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SCREENING STUDY FOR MISCELLANEOUS SOURCES OF HYDROCARBON EMISSIONS IN PETROLEUM REFINERIES

U.S. ENVIRONMENTAL PROTECTION AGENCY
Office of Air and Waste Management
Office of Air Quality Planning and Standards
Research Triangle Park, North Carolina 27711

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SCREENING STUDY FOR MISCELLANEOUS SOURCES OF HYDROCARBON EMISSIONS IN PETROLEUM REFINERIES

by

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ABSTRACT

Background information on miscellaneous sources of hydrocarbons in the petroleum refineries is summarized. The information is used to estimate the expected atmospheric emission reduction of potential new source performance standards (NSPS) for the petroleum refining industry. Miscellaneous sources of emissions included in the study were pipeline valves and flanges, pressure relief valves, blowdown systems, pump and compressor seals, and process drains and wastewater separators. Additionally, the background information includes a general review of the petroleum refining industry, a discussion of pertinent emission control methods, and a summary of pertinent available air pollution regulations.

New source performance standards requiring application of best available control technology will result in an estimated 1985 hydrocarbon emission level of 750 Gg/yr, a reduction of 67% from 1985 emissions estimates for a condition of no controls and a reduction of 41% from 1985 emissions estimated under application of existing state regulations to both new and existing sources.

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SECTION I

INTRODUCTION

Section 111 of the Clean Air Act charges the Administrator of the Environmental Protection Agency with the responsibility of establishing Federal standards of performance for new stationary sources which may significantly contribute to air pollution. These new source performance standards (NSPS) will reflect the degree of emission limitation achievable through the application of the best system of emission reduction which (taking into account the cost of achieving such reduction) the administrator determines has been adequately demonstrated.

This document identifies available data to allow determination of the emission levels that can be achieved with the most effective demonstrated control systems, and estimates the emission reductions that would result through promulgation of new source performance standards for miscellaneous sources of hydrocarbon emissions in petroleum refineries. Miscellaneous sources of hydrocarbon emissions were defined for the purposes of this study as pipeline valves and flanges, pressure relief valves, blowdown systems, pump and compressor seals, and process drains and wastewater separators.

SECTION II

CONCLUSIONS AND RECOMMENDATIONS

New source performance standards requiring application of best available control technology to the miscellaneous sources considered in this study will result in an estimated 1985 hydrocarbon emission level of 740 Gg/yr (8.16×10^5 tons/yr), a reduction of 67% from 1985 emissions estimates for a condition of no controls and a reduction of 41% from 1985 emissions estimated under application of existing state regulations to both new and existing sources.

Technology currently exists for control of hydrocarbon emissions from miscellaneous sources. The best available control technologies include: improved maintenance and use of best available packing materials for valve stem emissions, closed manifold systems for pressure relief valve and blowdown system emissions, dual seals with barrier fluids for pumps and compressor seal emissions, and liquid traps used in conjunction with sealed sewer openings and covered wastewater separators for process drain systems. Estimated efficiencies for these technologies are 50%, 98%, 98%, and 90%, respectively. These technologies are currently being employed in petroleum refineries and the chemical process industries for a number of reasons, including product recovery, plant safety and hygiene, and air pollution control.

An extensive review of the literature and contact with representatives of petroleum refining companies and equipment vendors indicated that little effort is currently being made by industry to quantify emissions from miscellaneous sources of hydrocarbon emissions. The emission factors currently employed by EPA are based on refining technology, equipment, and practices of the late 1950's. These factors are being employed by both industry and air pollution agencies to estimate emissions from miscellaneous sources, with little or no modification to reflect current refinery equipment, technology, and practices. Therefore, a need exists to determine the adequacy of these emission factors for estimation of miscellaneous source emissions in light of current refining technology and equipment. At a minimum, emissions from refinery equipment employing both the control technologies mentioned above and those technologies prescribed by state regulations should be determined in order that more realistic and defensible estimates of both emissions and achievable emissions reductions can be formed.

urrent state air pollution regulations are not adequate to ensure hat emission reduction will be achieved even if the regulations re implemented. This arises from a lack of specificity in re-uired control device performance. It is recommended that new ource performance standards, if formulated, specify equipment or aterials of prescribed performance.

SECTION III

THE PETROLEUM REFINING INDUSTRY

A. GENERAL DESCRIPTIONS OF THE PETROLEUM REFINING INDUSTRY

The petroleum refining industry is involved primarily in the conversion of crude oil into more than 2,500 products including liquefied petroleum gas, gasoline, kerosene, aviation fuel, diesel fuel, a variety of fuel oils, lubricating oils, and feedstock for the petrochemical industry.[1] Petroleum refinery activities start with crude oil storage and terminate with storage of the refined products.

B. REFINING PROCESS

A petroleum refinery is a complex combination of interdependent operations and processes, which can be divided into six major groups:

1. Storage; e.g., of crude oil, intermediates, and final products
2. Fractionation; e.g., distillative separation and vacuum fractionation
3. Decomposition; e.g., thermal cracking, catalytic cracking, and hydrocracking
4. Hydrocarbon rebuilding and rearrangement; e.g., polymerization, alkylation, reforming, and isomerization
5. Extraction; e.g., solvent refining, and solvent dewaxing
6. Product finishing; e.g., drying and sweetening, lube oil finishing, blending, and packaging

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[1]Dickerman, J. C., T. D. Raye, and J. D. Colley. The Petroleum Refining Industry. EPA Order No. 5-02-5609B, U.S. Environmental Protection Agency, Research Triangle Park, North Carolina, 20 May 1975. 139 pp.

Twenty separate operations have been selected as the fundamental steps for production of final products from crude oil. They are presented in Table 1,[2] with brief definitions, in a sequence as close to a refinery process flow as such a complex combination permits. Figure 1 is a block flow diagram of typical petroleum refining operations.[3]

C. REFINING PROCESS UTILIZATION

The degree of application or use of the various fundamental refinery processes and subprocesses is prerequisite to the development of any meaningful industry profile. Since an exhaustive compilation of every process in every refinery would be impractical, the analysis of process utilization in this report is confined to the major subprocess alternatives under each of the selected processes. Table 2[2] summarizes the trend in the refinery process utilization between the years 1950 and 1972 and estimates the trend for the year 1977.

In a number of cases, the fundamental process figure and the sum of the listed subprocesses do not agree. There are two reasons for such apparent discrepancies. A single refinery may use two or more subprocesses in a given fundamental process area, such as Thermal Cracking, or all the applicable subprocesses may not be listed; e.g., Hydrotreating, which comprises many alternatives.

D. CURRENT TRENDS IN REFINING CAPACITY

As of 1 January 1976, 256 refineries, with a total throughput of 28.9 m^3/s (15,687,321 bbl/sd)[a] were operating in the United States This January 1976 refinery count and production capacities are presented for each state in Table 3.[4] A detailed state listing of refineries, and refining operations production capacities, is presented in Appendix A.

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[a] Barrels per stream day.

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[2] The Cost of Clean Water. Vol. III, Industrial Waste Profile No. 5, Petroleum Refining. PWPCA Publication No. I.W.P.-5 (PB 218 222), U.S. Department of the Interior, Washington, D.C., November 1967. 197 pp.

[3] Atmospheric Emissions From Petroleum Refineries; A Guide for Measurement and Control, PHS-Publication 763 (PB 198 096). Public Health Service, Cincinnati, Ohio. Division of Air Pollution, 1960. 64 pp.

[4] Cantrell, A. Annual Refining Survey. The Oil and Gas Journal, 74(13):124-156, 1976.

TABLE 1. SUMMARY OF REFINERY OPERATIONS[2]

Operation	Description
Crude Oil and Product Storage	Tanks of varying size are used to provide adequate supplies of crude oils for primary fractionation runs of economical duration, to equalize process flows and provide feedstocks for intermediate processing units, and to store final products prior to shipment in adjustment to market demands. Water separates out during storage and is drawn off to the sewer.
Crude Desalting	Electrostatic and chemical processes are used for removing inorganic salts and suspended solids from crude oil prior to fractionation. The crude oil is mixed with water to form an emulsion, which is broken by the action of an electrostatic field or specific demulsifying chemicals; the water sequesters the salts and other impurities from the crude oil, settles out, and is discharged to the sewer.
Crude Oil Fractionation	This is done by distillation where the heated crude oil is separated into light overhead products, such as: gases and gasoline; kerosene, heating oil, gas oil, lube oil and other sidestream distillate cuts; and reduced crude bottom products. The trend is toward more complex combinations of atmospheric and vacuum towers with more individual sidestream products. The crude oil fractionation still or stills provide feedstock for the downstream processing units and also some final products.
Thermal Cracking	Thermal cracking operations may include visbreaking and coking as well as regular thermal cracking. In each of these operations heavy oil fractions are broken down into lighter fractions such as domestic heating oil, catalyst cracking stock, etc., by the action of heat and pressure; heavy fuels or coke are produced from the uncracked residue. Regular thermal cracking, which was an important process before the development of catalytic cracking is being phased out, but visbreaking and coking units are installed in a significant number of refineries, and their application is expected to increase.
Catalytic Cracking	Like thermal cracking, the catalytic cracking process breaks heavy fractions, principally gas oils, into lighter fractions. Catalytic cracking is the key process in production of large volumes of high-octane gasoline stocks; furnace oils and other useful middle distillates are also produced. The use of a catalyst permits operations at lower temperatures and pressures than with thermal cracking and inhibits the formation of undesirable polymerized products. Fluidized catalytic cracking processes, in which the finely-powdered catalyst is handled as a fluid, have largely replaced the fixed-bed and moving bed processes, which use a beaded or pelleted catalyst.

(continued)

TABLE 1. (continued)

Operation	Description
Hydrocracking	Hydrocracking is basically catalytic cracking in the presence of hydrogen with lower temperatures and higher pressures than fluid catalytic cracking. The products are similar to catalytic cracking, but hydrocracking has greater flexibility in adjusting operations to meet changing product demands. It is one of the most rapidly growing refinery processes.
Reforming	Reforming is a molecular rearrangement process to convert low-octane feedstocks to high-octane gasoline blending stock or to produce aromatics for petrochemical uses. Multi-reactor, fixed-bed catalytic processes have almost completely replaced the older thermal process. There are many variations, but the essential, and frequently the only difference, is the composition of the catalyst involved.
Polymerization	Polymerization is a process to convert olefin feedstocks (primarily propylene) into a higher molecular weight polymer gasoline. This is a marginal process because the product octane is not sufficiently higher than that of the basic gasoline blending stocks to provide much help in up-grading the overall motor fuel pool, and because alkylation yields per unit of olefin feed are much better than polymerization yields. Consequently, the current polymerization downtrend is expected to continue.
Alkylation	Alkylation involves the reaction of an isoparaffin (usually isobutane) 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 are also used. Alkylation process capacity is expected to continue to increase with the demand for high-octane gasoline.
Isomerization	Isomerization is another molecular rearrangement process very similar to reforming. The charge stocks generally are lighter and more specific (normal butane, pentane, and hexane). The desired products are isobutane for alkylation feedstocks and high-octane isomers of the original feed materials for motor fuel.
Solvent Refining	Operations here include a large number of alternative subprocesses designed to obtain high-grade lubrication oil stocks or aromatics, from feedstocks containing naphthenic, acidic, organo-metallic or other undesirable materials. Basically, it is a solvent extraction process dependent on the differential solubilities of the desirable and undesirable components of the feedstock. The principal steps are countercurrent solvent extraction, separation of solvent product by heating and fractionation, removal of traces of solvent from the product, and solvent recovery.

(continued)

TABLE 1. (continued)

Operation	Description
Dewaxing	Dewaxing is removal of wax from lube oil stocks, generally after deasphalting and solvent refining to produce lubricants with low pour points, and to recover micro-crystalline wax. Except for Pressing and Sweating, a strictly physical process now used very little, the various dewaxing processes use solvents, (principally methyl ethyl ketone, MEK) to promote wax crystallization. Solvent is introduced into the waxy distillate stream at selected points in chilling equipment, and the wax is recovered in vacuum filters. Through selection of feedstocks and variation of operating conditions the emphasis can be shifted from dewaxing of a lube oil stock to deoiling of a wax stock.
Hydrotreating	Hydrotreating is a process for the removal of sulfur compounds, odor, color and gum-forming materials, and other impurities from a wide variety of petroleum fractions by catalytic action in the presence of hydrogen. 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 products are separated. Hydrotreating was originally applied to blending feedstocks, but with more operating experience and improved catalysts, it has been applied to increasingly heavy fractions such as lube oils and waxes. Along with hydrocracking, it is one of the most rapidly growing refinery processes.
Deasphalting	Deasphalting involves removal of asphalt or resins from viscous hydrocarbon fractions, such as reduced crude, to produce stocks suitable for subsequent lube-oil or catalytic cracking processes. This is a solvent extraction process, generally with propane as the solvent for the asphaltic materials. After contacting propane and the pipe still bottom products or other heavy stock in an extraction tower, the deasphalted oil overhead and asphaltic bottom products are processed to remove and recover propane.
Drying and Sweetening	This is a relatively broad process category which primarily involves removal of sulfur compounds, water, and other impurities from gasoline, kerosene, jet fuels, domestic heating oils, and other middle distillate products. "Sweetening" pertains to the removal 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 are oxidation of mercaptans to disulfides, removal of mercaptans, and destruction and removal of all sulfur compounds (and elemental sulfur). Drying is accomplished by salt filters or adsorptive clay beds. Electric fields are sometimes used to facilitate separation of the product and the treating solution.

(continued)

TABLE 1. (continued)

Operation	Description
Wax Manufacture	The current widely used fractionation process for production of paraffin (and at times microcrystalline) waxes of low oil content is similar in most respects to MEK Dewaxing. The principal differences are the selection of a solvent or solvent mixture more suitable to the crystallization and separation of paraffin wax, and a more complicated crystallization-filtration flow involving redissolving and recrystallization.
Grease Manufacture	This process for the manufacture of various lubricating greases involves preparation of a soap base from an alkali earth hydroxide and a fatty acid, followed by addition of oil and special additives. The major equipment consists of an oil circulation heater, a high-dispersion contactor, a scraper kettle, and a grease polisher. Because of developments in sealed grease fittings and longer lasting greases, grease production is expected to continue to decline.
Lube Oil Finishing	Solvent refined and dewaxed lube-oil stocks are further refined by clay or acid treatment to remove color-reforming and other undesirable materials. Continuous contact filtration, in which an oil-clay slurry is heated and the oil removed by vacuum filtration, and percolation filtration, wherein the oil is filtered through clay beds, are the most widely used subprocesses. Percolation also involves naphtha washing and kiln-burning of spent clay to remove carbonaceous deposits and other impurities.
Blending and Packaging	Blending is the final step in producing 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) and anti-knock (tetraethyl lead), anti-rust, anti-icing, and other additives. Diesel fuels, lube-oils, waxes, and asphalts are other refinery products which normally involve blending of various components and/or additives. Packaging at refineries is generally highly automated and restricted to high-volume, consumer-oriented products such as motor oils.
Hydrogen Manufacture	The rapid growth of hydrotreating and hydrocracking has increased the newer refineries' demand for hydrogen beyond the level of by-product hydrogen available from reforming and other refinery processes. Hydrogen is also in demand as a feedstock for ammonia and methanol manufacture. The most widely used subprocess is steam reforming, in which desulfurized refinery gases are converted to hydrogen, carbon monoxide, and carbon dioxide in a catalytic reaction; generally there is an additional shift converter to convert carbon monoxide to carbon dioxide.

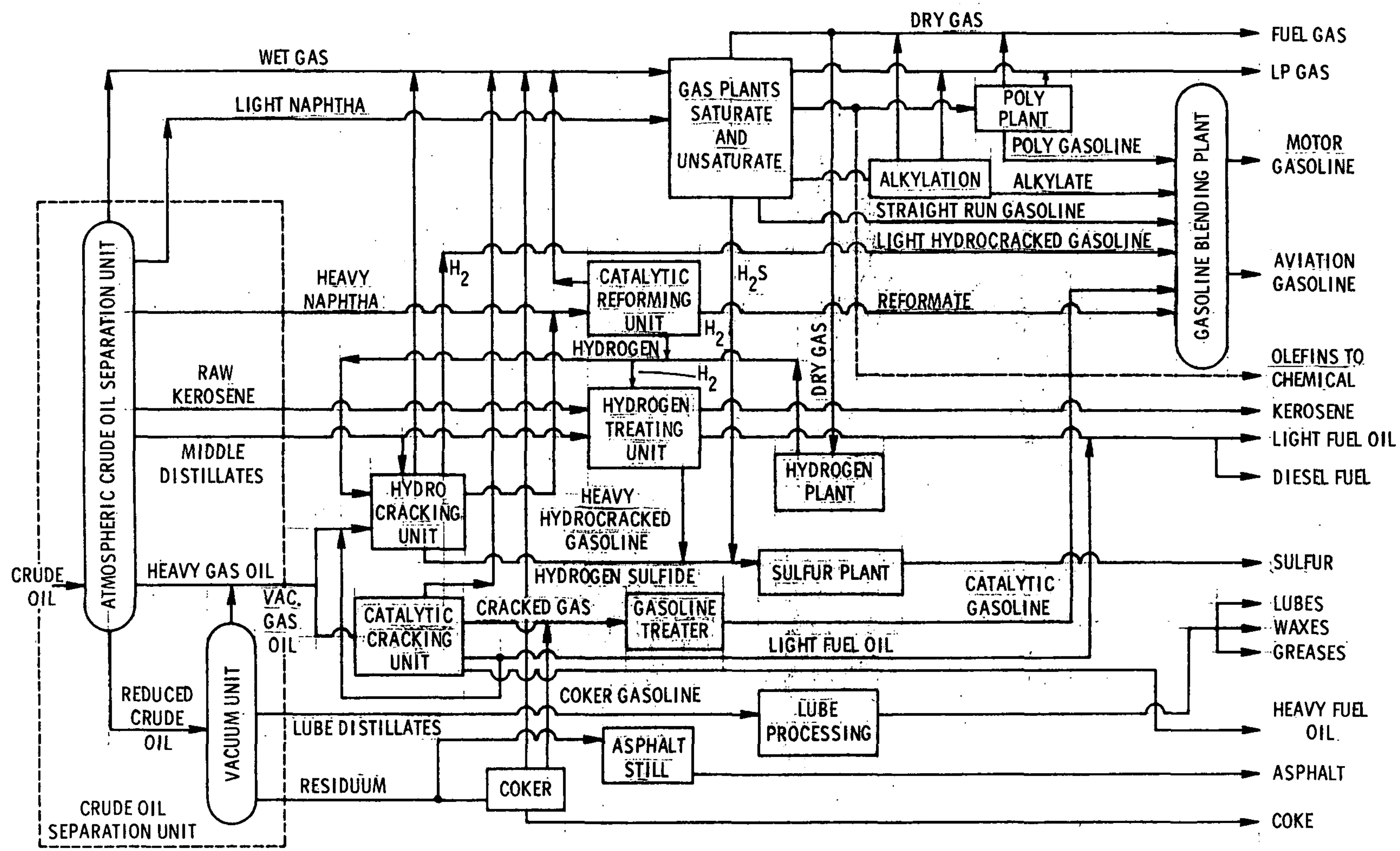

Figure 1. Block flow diagram of typical petroleum rifinery operation.[3]

