wastewater treatment system. A process flow diagram also should be provided to illustrate each step of treatment scheme. Generally most refineries use the following basis treatment approach:

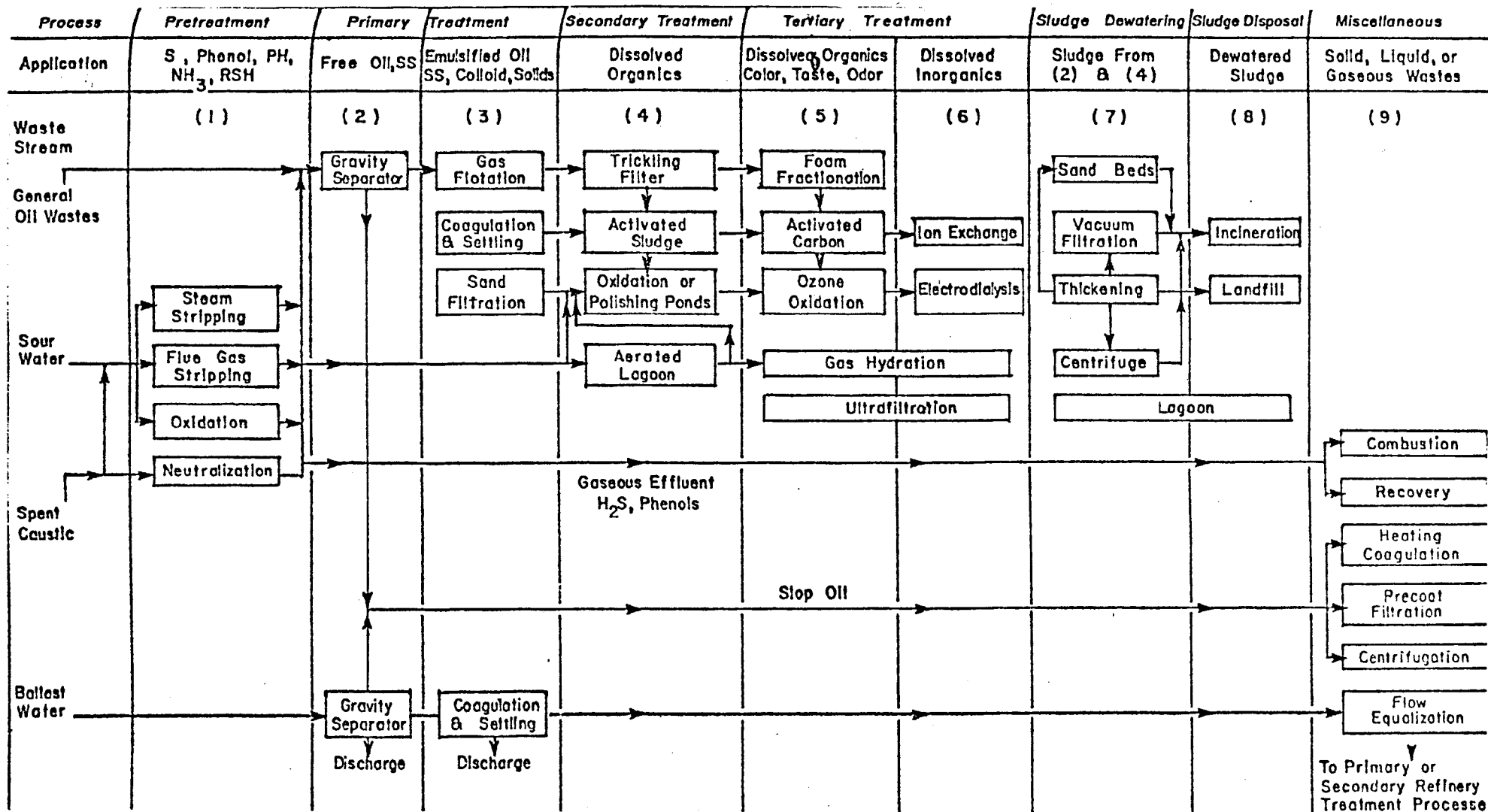
- Pretreatment to remove phenols, sulfides, mercaptans, ammonia and adjust ph (processes utilized are steam stripping, flue gas stripping, oxidation and neutralization)
- Removal of free oil and suspended solids by gravity
- Removal of emulsified oil, suspended solids, colloids and solids by coagulation and settling, sand filtration and gas flotation
- Biological treatment to remove dissolved organics

- Tertiary treatment to remove dissolved organics and inorganics color, odor and taste with foam fractionation, activated carbon, ion exchange, electrodialysis or ultrafiltration
- Disposal of high organic containing liquids or solids by combustion (incineration)
- Sludge arising from biological systems and solids separation processes are dewatered with the use of sand filtration, vacuum filtration or centrifugation; sludge is then disposed of by landfill or incineration

Figure 7 shows the diverse combinations of waste treatment processes that can be used to treat refinery wastewater streams. In addition, Table 20 estimates efficiencies of the various treatment practices on refinery effluent streams. By viewing Figure 7 and Table 20 collectively, one can obtain a first order estimation of treatment efficiency for a particular oil refining facility.

To determine the optimum wastewater treatment system, there are a number of key factors which should be considered. Specifically, the applicant should demonstrate in the EIA, the analysis and selection method(s) used to arrive at the proposed wastewater treatment design. At least the following information should be presented:

- Systematic consideration and analysis of all alternative wastewater treatment approaches
- Waste loadings from various process systems
- Efficiency of alternative waste treatment sequences (system's reliability and susceptibility to upset)
- Energy and material demands of various treatment systems
- Margin for system expansion



Source: US-DOI. 1967. The cost of clean water. Volume III, Industrial Waste Profile No. 5: Petroleum Refining. FWPCA Publication No. I.W.P.-5. Available from US-GPO, Washington, DC.