TABLE 2. UTILIZATION OF REFINING PROCESSES[2]

Process	Percentage of refineries utilizing process, by year[2]				
	1950	1963	1967	1972	1977
Thermal cracking, all processes	59	48	45	40	35
Thermal cracking - regular		28	18	8	1
Coking		14	16	20	25
Visbreaking		13	16	18	22
Catalytic cracking, all processes	25	51	56	60	65
Fluid catalytic cracking		39	45	50	60
Thermofor catalytic cracking		13	12	10	6
Houdriflow		3	4	2	0
Hydrocracking, all processes	0	2	8	25	34
Isomax			4	11	15
Unicracking			2	8	12
H-G Hydrocracking		0.3	0.8	3	3
H-Oil			0.4	1	1
Reforming, all processes		62	67	74	79
Platforming		37	40	44	47
Catalytic reforming-Engelhard		5	9	11	12
Powerforming		1	2	3	3
Ultraforming		6	6	7	8
Polymerization, all processes	25	42	33	26	7
Alkylation, all processes	10	38	47	54	62
Sulfuric acid		22	26	32	38
HF		16	21	22	25
Hydrotreating, all processes		47	56	70	80
Unifining		22	23	30	35
Hydrofining		3	3	5	8
Trickle hydrodesulfurization		0.3	2	4	5
Ultrafining		3	5	8	10
Lube oil finishing, all processes		19	19	20	20
Percolation filtration		11	7	5	2
Contin. contract filtration		6	7	7	7
Hydrotreating		2	5	8	11

TABLE 3. SUMMARY OF JANUARY 1976 REFINERIES AND CRUDE THROUGHPUT BY STATE[4]

State	Plants	Crude throughput[a]			
		m^3/s[b]	(bbl/sd)	m^3/s[b]	(bbl/cd)
Alabama	3	0.10	(53,000)	0.09	(49,875)
Alaska	4	0.14	(78,158)	0.14	(74,250)
Arizona	1	0.01	(4,211)	0.01	(4,000)
Arkansas	4	0.11	(62,425)	0.11	(60,786)
California	35	3.67	(1,993,503)	3.50	(1,903,935)
Colorado	3	0.12	(65,000)	0.11	(62,125)
Delaware	1	0.28	(150,000)	0.26	(140,000)
Florida	1	0.01	(6,000)	0.01	(5,700)
Georgia	2	0.04	(19,400)	0.03	(18,000)
Hawaii	2	0.20	(107,000)	0.19	(101,750)
Illinois	11	2.27	(1,232,958)	2.16	(1,176,050)
Indiana	7	0.97	(527,300)	1.03	(561,160)
Kansas	11	0.86	(486,940)	0.83	(451,180)
Kentucky	3	0.31	(169,500)	0.30	(164,000)
Louisiana	19	3.36	(1,827,031)	3.23	(1,753,095)
Maryland	2	0.06	(31,211)	0.05	(28,500)
Michigan	6	0.28	(151,395)	0.27	(147,200)
Minnesota	3	0.41	(223,905)	0.40	(216,800)
Mississippi	5	0.64	(346,842)	0.61	(329,500)
Missouri	1	0.20	(108,000)	0.20	(107,000)
Montana	7	0.30	(164,016)	0.29	(156,181)
Nebraska	1	0.01	(5,500)	0.01	(5,000)
New Jersey	4	1.04	(562,764)	0.99	(539,000)
New Mexico	7	0.20	(106,305)	0.19	(104,230)
New York	2	0.21	(114,500)	0.20	(111,385)
North Dakota	3	0.11	(60,163)	0.11	(58,658)
Ohio	7	1.13	(614,500)	1.09	(589,770)
Oklahoma	12	1.03	(559,719)	1.00	(545,775)
Oregon	1	0.03	(14,737)	0.03	(14,000)
Pennsylvania	11	1.47	(796,415)	1.39	(757,020)
Tennessee	1	0.08	(44,800)	0.08	(43,900)
Texas	46	7.63	(4,144,778)	7.30	(3,966,330)
Utah	7	0.29	(158,878)	0.28	(152,000)
Virginia	1	0.10	(55,000)	0.10	(53,000)
Washington	7	0.70	(383,105)	0.68	(366,900)
West Virginia	3	0.04	(20,200)	0.04	(19,450)
Wisconsin	1	0.09	(46,800)	0.08	(45,400)
Wyoming	11	0.36	(194,557)	0.34	(187,340)
TOTAL	256	28.86	(15,687,321)	27.73	(15,074,845)

[a]Calendar-day (cd) figures were converted to a stream-day (sd) basis, using a factor of 0.95 for crude and vacuum units, and a factor of 0.09 conversion for all other purities.

[b]Values have been rounded.

The total number of U.S. refineries and throughput for the period between 1965 and 1975 is presented in Table 4.[4-14] Over this period, crude throughput has increased at an average compound rate of 3.9% per year.

TABLE 4. OPERATING REFINERIES AND CRUDE THROUGHPUT, 1965 - 1975[4-14]

Year	Operating refineries	Crude throughput m^3/s	Crude throughput (bbl/sd)
1965	265	19.7	(10,721,550)
1966	261	20.2	(10,952,495)
1967	269	21.5	(11,657,975)
1968	263	22.2	(12,079,201)
1969	262	23.3	(12,651,375)
1970	253	24.5	(13,284,985)
1971	247	25.2	(13,709,442)
1972	247	25.8	(13,991,580)
1973	247	27.4	(14,876,650)
1974	259	28.5	(15,463,650)
1975	256	28.9	(15,687,321)

[5]Cantrell, A. Annual Refining Survey. The Oil and Gas Journal, 73(14):96-118, 1975.

[6]Cantrell, A. Annual Refining Survey. The Oil and Gas Journal, 72(13):82-103, 1974.

[7]Cantrell, A. Annual Refining Survey. The Oil and Gas Journal, 71(14):99-121, 1973.

[8]Cantrell, A. Annual Refining Survey. The Oil and Gas Journal, 70(13):135-156, 1972.

[9]Cantrell, A. Annual Refining Survey. The Oil and Gas Journal, 69(12):93-120, 1971.

[10]Lotven, C. Annual Refining Survey. The Oil and Gas Journal, 68(14):115-141, 1970.

[11]Stormont, D. H. Annual Refining Survey. The Oil and Gas Journal, 67(12):115-134, 1969.

[12]Stormont, D. H. Annual Refining Survey. The Oil and Gas Journal, 66(14):130-153, 1968.

[13]Stormont, D. H. Annual Refining Survey. The Oil and Gas Journal, 65(14):183-203, 1967.

[14]Stormont, D. H. Annual Refining Survey. The Oil and Gas Journal, 64(13):152-171, 1966.

Obsolescence rates of refinery crude capacity for the period 1965 to 1975 are presented in Table 5 in terms of the percent of total operable crude capacity determined to be inoperable and requiring extensive reconditioning for the year specified.[15-24] Obsolete capacity ranged from 0.32% in 1969 to 1.58% of total operable crude capacity in 1968, with an average value of 1.02% of total operable crude capacity for the ten-year period.

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[15]Mineral Industry Surveys. Petroleum Refineries in the United States and Puerto Rico. U.S. Department of the Interior, Bureau of Mines, Washington, D.C., 1 January 1975. 17 pp.

[16]Mineral Industry Surveys. Petroleum Refineries in the United States and Puerto Rico. U.S. Department of the Interior, Bureau of Mines, Washington, D.C., 1 January 1974. 21 pp.

[17]Mineral Industry Surveys. Petroleum Refineries in the United States and Puerto Rico. U.S. Department of the Interior, Bureau of Mines, Washington, D.C., 1 January 1973. 15 pp.

[18]Mineral Industry Surveys. Petroleum Refineries in the United States and Puerto Rico. U.S. Department of the Interior, Bureau of Mines, Washington, D.C., 1 January 1972. 15 pp.

[19]Mineral Industry Surveys. Petroleum Refineries in the United States and Puerto Rico. U.S. Department of the Interior, Bureau of Mines, Washington, D.C., 1 January 1971. 15 pp.

[20]Mineral Industry Surveys. Petroleum Refineries in the United States and Puerto Rico. U.S. Department of the Interior, Bureau of Mines, Washington, D.C., 1 January 1970. 15 pp.

[21]Mineral Industry Surveys. Petroleum Refineries in the United States and Puerto Rico. U.S. Department of the Interior, Bureau of Mines, Washington, D.C., 1 January 1969. 15 pp.

[22]Mineral Industry Surveys. Petroleum Refineries in the United States and Puerto Rico. U.S. Department of the Interior, Bureau of Mines, Washington, D.C., 1 January 1968. 15 pp.

[23]Mineral Industry Surveys. Petroleum Refineries in the United States and Puerto Rico. U.S. Department of the Interior, Bureau of Mines, Washington, D.C., 1 January 1967. 13 pp.

[24]Mineral Industry Surveys. Petroleum Refineries in the United States and Puerto Rico. U.S. Department of the Interior, Bureau of Mines, Washington, D.C., 1 January 1966. 11 pp.

TABLE 5. REFINERY OBSOLESCENCE RATE FOR THE PERIOD 1965 to 1975[15-24]

Year	Obsolescence rate,[a] %
1965	0.34
1966	0.95
1967	0.95
1968	1.58
1969	0.32
1970	0.44
1971	1.24
1972	1.09
1973	0.97
1974	0.89
1975	1.39

[a] Percent of total operable capacity.

SECTION IV

MISCELLANEOUS SOURCES OF HYDROCARBON EMISSIONS

A. INTRODUCTION

Sources of hydrocarbon emission addressed in this screening study are the following:

- Pipeline valves and flanges
- Pressure relief valves
- Blowdown systems
- Pump seals
- Compressor seals
- Process drains and wastewater separators

EPA recommended factors for hydrocarbon emissions from miscellaneous sources in petroleum refineries are presented in Table 6.[25]

TABLE 6. EPA RECOMMENDED EMISSION FACTORS FOR PETROLEUM REFINERIES[25]

No.	Miscellaneous source (uncontrolled)	Hydrocarbon emission factor refining capacity kg/10^3 liter	Hydrocarbon emission factor refining capacity (lb/10^3 bbl)
1	Pipeline valves and flanges	0.080	(28)
2	Vessel relief valves	0.031	(11)
3	Pump seals	0.049	(17)
4	Compressor seals	0.014	(5)
5	Blowdown systems	0.860	(300)
6	Process drains and wastewater separators	0.570[a]	(200)[b]

[a]kg hydrocarbons/10^3 liters wastewater.

[b]lb hydrocarbons/10^3 bbl wastewater.

[25]Compilation of Air Pollutant Emission Factors. Publication No. AP-42, U.S. Environmental Protection Agency, Research Triangle Park, North Carolina, March 1975. pp. 9.1-1 to 9.1-8.

These emission factors were derived in an extensive survey of Los Angeles County refineries conducted in the late 1950's.[26-30] As such, they represent emissions based on sampling of a limited number of refineries employing refining technology and practices which may be out of date by today's standards.

In order to determine the adequacy of these factors for estimating emissions from current refining technology, extensive contacts were made with petroleum refineries, state air pollution agencies, trade associations, and selected equipment manufacturers, and a rigorous review of the technical literature was undertaken. It was determined that the factors presented in Table 6 are universally applied and factor modifications to reflect emission control practices or plant or process changes are rarely made. Only in rare instances could the sources investigated supply information which could be used to assist in emission factor updating.

The emission factors were applied to total refinery calendar throughput as of 1 January 1976 (7.74 m^3/s [15,074,845 bbl/cd]) and 1 January 1973 (7.18 m^3/s [13,991,580 bbl/cd]) to determine total uncontrolled miscellaneous hydrocarbon emissions for refineries in 1972 and 1975 (Table 7).

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[26]Emissions to the Atmosphere from Petroleum Refineries in Los Angeles County. Final Report No. 9, Joint District, Federal and State Project for the Evaluation of Refinery Emissions. Air Pollution Control District, County of Los Angeles, California, 1958. 136 pp.

[27]Palmer, R. K. Hydrocarbon Losses from Valves and Flanges. Report No. 2, (PB 216 682), Joint District, Federal and State Project for the Evaluation of Refinery Emissions. Air Pollution Control District, County of Los Angeles, California, March 1957. 17 pp.

[28]Steigerwald, B. J. Hydrocarbon Leakage from Pressure Relief Valves. Report No. 3, (PB 216 715), Joint District, Federal and State Project for the Evaluation of Refinery Emissions. Air Pollution Control District, County of Los Angeles, California, May 1957. 27 pp.

[29]Steigerwald, B. J. Emissions of Hydrocarbons to the Atmosphere from Seals on Pumps and Compressors. Report No. 6, (PB 216 582), Joint District, Federal and State Project for the Evaluation of Refinery Emissions. Air Pollution Control District, County of Los Angeles, California, April 1958. 37 pp.

[30]Emissions to the Atmosphere from Eight Miscellaneous Sources in Oil Refineries. Report No. 8 (PB 216 668), Joint District Federal and State Project for the Evaluation of Refinery Emissions. Air Pollution Control District, County of Los Angeles, California, June 1958. 57 pp.

TABLE 7. MISCELLANEOUS HYDROCARBON EMISSIONS FROM PETROLEUM REFINERIES

No.	Miscellaneous sources (uncontrolled)	1972 Total hydrocarbon emissions metric tons/yr (tons/yr)	1975 Total hydrocarbon emissions metric tons/yr (tons/yr)
1	Pipeline valves and flanges	64,850 (71,497)	69,870 (77,032)
2	Vessel relief valves	25,477 (28,088)	27,449 (30,263)
3	Pump seals	39,373 (43,409)	42,422 (46,770)
4	Compressor seals	11,580 (12,767)	12,477 (13,756)
5	Blowdown systems	694,820 (766,039)	748,615 (825,348)
6	Process drains and wastewater separators	463,214 (510,693)	499,077 (550,232)
TOTAL		1,299,314 (1,432,493)	1,399,910 (1,543,400)

Though insignificant when inspected on an individual equipment basis, miscellaneous hydrocarbon emissions from petroleum refineries in 1972 (most recent national emissions summary) represented 5.2% of the total nationwide emissions of all hydrocarbon emissions (Table 8).[31]

TABLE 8. CONTRIBUTION OF MISCELLANEOUS HYDROCARBON EMISSIONS FROM PETROLEUM REFINING TO NATIONAL HYDROCARBON EMISSIONS[31]

Pollutant	National emissions, 10^6 metric tons/yr	Emissions from refinery miscellaneous sources, 10^6 metric tons/yr	Contribution, %
Hydrocarbon	25.05	1.30	5.2

[31] 1972 National Emissions Report. Publication No. EPA-450/2-74-012. U.S. Environmental Protection Agency, Research Triangle Park, North Carolina, June 1974. 57 pp.

The following paragraphs describe miscellaneous sources of hydrocarbon emissions, and the basis for determination of EPA emission factors. Also, the current refinery practices of miscellaneous source emission control are presented. An indication of the number of miscellaneous sources in some refineries may be found in Appendix B.

B. SOURCE DESCRIPTIONS

1. Valves

One of the most common pieces of equipment in petroleum refineries, or in any fluid transport or processing system, is the valve. It is estimated that there are fifteen to twenty valves for each pump and compressor in a petroleum refinery.[32] Types of valves commonly used in refinery applications include control valves for precise flow regulation, globe and plug valves for both throttling and flow regulation, gate and ball valves for complete flow stoppage, and check valves to prevent fluid backflow.[33]

All of the above valves except check valves, are actuated by motion of the valve stem, which penetrates the valve housing and moves the surface (or surfaces) restricting the flow. Valve stem motion may be linear, rotational, or both depending on the specific valve configuration. A seal is maintained between the valve stem and housing by a compressed packing which prevents fluid flow along the stem from the valve interior to the atmosphere. The degree of compression in the packing is regulated by an adjustable collar. Packing materials include asbestos fibers, graphite or graphite impregnated fibers, and TFE, depending on the specific valve application and configuration.[34]

In 1956, eleven Los Angeles County refineries, with a total crude throughput of approximately 1.29 m^3/s (700,000 bbl/day) were surveyed to determine the magnitude of refinery valve stem leakage.[27] These refineries contained an estimated 132,000 valves, with 23.6%

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[32]Personal Communication. W. H. Connell, A. M. Gerdman, M. S. Hamshd, J. B. Hermiller, D. D. Ray, R. T. Roffee, and P. C. Tranquill, The Standard Oil Company of Ohio, Lima Refinery, Lima, Ohio, 24 June 1976.

[33]Sims, A. V. Field Surveillance and Enforcement Guide for Petroleum Refineries. EPA-450/3-74-042 (PB 236 669), U.S. Environmental Protection Agency, Research Triangle Park, North Carolina, July 1974. 369 pp.

[34]Lyons, J. L., and C. L. Askland, Jr. Lyons' Encyclopedia of Valves. Van Nostrand Reinhold Company, New York, New York, 1975.

handling gaseous products and 76.4% handling liquid products. Approximately 6% of the valves were inspected for leakage. Results of the inspection are presented in Table 9.

TABLE 9. SUMMARY OF PIPELINE VALVE TESTING[27]

Valves handling gaseous products:
83.5% showed no leakage
11.3% had an estimated loss of 0.52 mg/s/valve (0.1 lb/day/valve)
5.2% had an average measured loss of 47.8 mg/s/valve (9.1 lb/day/valve)
Average loss = 2.57 mg/s/valve (0.49 lb/day/valve)
Valves handling liquid products:
88.3% showed no leakage
10.6% had an estimated loss of 0.52 mg/s/valve (0.1 lb/day/valve)
1.0% had an average measured loss of 13.6 mg/s/valve (2.6 lb/day/valve)
0.1% had an average measured loss of 872 mg/s/valve (166.1 lb/day/valve)
Average loss = 0.21 mg/s/valve (0.04 lb/day/valve) (excluding large leaks)

The average loss figure for all refinery valves was estimated to be 0.79 mg/s/valve (0.15 lb/day/valve) or 79.9 $kg/10^3m^3$ (28 $lb/10^3$ bbl) of refinery throughput.[26] This value is used by EPA in its compilation of air pollutant emission factors.[26]

The American Petroleum Institute (API) standards allow no leakage from new valve packings,[35] and properly maintained valves should not leak in normal operations with good maintenance practices.[32,33] From Table 7 it can be seen that 87% of all valves inspected showed no evidence of leakage.

Valve leakage in refineries is not tolerated. Two refining companies contacted stated that their policies instructed operators to adjust valve stem packings upon detection at leakage.[32,36]

[35]Valve Inspection on Test. American Petroleum Institute, Division of Refining, New York, New York, API Standard 598, Second Edition, September 1970.