Figure 7. Sequence/substitute diagram of various wastewater treatment systems.

Table 20. Efficiency of oil refinery waste treatment practices based on effluent quality

	Process Influent <sup>a</sup>	BOD	COD	Separable Oil	Emul- sified Oil	Phenol	Sulfide S	Sus- pended Solids	Chloride	Ammonia	Cyanide	pH	Toxicity	Temp. (°F)
<b>Physical Treatment</b>														
API separators	Raw waste	5-35 <sup>b</sup>	5-30 <sup>b</sup>	60-99	n.a.	Reduced	n.a.	10-50	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Earthern separators	Raw waste	5-50	5-40	50-99	n.a.	Reduced	n.a.	10-85	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Evaporation	API effluent	100	100	n.a.	100	100	100	100	100	100	100	n.a.	n.a.	n.a.
Air flotation without chemicals	API effluent	5-25	5-20	70-95	10-40	n.a.	10-40 Reduced	n.a. 10-40	n.a. n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
<b>Chemical Treatment</b>														
Air flotation with chemicals	API effluent	10-60	10-50	75-95	50-90	n.a.	Reduced	50-90	n.a.	Reduced	n.a.	n.a.	n.a.	n.a.
Chemical coagulation and precipitation	API effluent	10-70	10-50	60-95	50-90	n.a.	n.a.	50-90	n.a.	n.a.	n.a.	Altered	n.a.	n.a.
<b>Biological Treatment</b>														
Activated sludge	API effluent	70-95	30-70	n.a.	50-80	65-99	90-99	60-85	n.a.	50-95	65-99	Altered	Reduced	10-60
Aerated lagoons	API effluent	50-90	25-60	n.a.	50-80	65-99	90-99	0-40	n.a.	0-45	65-99	Altered	Reduced	10-90
Trickling filters	API effluent	50-90	25-60	n.a.	50-80	65-99	80-99	60-85	n.a.	50-99	65-99	Altered	Reduced	10-60
Oxidation ponds	API effluent	40-80	20-50	n.a.	40-70	65-99	70-90	20-70	n.a.	20-90	65-99	Altered	Reduced	10-90
Activated carbon	Secondary <sup>c</sup> effluent	50-90	50-90	n.a.	50-90	80-99	80-99	n.a.	n.a.	10-30	80-99	n.a.	Reduced	n.a.
Ozonation	Secondary effluent	50-90	50-90	n.a.		80-99	80-99	n.a.	n.a.	10-30	80-99	n.a.	Reduced	n.a.

<sup>a</sup>Most probable process influent-indicates the kind or extent of prior treatment required for efficient utilization of the specific process under consideration.

<sup>b</sup>BOD and COD from separable oil not included.

<sup>c</sup>Chemical or biological treatment.

LEGEND: API = American Petroleum Institute, n.a. = Not Applicable

Source: US-DOI. 1967. The cost of clean water. Volume III, Industrial Waste Profile No. 5: Petroleum Refining. FWPCA Publication No. I.W.P.-5. Available from US-GPO, Washington, DC.

- Ability to meet receiving water quality standards

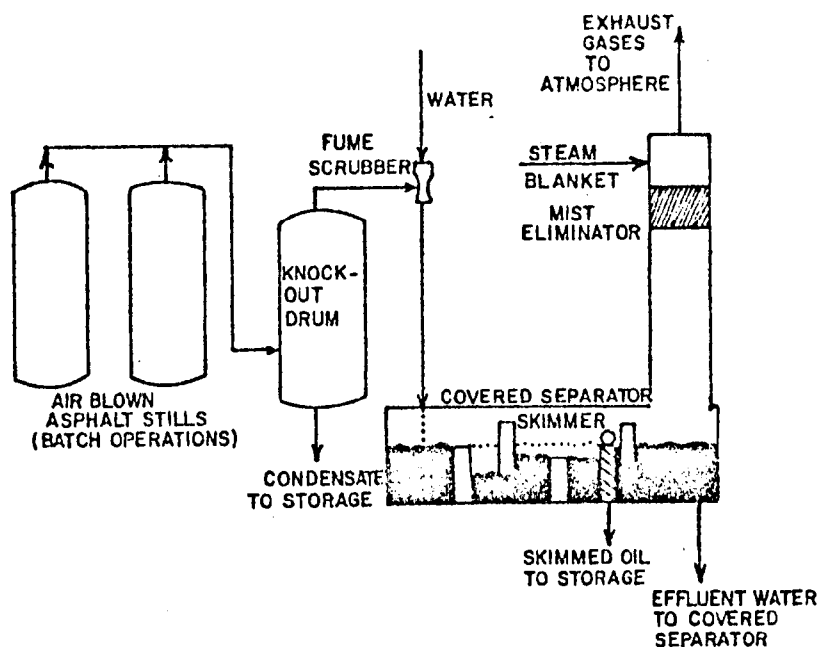
### III.C. STANDARDS OF PERFORMANCE TECHNOLOGY: END-OF-PROCESS CONTROL (AIR STREAMS)

Refinery operations result in emission of sulfur oxides, nitrogen oxides, particulate matter, CO and various hydrocarbons. Other emissions which lately have earned considerable interest are trace elements such as asbestos, mercury benzene, etc. The US EPA has enacted New Source Performance Standards petroleum refineries. State and local air quality and emission standards also may be imposed. To comply with these regulations, the operator of a new source refinery has available various air pollution control devices and techniques to reduce emissions to within allowable levels. At a minimum, the following air pollution control measures for each pollutant should be considered and described in the EIA:

- Hydrocarbon emissions can be limited through the use of floating-roof tops; manifolding purge lines to a recovery system (condenser or carbon adsorber) or to a flare (see Figure 8); vapor recovery systems on loading facilities; preventive maintenance; enclosed waste treatment plant; mechanical seals on compressors and pumps, and trained and cognizant personnel. A typical scrubbing system for emissions from air-blown asphalt stills is shown in Figure 9.
- Particulates can be controlled with the use of wet scrubbers and high-efficiency mechanical collectors (cyclones, bag houses); electrostatic precipitators on catalyst regenerators and power plant stacks; controlled combustion to reduce smoke; controlled







Source: API. 1973. Hydrocarbon emissions from refineries. Publication 0.928 Washington, D.C.

Figure 9. Simplistic low diagram for typical scrubbing system for emission control from air-blown asphalt stills.

stack and flame temperatures, and improved burner and incinerator design.

- Carbon monoxide emissions can be controlled at the catalytic cracker and fluid coker units with a CO boiler and at other sites through proper furnace and burner design.
- Odor controls include a good preventive maintenance program; the treatment of  $H_2S$ -rich wastewater streams from the catalytic crackers; gas-processing units and vacuum distillation towers; and the flaring of  $H_2S$ , mercaptans, other sulfides and other odor-producing compounds.
- Sulfur dioxide emissions can be controlled primarily through the burning of low-sulfur fuels in furnaces and boilers, the wet scrubbing of high-sulfur dioxide flue gases, and the desulfurization of fuels before use.
- Nitrogen oxide emissions can be controlled through an improved combustion process (i.e., lower flame temperature, less excess air), low nitrogen fuel burning, and good stack dispersion.

Table 21 presents a summary of the principal emission control devices currently employed at oil refinery facilities.

Other emission control technologies that currently are not used widely commercially, but are emerging include:

- Amine scrubbing
- Hot potassium carbonate process
- Sulfnox process (Shell Oil Co.)
- Seaboard and vacuum carbonate process (Koppers Co.)
- Phosphate process (Shell Development Co.)

Table 21. Summary of emission control technologies currently in use for various air pollutants generated from refinery processes.

PROCESS	EMISSION	UNCONTROLLED LEVEL	CONTROL TECHNOLOGY	APPROX. CONTROL EFFICIENCY
Catalyst Regeneration	Particulates	90-350 Lb/10 <sup>3</sup> BBL Fresh Feed	Cyclones	65-85%
			Multiple Cyclones	70-90%
			Electrostatic Precipitation	> 95%
	SO <sub>x</sub> CO	310-525 Lb/10 <sup>3</sup> BBL Fresh Feed 13,700	Wet Scrubber (high energy venturi)	> 90%
			Wet Scrubber (high energy venturi)	> 80%
			Waste Heat Boiler	> 99%
Fluidized Coking	Particulates	520	Cyclones	65-85%
			Multiple Cyclones	70-90%
			Electrostatic Precipitation	> 95%
Boilers/ Process Heaters	SO <sub>x</sub>	Essentially all fuel sulfur is emitted as SO <sub>x</sub>	Fuel Blending/Switching	
	Particulates	0.1-10 Lb/10 <sup>3</sup> Lb Fuel Burned	Electro. Precip.	> 95%
Sulfur Recovery	SO <sub>2</sub> /H <sub>2</sub> S	5-10% of Sulfur Input	Additional Claus Stages	Total Process Achieves S Removal of 97%
			Tail Gas Scrubbing	> 90%
			Tail Gas Recovery (IFP, Beagon, Cleanair)	> 90%
Storage Tanks	Hydrocarbon	1-10 Lb/day/10 <sup>3</sup> gallons throughput	Floating Roof	99%
			Pressurized Tanks	
			Vapor Recovery	90-95%
Loading Facilities	Hydrocarbon	1-12 Lb/10 <sup>3</sup> Gallons Transferred	Submerged Loading	50-70%
Incineration	Particulates	Variable	Cyclones	65-85%
			Multiple Cyclones	70-90%
			Wet Scrubber - Packed Tower	>90%
			Venturi	>90%
Light Ends	Hydrogen Methane	Variable	Flare	

- Wet iron box process
- Thylox process
- Dolomite acceptor process

### III.C. STATE OF THE ART TECHNOLOGY: END-OF-PROCESS CONTROLS (SOLID WASTE DISPOSAL)

Petroleum refineries generate an estimated 625,000 metric tons per year of waste (dry weight) in the course of distilling crude petroleum and processing of petroleum products (US-EPA 1976). The volume of waste generated as well as the economics of material recovery are determined to a large degree by the type, age, and condition of process units and the market for product "mix." Further, refineries in different geographic areas encounter widely varying requirements and problems associated with their individual solid waste streams. Treatment and disposal methods used in oil refineries are contingent upon the nature, concentration, and quantities of waste generated, as well as upon the potential toxicity or hazardousness of these materials. Pollution control methods are further affected by geographic conditions, transportation distances, disposal site hydrogeological characteristics, and regulatory agency requirements.

(Much of the material wasted by refineries only 20 to 25 years ago has either been eliminated by process changes, is now processed into marketable products, is recycled for reprocessing, or is sold to secondary material processors for extraction of valuable constituents. Noble metal catalysts, caustic solutions containing recoverable quantities of phenolic compounds, and some alkylation sludges reprocessed for sulfuric acid are examples of such waste streams.)

The types of wastes requiring disposal have been listed and described in Section II.C. of this report.