[36]Personal Communication. R. Fritz, K. Hanevaek, J. McKensie, and F. DeVine, Exxon Research and Engineering Company, 3 May 1976.

API consideres the EPA emission factor presented above "undoubtedly high" in refineries where good maintenance is practiced.[37] However, information was not available to allow updating of the EPA recommended emission factor of 79.9 kg/$10^3 m^3$ (28 lb/10^3bbl) of refinery throughput.

2. Flanges

Flanges are employed wherever a pipe or component (such as vessels, pumps, compressors and valves) in the process may require isolation or removal.

The primary cause of flange leakage is flange seal deformation due to thermal stresses on the piping system.[38] Thermal expansion or contraction of piping on either side of the flange can deform the seal between the flange faces, resulting in leakage around the seal.

In 1956, 326 flanges in Los Angeles County were inspected; of these, four were found to leak. Three of the leaks detected were "small" and therefore flange leakage was determined to be an insignificant source of fugitive hydrocarbons and further investigations were not performed.[27] EPA does not list a unique emission factor for flanges, but includes them in the category "pipeline valves and flanges," with the emission factor for this combination of sources identical to that previously presented for valves.[25]

Minor flange leakage can be controlled through tightening the flange bolts until leakage is stopped.[32] Major flange leakage requires replacement of the seal or application of a supplemental seal arrangement around the leaking flange. If the line containing the flange cannot be shut down to allow replacement of the seal, one of the following methods can be applied:[39,40]

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[37] Manual on Disposal of Refinery Wastes, Volume on Atmospheric Emissions, Chapter 7 - Hydrocarbon Emissions. American Petroleum Institute, Refining Department, Washington, D.C., API Publication 931, February 1976.

[38] McFarland, I. Preventing Flange Fires. Chemical Engineering Progress, 65(8):59-61, 1969.

[39] Hutton, B. Repair Flange Leads-Onstream. Hydrocarbon Processing, 52(1):75-76, 1973.

[40] Brown, G. W. Valve Problems: Causes and Cures. Hydrocarbon Processing, 53(6):97-99, 1974.

- A metal band is cold-welded around the flange circumference and the space within the band is filled with a setting sealant.

- A vapor-tight box is cold-welded around the flange and piping.

- Commercial flange covers are applied and the interior is filled with a setting sealant.

The current trend in refinery construction is to eliminate pipe flanges where possible through use of welded connections.[32,36,40] In situations where flanges must be used, "delta" type joints which minimize thermal flange distortion have been suggested,[40] but the reference gave no indications of refinery experience with this equipment.

3. Pressure Relief Valves

Engineering codes require pressure-relieving devices or systems in applications where overpressure, i.e., pressure above the vessel maximum allowable working pressure, is likely to occur.

Pressure relief valves are the most common pressure-relieving devices used in petroleum refineries. Pressure relief valves are typically spring-loaded valves designed to open at a set pressure, allow flow until system pressure is reduced to tolerable levels, and then reseat, reforming the seal. Relief valves are installed singly or in parallel depending on the volume of product requiring venting in the event of a vessel overpressure.[28]

Pressure relief valves will emit hydrocarbons under the following circumstances:[33,41]

(a) Vessel overpressure, resulting in valve opening and vapor blowoff at valve set pressure;

(b) Valve "simmering," due to proximity of vessel operating pressure to valve set pressure;

(c) Improper sealing upon valve reseating, due to valve seat corrosion and abrasion, resulting in continuous leakage around valve seat; and

(d) Leakage around valve seat due to seat corrosion or abrasion (API specifications allow a finite amount of leakage from properly operating valves.

[41]Bright, G. Halting Product Loss Through Safety Relief Valves. Chemical Engineering Progress, 68(5):59-68, 1972.

Emissions due to a, b, and c above can be reduced through process control, choice of valve set pressure, choice of valve materials, and valve inspection and maintenance.[41] The above practices, however, will control emission with certainty only to the levels allowed for properly operating and maintained valves (case d above).

In 1955, seven Los Angeles County refineries, with a combined crude throughput of approximately 0.59 m^3/s (320,000 bbl/day) were surveyed to determine an inventory of refinery relief valves and to estimate hydrocarbon emissions from valve leakage.[28] Quantification of emissions from relief valve blowoff was not attempted.

The relief valve inventory from this survey is presented in Table 10.[28] Relief valves on lines carrying liquid products showed no evidence of leakage and therefore were removed from further consideration.

TABLE 10. PRESSURE RELIEF VALVE INVENTORY[28,a]

Relief valve application	Venting to atmosphere		Venting to recovery systems
	Vapor systems	Liquid lines	
Operational units	1,113	400	1,589
Pressurized storage			
Single type	237	290	179
Dual type	115		
TOTAL	1,465	690	1,768

[a]Seven Los Angeles refineries with a total throughput of approximately 0.59 m^3/s (320,000 bbl/day) crude (1955).

Approximately 29% of the relief valves venting vapors to the atmosphere from operational units and pressurized storage were inspected for leakage. The results of the leakage inspection are presented in Table 11.[28] The average emission from all pressure relief valves venting vapor to the atmosphere was determined to be 12.6 mg/s/valve (2.4 lb/day/valve) or 31.4 $kg/10^3 m^3$ (11 $lb/10^3$ bbl) of refinery throughput. The latter emission factor is currently used by EPA in its Compilation of Air Pollutant Emission Factors,(see vessel relief valves, Table 6).[25]

The emission factor contained in AP-42 represents the average emission from pressure relief valves venting to the atmosphere. However, only 45.3% of the relief valves on operational units and process vessels (excluding those on liquid lines) vented to the atmosphere while 54.7% vented to vapor recovery systems (Table 10). As a result, this factor actually represents controlled emissions, with an average efficiency of control of 54.7%.

TABLE 11. SUMMARY OF PRESSURE RELIEF VALVE TESTING[28]

Operational Units

81.8% showed no leakage
13.3% had an average estimated loss of 4.72 mg/s/valve (0.9 lb/day/valve)
3.6% had an average measured loss of 133 mg/s/valve (25.3 lb/day/valve)
1.2% had an average measured loss of 808 mg/s/valve (154 lb/day/valve)

Average loss = 15.2 mg/s/valve (2.9 lb/day/valve)

Pressurized Storage

All Valves

73.5% showed no leakage
21.7% had an average estimated loss of 4.72 mg/s/valve (0.9 lb/day/valve)
9.7% had an average measured loss of 46.7 mg/s/valve (8.9 lb/day/valve)

Average loss = 3.15 mg/s/valve (0.6 lb/day/valve)

Single (67.3% of total)

81.0% showed no leakage
16.7% had an average estimated loss of 4.72 mg/s/valve (0.9 lb/day/valve)
2.3% had an average measured loss of 39.4 mg/s/valve (7.5 lb/day/valve)

Average loss = 1.57 mg/s/valve (0.3 lb/day/valve)

Dual (32.7% of total)

57.0% showed no leakage
32.9% had an average estimated loss of 4.72 mg/s/valve (0.9 lb/day/valve)
10.0% had an average measured loss of 49.3 mg/s/valve (9.4 lb/day/valve)

Average loss = 6.51 mg/s/valve (1.24 lb/day/valve)

Average loss, all valves = 12.6 mg/s/valve (2.4 lb/day/valve)

An emission factor representing a condition of no control may be determined as follows:

$$\text{Uncontrolled emission} = \frac{\text{AP-42 factor}}{(1 - 0.547)}$$

$$= \frac{0.031}{45.3}$$

$$= 0.068 \text{ kg}/10^3 \text{ liter}$$

Hydrocarbon releases from pressure relief valve blowoff and leakage present several hazards in refineries, including formation of flammable mixtures at grade level or on elevated structures, exposure of personnel to toxic vapors or corrosive chemicals, possible ignition of relief streams at point of emission, excessive noise levels, and air pollution.[42]

Several practices are currently being employed to reduce hydrocarbon emissions from relief valve leakage. These include the following:[41,43-45]

- Periodic maintenance to prevent foreign material buildup or corrosion on seat
- Installation of rupture disks upstream of relief valve
- Manifold systems to convey relief valve discharges to vapor recovery, fuel gas, or flare systems.

The last practice above is the most efficient system for control of pressure relief valve blowoff and leakage because it is a closed system with hydrocarbon incineration in process heaters or flares before release to the atmosphere. From Table 10, 45% of Los Angeles County's relief valves were being manifolded to some kind of recovery or flare system.

The degree to which a refinery will manifold pressure relief valves to flare or other systems depends upon the capacity of

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[42]Guide for Pressure Relief and Depressurizing Systems. American Petroleum Institute, Washington, D.C. Publications No. API RPS21, September 1969. 28 pp.

[43]Elkin, H. F., and R. A. Constable. Control of Air Pollution in Petroleum Refineries. Recent Advances in Air Pollution Control. AIChE Symposium Series, 70(137):26-36, 1974.

[44]Bock, J. D., and J. H. Raidl. Relief Valve Reliability is Upgraded. The Oil and Gas Journal, 71(5):74-76, 1973.

[45]Kayser, D. S. Rupture Disk Selection. Chemical Engineering Progress, 68(5):61-64, 1972.

the manifold system to handle the volume of material released during a process upset. Sohio's Lima refinery, which is under no state or federal regulations limiting its hydrocarbon emissions from relief valves, vents to a central flare all its pressure relief valves except those on the catalytic cracker and regenerator because the flare system currently in place could not handle the volume resulting from an upset in these two pieces of equipment.[32]

In a recent completed expansion of Texaco's refinery at Heide, Germany, all pressure relief valves on units releasing gases or vapors are connected to a vapor recovery or flare system. Released gases are either compressed and fed into the plant fuel gas system or incinerated in the waste gas flare.[46]

4. Blowdown Systems

Refinery units are periodically shut down and emptied for internal inspection and maintenance. The process of unit shutdown, repair, and restart is termed a unit turnaround. The purging of the contents of a vessel to provide a safe interior atmosphere for workmen is termed a vessel blowdown. A typical vessel blowdown procedure is as follows:[30]

- Liquid contents of the vessel are pumped to an operating unit for storage.
- Vapors are purged from the vessel.
- The vessel is flushed with water, steam, or nitrogen.
- The vessel is ventilated for workmen.

Depending on the specific refinery configuration, the vapor content of the vessel may be vented to vapor recovery or fuel gas systems or flares, or be released directly to the atmosphere.[30,32,34] A blowdown stack is often employed when vapors are released directly to the atmosphere. The blowdown stack is typically located in such a manner as to ensure that combustible mixtures will not be released within the refinery.[26,32]

The current EPA emission factor for uncontrolled refinery blowdowns is 856 $kg/10^3m^3$ (300 $lb/10^3bbl$) refinery throughput.[25,30] This factor is based on a one-year (1956) record of refinery turnarounds in Los Angeles County.[30]

[46]The Expansion of the Refinery at Haig. Erdol Kohle (Itamburg), 26(9):500-502, 1973.

In this one-year period, eight refineries reported 382 turnarounds with blowdown; 56% of these resulted in emission to the atmosphere, while 44% resulted in no emissions, due most probably to the manifolding of blowdown vapors to recovery, fuel gas, or flare systems. Two refineries reported no emissions in 47 turnarounds.

It has been estimated that the current status of control for blowdown systems will result in an average emission reduction of 51%, with a resulting national average blowdown emission of 456 $kg/10^3m^3$ (160 $lb/10^3bbl$) refinery capacity.[47] Information supporting this estimate could not be identified; hence, its validity could not be determined.

5. Pumps

Refinery pumps fall into two broad categories depending on the method of generating flow and pressure in the fluid being pumped. Centrifugal devices generate flow and pressure through centrifugal forces generated by a rotating impeller. Centrifugal devices include centrifugal pumps, axial pumps, and turbine pumps. Shaft motion in all centrifugal devices is rotational. Positive displacement devices generate flow and pressure through fluid displacement by a piston or other surface. Positive displacement devices include reciprocating piston pumps, plunger pumps, diaphragm pumps, and rotary vane and rotary gear pumps. Shaft motion for reciprocating, plunger, and diaphragm pumps is linear while motion is rotational for rotary vane and gear pumps.[33]

In all cases except shaftless pumps, such as canned pumps, and diaphragm pumps, a shaft seal is required to isolate the pump interior from the atmosphere at the point where the shaft penetrates the pump housing. Shaft seals fall into one of two general categories: packed seals and mechanical seals. Packed seals can be used in most pump services, and can be applied to both rotating and linear shaft motions. Mechanical seals are limited to applications with rotating shaft motion. Current mechanical seal technology will allow their use in applications up to approximately 589 K (600°F).[30]

In normal service both packed and mechanical seals can leak hydrocarbons. These losses may be vapor or liquid and occur when shafts become scarred or move eccentrically, or through failure of the packing or seal faces. The rate at which this destruction of seal efficiency progresses depends upon the abrasive and corrosive properties of the product handled and the degree of pump and seal maintenance.[29]

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[47] Burklin, C. E., E. C. Cavanaugh, J. C. Dickerman, S. R. Fernandes, and G. C. Wilkins. Control of Hydrocarbon Emissions from Petroleum Liquids. EPA-600/2-75-042 (PB 246 650), U.S. Environmental Protection Agency, Research Triangle Park, North Carolina, September 1975. 245 pp.

Packed seals, also referred to as stuffing boxes, consist of rings of semiplastic packing which are placed in the pump gland and compressed, forming a seal around the shaft. Packing materials include asbestos, TFE, and graphite, either molded into rings or impregnated in fiber bundles. Packings must be lubricated to prevent overheating, and lubrication is typically provided by slight leakage of the product being pumped. A typical packed seal arrangement is shown in Figure 2. In this seal configuration, a slotted metal lantern ring is placed approximately halfway down the packing. The lantern ring allows leakage through the packing for lubrication and reduces pressure on the outside packing rings. Lantern rings are also used to inject lubrication into the packing. The lubricant will travel in both directions through the packing and hence must be compatible with the fluid being pumped. This type of packing lubrication has the distinct advantage of preventing damage due to abrasive particles in the pumped liquid.[48] If a lubricating liquid with low vapor pressure is used, this lubrication method will also reduce emissions from evaporation of leaked product.

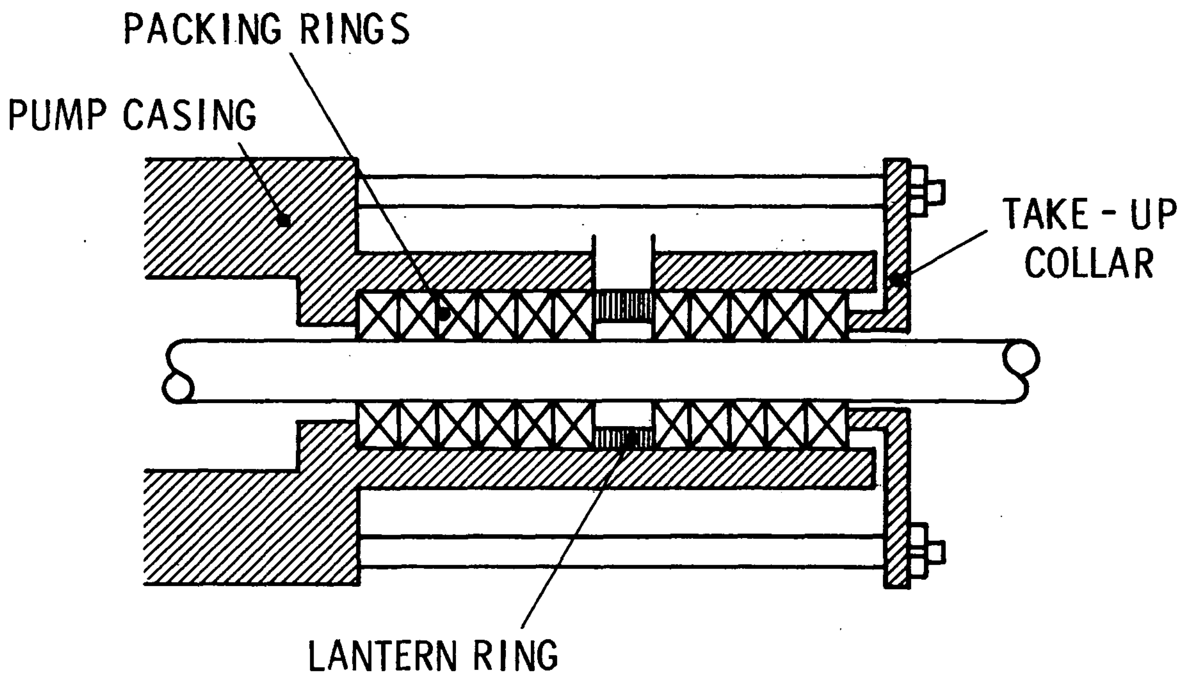
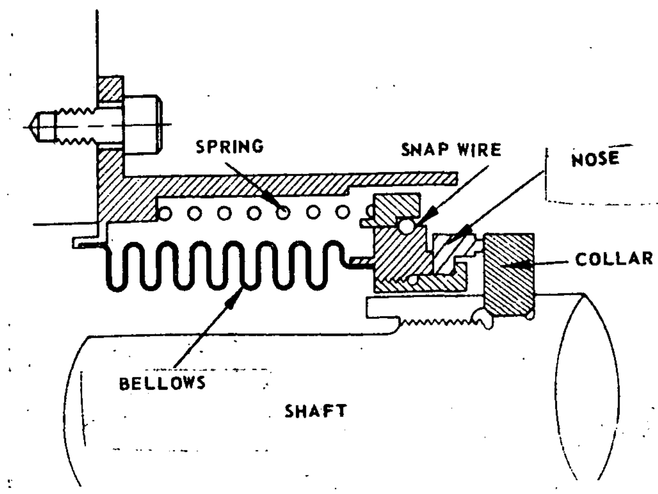


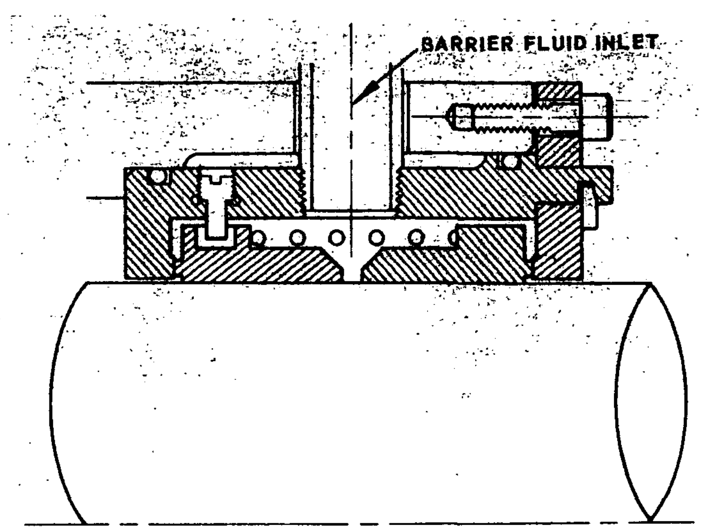
Figure 2. Typical packed seal configuration.

[48]Walker, R. Pump Selection: A Consulting Engineer's Manual. Ann Arbor Science Publishers, Inc., Ann Arbor, Michigan, 1972. pp. 30-31.

Mechanical seals for pump applications are of various designs and configurations, but all consist of two primary parts: a stationary member secured to the pump casing and a rotating member secured to the pump shaft. A seal is created between the stationary and rotating members by contact in the case of face seals and by viscous drag between two closely spaced moving surfaces in the case of bushing seals. In the refinery pumps, the face type seal is typically employed.[49] Typical face and bushing seals are shown in Figure 3.[49]



FACE SEAL



BUSHING SEAL

Figure 3. Typical mechanical seal configurations.[49]

[49]Personal Communication. R. Schmall, Stein Seal Company, Pittsburgh, Pennsylvania. 28 April 1976.

In 1956 Los Angeles County refineries, with a total crude throughput of approximately 1.27 m^3/s (690,000 bbl/day), were surveyed to determine pump seal applications and emissions. The survey identified a total of 1,985 pumps and 2,786 seals. Seventeen percent of the seals were inspected for leakage. The results of the survey are summarized in Table 12.[29] Average emission rates were determined to be 22.0 mg/s/seal (4.2 lb/day/seal), 31.5 mg/s/pump (6.0 lb/day/pump), or 48.5 $kg/10^3m^3$ or (17 $lb/10^3bbl$) of refinery throughput. The latter estimate is used by EPA in its Compilation of Air Pollutant Emissions Factors.[25]

TABLE 12. SUMMARY OF REFINERY PUMP SURVEY[29]

	Percent of total		Average loss			
			Per seal		Per pump	
Pump, seal type	Seals	Pumps	mg/s	(lb/day)	mg/s	(lb/day)
Centrifugal, mechanical	42.2	45.6	16.8	3.2	22.6	4.3
Centrifugal, packed	34.7	32.2	25.2	4.8	37.3	7.1
Reciprocating, packed	23.0	22.2	28.3	5.4	40.4	7.7
Average			22.0	4.2	31.5	6.0

In order to estimate total uncontrolled emissions from pump seals under a condition of no control, it was assumed that packed seals represent a condition of no control. Using the information contained in Table 12, it can be determined that the AP-42 emission factor includes an effective degree of control of:

$$\frac{[(0.222)(40.4) + (1 - 0.222)(37.3)] - 31.5}{[(0.222)(40.4) + (1 - 0.222)(37.3)]} = 0.171$$

or 17.1%. The AP-42 emission factor may therefore be adjusted to yield an uncontrolled emission factor as follows:

$$\text{Uncontrolled emission} = \frac{\text{AP-42 factor}}{(1 - 0.171)} = \frac{48.5}{0.829} = 58.5 \text{ kg}/10^3\text{m}^3$$

The current trend in seal application is to employ mechanical seals whenever the specific application will allow their use. Current mechanical seal technology will allow seal application in situations where temperatures below approximately 589 K (600°F) are encountered.[8] Approximately 75% of refinery pumps are in applications in which mechanical seals may be used.[32,36,49]

6. Compressors

Like refinery pumps, refinery compressors are of two basic types: centrifugal and positive displacement, with the specific compressor and seal configuration dictated by the service requirements and operating conditions. Historically, reciprocating compressors have dominated refinery compressor installations. In 1957, most of the compressors in operation in Los Angeles County were of the reciprocating type.[29] The current trend, however, is toward centrifugal units.[32,50,51]

In 1957, Los Angeles County refineries, with a total crude throughput of approximately 1.10 m^3/day (600,000 bbl/day) were surveyed to determine compressor installations and emissions.[29] Most of the compressors were reciprocating units equipped with packed seals or throttle bushings, however, no numerical breakdown of compressor or seal types was presented. The results of the compressor inventory are presented in Table 13.[29] Of the seals venting to the atmosphere, 326 were tested for leakage. The results of these are presented in Table 14.[29]

TABLE 13. LOS ANGELES REFINERY COMPRESSOR CENSUS[29]

Classification	Number of compressors	%	Number of seals	%
Units venting to atmosphere	162	89.0	345	88.5
Units venting to recovery systems	20	11.0	45	11.5
TOTAL	182	100.0	390	100.0

TABLE 14. SUMMARY OF REFINERY COMPRESSOR EMISSION TESTING[29]

45.7%	showed no leakage
26.7%	had an average estimated loss of 21.0 mg/s (4.0 lb/day) per seal
27.5%	had an average measured loss of 141 mg/s (26.9 lb/day) per seal

Average loss = 446 mg/s (8.5 lb/day) per seal
= 0.014 kg/m^3 (5 lb/10^3 bbl)

[50] Dencer, F. C. Compression Equipment for Hydrocracking and Similar Processes. American Society of Mechanical Engineers, New York, New York. Paper No. 67-PET-41. 4 pp.

[51] Personal Communication. E. D. Opersteny, Corporate Engineering Department, Monsanto Company, St. Louis, Missouri. 26 April 1976.

Eighty-nine percent of the units inspected were vented to the atmosphere, while the remaining 11% were vented to vapor recovery systems. The emission factor presented in AP-42 represents an average, based on emissions from all compressors. The emission factor in AP-42 can therefore be adjusted to yield a total uncontrolled emission factor as follows:

$$\text{Uncontrolled emission} = \frac{\text{AP-42}}{(1 - 0.11)} = \frac{0.014}{0.89} = 0.016 \text{ kg}/10^3 \text{ liter}$$

It was mentioned above that the current trend in compressor installations is toward use of centrifugal compressors. For centrifugal compressors in the petrochemical industry, almost exclusive use is made of liquid film seals in which oil provides the seal between the rotating shaft and the stationary gland. In this case the oil leaves the machine from a chamber on each of the two sides of the gland through two separate pipes. Thus, the inside of the gland is under gas pressure and the outside is under atmospheric pressure. The two oil pipes are kept separate because gas is present in the pipe connected to the inside of the gland.[52] A typical film-riding seal is shown in Figure 4.[53]

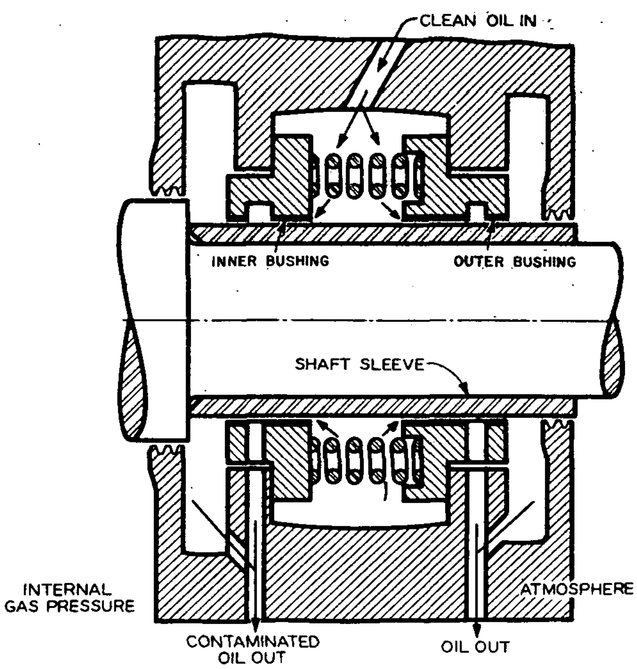


Figure 4. Liquid-film shaft seal with cylindrical bushing.[53]

[52] Bauermeister, K. J. Turbocompressors in Process Plant. Chemical and Process Engineering, 50(9):79-81, 1969.

[53] API Standard 617, Centrifugal Compressors for General Refinery Services, Third Edition, American Petroleum Institute, Washington, D.C., October 1973.

7. Process Drains and Wastewater Separators

Contaminated wastewater originates from several sources in petroleum refineries including, but not limited to, leaks, spills, pump and compressor seal cooling and flushing, sampling, and equipment cleaning. Contaminated wastewater is collected in the process drain system and directed to the refinery treatment system where oil is skimmed in a separator and the wastewater undergoes additional treatment as required.[30]

Refinery drains and treatment facilities are a source of emissions due to evaporation of the volatile hydrocarbons contained in the wastewater. Hydrocarbons will be emitted wherever the wastewater is exposed to the atmosphere. As such, emission points include open drains and drainage ditches, manholes, sewer outfalls, and the surfaces of the separator and treatment ponds.

The uncontrolled emission factor for process drains and wastewater separators, 571 $kg/10^3m^3$ (200 lb/1,000 bbl) of wastewater processed, is based on 1957 estimates of uncontrolled emissions from both process drains and wastewater separators by Los Angeles County refineries and the local air pollution control agency, and was not determined through source sampling.[30]

Owing to the safety hazards associated with hydrocarbon-air mixtures in refinery atmospheres, the current refinery practice is to seal sewer openings and use liquid traps downstream of process drains, thus minimizing hydrocarbon emissions from drainage within the refinery proper. Hydrocarbons evaporated from refinery wastewater will be emitted when the system is exposed to the atmosphere at the sewer outfall. Further evaporation will take place from the water surface in the wastewater treatment system.

SECTION V

BEST AVAILABLE CONTROL TECHNOLOGY

Table 15 summarizes the best available technology for the control of hydrocarbon emission for miscellaneous sources in petroleum refineries and provides estimates of the emission reduction achievable with these technologies. The technologies applicable to individual sources of miscellaneous hydrocarbon emissions are discussed below.

A. VALVES

A conscientious program of valve stem and packing maintenance combined with use of the best available packing materials are the best available methods of controlling emissions from refinery valves. Valves leak due to failure of the stem packing; hence, packing materials maintenance is essential in controlling leakage.

Packing failure is due to two causes:

- Mechanical abrasion from roughened stems, and
- Packing degradation under heat and pressure of operation

Valve stems may become roughened or scored through corrosion and careless handling, and the roughened stem will damage the packing each time the valve is operated. The stem must be kept smooth and clean through valve maintenance programs.[54]

Graphite packings are currently available for use in refinery valves, and it appears that these packings have good performance and maintenance characteristics in refinery service.[32,55] These packings are self-lubricating, and they do not contain resins,

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[54]Selection, Maintenance Can Cut Valve Failure. The Oil and Gas Journal, 73(24):72, 1975.

[55]All Graphite Packaging Stops Leakage of Hydrocarbon from 89 Gate Valves. Chemical Processing, 39(7):75, 1976.

TABLE 15. SUMMARY OF BEST AVAILABLE TECHNOLOGY FOR CONTROL OF MISCELLANEOUS SOURCES OF HYDROCARBON EMISSIONS IN PETROLEUM REFINING INDUSTRY

Emission source	Available techniques of emission control	Estimated efficiency of control, %[a]	Emission achievable after control application: $kg/10^3 m^3$	Emission achievable after control application: $(lb/10^3 bbl)$
Pipeline valves	Valve and packing maintenance, use of improved packing materials	50	40.0	(14)
Flanges	Maintenance, flange elimination where possible, proper flange and piping network design			
Pressure relief valves	Rupture disks	90	6.8	(2.4)
	Manifolding to fuel gas, recovery, or flare system	98	1.4	(0.49)
Blowdown systems	Manifolding to fuel gas, recovery, or flare system	98	17.1	(6.0)
Pump seals	Mechanical seals	90	5.9	(2.1)
	Dual seals with barrier fluid	99	0.59	(0.21)
Compressor seals	Mechanical seals	90	1.6	(0.56)
	Dual seals with barrier fluid	99	0.16	(0.06)
Process drains/ wastewater separators[b]	Liquid traps for drains covered separator	90	57	(20)

[a]In reference to no control conditions.

[b]Assuming 1 bbl wastewater is generated in refining 1 bbl crude oil.[43]

binders, or inorganic fillers which can char, harden, or otherwise deteriorate and impair the ability of the packing to maintain an adequate seal.[55]

Since maintenance practices will vary widely from one refinery to another, the achievable emission reduction due to a valve maintenance program is not easily determined. However, it should not be overly optimistic to assume that improved maintenance and the use of improved packing materials will result in emission reduction approaching 50%.

B. FLANGES

As discussed in Section IV, thermal stresses in refinery piping systems often result in flange seal deformation and product leakage. In order to minimize flange leakage, therefore, it is necessary to design the facilities in such a way as to reduce piping deflection due to thermal stresses. Flanges should also be eliminated wherever possible through use of welded connections. It can be assumed that proper refinery design, operation, and maintenance practices could effectively eliminate hydrocarbon emissions from flange leakage.

C. PRESSURE RELIEF VALVES AND BLOWDOWN SYSTEMS

The best available technology for the control of emissions from pressure relief valves and blowdown systems is to manifold emissions from relief valve horns and vessel vents to vapor recovery, fuel gas, or flare systems. Figure 5 presents a conceptual design of an integrated recovery system.[36] In such a design, relief valve leakage and vessel blowdown are collected in the header system, compressed, and routed to the refinery fuel gas system. In the event of vessel overpressure and relief valve blowoff, gas in excess of recovery system capacity is vented to the refinery flare and incinerated.

A closed vent system as described above is the only technology identified in the literature for control of hydrocarbon emissions during vessel blowdown, and when properly operating, should effectively eliminate emissions from this source. It is estimated that emission reductions of 98% are achievable in controlling relief valve and vessel blowdown in this manner.[36]

In situations where relief valves are not integrated into a recovery system as described above, rupture disks may be installed upstream of the relief valve. Rupture disks will effectively control relief valve leakage until vessel overpressure, at which time the disk will rupture and allow flow. After rupture, the disks must be replaced. It is estimated in the literature that the use of rupture disks alone will reduce relief valve emissions by 90%.[37]

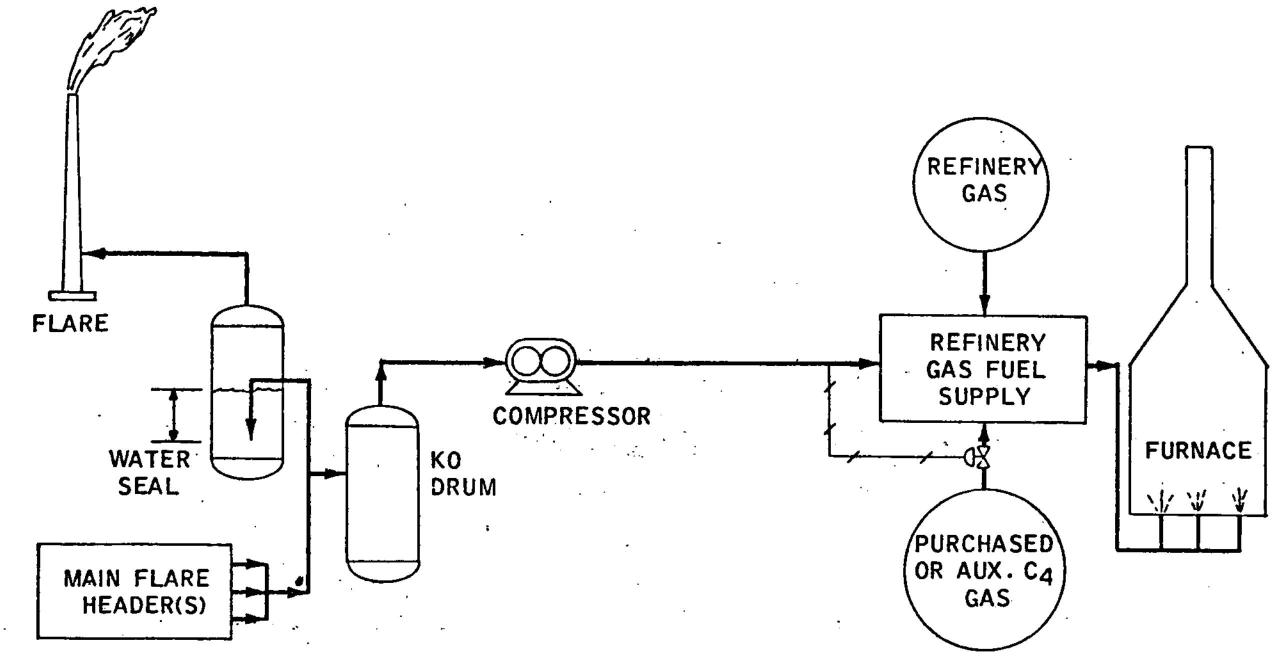

Figure 5. Basic elements of flare gas recovery system.

D. PUMP AND COMPRESSOR SEALS

As discussed in Section IV, mechanical seals are superior to packed seals in preventing leakage from pumps and compressors. In the Los Angeles survey of refinery pumps,[29] the mechanical seals tested emitted, on the average, 33% fewer hydrocarbons than did packed seals. Other sources have estimated that current available mechanical seals are 90%[33] to 99%[50] more effective than packings in reducing emissions from pump and compressor seals. For the purpose of this report it is estimated that 90% reduction is achievable through application of currently available mechanical seals to centrifugal refinery pumps and compressors. Due to linear shaft motion, mechanical seals cannot be applied to reciprocating pumps and compressors. For these types of equipment, dual seals, described below, represent the best available control equipment.

The most effective system for control of shaft seal emissions is the use of dual seals (either mechanical or packed) with a barrier fluid as shown in Figure 6.[1,47,49,51] In this seal arrangement, a nonvolatile barrier fluid flushes away leakage from the primary shaft seal. Leakage of the barrier fluid through the secondary seal will be minimal, because the barrier fluid can be at a relatively low pressure. Dual seals with barrier fluids

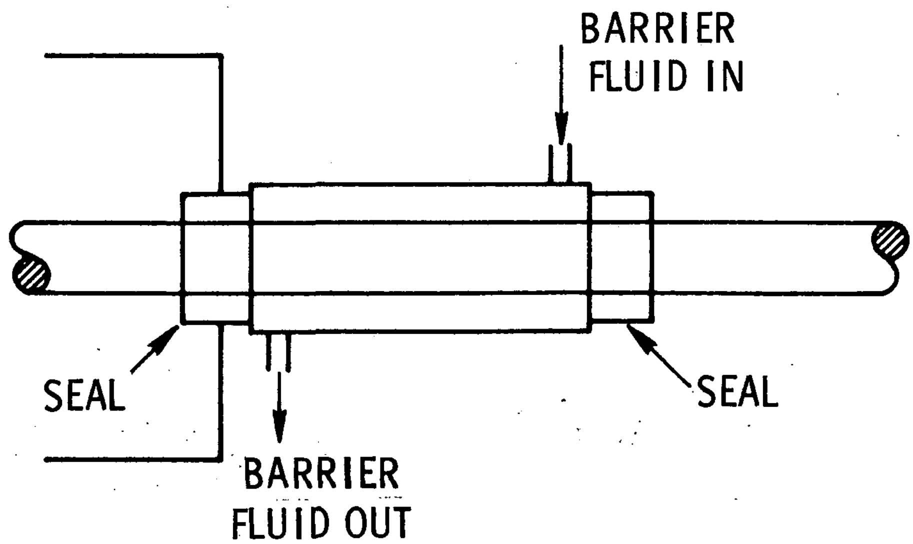

Figure 6. Dual shaft seal with barrier fluid.

can be applied to both rotating and reciprocating shafts. They are being successfully employed in the chemical process industry in situations where obnoxious or toxic substances are being pumped and compressed.[51]

It is estimated that dual seals and barrier fluids will result in emission reductions of 99%.