The paragraphs that follow discuss the primary treatment and disposal techniques for handling solid wastes from refineries. These and any other developing technologies should be considered by the permit applicant prior to selection of the proposed disposal method.

#### III.D.1. Landfilling

Landfilling is presently the most widely used method for disposing of all types of petroleum refinery waste products. The environmental adequacy of this method is contingent not only upon the types and characteristics of generated wastes, but also upon methods of operation and on specific site geologic and climatologic conditions. Of all the land disposal methods used by the refining industry, perhaps the greatest variations in operations and in site suitability are experienced with landfills. Landfilling operations range from open dumping of construction and refinery debris to controlled disposal in secure landfills in certain western states.

The environmental adequacy of a refinery waste landfill is affected by the following operational and management practices:

- The extent of segregation of wastes to prevent mixing of incompatible compounds, such as solids containing heavy metals with acids, or solutions with other wastes which together produce explosions, heat, or noxious gases
- The extent to which liquid or semi-liquid wastes are blended with soil or refuse materials to suitably absorb their moisture content and reduce their fluid mobility within the landfill
- The extent to which acids or caustic sludges are neutralized to minimize their reactivity

- Selection of sites in which the active fill area is large enough to allow efficient truck discharging operations, as well as to assure that blended wastes may be spread, compacted, and covered daily with approximately six inches of cover soil; A site operated in this manner is called a sanitary landfill
- The routing of ground and surface waters around the landfill site and sloping of cover soil to avoid on-site runoff and erosion

### III.D.2. Landspreading

Landspreading is a relatively inexpensive method of disposal of petroleum refinery wastes, which is being used by a growing number of refineries. The success of landspreading in the warm Southwestern states has prompted many U.S. refineries in colder climates to experiment with this method of disposal. Many refineries, however, which employ landspreading have done so for only about one to three years; only a few have a working experience with this process for a longer period of time.

Historically, refineries have been concerned largely with possible oil contamination of ground and surface waters which may result from landspreading. Few refineries have considered other environmental effects which may result from this operation. The real concern is not only the recognized short-term oil problem and incomplete treatment of organic acids and other intermediate byproducts, but the long-term implications of trace metal accumulation in the soil over long periods of operation. The problem posed by disposal of heavy metals on or in land largely is the same for all treatment and disposal technologies. The major difference is a quantitative one, with repeated applications of oily wastes to the same land areas potentially producing greater concentrations of heavy metals than result from other disposal methods, In

a confined secure disposal area, these heavy metals and other hazardous organic acids or degradation products do not pose the same level of hazard to the environment. Therefore, landspreading may be emerging as an important method for disposal of certain refinery wastes and should be carefully assessed during the EIA process.

#### III.D.3. Lagoons, Ponds, Sumps, and Open Pits

Lagoons, ponds, sumps and open pits have been used for many decades by the petroleum refining industry for the disposal of liquid and semi-solid waste.

The expediency of past disposal by simply dumping wastes into lagoons or sumps has turned into a major disposal problem in many parts of the country (Oil and Gas Journal 1972). The demand for elimination of these unsightly sumps has been prompted by many factors, among which, are the following:

- The need for additional land for refinery expansion
- Increasing land values which demand that land be put to a higher and more profitable use
- The envelopment of these lands by urban areas, and the resulting increased potential dangers to people
- Increasingly stringent regulatory agency requirements
- The desire to eliminate potentially catastrophic situations which may arise as a result of flooding rivers carrying large amounts of petroleum sludge with them

Action is now being taken by a number of states (California, Oklahoma, Texas, and Pennsylvania), to phase out the use of sumps and lagoons as permanent disposal methods, allowing them to be used only as temporary retention or treatment ponds. They are thus being relegated to use wastewater treat-



ment units, such as primary and secondary clarifiers, biostabilization or oxidation ponds, or thickening basins. Other uses included evaporation ponds or emergency diversion basins. As wastewater treatment requirements have become more stringent, many simple facultative and anaerobic lagoons have been converted into aeration basins by the addition of mechanical aerators. Because of their simplicity and ease of construction, many of the newer refineries make considerable use of earthen or lined lagoons as primary or secondary sedimentation chambers, aeration basins, oxidation ponds, storm runoff ponds, and emergency oil spill retention basins.

The environmental acceptability of lagoons for any of the prescribed purposes is very much dependent upon the method and materials of construction, specific local hydrogeologic conditions, and the types of waste which are handled.

The potential for significant contamination of underlying water aquifers from many inadequately lined lagoons, both old and new, is appreciable because of improper location and inadequate safeguards. Although many of the units are acceptable, the applicant should ascertain that adequate design and construction practices are followed in areas with high water tables, porous soils, or other environmental constraints.

#### III.D.4. Leaded Gasoline Sludge Treatment and Disposal

Because organic lead vapors are known to be toxic at very low concentrations (approximately 0.075 to 0.15 mg/m<sup>3</sup>, depending on lead compound), special procedures have been developed exclusively for the treatment and disposal of leaded gasoline sludges which accumulate in aviation and motor gasoline storage tanks.

Two basic procedures exist for the disposal of leaded-gasoline sludge from gasoline product storage tanks. The first procedure is the older of the two and largely has been superseded by an improved method which ensures faster and more complete degradation. Both procedures basically involve the construction of a dike surrounding the tank to be cleaned. After the tank contents (except sludge) is pumped to another tank, the remaining sludge is either pumped into the dike for weathering and degradation or is transported to a weathering pad elsewhere within the refinery. It subsequently is roto-disked into the soil or buried on refinery property. The volume of leaded-gasoline sludge generated is quite small and the frequency of cleaning is subsequently low - on the order of every one to ten years. Even then, the frequency of tank cleaning is dictated more by required tank maintenance than by need for sludge removal.