E. PROCESS DRAINS AND WASTEWATER SEPARATORS

Current EPA emission factors for hydrocarbon evaporation from refinery wastewater are based on estimates of emissions from both process drains and wastewater separators. In reducing emissions due to hydrocarbon evaporation, controls must be applied to both process drains and wastewater separators.

Control of emissions from process drains requires that the hydrocarbons evaporated from the wastewater in the refinery sewer system be contained within the sewer while wastewater is allowed access. All sewer lines should be closed and placed underground. At drain openings, control can be achieved by isolating the vapor space in the sewer system from the atmosphere by liquid seals or traps similar to traps currently employed in household plumbing systems. In addition, all sewer vent lines and manholes should be sealed.[43]

To reduce emissions from the wastewater separator, covers -- either fixed or floating -- should be installed, and untreated wastewater should not be exposed to the atmosphere. It has been estimated in the literature[24] that the above controls will reduce emissions from 90% to 98%. A conservative estimate of 90% reduction is assumed to be achievable.

F. REFINERY MAINTENANCE

In discussing emissions control for miscellaneous sources in petroleum refineries, mention must be made of the importance of inspection and maintenance programs and the possible effect of these programs on refinery emissions.

Pressure relief and pipeline valves, pump seals, and compressor seals maintain their sealing effect through proper mating of two sealing surfaces. If these seals are not properly maintained, be they compressed packings, finely machined surfaces (as in mechanical seals), or seats (as in pressure relief valves), they can degrade to the point where their capability to seal is reduced. The net result of this degradation is that the seals and seats become a source of emission.

Table 16 shows the percentage of total units inspected in the Los Angeles County which were determined to be sources of emission. In all cases, except for blowdown systems, less than 50% of the equipment inspected was found to be leaking. If, for example, improved maintenance and inspection procedures could eliminate leakage from only an additional 6% of the valves in a refinery (on the average), the average emission rate for all pipeline valves would be reduced by 50%. Similarly, elimination of leakage from only an additional 11.5% of the total pressure relief valve population would result in a 50% reduction in the average loss emission from these sources.

TABLE 16. UNITS IDENTIFIED AS LEAKING IN LOS ANGELES COUNTY REFINERIES

Emission source	Units identified as leaking, %
Pipeline valves	12
Pressure relief valves	23
Blowdown systems	56[a]
Pump seals	36
Compressor seals	46

[a] 99% of blowdowns did not result in emissions to the atmosphere.

Not only can refinery inspection and maintenance reduce emissions from miscellaneous sources, they can also benefit refinery safety. As such, routine equipment inspection and maintenance should be an integral part of refinery pollution control programs.

SECTION VI

AIR POLLUTION REGULATIONS

State regulations were obtained and reviewed, and those applicable to emissions from miscellaneous sources in petroleum refineries were extracted and summarized. No states were found to have emission regulations specific to petroleum refineries. However, some state regulations have been promulgated to limit hydrocarbon emissions from the following sources: wastewater separators, pumps, compressors, blowdown systems, and pressure relief valves. These regulations are not industry specific but nevertheless should apply to petroleum refineries. No states are currently restricting emissions from valves, flanges, or process drains.

Table 17 summarizes the current status of state and selected local regulations pertinent to hydrocarbon emissions from miscellaneous sources. To indicate the wording, the text of Colorado regulations is detailed in Appendix C.

Reviewing the state hydrocarbon emission regulations indicates that no regulations are comprehensive enough to assure reduced refinery hydrocarbon emissions from all miscellaneous sources. The state regulations typically require the use of available control devices with no specifications for the device performance and/or permissible hydrocarbon emission levels.

Table 18 presents a comparison of emission reductions achievable through the application of the state regulations and those achievable through application of the best available control technology. It can be seen that in certain instances, state regulations will result in emission reductions equal to those obtained through application of best available control technology. Table 19, providing a breakdown of refining throughput affected by state regulations, indicates that the national emission reductions achievable through application of current state regulations will be below those indicated in Table 18. Average emission factors for miscellaneous sources are presented in Section VII.B.3, Table 21.

TABLE 17. SUMMARY OF STATE AIR POLLUTION REGULATIONS[4]

State	Number of refineries	1976 Refinery throughput m^3/s	1976 Refinery throughput (bbl/sd)	Wastewater separators	Compressors	Blowdown, pressure relief systems
Alabama	3	0.10	(53,000)	x	x	
Alaska	4	0.14	(78,158)			
Arizona	1	0.01	(4,000)		x	
Arkansas	4	0.11	(62,425)			
California	35	3.67	(1,993,503)	x	x	x
Colorado	3	0.12	(65,000)	x	x	x
Connecticut	0	0				
Delaware	1	0.28	(150,000)			
Florida	1	0.01	(6,000)		x	
Georgia	2	0.04	(19,400)			
Hawaii	2	0.20	(107,105)	x	x	x
Idaho	0	0				
Illinois	11	2.27	(1,232,958)	x[a]	x	x
Indiana	7	0.97	(527,300)			
Iowa	0	0				
Kansas	11	0.86	(468,940)			x
Kentucky	3	0.31	(169,500)	x	x	
Louisiana	19	3.36	(1,827,031)	x	x	
Maine	0	0				
Maryland	2	0.06	(31,211)	x[b]		
Massachusetts	0	0				
Michigan	6	0.28	(151,395)			
Minnesota	3	0.41	(223,905)			
Mississippi	5	0.64	(346,842)			
Missouri	1	0.20	(108,000)			
Montana	7	0.30	(164,016)	x		
Nebraska	1	0.01	(5,500)			
Nevada	0	0				
New Hampshire	0	0				
New Jersey	4	1.04	(562,764)			
New Mexico	7	0.20	(106,305)	x[b]		
New York	2	0.21	(114,500)	x	x	
North Carolina	0	0				
North Dakota	3	0.11	(60,163)		x	x
Ohio	7	1.13	(614,500)	x		x
Oklahoma	12	1.03	(559,719)	x	x	x[c]
Oregon	1	0.03	(14,737)	x	x	
Pennsylvania	11	1.47	(796,415)	x	x	
Rhode Island	0	0				
South Carolina	0	0				
South Dakota	0	0				
Tennessee	1	0.08	(44,800)			
Texas	46	7.63	(4,144,778)	x		
Utah	7	0.29	(158,878)			
Vermont	0	0				
Virginia	1	0.10	(55,000)	x	x	x[c]
Washington	7	0.70	(383,105)			
West Virginia	3	0.04	(20,200)			
Wisconsin	1	0.09	(46,800)			
Wyoming	11	0.36	(194,557)			x
TOTAL U.S.	256	28.86	(15,687,321)[d]			

[a] Control in excess of 85% is required.

[b] Designated areas only.

[c] Excludes emergency relief valves.

[d] Actual total is 15,672,621 and does not agree with the original reference.

TABLE 18. EMISSION REDUCTION UNDER STATE REGULATIONS AND BEST AVAILABLE CONTROL TECHNOLOGY

	Control required by state regulations				Achievable control with best available control technology			
		Estimated reduction,	Allowable emission			Estimated reduction,[a]	Allowable emission	
Emission source	Description	%	g/m^3	($lb/10^3$ bbl)	Description	%	g/m^3	($lb/10^3$ bbl)
Pipeline valves and flanges	None	0	80	(28)	Conscientious maintenance	50	40	(14)
Pressure relief valves	Flare or equivalent	98	1.4	(0.49)	Manifold to fuel gas, recovery, or flare system	98	1.4	(0.49)
Blowdown systems	Flare or equivalent	98	17.1	(6.0)	Manifold to fuel gas, recovery, or flare system	98	17.1	(6.0)
Pump seals	Mechanical seals or equivalent	90	5.9	(2.1)	Dual seals with barrier fluid	99	0.59	(0.21)
Compressor seals	Mechanical seals or equivalent	90	1.6	(0.56)	Dual seals with barrier fluid	99	0.16	(0.06)
Process drains and wastewater separator	Covered separator	85[b,c]	86	(30)	Liquid traps for drains, covered separator	90	57	(20)

[a]From Table 15.

[b]Minimum efficiency required by State of Illinois.

[c]Wastewater generation of 1 bbl/bbl crude throughput is assumed.

TABLE 19. 1976 REFINERY THROUGHPUT AFFECTED BY STATE REGULATIONS

Emission source	1976 throughput in states with regulations m^3/s	(bbl/day)	Total throughput "controlled,"[a] %
Wastewater separators	20.66	(11,225,863)	72
Pumps and compressors	11.53	(6,265,216)	40
Blowdown and pressure relief systems	8.72	(4,739,726)	30
Blowdown systems, excluding pressure relief systems	1.13	(614,719)	4

[a]Assuming regulations pertain to both new and existing sources. Whether or not the existing specific state regulations apply to both new and existing sources cannot be determined from the text of these regulations.

SECTION VII

ESTIMATED EMISSION REDUCTION

Model IV was developed by the EPA to be used by the Emission Standards and Engineering Division. It is used to assess numerous industries for the purpose of establishing priorities for setting standards. The model mathematically expresses the differential in atmospheric emissions that can be expected with and without NSPS.[56]

The model by which emission differential was calculated uses 1975 capacity as the baseline to which estimated growth and obsolescence rates over the next ten years are applied. This gives the new and modified capacity that can be regulated by NSPS in the period 1975 to 1985. The best available level of control is then applied to this capacity to determine the level of emissions under controls required by NSPS in 1985. Similarly, another set of emission levels is determined for 1985 by applying to the current, new, and modified capacity the current levels of emissions. Both sets of emission levels represent maximum values based on capacity. The capacity utilization factor is used to convert emission levels from operation at capacity to operation at production rates anticipated in 1985. The difference between the two values of emission levels represents the control effectiveness of NSPS.

Certain variables needed to develop the relationship between projected emissions under baseline year levels of control and controls required under NSPS for miscellaneous sources of emissions in petroleum refineries will be defined under three groups: industrial prime variables, emission factors, and intermediate variables

A. INDUSTRIAL PRIME VARIABLES

1. Normal Fractional Utilization, "K"

The variable, "K," represents that fraction of total existing capacity which is brought into service to produce a given output.

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[56] Hopper, T. G., and W. A. Marrone. Impact of New Source Performance Standards on 1985 National Emissions from Stationary Sources, Volume I. EPA Contract 68-02-1382, Task 3, U.S. Environmental Protection Agency, Research Triangle Park, North Carolina, 24 October 1975. 178 pp.

By applying this factor to the capacity-based values A, B, and C, actual production output can be determined.[56]

The purpose of "K" is to convert design capacity to production capacity. Production figures are then applied to emission factors to calculate actual emissions. Petroleum refineries report production figures in either barrels per calendar day or barrels per stream day.[4-14]

Calendar day figures are refiners' yearly averages for the number of barrels processed by a refinery or refinery operation. The basis for calculating calendar day production is the total refinery or refinery operation throughput per year divided by 365 days. Stream day figures represent the sum of the number of barrels a refinery or refinery operation processes each day, divided by the number of operating days.[4-14]

Production figures used in this report were obtained from the American Petroleum Institute (API). API reports production figures for crude capacity in barrels per stream day (bbl/sd) having used a conversion factor of 0.95 to convert calendar day figures to stream day figures. The factor 0.95 is not a ratio of production capacity to design capacity and does not satisfy the above definition of "K". But for this report, API production data reported in barrels per stream day were used and, therefore, "K" was given the value of 0.95.

2. Production Capacity, "A"

The variable, "A," is defined as the industrial production capacity in the baseline year.[56] For 1975 the crude capacity has been reported in the literature to be 28.90 m^3/s (15,687,321 bbl/sd).[3] Therefore, "A" was given the value 28.90 m^3/s (15.69×10^6 bbl/sd).

3. Increase in Industrial Capacity Over Baseline Year Capacity - P_c

The variable, P_c, is defined as the average anticipated growth rate in industrial capacity during the period between the baseline year and 1985.[56]

Production capacity data for crude processed from 1965 through 1975 shown in Table 4 were plotted (Figure 7).[4-14] Assuming the yearly rate of increase in capacity to remain constant through 1985, P_c was calculated using compound growth.

$$P_c = \sqrt[x-y]{\frac{\text{Capacity in year "X"}}{\text{Capacity in year "y"}}} - 1.0$$

where $x > y$

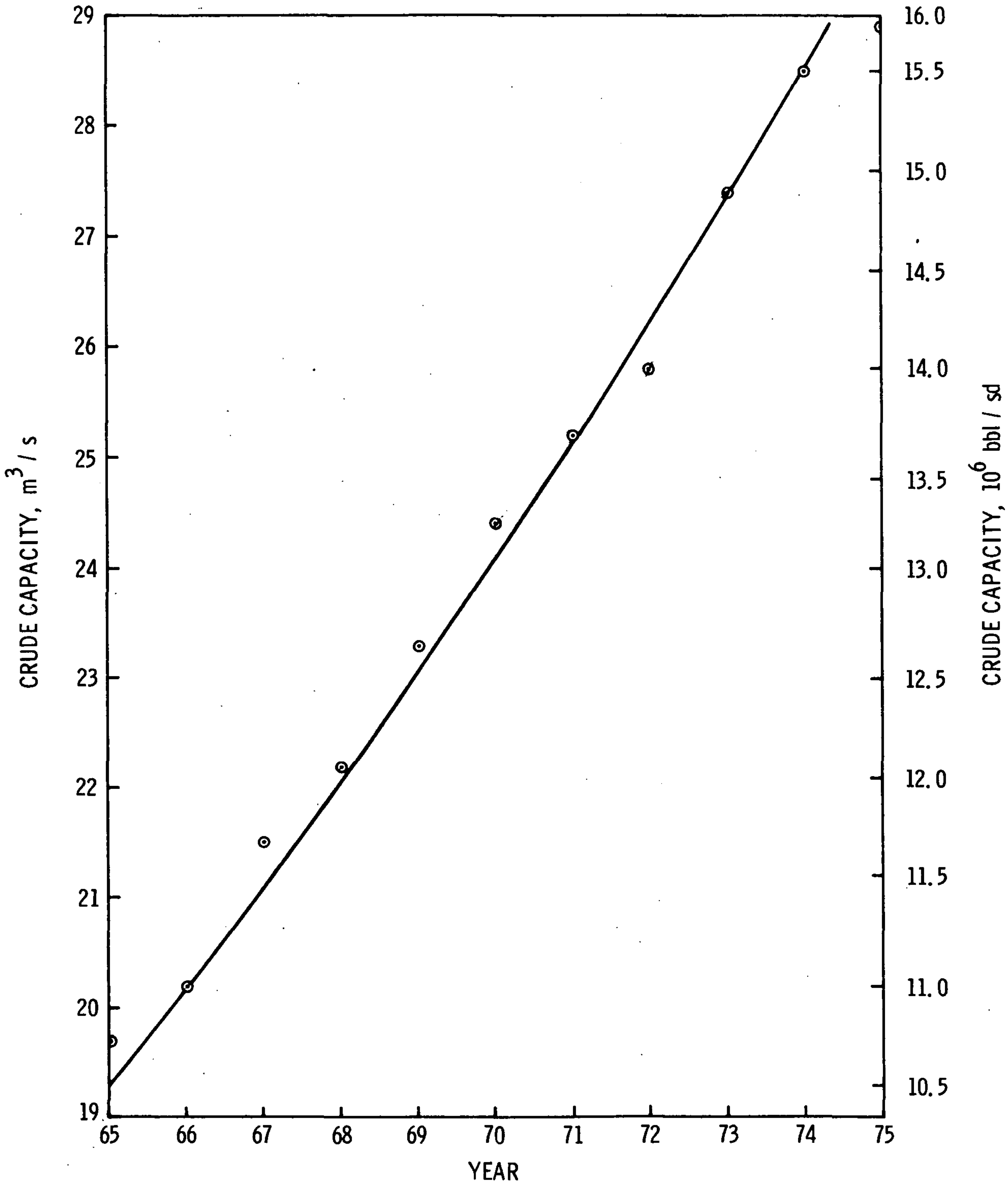

Figure 7. Petroleum refining production capacity, 1965-1975.

letting x = 1973 and y = 1966

$$P_c = \sqrt[7]{\frac{27.4}{20.2}} - 1.0 \left(\sqrt[7]{\frac{14,876,050}{10,952,495}} - 1.0\right)$$

$= 4.45 \times 10^{-2}$ decimal fraction of baseline capacity/yr

4. <u>Replacement Rate of Obsolete Production Capacity - P_b</u>

The variable, P_b, is defined as the average rate at which obsolete production capacity is replaced during the period between the baseline year and 1985.[56]

Table 20 lists total yearly refinery obsolete capacities between 1965 and 1975.[15-24] These data are also plotted in Figure 8.[15-24]

TABLE 20. REFINERY OBSOLETE CAPACITY[15-24]

	Inoperable shutdown		Total obsolete capacity since Jan. 1966	
Year	m^3/s	(bbl/sd)	m^3/s	(bbl/sd)
1966	0.181	(98,900)	0.181	(98,900)
1967	0.186	(101,200)	0.368	(200,100)
1968	0.330	(179,450)	0.698	(379,550)
1969	0.068	(37,200)	0.767	(416,750)
1970	0.097	(53,050)	0.864	(469,800)
1971	0.294	(159,750)	1.15	(629,550)
1972	0.267	(145,000)	1.42	(774,550)
1973	0.243	(132,200)	1.67	(906,750)
1974	0.235	(127,900)	1.90	(1,034,650)
1975	0.382	(209,100)	2.29	(1,242,750)

From Figure 8 it is seen that the rate of obsolescence between the years of 1965 and 1975 has remained fairly constant. Assuming this will continue through 1985, P_b was calculated using the equation:

$$P_b = \frac{\text{Obsolete capacity up to year "x" - obsolete capacity up to year "y"}}{\text{(x - y) Capacity in 1975}}$$

where $x > y$

Letting x = 1974 and y = 1967

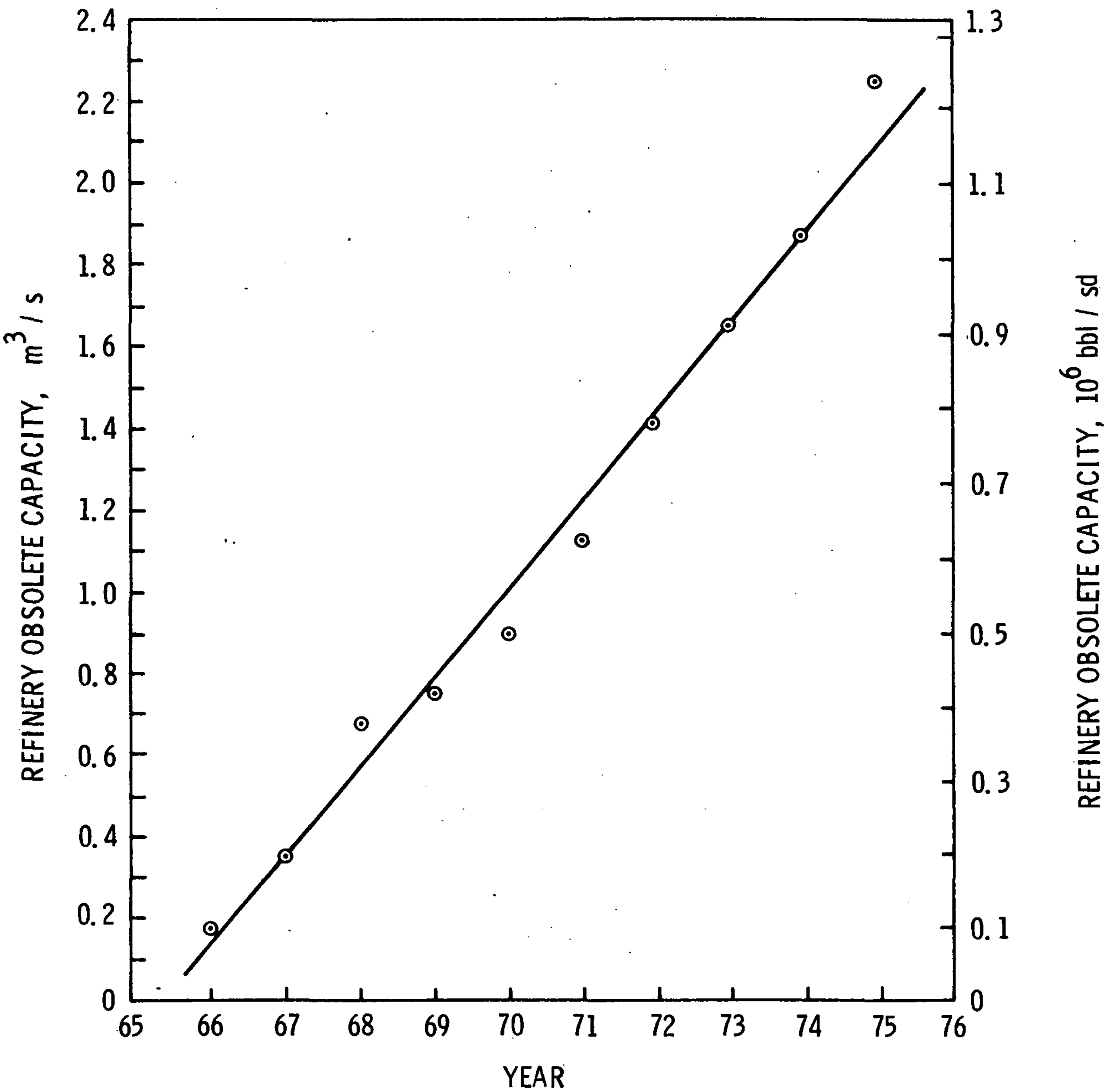

Figure 8. Refinery obsolete capacity 1966-1975.[15-26]

$$P_b = \frac{1.91 - 0.37}{7 \times 10.44} \left(\frac{1,034,650 - 200,100}{7 \times 5,672,898} \right)$$

$$= 2.10 \times 10^{-2} \text{ decimal fraction of baseline capacity/yr}$$

B. EMISSION FACTORS

1. Uncontrolled Emission Factor - E_u

The variable, E_u, is the emission factor representing a condition of no control. Uncontrolled emission factors for miscellaneous sources have been presented in Section IV.

2. Controlled Emission Factor - E_n

The variable, E_n, is the emission factor representing the condition of the best available control applied to new sources. Emissions under the best applicable systems of control have been presented in Table 15.

3. Estimated Allowable Emissions Under 1975 Regulations - E_s

The variable, E_s, is the emission factor which represents the 1975 level of control required under state regulations. Emission reduction under application of state standards to both new and existing sources has been presented in Table 18. The 1975 refining throughput in states requiring controls has been presented in Table 19. E_s was therefore calculated by assuming that the refining capacity of Table 19 is controlled to the extent identified in Table 18 and that the remaining refining capacity is uncontrolled. The values for E_s are presented in Table 21.

TABLE 21. ESTIMATED EMISSIONS UNDER CURRENT STATE EMISSION REGULATIONS (NATIONAL BASIS)

	E_s	
Emission source	g/m^3	$(lb/10^3\ bbl)$
Pipeline valves and flanges	80	(28)
Pressure Relief valves	48	(17)
Blowdown systems	573	(201)
Pump seals	38	(13)
Compressor seals	10	(3.6)
Process drains and waste-water separators	221	(77)

C. INTERMEDIATE VARIABLES

1. Production Capacity from Construction and Modification to Replace Obsolete Facilities - B

The value, B, represents the capacity added to replace facilities for the period 1975 to 1985. Assuming simple growth, it is represented by the equation:

$$B = AiP_b$$

$$= 6.07 \text{ m}^3/\text{s} \ (3.29 \times 10^6 \text{ bbl/sd})$$

where A = 1975 production capacity - 28.9 m^3/s (15.69 x 10^6 bbl/sd)
i = number of years in period 1975-1985 = 10
P_b = replacement of obsolete production capacity

2. Production Capacity from Construction and Modification - C

The value, C, is defined as the production capacity from construction and modification added in the period 1975-1985 to increase output above the 1975 baseline capacity and is given (assuming compound growth) by the formula:

$$C = A[(1 + P_c)^i - 1]$$

$$= 15.77 \text{ m}^3/\text{s} \ (8.56 \times 10^6 \text{ bbl/sd})$$

where A = baseline production capacity 28.9 m^3/s (15.69 x 10^6 bbl/sd)
i = number of years in period 1975-1985 = 10
P_c = increase in production capacity over baseline capacity = 4.45 x 10^{-2}

Figure 9 provides a graphical representation of estimated petroleum refinery growth and obsolescence for the period 1975-1985.

3. Total Emissions in Baseline Year (1975) Under Baseline Year Regulations - T_a

The variable, T_a, is defined as the total emissions in 1975 under current (1975) regulations and can be calculated using the equation:

$$T_a = E_s KA$$

4. Total Emissions in 1985 Assuming No Control - T_u

The variable, T_u, for 1985 can be calculated using the equation:

$$T_u = E_u K(A - B) + E_u K(B + C)$$

$$= E_u K(A - B + B + C)$$

$$= E_u K(A + C)$$

5. Emissions in 1985 Under Baseline Year Control Regulations - T_s

The variable, T_s, for 1985 is calculated by using the equation:

$$T_s = E_s K(A - B) + E_s K(B + C)$$

$$= E_s K(A - B + B + C)$$

$$= E_s K(A + C)$$

Implicit in this definition is the assumption that state regulations will apply to both new and existing sources.

6. Emissions in 1985 Under New or Revised Standards of Performance - T_n

The variable, T_n, for 1985 is calculated by using the equation:

$$T_n = E_s K(A - B) + E_n K(B + C)$$

D. SUMMARY OF EMISSION REDUCTION

Table 22 summarizes the input variables, emission factors, and intermediate variables, forming the basis for determination of the impact of New Source Performance Standards (NSPS) requiring application of the best available control technology in reducing emissions from miscellaneous sources in petroleum refineries. It is seen from the bottom row of values in this table that NSPS as described above will reduce total emission from 24% (in the case of pipeline valves and flanges) to 48% (in the case of pump and compressor seals) over those emissions anticipated under the strictest interpretation of the state standards currently in force (application to both new and existing sources).

Reductions over uncontrolled emissions achievable through implementation of both state regulations and NSPS, are compared in Table 23.

TABLE 22. SUMMARY OF ESTIMATED EMISSION REDUCTION

Emission source		Pipeline valves and flanges	Pressure relief valves	Blowdown systems	Pump seals	Compressor seals	Process drains and wastewater separators
Normal fractional utilization factors	K	0.95	0.95	0.95	0.95	0.95	0.95
Emission rate, g/m^3 ($lb/10^3 bbl$)	E_u	80 (28)	68 (24)	856 (300)	59 (21)	16 (5.6)	570 (200)
	E_s	80 (28)	48 (17)	573 (201)	38 (13)	10 (3.6)	221 (77)
	E_n	40 (14)	1.4 (0.67)	17.1 (6.0)	0.59 (0.21)	0.16 (0.06)	57 (20)
Growth rates, decimal/year	P_c	4.45×10^{-2}	4.45×10^{-2}	4.45×10^{-2}	4.45×10^{-2}	4.45×10^{-2}	4.45×10^{-2}
	P_b	2.10×10^{-2}	2.10×10^{-2}	2.10×10^{-2}	2.10×10^{-2}	2.10×10^{-2}	2.10×10^{-2}
Industrial capacity, m^3/s ($10^6 bbl/sd$)	A (1975)	28.90 (15.69)	28.90 (15.69)	28.90 (15.69)	28.90 (15.69)	28.90 (15.69)	28.90 (15.69)
	B (1985)	6.07 (3.29)	6.07 (3.29)	6.07 (3.29)	6.07 (3.29)	6.07 (3.29)	6.07 (3.29)
	C (1985)	15.77 (8.56)	15.77 (8.56)	15.77 (8.56)	15.77 (8.56)	15.77 (8.56)	15.77 (8.56)
Emissions, Gg/yr (10^3 tons/yr)	T_a	69.3 (76.4)	41.6 (45.9)	496 (547)	32.7 (36.1)	8.83 (9.73)	192 (212)
	T_u	107 (118)	91.0 (100)	1,151 (1,269)	79.0 (87.1)	21.4 (23.6)	763 (841)
	T_s	107 (118)	64.2 (70.8)	767 (845)	50.6 (55.8)	13.7 (15.1)	296 (326)
	T_n	80.9 (89.2)	33.8 (37.3)	403 (444)	26.2 (28.9)	7.08 (7.80)	189 (208)
Impact, Gg/yr (10^3 tons/yr)	$T_s - T_n$	26.2 (28.9)	30.5 (33.6)	363 (401)	24.4 (26.9)	6.57 (7.24)	107 (118)
Reduction, %		24	47	47	48	48	36

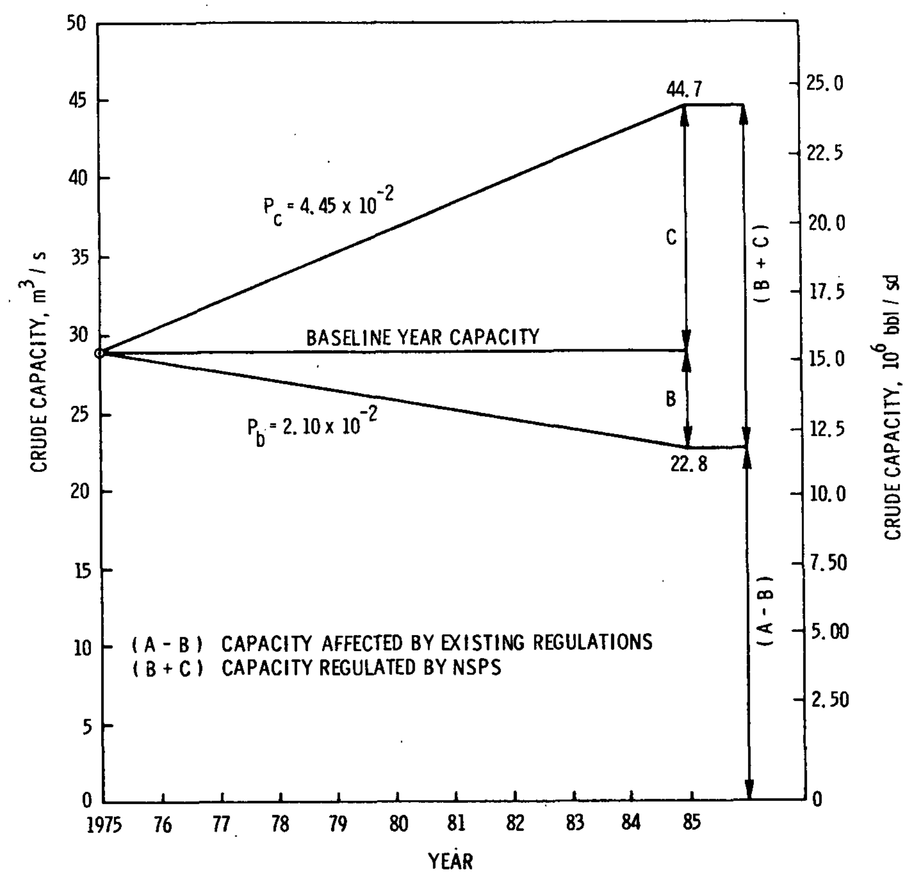

Figure 9. Applicability of NSPS to construction and modification.

TABLE 23. PERCENT REDUCTION OVER UNCONTROLLED EMISSIONS THROUGH APPLICATION OF CONTROL TECHNOLOGY, 1985

Emission source	Required by states,[a] %	Required by NSPS,[b] %
Pipeline valves and flanges	0	24
Pressure relief valves	29	63
Blowdown systems	33	65
Pump seals	36	67
Compressor seals	36	67
Process drains/wastewater	61	75
All miscellaneous sources	41	67

[a]Applied to both new and existing capacity.

[b]For new sources only, with existing sources regulated by state regulations.

SECTION VIII

MODIFICATION AND RECONSTRUCTION

The miscellaneous sources addressed in this report can be considered common to all aspects of the petroleum refining industry. Valves, pumps, and compressors will be found in all processing systems where liquids and gases are handled, processed, and stored.

Increases of total refinery production will require either that the plant capacity factor be increased, or that the total refinery capacity be increased through construction of new facilities, or that additional capacity be installed at existing facilities. The expansions of total installed refinery capacity through construction of new facilities will require the installation of additional valves, pumps, compressors, drains, etc., and will therefore result in increased emission from these miscellaneous sources.

There will obviously be differences in the application and performance of these miscellaneous sources in the various phases of the refining process, but determination of the factors affecting application and performance of these sources was beyond the scope of this project, and their quantification was not attempted.

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APPENDIX A

SUMMARY OF PETROLEUM REFINERIES IN THE UNITED STATES

Calendar-day figures reported in this survey (Table A-1) are refiners' averages for how many barrels each day a refinery unit yields on the average, including downtime used for turnarounds. These figures are actual yearly throughputs divided by 365.

Stream-day figures represent the potential a refinery unit can yield when running at full capacity.

Operating plants in this survey are restricted to facilities charging whole crude, plus lube plants not charging whole crude.

The total figures for most plants are given in barrels per stream day. However, a few companies reported only calendar-day figures. Therefore, to keep consistent stream-day totals for states or provinces, calendar-day figures were converted to a stream-day basis, using a 0.95 factor for curde and vacuum units, and a 0.90 conversion for all other processes. This explains what may appear to be discrepancies in the addition of some columns.

The term NR means not reported. When this term is noted in the crude columns, the totals show figures to have been converted to either a stream-day or calendar-day basis to make each column complete.

In the case of cat-cracking, if a recycle figure was not reported, then state or province totals include figures converted on an estimate of 30% of the fresh feed reported.

LEGEND FOR TABLE A-1[a]

LEGEND

Processes in table are identified by numbers

CAT HYDROREFINING

1. Residual desulfurizing
2. Heavy gas-oil desulfurizing
3. Residual visbreaking
4. Cat-cracker and cycle-stock feed pretreatment
5. Middle distillate
6. Other

CAT HYDROTREATING

1. Pretreating cat-reformer feeds
2. Naphtha desulfurizing
3. Naphtha olefin or aromatics saturation
4. Straight-run distillate
5. Other distillates
6. Lube-oil "polishing"
7. Other

AROMATICS/ISOMERIZATION

1. BTX
2. Hydrodealkylation
3. Cyclohexane
4. C_4 feed
5. C_5 feed
6. C_5 and C_6 feed

CAT REFORMING

Semiregenerative:

1. Conventional catalyst
2. Bimetallic catalyst

Cyclic:

3. Conventional catalyst
4. *Bimetallic catalyst*

Other:

5. Conventional
6. Bimetallic

CAT HYDROCRACKING

1. Distillate upgrading
2. Residual upgrading
3. Lube-oil manufacturing
4. Other

THERMAL PROCESS

1. Gas-oil cracking
2. Visbreaking
3. Fluid coking
4. Delayed coking
5. Other

ALKYLATION

1. Sulfuric acid
2. Hydrofluoric acid

CAT CRACKING

1. Fluid
2. Thermofor
3. Houdriflow

HYDROGEN

1. Steam methane reforming
2. Steam naphtha reforming
3. Partial oxidation
4. Cryogenic
5. Other

NR—not reported

SHUT DOWN but still in operating condition (capacities are given in barrels per stream day):

C & H Refinery, Lusk, Wyo. 500.

Imperial Oil Co., Calgary, Alta., Canada, 22,315.

Imperial Oil Co., Winnipeg, Man., Canada, 22,526.

Imperial Oil Co., Regina, Sask., Canada, 32,316.

Jet Fuel Refinery, Mosby, Mont., 200.

Mobil Oil Corp., East Providence, R.I., 10,000.

Pioneer Division, Witco Chemical Co., Hammond, Ind., 10,000.

Texas Fuel & Asphalt, LaCoste, Texas, 1,500.

[a]Reprinted from The Oil and Gas Journal, 12 March 1976.