#### III.D.5. Incineration

Incineration of semi-solid and solid organic and inorganic refinery-generated wastes requires a special type of system which provides adequate detention times, stable combustion temperatures, sufficient mixing, and high heat transfer efficiency. A fluidized bed is one of the few systems which can satisfy all these criteria. In addition, the fluidized bed of heated solids serves as a heat sink to ignite volatilized hydrocarbons, thereby reducing or eliminating the possibility of creating an extremely dangerous explosive mixture of unburned gaseous hydrocarbons and air. The material to be incinerated can be injected either into the fluidized bed or immediately above it. Refinery wastes known to be incinerated by such systems include spent caustic solutions, API separator bottoms, DAF float, waste bio sludge, and slop oil

emulsion solids. Experience has shown that the reaction is self-sustaining if the thermal content of the total wastes incinerated exceeds about 29,000 BTU per gallon. Normal range of operating temperature is from 1300 to 1500 F. Loss of fluidization and plugging of the bed is still a major problem in the operation of these units.

#### III.D.6. Deep Well Disposal

Subsurface or deep well injection is an ultimate disposal method which originated with the oil and gas extraction industry. Connate brines, separated from the extracted gas and oil, are pumped back into the formations from which the fluid is originally taken, thus restoring the formation pressure and facilitating the extraction of additional gas and oil. Gradually the injection practice has been extended to include a multitude of wastes which would be difficult to dispose of by any other means.

Several refineries in the Southern California area are known to inject waste brines into deep wells. Deep well injection capital and operating costs can be considerable. The future of deep well injection has been clouded by recent legal and regulatory agency decisions (Ricci 1974; Ruckelshaus 1973).

#### III.D.7. Ocean Disposal

The 1971 Dillingham report (Smith and Brown 1971) for the EPA on ocean disposal of barge-delivered liquid and solid wastes reported that approximately 500,000 tons of refinery wastes have been dumped into the ocean. The Marine Protection Act of 1972 (PL 92-532) has transferred regulation and control of all ocean dumping from the district office of the U.S. Corps of Engineers to the Environmental Protection Agency. Ocean disposal of certain prescribed

hazardous wastes is prohibited, although permits for other less hazardous wastes are becoming increasingly difficult to obtain as alternative methods of ultimate disposal become available. Present trends indicate that ocean disposal will be gradually eliminated.

#### III.D.8. Special Treatment and/or Disposal Practices

A procedure for reducing the volume of crude tank bottoms is the use of polyelectrolytes. The process is performed prior to cleaning the tanks, at which time any crude oil remaining in the tank is pumped out to the sludge layer and replaced with approximately 5,000 to 6,000 barrels of "Canadian Condensate" or "off-gas" from field wells. The material in the tank is heated with steam and mixed with the crude tank bottoms to a temperature of approximately 130 F.

Another special practice that may be observed <sup>for</sup> treatment of both liquid and solid wastes is that of chemical fixation. Among the chemical fixation methods which are in use in the petroleum refining industry are the following:

- Use of chemical coagulants to create an insoluble precipitate. Often the one waste stream that is deliberately treated to produce a chemically inert precipitate is the routing of cooling tower blowdown containing hexavalent chromium through the API separator where available sulfides bring about the reduction of hexavalent chromium to trivalent chromium. From the API separator, reduced chromium ion is routed through the spent lime slurry tank where it is further precipitated by lime to chromium hydroxide. The lime sludge containing the precipitated hydroxide usually is removed by vacuum truck.
- Sorption of solvent-like hydrocarbons on imbibor beads

- The use of a variety of chemical systems have been devised to overcome the fluidity of certain petroleum wastes. These chemical systems react with various components of the waste to form a semi-solid material which effectively encapsulates or otherwise ties up the harmful constituents. The majority of these methods tend to isolate the material from the environment by either isolating the waste component as a solid mass, drying out the liquid, or achieving some form of chemical bonding or sorption. Chemical fixation or solidification is used by a few refineries to solve specific disposal problems, such as the permanent disposal of environmentally unacceptable lagoons filled with API separator bottoms or crude tank bottoms. The Chemfix Process is an example of such a chemical system. It consists of adding metered quantities of reactants to 300 to 500 gallons of waste slurry at intervals of one minute, and mixing to obtain homogeneity. The volume of reactant added to the waste is usually less than ten percent and often below five percent by volume. If cement were used to solidify the same waste, a volume increase of about 100% would typically be required to obtain a solid waste containing the entire liquid portion. The process is continuous and occurs at ambient temperature and pressure.

### III.E. TECHNOLOGIES FOR CONTROL OF POLLUTION FROM CONSTRUCTION SITES

The major pollutant at a construction site is loosened soil that finds its way into the adjacent water bodies and becomes "sediment." This potential problem of erosion and sedimentation is not unique to refinery construction, but applies widely to all major land disturbing activities. Common remedial

measures include, but are not limited to, proper planning at all stages of development and application of modern control technology to minimize the production of huge loads of sediment. Specific control measures include:

- The use of paved channels or pipelines to prevent surface erosion
- Staging or phasing of clearing, grubbing, and excavation activities to avoid high rainfall periods
- The use of storage ponds to serve as sediment traps, where the overflow may be carefully controlled
- The use of mulch or seeding immediately following disturbance

If the applicant chooses to establish temporary or permanent ground cover, grasses normally are more valuable than shrubs or trees because of their extensive root systems that entrap soil. Grasses may be seeded by sodding, plugging, or sprigging. During early growth, grasses should be supplemented with mulches of wood chips, straw, and jute mats. Wood fiber mulch has also been used as an antierosion technique. The mulch, prepared commercially from waste wood products, is applied with water in a hydroseeder.