TABLE A-1. SURVEY OF OPERATING REFINERIES IN THE U.S. AS OF 1 JANUARY 1976[4,a]

				Charge capacity—b/sd								Production capacity—b/sd					
State	No. plants	Crude capacity b/cd	Crude capacity b/sd	Vacuum distillation	Thermal operations	Cat cracking Fresh feed	Cat cracking Recycle	Cat reforming	Cat hydro-cracking	Cat hydro-refining	Cat hydro-treating	Alkyla-tion	Aromatics/isomerization	Lubes	Asphalt	Hydrogen (MMcfd)	Coke (t/d)
Alabama	3	49,875	53,000	17,500	......	......	....	5,500	....	9,000	11,400	....	....	....	10,500	....	....
Alaska	4	74,250	78,158	......	......	......	....	6,000	....	......	6,000	....	....	....	300	....	....
Arizona	1	4,000	4,211	2,500	......	......	....	......	....	......	......	....	....	....	....	....	....
Arkansas	4	60,786	62,425	23,100	......	15,000	3,000	5,750	....	......	13,100	4,500	....	4,250	7,700	2.9	....
California	35	1,903,935	1,993,503	944,650	473,083	485,611	135,600	495,339	319,822	149,244	681,622	90,028	22,490	22,300	109,760	734.1	15,233
Colorado	3	62,125	65,000	10,500	22,000	22,500	1,400	13,100	....	......	18,500	....	....	....	3,300	1.0	30
Delaware	1	140,000	150,000	90,700	44,000	62,000	15,000	42,000	17,000	......	110,000	8,000	....	....	....	72.0	1,500
Florida	1	5,700	6,000	3,400	......	......	...	......	....	......	......	....	....	....	2,400	...	....
Georgia	2	18,000	19,400	......	......	......	......	......	....	......	......	....	....	200	11,600	....	....
Hawaii	2	101,750	107,105	15,000	......	14,100	8,900	11,000	....	......	12,400	4,130	1,350	....	1,300	2.5	....
Illinois	11	1,176,050	1,232,958	420,499	145,300	429,277	94,000	315,377	66,500	108,000	494,243	105,822	10,100	5,600	42,500	82.0	3,933
Indiana	7	561,160	527,300	267,000	24,000	193,000	10,800	127,100	....	30,160	210,500	30,200	3,200	11,300	56,600	....	885
Kansas	11	451,180	468,940	138,650	36,400	163,700	42,750	104,200	3,100	3,000	145,700	39,100	3,400	4,000	18,800	4.2	1,500
Kentucky	3	164,000	169,500	68,000	4,000	54,000	1,000	30,500	....	......	43,000	6,400	18,500	....	23,500	....	....
Louisiana	19	1,753,095	1,827,031	502,342	141,333	617,778	59,950	377,033	80,500	114,500	415,311	131,089	26,800	24,750	39,850	73.0	5,850
Maryland	2	28,500	31,211	13,800	......	......	....	......	....	......	......	....	....	....	21,700	....	....
Michigan	6	147,200	151,395	42,000	......	39,500	7,400	29,500	....	12,500	33,200	4,900	....	....	11,450	....	....
Minnesota	3	216,800	223,905	137,000	23,000	71,500	3,000	30,100	....	20,000	72,100	11,500	....	....	57,000	....	1,300
Mississippi	5	329,500	346,842	156,000	6,700	70,500	6,350	70,700	71,000	53,000	53,450	9,200	6,000	....	....	109.0	320
Missouri	1	107,000	108,000	40,000	10,000	41,000	12,000	14,000	....	......	53,000	4,500	....	....	6,500	....	550
Montana	7	156,181	164,016	49,250	14,950	46,300	26,200	42,550	5,020	14,000	89,900	10,200	4,600	....	24,425	16.7	250
Nebraska	1	5,000	5,500	2,400	......	2,400	500	1,100	....	......	......	....	....	....	....	....	....
New Jersey	4	539,000	562,764	286,653	38,144	229,444	40,000	118,944	....	110,000	314,945	17,133	....	6,400	73,000	....	975
New Mexico	7	104,230	106,305	12,400	2,250	12,400	5,160	10,920	....	......	11,550	2,925	....	....	700	...	....
New York	2	111,385	114,500	43,000	......	41,000	6,000	24,000	....	20,000	41,500	2,800	3,000	....	18,000	....	....
North Dakota	3	58,658	60,163	......	1,100	23,000	11,000	10,200	....	......	11,600	2,600	....	....	....	....	....
Ohio	7	589,770	614,500	207,500	28,600	202,460	46,040	162,500	83,000	45,000	157,500	35,300	....	2,100	30,400	24.0	1,280
Oklahoma	12	545,775	559,719	173,863	51,866	191,200	40,475	131,147	4,500	......	160,803	44,133	15,606	11,100	33,000	59.5	1,655
Oregon	1	14,000	14,737	15,000	......	......	....	......	....	......	......	....	....	....	8,600	....	....
Pennsylvania	11	757,020	796,415	328,378	2,750	206,000	18,300	221,708	53,700	161,000	278,250	38,100	11,300	29,575	36,500	45.0	...
Tennessee	1	43,900	44,800	15,000	......	13,500	....	10,000	....	......	11,000	4,000	....	....	8,000	....	....
Texas	46	3,966,330	4,144,778	1,348,241	317,188	1,257,166	270,405	1,009,542	153,167	374,500	1,478,143	222,751	201,516	93,922	64,900	159.0	6,257
Utah	7	152,000	158,878	44,050	18,500	53,600	16,560	23,800	1,000	5,500	29,500	10,450	2,550	....	4,700	..	350
Virginia	1	53,000	55,000	28,000	14,000	27,000	5,000	9,000	....	......	24,000	....	....	.	.	....	710
Washington	7	366,900	383,105	135,616	36,000	91,500	27,100	93,222	35,000	20,500	155,667	25,333	2,900	1,900	6,600	60.0	1,500
West Virginia	3	19,450	20,200	8,675	......	......	....	6,160	....	4,440	7,510	....	....	6,700	. .	1.2	...
Wisconsin	1	45,400	46,800	15,500	......	9,700	1,000	10,000	....	5,800	10,000	1,200	....	....	12,000	...	.
Wyoming	11	187,340	194,557	66,726	4,444	58,778	15,300	30,794	....	16,644	59,194	7,840	1,500	1,470	14,817	...	139
Total	**256**	**15,074,845**	**15,687,321**	**5,672,893**	**1,459,608**	**4,744,914**	**930,190**	**3,592,786**	**893,309**	**1,276,788**	**5,211,888**	**874,134**	**334,812**	**225,567**	**760,402**	**1,446.1**	**44,217**

[a]Reprinted from The Oil and Gas Journal, 12 March 1976.

TABLE A-1 (continued)[4,a]

Company and location	Crude capacity b/cd	Crude capacity b/sd	Charge capacity—b/sd: Vacuum distillation	Thermal operations	Cat cracking: Fresh feed	Cat cracking: Recycle	Cat reforming	Cat hydro-cracking	Cat hydro-refining	Cat hydro-treating	Production capacity—b/sd: Alkylation	Aromatics-isomerization	Lubes	Asphalt	Hydrogen (MMcfd)	Coke (t/d)
ALABAMA																
Hunt Oil Co.—Tuscaloosa	29,000	30,000	17,500	......	......	....	[3]5,500	....	[2]9,000	[1]5,900 [4]5,500	....	....	....	9,000	....	....
Marion Corp.—Theodore	18,000	20,000	......	......	......	....	......	....	......	......	....	....	....	....	....	....
Warrior Asphalt Corp.—Tuscaloosa	2,875	3,000	......	......	......	....	......	....	......	......	....	....	....	1,500	....	....
Total	**49,875**	**53,000**	**17,500**	......	......	....	**5,500**	....	**9,000**	**11,400**	....	....	....	**10,500**	....	....
ALASKA																
Atlantic Richfield Co.—North Slope	13,000	NR	......	......	......	....	......	....	......	......	....	....	....	....	....	....
British Petroleum Co.—North Slope	1,250	NR	......	......	......	....	......	....	......	......	....	....	....	....	....	....
Standard Oil Co. of California—Kenai	22,000	NR	......	......	......	....	......	....	......	......	....	....	....	300	....	....
Tesoro-Alaskan Petroleum Corp.—Kenai	38,000	40,000	......	......	......	....	[2]6,000	....	......	[1]6,000	....	....	....	....	....	....
Total	**74,250**	**78,158**	......	......	......	....	**6,000**	....	......	**6,000**	....	....	....	**300**	....	....
ARIZONA																
Arizona Fuels Corp.—Fredonia	4,000	NR	2,500	......	......	....	......	....	......	......	....	....	....	....	....	....
Total	**4,000**	**4,211**	**2,500**	......	......	....	......	....	......	......	....	....	....	....	....	....
ARKANSAS																
Cross Oil & Refining Co.—Smackover	5,850	6,000	3,100	......	......	....	......	....	......	[6]1,200	....	....	1,500	1,400	[1]2.9	..
Crystal Oil Co.—Stephens	3,536	3,625	......	......	......	....	......	....	......	......	....	....	....	1,050	....	....
Lion Oil Co.—El Dorado	47,000	48,300	17,000	......	[1]15,000	3,000	[1]5,750	....	......	[1]7,500 [4]3,300 [6]1,100	[1]4,500	....	800	3,750	....	....
Macmillan Ring-Free Oil Co.—Norphlet	4,400	4,500	3,000	......	......	....	......	....	......	......	....	....	1,950	1,500	....	....
Total	**60,786**	**62,425**	**23,100**	......	**15,000**	**3,000**	**5,750**	....	......	**13,100**	**4,500**	....	**4,250**	**7,700**	**2.9**	....
CALIFORNIA																
Atlantic Richfield Co.—Carson	181,500	193,000	93,000	[1]12,500 [2]42,000 [4]30,000	[1]57,000	8,000	[1]34,000	[1]19,700	[5]18,000	[1]34,000 [2]18,000	[1]7,200	[1]2,490 [5]10,000	....	....	[1]50.0	1,800
Beacon Oil Co.—Hanford	12,300	12,400	......	[1]500 [2]2,750	......	....	[1]1,650	....	......	......	....	....	....	....	....	....
Champlin Petroleum Co.—Wilmington	30,600	31,500	20,000	[4]10,500	......	....	......	....	......	......	....	....	....	....	....	650
Douglas Oil Co.—Paramount	46,500	48,000	28,000	......	......	....	[2]12,000	....	[2]10,000 [5]9,800	[2]12,000	....	....	....	18,000	....	....
Santa Maria	9,500	10,000	7,800	......	......	....	......	....	......	......	....	....	....	6,800	....	....
Edgington Oil Co.—Long Beach	29,500	30,000	15,000	......	......	....	......	....	......	......	....	....	....	12,000	...	....
Edgington Oxnard Refinery—Oxnard	NR	2,500	......	......	......	....	......	....	......	......	....	....	....	....	....	....
Exxon Co.—Benicia	88,000	97,000	54,000	[2]24,600	[1]45,000	13,000	[2]24,000	[1]23,000	[2]23,000	[2]47,200 [5]23,000	[1]11,500	....	....	....	104.0	900
Fletcher Oil & Refining Co.—Carson	19,200	20,000	......	......	......	....	[4]4,700	....	......	[1]4,700	....	....	....	....	....	....
Golden Bear Division, Witco Chemical Corp.—Oildale	10,500	11,000	9,500	......	......	....	......	....	......	......	....	....	4,000	3,200	....	....

[a]Reprinted from The Oil and Gas Journal, 12 March 1976.

TABLE A-1 (continued)[4,a]

Company and location	Crude capacity b/cd	Crude capacity b/sd	Charge capacity—b/sd: Vacuum distillation	Thermal operations	Cat cracking: Fresh feed	Cat cracking: Recycle	Cat reforming	Cat hydro-cracking	Cat hydro-refining	Cat hydro-treating	Production capacity—b/sd: Alkyla-tion	Aromatics-isomerization	Lubes	Asphalt	Hydrogen (MMcfd)	Coke (t/d)
Golden Eagle Refining Co.—Carson	NR	13,000	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Gulf Oil Co.—Hercules	27,000	28,300	5,900	...	...	...	[1]15,800	[1]2,900	...	[1]15,400	...	...	...	...	...	...
Gulf Oil Co.—Santa Fe Springs	51,500	53,800	25,000	[2]13,800	[1]13,500	300	19,000	[1]11,000	...	[1]12,000	[2]3,000	...	...	4,000	[6]12.0	...
Kern County Refinery Inc.—Bakersfield	15,900	15,595	...	[3]6,500	...	...	[2]2,500	...	...	...	...	...	...	...	...	...
Lunday-Thagard Oil Co.—South Gate	5,400	4,300	2,150	...	...	...	...	...	...	...	...	...	...	2,150	...	...
MacMillan Ring-Free Oil Co.—Signal Hill	NR	12,200	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Mobil Oil Corp.—Torrance	123,500	130,000	95,000	[2]16,000 [4]46,000	[1]56,000	NR	[2]36,000	[1]18,000	...	[1]23,000 [2]15,000 [5]25,000	[2]10,000	...	...	...	[1]55.0	2,800
Mohawk Petroleum Corp. Inc.—Bakersfield	22,100	22,800	...	...	...	...	[2]2,600	...	...	[1]2,600	...	...	...	...	...	...
Newhall Refining Co. Inc.—Newhall	11,500	NR	6,000	...	...	...	...	...	...	...	...	...	...	3,000	...	...
Phillips Petroleum Co.—Martinez	110,000	NR	74,500	[2]42,000	[1]47,000	NR	[1]32,500	[1]22,000	...	[2]34,500	[1]10,500	[4]2,700	200	...	...	1,200
Powerine Oil Co.—Santa Fe Springs	44,120	NR	...	...	[1]11,000	1,000	[2]6,300	...	[3]8,000 [4]8,000 [6]8,000	[1]7,000	[2]2,300	...	...	5,000	...	...
Road Oil Sales Inc.—Bakersfield	1,500	NR	...	...	...	...	...	...	...	...	...	...	...	1,300	...	...
Sabre Refining Inc.—Bakersfield	3,500	NR	...	...	...	...	...	...	...	...	...	...	...	...	...	...
San Joaquin Refining Co.—Oildale	29,300	27,600	...	...	...	...	...	...	...	...	...	...	...	3,360	...	...
Shell Oil Co.—Martinez	100,000	103,000	55,300	...	[1]46,000	40,000	[2]25,000	[1]20,000	[4]50,000	[2]17,000 [3]11,000 [5]16,000 [6]6,300 [7]11,000	[1]7,000	...	4,500	10,400	[1]65.0	...
Wilmington	96,000	101,000	60,000	[4]37,000	[1]35,000	5,000	[1]21,000	...	...	[2]26,000 [3]11,000 [5]28,700	[1]8,600	[4]3,800	...	...	...	1,800
Standard Oil Co. of California—Bakersfield	26,000	NR	...	[5]9,800	...	...	[1]5,400	...	...	[1]5,400	...	...	...	1,100	...	...
El Segundo	230,000	NR	103,000	[4]54,000	[1]43,500	11,000	[2]60,000	[1]49,000	...	[1]40,000 [4]12,000 [7]18,000	[1]5,900	[1]1,500	...	8,300	[2]67.5 [3]57.5	2,200
Richmond	190,000	NR	150,000	...	[1]43,500	11,000	[2]70,500	[1]41,500 [4]26,000	...	[1]44,000 [6]3,200	[1]9,200	[1]2,000	10,000	11,000	[2]135.0	...
Sunland Refining Corp.—Bakersfield	14,250	15,000	...	...	...	...	[1]1,100	...	...	[1]2,000	...	...	...	...	...	...
Texaco Inc.*—Wilmington	75,000	NR	...	[4]48,000	[1]28,000	NR	[1]35,000	[1]20,000	[3]13,000	[1]20,000	[1]4,400	...	...	...	[2]48.0	1,650
Toscopetro Corp.—Bakersfield	39,450	40,000	19,000	[5]6,700	[2]12,000	None	[1]14,400	[1]13,500	...	[1]5,400	[1]1,940	...	...	...	[1]20.0	200
Union Oil Co. of California—Los Angeles	108,000	111,000	83,000	[2]20,000	[1]45,000	7,000	[2]42,000	[1]21,000	...	[1]52,000 [5]33,000	[1]8,000	...	...	10,000	[1]49.4	...
Rodeo	111,000	117,000	38,500	[4]42,500	...	...	[2]26,000	[1]30,000	...	[1]21,000 [5]9,000 [7]14,000	...	...	3,600	6,150	[1]70.0	1,850
West Coast Oil Co.—Bakersfield	15,000	NR	...	[2]2,000	...	...	...	...	...	...	...	...	...	4,000	...	...
Total	**1,876,935**	**1,965,503**	**838,750**	**473,083**	**485,611**	**135,600**	**479,539**	**316,922**	**149,244**	**666,222**	**90,028**	**22,490**	**22,300**	**109,760**	**734.1**	**15,233**

*All figures are calendar day. Stream-day figures not reported.

COLORADO

Company and location	Crude capacity b/cd	Crude capacity b/sd	Vacuum distillation	Thermal operations	Cat cracking: Fresh feed	Cat cracking: Recycle	Cat reforming	Cat hydro-cracking	Cat hydro-refining	Cat hydro-treating	Alkyla-tion	Aromatics-isomerization	Lubes	Asphalt	Hydrogen (MMcfd)	Coke (t/d)
Continental Oil Co.—Denver	32,500	33,500	7,000	...	[1]15,000	1,000	[2]6,500	...	...	[1]7,000 [4]8,500	...	...	...	3,300	...	...
Gary Western Co.—Fruita	9,200	10,000	...	[1]6,000 [4]10,000	...	...	[2]2,800	...	...	[1]3,000	...	...	...	...	[1]1.0	30
Refinery Corp.—Commerce City	NR	21,500	3,500	[5]6,000	[1]7,500	400	[1]3,800	...	...	...	...	...	...	...	...	...
Total	**62,125**	**65,000**	**10,500**	**22,000**	**22,500**	**1,400**	**13,100**	...	...	**18,500**	...	...	...	**3,300**	**1.0**	**30**

[a]Reprinted from The Oil and Gas Journal, 12 March 1976.