The extent of control technologies used will be determined, in part, by the quantity of soil removed because there is a range in unit cost per acre.

The acreage involved from refinery will vary to some degree with capacity and site layout plans, therefore, the applicant should determine the most suitable control measures on a case by case basis.

#### IV. OTHER CONTROLLABLE IMPACTS

##### IV.A. AESTHETICS

New source petroleum refineries may be large and complex facilities occupying an area of up to several hundred acres. Cooling towers, air emission stacks, material storage and handling areas, and other plant components may detract considerably from the surrounding landscape. Particularly in rural and suburban areas, this configuration may represent a significant intrusion on the landscape; existing industrial areas would be less affected. Measures to minimize the impact on the environment should be developed primarily during site selection and design. The applicant should consider, as applicable, the following factors to reduce potential aesthetic impacts:

- Existing Nature of the Area--The topography and major land uses in the area of the candidate sites can be important aesthetic considerations. Natural topographic conditions perhaps could serve to screen the refinery from public view. A lack of topographic relief will require other means of minimizing impact, such as regrading or establishing (or leaving) vegetation buffers. Analysis of major land uses may be useful to assist in the design and appearance of the facility. Design of the refinery should reflect the nature of the area in which it is to be placed (i.e., the structures should blend into the existing environment as much as possible). The use of artists' conceptions, preferably in color, will be most useful in determining the visual impact and appropriate mitigation measures and should be included in the EIA.
- Proximity of Sites to Parks and Other Areas Where People Congregate for Recreation and Other Activities-- The location of these areas should be mapped and presented in the EIA. Representative

views of the plant (site) from observation points and the visual effects on these areas should be described in the EIA in order to develop the appropriate mitigation measures.

- Pipeline and Transportation System-- The visual impact of new pipelines, access roads, railroad lines, barge loading/unloading facilities, etc. on the landscape should be considered. Specific locations, construction methods and materials, maintenance activities and mitigation plans should be specified.
- Creation of Aesthetically Pleasing Areas--In some cases, the development of a refinery will create aesthetically pleasing areas. Screening the facility by vegetation or using the natural topography may improve the appearance of an area. Creation of open space and development of recreational facilities also can improve the area. Such positive impacts should be described in the EIA.

#### IV.B. NOISE

Oil refineries may have a significant impact on ambient noise levels at the fence line. Among the major sources of noise in a refinery are the following:

- Compressors
- Pumps and motors
- Flares

In addition construction activities also generate substantial noise levels. The applicant should undertake a site ambient noise survey prior to construction. This survey should be undertaken according to standard procedures (Miller 1976). Then fence line noise levels should be projected during construction and operation using estimates based on active noise levels of various equipment as determined from other refineries and from equipment



suppliers.

Noise levels can be reduced by:

- Use of quieter equipment
- Shielding equipment
- Good maintenance
- Shielding the plant with a noise barrier

To evaluate noise generated from a proposed site, the applicant should follow the sequence listed below:

- Identify all noise-sensitive land uses and activities adjoining the site
- Identify existing noise sources, such as traffic, aircraft flyover, and other industry, in the study area as defined
- Identify all applicable State and/or local noise regulations
- Estimate the noise level of the refinery during construction and operation and compare with the existing community noise levels and the applicable noise regulations
- Calculate the change in community noise levels resulting from construction of the refinery
- Assess the noise impact of the refinery operational noise and construction noise, and, if required, determine noise abatement measures to minimize the impact

#### IV.C. SOCIOECONOMIC

Introduction of a large oil refining facility into a community may cause economic and social changes. Therefore, it is necessary for an applicant to understand the types of impacts or changes that may occur so that they can be evaluated adequately in the EIA. The importance of these changes

usually depends on the nature of the area where the refinery is located (e.g., size of existing community, existing infrastructure). Normally, however, the significance of the changes caused by a refinery of a given size will be greater in a small, rural community than in a large, urban area. This is primarily because a small, rural community is likely to have a non-manufacturing economic base and a lower per capita income, fewer social groups, a more limited socioeconomic infrastructure, and fewer leisure pursuits than a large, urban area. There are situations, however, in which the changes may not be significant in a small community and, conversely, in which they may be considerable in an urban area. For example, a small community may have had a manufacturing (or natural resource) economic base that has declined. As a result, such a community may have a high incidence of unemployment in a skilled labor force and a surplus of housing. Conversely, a rapidly growing urban area may be severely strained if a new oil refinery is located there.

The rate at which the changes occur (regardless of the circumstances) also is an important determinant of the significance of the changes. The applicant should distinguish clearly between those changes occasioned by the construction of the plant and those resulting from its operation. The former changes could be substantial but usually are temporary; the latter may or may not be substantial but normally are more permanent in nature.

During the construction phase, the impact usually will be greater if the project requires large numbers of construction workers to be brought in from outside the community than if local, unemployed workers are available. The impacts are well known and include:

- Creation of social tension
- Demand for increased housing, police and fire protection, public

utilities, medical facilities, recreational facilities, and other public services

- Strained economic budget in the community where existing infrastructure becomes inadequate

Various methods of reducing the strain on the budget of the local community during the construction phase should be explored. For example, the company itself may build the housing and recreation facilities and provide the services and medical facilities for its imported construction force. Or the company may prepay taxes and the community may agree to a corresponding reduction in the property taxes paid later. Alternatively, the community may float a bond issue, taking advantage of its tax-exempt status, and the company may agree to reimburse the community as payments of principal and interest becomes due.

During refinery operation, the more extreme adverse changes of the construction phase are likely to disappear. Longer run changes may be profound, but less extreme, because they evolve over a longer period of time and may be both beneficial and harmful.

The permit applicant should document fully in the EIA, the range of potential impacts that are expected and demonstrate how possible adverse changes will be handled. For example, an increased tax base generally is regarded as a positive impact. The revenue from it usually is adequate to support the additional infrastructure required as the operating employees and their families move into the community. The spending and respending of the earnings of these employees has a multiplier effect on the local economy, as do the interindustry links created by the new refinery. Socially, the community may benefit as the increased tax base permits the provision of more diverse and higher quality services and the variety of its interests increases with

growth in population. Contrastingly, the transformation of a small, quiet community into a larger, busier community may be regarded as an adverse change by some of the residents, who chose to live in the community, as well as by those who grew up there and stayed, because of its amenities. The applicant also should consider the economic repercussions if, for example, the quality of the air and water declines as a result of various waste streams from the new source oil refinery and its ancillary facilities.

In brief, the applicant's framework for analyzing the primary and secondary socioeconomic impacts of constructing and operating a refinery must be comprehensive. Most of the changes described should be measured to assess fully the potential costs and benefits. The applicant should distinguish clearly between the short term (construction) and long term (operation) changes, although some changes may be common to both (e.g., the provision of infrastructure) because the significance of the changes depends not only on their absolute magnitude, but on the rate at which they occur.

The applicant should develop and maintain close coordination with State, regional, and local planning and zoning authorities to ensure full understanding of all existing and/or proposed land use plans and other related regulations.

#### IV.D. ENERGY SUPPLY

The impact of a petroleum refinery on local energy supplies will depend largely on the type of processes proposed and the ancillary facilities. The applicant should evaluate the energy efficiencies of all processes considered during project planning and then consider the alternatives. Feasible design modifications also should be considered in order to reduce energy consumption.

At a minimum, the applicant should provide the following information:

- Total external energy demand for operation of the refinery
- Total energy available on site
- Energy demands by type
- Proposed measures to reduce energy demand and increase plant efficiency

#### IV.E. IMPACT AREAS NOT SPECIFIC TO PETROLEUM REFINERIES

The intent of the preceding sections was to provide guidance to new source NPDES permit applicants on those impact areas that are specific to or representative of new source refinery operations. It is recognized that many impacts resulting from the construction and operation of an oil refinery are similar to impacts associated with many other new sources industries; therefore, no effort has been made to discuss these types of impacts, but instead, to reference other more general guideline documents. For example, general guidelines for developing a comprehensive inventory of baseline data (preproject conditions) and a general methodology for impact evaluation are contained in Chapters 1 and 2 of the EPA document, Environmental Impact Assessment Guidelines for Selected New Source Industries. Although broad in scope, this document and other appropriate guidance materials should be used by the applicant for assistance in evaluating impacts which are not unique to petroleum refineries.

V. EVALUATION OF AVAILABLE ALTERNATIVES

V.A. SITE ALTERNATIVES

As with most industries, the petroleum refinery industry locates plants on the basis of market demand for specific products, convenience to raw materials, an adequate labor force and water supply, proximity to energy supplies and transportation, minimization of environmental problems, and other factors. Preliminary site selection activities should occur before the EIA document is prepared. A variety of candidate sites initially should be considered and, following a detailed analysis of each one, a preferred site should be selected that best satisfies project objectives and that is expected to result in the least adverse environmental impact.

The factors considered in selecting each site, and especially those that influenced a positive or negative decision on its suitability, should be documented carefully in the permit applicant's EIA. Adequate information on the feasible alternatives to the proposed site is a necessary consideration in issuing, conditioning, or denial of an NPDES permit (see 40 CRR, Part 6.924).

Specifically the advantages and disadvantages of each alternative site must be catalogued with due regard to preserving natural features such as wetlands and other sensitive ecosystems and to minimizing significant adverse environmental impacts. The applicant should ascertain that all impacts are evaluated as to their significance, magnitude, frequency of occurrence, cumulative effects, reversibility, secondary or induced effects, and duration of impacts. If site selection could influence accidents or spills of hazardous or toxic substances, it should be discussed fully in the EIA.

In the EIA the applicant also should display the alternative site locations on maps, charts, etc., that show the refinery layout, environmental conditions, and other relevant site information. (A consistent identification system for the alternative sites should be established and retained on all graphic and text material) Pertinent and useful information might include, but is not limited to:

- All candidate areas and sites considered by the applicant
- Major centers of population density (urban, high, medium, low density, or similar scale)
- Water bodies suitable for use in cooling system and/or in other systems
- Railways, highways (existing and planned), and waterways suitable for the transportation of fuels, wastes, raw materials, products, and byproducts
- Important topographic/geological features (mountains, marshes, rock outcroppings)
- Dedicated land use areas (parks, historic sites, wilderness areas, testing grounds, airports, etc.)
- Other sensitive environmental areas (wetlands, prime agricultural lands, critical wildlife habitat, etc.)
- Major interconnections with power suppliers
- Other industrial complexes, significant mineral deposits, and mineral industries

Quantification, although desirable, may not be possible for all factors because of lack of adequate data. Under such circumstances, qualitative and general comparative statements, supported by documentation, may be used. Where possible,

experience derived from operation of other refineries at the same site, or at an environmentally similar site, may be helpful in appraising the nature of expected environmental impacts.

Economic estimates should be based at least on a preliminary conceptual design that considers how construction costs are affected by such site-related factors as topography, geology, and tectonics; distance from water supply source; and cooling tower configuration as determined by meteorological factors.

Once a specific site for location of the refinery is proposed it may receive considerable opposition locally, statewide or even nationally. Such opposition may derive from the fact that the proposed refinery would significantly impact a unique recreational, archaeological, or other important natural or manmade resource. It may destroy the rural or pristine character of an area or conflict with planned development for the area. It may have significant geological and hydrological constraints. It may be subject to periodic flooding, hurricanes, earthquakes, or other natural disasters.

Therefore, if the proposed site location proves undesirable, then alternative sites from among those originally considered should be reevaluated or new sites should be identified and evaluated. Expansion or technological changes at an existing plant site may be a possible alternative. Therefore, it is critical that a permit applicant systematically identify and assess all feasible alternative site locations as early in the planning process as possible.

Several different agencies may be able to assist the applicant in evaluating potential areas for location of the new source industry. Those include:



- State, regional, county, or local zoning or planning commissions can describe their land use programs and where variances would be required. Federal lands are under the authority of the appropriate Federal land management agency (Bureau of Reclamation, U.S. Forest Service, National Park Service, etc.)
- State or regional water resource agencies can provide information relative to water appropriations and water rights
- Air pollution control agencies can provide assistance relative to air quality allotments and other air-related standards and regulations
- The Soil Conservation Service and State Geological Surveys can provide data and consultation on soil conditions and geologic characteristics

If the State has an industry siting law, the requirements also should be cited and any applicable constraints described.

#### V.B. PROCESS ALTERNATIVES

Typically, when the decision is made to expand refining capacity--either through a new refinery or an addition to an existing one--the type of facility to be constructed is already fixed; that is, the demand for any given product which initiated the decision would have dictated the type of process to be used. The limitation on process alternatives is not as severe as it once was because of improved process versatility and the development of new process technologies.

In addition to demand, process alternatives should be selected on the basis of economics, engineering, and environmental considerations. The applicant

should present clearly and systematically in the EIA, the methodology used to identify, evaluate, and select the preferred process alternative. All process alternatives that appear practical should be evaluated on the basis of criteria such as:

- Land requirements, fuel storage facility requirements, and waste storage facility requirements
- Release to air of CO, sulfur dioxide, nitrogen oxides, hydrogen sulfide or other potential pollutants, subject to Federal, State, or local limitations
- Releases to water of heat, chemicals, and trace metals, etc. subject to Federal, State, and local regulations
- Water consumption rate
- Fuel consumption and the generation of wastes with associated waste treatment and disposal problems
- Economics
- Aesthetic considerations for each alternative process
- Reliability and energy efficiency of process

A tabular or matrix form of display often is helpful to compare costs and benefits of feasible process alternatives. Processes which are not feasible should be dismissed with an objective explanation for rejection.

#### V.C. NO-BUILD ALTERNATIVE

In all proposals for industrial development, the applicant must consider and evaluate the alternative of not constructing the proposed new source facility. Because this analysis is not unique to the development of petroleum refineries, no specific guidance is provided as part of this document. The permit applicant, therefore, is referred to Chapter IV (Alternatives to the Proposed New Source) in the EPA document, Environmental Impact Assessment Guidelines for Selected New Sources Industries, which was published in October 1975.

VI. REGULATIONS OTHER THAN POLLUTION CONTROL

The applicant should be aware that various regulations other than pollution control may apply to the siting and operation of new petroleum refineries. The applicant should consult with the appropriate EPA Regional Administrator regarding applicability of such regulations to the proposed new source.

Some Federal Regulations than my be pertinent to a proposed facility are:

- Coastal Zone Management Act of 1972 (16 USC 1451 et seq.)
- Fish and Wildlife Coordination Act of 1974 (16 USC 661-666)
- National Environmental Policy Act lf 1969 (42 USC 4321 et seq.)
- USDA Agriculture Conservation Service Watershed Memorandum  
108 (1971)
- Wild and Scenic Rivers Act of 1969 (16 USC 1274 et seq.)
- Flood Control Act of 1944
- Federal-Aid Highway Act, as amended (1970)
- Wilderness Act of 1964
- Endangered Species Preservation Act, as amended (1973)  
(16 USC 1531 et seq.)
- National Historical Preservation Act lf 1974 (16 USC 470 et seq.)
- Executive Order 11593
- Archaeological and Historic Preservation Act of 1974 (16 USC 469  
et seq.)
- Procedures of the Council on Historic Preservation (1973)
- Occupational Safety and Health Act of 1970

In connection with these regulations, the applicant should place particular emphasis on obtaining the services of a recognized archaeologist to determine the potential for disturbance of an archaeological site, such as an early

Indian settlement or a prehistoric site. The National Register of Historic Places also should be consulted for historic sites such as battlefields. The applicant should consult the appropriate wildlife agency (State and Federal) to ascertain that the natural habitat of a threatened or endangered species will not be affected adversely.

From a health and safety standpoint, most industrial operations involve a variety of potential hazards and to the extent that these hazards could affect the health of plant employees, they may be characterized as potential environmental impacts. All refinery operators should emphasize that no phase of operation or administration is of greater importance than safety and accident prevention. Company policy should provide and maintain safe and healthful conditions for its employees and establish operating practices that will result in safe working conditions and efficient operation.

The refinery must be designed and operated in compliance with the standards of the U.S. Department of Labor, the Occupational Safety and Health Administration, and the appropriate State statutes relative to industrial safety. The applicant also should coordinate closely with local and/or regional planning and zoning commissions to determine possible building codes and restrictions.

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