TABLE A-1 (continued)[4,a]

Company and location	Crude capacity b/cd	Crude capacity b/sd	Charge capacity—b/sd: Vacuum distillation	Thermal operations	Cat cracking Fresh feed	Cat cracking Recycle	Cat reforming	Cat hydro-cracking	Cat hydro-refining	Cat hydro-treating	Production capacity—b/sd: Alkyla-tion	Aromatics-isomerization	Lubes	Asphalt	Hydrogen (MMcfd)	Coke (t/d)
DELAWARE																
Getty Oil Co. Inc.—Delaware City	140,000	150,000	90,700	[4]44,000	[1]62,000	15,000	[4]42,000	[1]17,000	....	[1]45,000 [2]10,000 [4]25,000 [5]30,000	[1]8,000	....	....	....	[1]72.0	1,500
Total	**140,000**	**150,000**	**90,700**	**44,000**	**62,000**	**15,000**	**42,000**	**17,000**	....	**110,000**	**8,000**	....	....	....	**72.0**	**1,500**
FLORIDA																
Seminole Asphalt Refining Inc.—St. Marks	NR	6,000	3,400	....	....	....	....	....	....	....	....	....	....	2,400	....	....
Total	**5,700**	**6,000**	**3,400**	....	....	....	....	....	....	....	....	....	....	**2,400**	....	....
GEORGIA																
Amoco Oil Co.—Savannah	13,000	14,000	....	....	....	....	....	....	....	....	....	....	....	9,000	....	....
Young Refining Corp.—Douglasville	5,000	5,400	....	....	....	....	....	....	....	....	....	....	200	2,600	....	....
Total	**18,000**	**19,400**	....	....	....	....	....	....	....	....	....	....	**200**	**11,600**	....	....
HAWAII																
Hawaiian Independent Refinery Inc.—Barbers Point, Oahu	NR	65,000	....	....	....	....	[3]11,000	....	....	[1]11,000	....	....	....	....	....	....
Standard Oil Co. of California—Barbers Point	40,000	NR	15,000	....	[1]14,100	8,900	....	....	....	[5]1,400	[4]4,130	[4]1,350	....	1,300	[2]2.5	....
Total	**101,750**	**107,105**	**15,000**	....	**14,100**	**8,900**	**11,000**	....	....	**12,400**	**4,130**	**1,350**	....	**1,300**	**2.5**	....
ILLINOIS																
Amoco Oil Co.—Wood River	105,000	107,000	40,000	....	[1]38,000	4,000	[4]12,300	....	....	[1]15,600 [7]17,000 [7]3,000	[1]5,500	....	....	10,800	....	....
Clark Oil & Refining Corp.—Blue Island	NR	70,000	27,000	....	[1]24,000	1,000	[3]30,500	[1]11,000	....	[1]20,500	[2]6,000	....	....	4,500	....	....
Hartford	NR	45,000	18,000	[4]13,000	[1]26,000	1,000	[3]9,200	....	....	[1]9,200 [4]10,000	[2]8,000	....	....	....	....	....
Marathon Oil Co.—Robinson	195,000	205,000	62,000	[1]2,800 [4]19,000	[1]36,500	8,000	[1]14,000 [3]33,300	[1]22,000	[6]6,000	[1]22,000	[2]7,600	....	....	....	[1]25.0	900
Mobil Oil Corp.—Joliet	175,000	186,000	82,000	[4]30,000	[1]85,000	NR	[3]47,000	....	[5]75,000	[1]74,000	[2]24,000	....	....	....	....	1,700
Shell Oil Co.—Wood River	283,000	295,000	95,500	[2]21,000	[1]94,000	NR	[3]22,000 [3]68,000	[1]33,500	[4]27,000	[3]64,000 [5]50,000 [6]7,000 [7]35,000 [7]6,000	[1]22,000	[1]3,200 [4]4,000	5,600	21,000	[1]57.0	....
Texaco Inc.*—Lawrenceville	84,000	NR	24,000	[1]9,000	[1]31,000	NR	[1]12,000 [3]12,000	....	....	[1]24,000 [5]17,000	[1]6,600	....	....	2,700	....	....
Lockport	72,000	NR	14,000	[4]27,000	[1]30,000	NR	[1]9,000 [3]10,000	....	....	[1]19,000 [5]17,000	[1]8,000	....	....	....	....	300
Union Oil Co. of California—Lemont	150,000	NR	55,000	[4]19,500	[1]58,000	8,000	[3]31,300	....	....	[1]31,300 [2]2,200 [3]4,500 [5]35,000 [7]2,500	[1]16,500	[1]2,900	....	3,200	....	1,000
Wireback Oil Co.—Plymouth	1,800	1,800	....	....	....	....	....	....	....	....	....	....	....	....	....	

[a]Reprinted from The Oil and Gas Journal, 12 March 1976.

TABLE A-1 (continued)[4,a]

Company and location	Crude capacity b/cd	Crude capacity b/sd	Charge capacity—b/sd Vacuum distillation	Thermal operations	Cat cracking Fresh feed	Cat cracking Recycle	Cat reforming	Cat hydro-cracking	Cat hydro-refining	Cat hydro-treating	Production capacity—b/sd Alkylation	Aromatics-isomerization	Lubes	Asphalt	Hydrogen (MMcfd)	Coke (t/d)
Yetter Oil Co.—Colmar	1,000	NR	1,000	......	......	....	......	....	......	......	....	....	....	....	....	....
Total	**1,176,050**	**1,232,958**	**420,499**	**145,300**	**429,277**	**94,000**	**315,377**	**66,500**	**108,000**	**494,243**	**105,822**	**10,100**	**5,600**	**42,500**	**82.0**	**3,933**

*All figures are calendar day. Stream-day figures not reported.

INDIANA

Company and location	Crude capacity b/cd	Crude capacity b/sd	Vacuum distillation	Thermal operations	Cat cracking Fresh feed	Cat cracking Recycle	Cat reforming	Cat hydro-cracking	Cat hydro-refining	Cat hydro-treating	Alkylation	Aromatics-isomerization	Lubes	Asphalt	Hydrogen (MMcfd)	Coke (t/d)
Amoco Oil Co.—Whiting	360,000	375,000	167,000	[4]24,000	[1]123,000	7,000	[2]21,000 [4]73,000	....	[6]3,800 [6]500 [6]860	[1]111,000 [3]39,000 [7]20,000	[1]20,000	[4]3,200	7,900	40,000	....	885
Atlantic Richfield Co.—East Chicago	126,000	140,000	70,000	......	[1]48,000	2,000	[1]20,000	....	[6]25,000	[1]20,000 [2]2,000 [6]3,500	[1]6,000	....	3,400	10,400	....	....
Crystal-Princeton Refining Co.—Princeton	NR	4,300	......	......	......	....	[1]1,500	....	......	[2]1,500	....	....	....	....	....	....
Gladieux Refinery Inc.—Fort Wayne	12,500	12,500	......	......	......	....	......	....	......	......	....	....	....	....	....	....
Indiana Farm Bureau Cooperative Association Inc.—Mt. Vernon	18,500	20,000	7,000	......	[1]6,000	NR	[2]3,000	....	......	[2]3,000	....	....	....	....	....	....
Laketon Asphalt Refining Inc.—Laketon	NR	8,500	6,000	......	......	....	......	....	......	......	....	....	....	3,000	....	....
Rock Island Refining Corp.—Indianapolis	32,000	33,000	17,000	......	[1]16,000	None	[2]8,600	....	......	[1]10,500	[2]4,200	....	....	3,200	....	....
Total	**561,160**	**527,300**	**267,000**	**24,000**	**193,000**	**10,800**	**127,100**	....	**30,160**	**210,500**	**30,200**	**3,200**	**11,300**	**56,600**	....	**885**

KANSAS

Company and location	Crude capacity b/cd	Crude capacity b/sd	Vacuum distillation	Thermal operations	Cat cracking Fresh feed	Cat cracking Recycle	Cat reforming	Cat hydro-cracking	Cat hydro-refining	Cat hydro-treating	Alkylation	Aromatics-isomerization	Lubes	Asphalt	Hydrogen (MMcfd)	Coke (t/d)
American Petrofina Inc.—El Dorado	25,000	NR	8,000	......	[1]11,000	500	[2]4,000	....	......	[1-2]4,000	[2]2,000	....	....	2,000	....	....
Apco Oil Corp.—Arkansas City	46,230	47,200	12,750	......	[1]9,400	800	[2]16,300	[1]3,100	......	[1]17,000	[2]2,600	....	....	2,800	[1]4.2	....
CRA Inc.—Coffeyville	48,000	50,000	14,500	[4]8,500	[1]14,500	1,500	[2]8,600	....	[5]3,000	[1]11,800	[2]4,500	....	1,500	....	....	300
Phillipsburg	25,000	26,000	9,000	......	[1]8,000	600	[2]5,300	....	......	[1]6,600	[2]1,800	....	....	2,000	....	....
Derby Refining Co.—Wichita	26,500	27,650	8,800	[4]3,800	[2]10,800	1,700	[2]5,000	....	......	[2]5,000	[2]3,000	....	....	....	....	160
Mid America Refinery Co.—Chanute	3,100	3,300	1,800	......	......	....	......	....	......	......	....	....	....	....	....	....
Mobil Oil Corp.—Augusta	50,000	52,000	18,300	[4]4,100	[2]21,500	2,000	[1]10,500 [4]10,000	....	......	[1]10,000	[2]3,800	....	....	8,000	....	....
National Cooperative Refinery Association—McPherson	54,150	57,000	18,000	[4]17,000	[1]20,000	1,000	[2]7,000	....	......	[3]8,000	[2]6,000	[4]2,000	....	....	....	425
North American Petroleum Corp.—Shallow Water	NR	10,000	5,500	[3]3,000	[5]5,500	NR	......	....	......	......	[2]1,000	....	....	1,000	....	...
Phillips Petroleum Co.—Kansas City	85,000	NR	15,000	......	[1]32,000	16,000	[1]16,000	....	......	[1]28,500 [5]27,500	[2]7,500	....	2,500	3,000	....	...
Skelly Oil Co.—El Dorado	78,700	80,000	27,000	......	[1]31,000	17,000	[1]21,500	....	......	[1]23,000 [4]4,300	[2]6,900	[1]1,400	....	....	....	615
Total	**451,180**	**468,940**	**138,650**	**36,400**	**163,700**	**42,750**	**104,200**	**3,100**	**3,000**	**145,700**	**39,100**	**3,400**	**4,000**	**18,800**	**4.2**	**1,500**

KENTUCKY

Company and location	Crude capacity b/cd	Crude capacity b/sd	Vacuum distillation	Thermal operations	Cat cracking Fresh feed	Cat cracking Recycle	Cat reforming	Cat hydro-cracking	Cat hydro-refining	Cat hydro-treating	Alkylation	Aromatics-isomerization	Lubes	Asphalt	Hydrogen (MMcfd)	Coke (t/d)
Ashland Petroleum Co.—Catlettsburg	135,800	140,000	55,000	[3]4,000	[1]54,000	1,000	[2]26,500	....	......	[1]26,500 [2]6,500 [3]4,500 [4]1,500	[2]6,400	[1]4,000 [2]2,500 [5]12,000	....	20,000	..	..
Louisville Refining, Division of Ashland Oil Inc.—Louisville	25,200	26,000	13,000	......	......	....	[2]3,000	....	......	[1]3,000	....	....	....	3,500	....	....
Somerset Refinery Inc.—Somerset	3,000	3,500	......	......	......	....	[2]1,000	....	......	[1]1,000	....	....	....	....	....	....
Total	**164,000**	**169,500**	**68,000**	**4,000**	**54,000**	**1,000**	**30,500**	....	....	**43,000**	**6,400**	**18,500**	....	**23,500**	...	...

[a]Reprinted from The Oil and Gas Journal, 12 March 1976.

TABLE A-1 (continued)[4,a]

Company and location	Crude capacity		Charge capacity—b/sd								Production capacity—b/sd				Hydrogen (MMcfd)	Coke (t/d)
	b/cd	b/sd	Vacuum distillation	Thermal operations	Cat cracking Fresh feed	Cat cracking Recycle	Cat reforming	Cat hydrocracking	Cat hydrorefining	Cat hydrotreating	Alkylation	Aromatics-isomerization	Lubes	Asphalt		
LOUISIANA																
Atlas Processing Co., Division of Pennzoil—Shreveport	45,000	NR	600	......	......	....	[1]10,000	....	......	[1]10,000 [4]1,800 [5]4,800	....	[1]1,000	....	....	....	....
Bayou State Oil Corp.—Hosston	3,500	4,000	2,000	[4]2,000	......	....	......	....	......	......	....	....	1,250	500	....	....
Calumet Refining Co.—Princeton	NR	2,400	2,400	......	......	....	......	....	......	......	....	....	1,500	450	....	....
Canal Refining Co.—Church Point	4,000	4,000	......	......	......	....	[3]1,500	....	......	......	....	....	....	....	....	....
Cities Service Oil Co.—Lake Charles	268,000	280,000	83,000	[4]28,000	[1]125,000	20,000	[2]46,000	....	[1]6,000 [5]30,000	[1]46,000 [4]14,000	[1]33,000	[1]2,300	7,000	....	....	1,000
Claiborne Gasoline Co.—Lisbon	6,790	7,000	......	......	......	....	[1]2,200	....	......	......	....	....	....	....	....	....
Continental Oil Co.—Lake Charles	83,000	85,000	8,000	[1]7,000	[2]27,000	5,000	[3]18,500	....	......	[1]19,000 [7]3,000	[1]4,600	....	....	....	....	500
Evangeline Refining Co. Inc.—Jennings	NR	5,000	......	......	......	....	600	....	......	......	....	....	....	....	....	....
Exxon Co.—Baton Rouge	455,000	475,000	165,000	[4]48,000	[1]169,000	None	[3]99,500	[1]23,000	......	[3]3,900 [5]80,000 [6]23,800 [7]2,200	[1]29,800	....	15,000	28,900	....	2,300
Good Hope Refineries Inc.—Metairie	NR	44,500	10,000	......	[1]8,500	NR	[3]3,000	....	......	[1]3,000	....	....	....	....	....	....
Gulf Oil Co.—Alliance Refinery, Belle Chasse	180,400	186.000	67,000	[4]16,000	[1]78,000	2,300	37,500	....	[4]16,000 [5]22,000	[1]42,000	[2]28,400	[1]11,100 [2]5,400	....	....	....	840
Venice	28,700	29,100	......	......	......	....	18,000	[1]11,500	......	[1]14,400	....	....	....	....	....	....
Kerr-McGee Refining Corp.—Cotton Valley	10,700	11,000	......	......	......	....	......	....	......	......	....	....	....	....	....	....
LaJet Inc.—St. James	NR	16,000	......	......	......	....	......	....	......	......	....	....	....	....	....	....
Murphy Oil Corp.—Meraux	92,500	95,400	14,500	......	[1]10,500	500	[2]19,000	....	[5]15,500	[1]25,700	[2]2,900	....	....	....	....	....
Placid Refining Co.—Port Allen	36,000	NR	......	......	......	....	[2]4,300	....	......	[1]6,000	....	....	....	....	....	....
Shell Oil Co.—Norco	240,000	250,000	90,000	[4]18,000	[1]100,000	2,000	[1]18,000 [3]30,600	[1]28,000	[1]25,000	[2]30,600	[1]13,500	....	....	10,000	[1]51.0	860
Tenneco Oil Co.—Chalmette	NR	100,000	23,000	[4]9,000	[1]22,000	NR	[2]35,000	[1]18,000	......	[1]24,000	[2]5,000	[1]7,000	....	....	[1]22.0	350
Texaco Inc.*—Convent	140,000	NR	35,000	[8]12,000	[1]70,000	NR	[1]30,000	....	......	[4-5]55,000	[1]12,500	....	....	....	....	....
Total	**1,753,095**	**1,827,031**	**502,342**	**141,333**	**817,778**	**59,950**	**377,033**	**80,500**	**114,500**	**415,311**	**31,089**	**26,800**	**24,750**	**39,850**	**73.0**	**5,850**

*All figures are calendar day. Stream-day figures not reported.

Company and location	Crude capacity b/cd	Crude capacity b/sd	Vacuum distillation	Thermal operations	Cat cracking Fresh feed	Cat cracking Recycle	Cat reforming	Cat hydrocracking	Cat hydrorefining	Cat hydrotreating	Alkylation	Aromatics-isomerization	Lubes	Asphalt	Hydrogen (MMcfd)	Coke (t/d)
MARYLAND																
Amoco Oil Co.—Baltimore	15,000	17,000	......	......	......	....	......	....	......	......	....	....	....	10,700	....	....
Chevron Asphalt Co.—Baltimore	13,500	NR	13,800	......	......	....	......	....	......	......	....	....	....	11,000	....	....
Total	**28,500**	**31,211**	**13,800**	......	......	....	......	....	......	......	....	....	....	**21,700**	....	....
MICHIGAN																
Bay Refining—Dow Chemical U.S.A.—Bay City	NR	22,000	....	....	[2]6,000	2,000	......	....	......	......	....	....	....	....	....	....
Crystal Refining Co.—Carson City	6,200	4,000	......	......	......	....	......	....	......	......	....	....	....	....	....	....
Lakeside Refining Co.—Kalamazoo	5,600	NR	......	......	......	....	[1]2,000	....	......	......	....	....	....	....	....	....
Marathon Oil Co.—Detroit	65,000	67,000	25,000	......	[1]21,500	3,900	[1]16,000	....	[4]12,500	[1]16,500	[1]3,500	....	....	8,650	....	....
Osceola Refining Co.—West Branch	9,500	9,500	......	......	......	....	[1]1,500	....	......	[1]1,500	....	....	....	....	....	....
Total Leonard Inc.—Alma	40,000	43,000	17,000	......	[1]12,000	1,500	[2]10,000	....	......	[1]10,000 [4]1,400 [7]3,800	[2]1,400	....	....	2,800	....	....
Total	**147,200**	**151,395**	**42,000**	......	**39,500**	**7,400**	**29,500**	....	**12,500**	**33,200**	**4,900**	....	....	**11,450**	....	.

[a]Reprinted from The Oil and Gas Journal, 12 March 1976.

TABLE A-1 (continued)[4,a]

Company and location	Crude capacity b/cd	Crude capacity b/sd	Charge capacity—b/sd: Vacuum distillation	Thermal operations	Cat cracking Fresh feed	Cat cracking Recycle	Cat reforming	Cat hydro-cracking	Cat hydro-refining	Cat hydro-treating	Production capacity—b/sd: Alkyla-tion	Aromatics-isomerization	Lubes	Asphalt	Hydrogen (MMcfd)	Coke (t/d)
MINNESOTA																
Continental Oil Co.—Wrenshall	23,500	24,000	9,000	....	[1]9,500	500	[8]3,600	....	....	[1]3,600	....	....	....	....	....	....
Koch Refining Co.—Pine Bend	127,300	131,905	90,000	[4]23,000	[1]41,000	1,000	[8]16,500	....	....	[1]16,500 [4]29,000 [6]8,000	[1]8,500	....	....	35,000	....	1,300
Northwestern Refining Co., Division of Ashland Oil Inc.—St. Paul Park	66,000	68,000	38,000	....	[1]21,000	1,500	[1]10,000	....	[4]20,000	[1]10,000 [5]5,000	[3]3,000	....	....	22,000	....	....
Total	**216,800**	**223,905**	**137,000**	**23,000**	**71,500**	**3,000**	**30,100**	....	**20,000**	**72,100**	**11,500**	....	....	**57,000**	....	**1,300**
MISSISSIPPI																
Amerada-Hess Corp.—Purvis	28,500	30,000	....	[4]6,700	[3]14,500	NR	[1]5,700	[6]3,000	....	[1]5,450	....	....	....	....	....	320
Southland Oil Co.—Lumberton	5,800	NR	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Sandersville	11,000	NR	5,500	....	....	....	....	....	....	....	....	....	....	....	....	....
Yazoo City	4,200	NR	2,500	....	....	....	....	....	....	....	....	....	....	....	....	....
Standard Oil Co. of Kentucky—Pascagoula	280,000	NR	148,000	....	[1]56,000	2,000	[2]65,000	[1]68,000	[4]23,000 [8]30,000	[1]48,000	[1]9,200	[1]6,000	....	....	[3]109.0	....
Total	**329,500**	**348,842**	**156,000**	**6,700**	**70,500**	**6,350**	**70,700**	**71,000**	**53,000**	**53,450**	**9,200**	**6,000**	....	....	**109.0**	**320**
MISSOURI																
Amoco Oil Co.—Sugar Creek	107,000	108,000	40,000	[1]10,000	[1]41,000	12,000	[8]14,000	....	....	[1]20,000 [7]33,000	[1]4,500	....	....	6,500	....	550
Total	**107,000**	**108,000**	**40,000**	**10,000**	**41,000**	**12,000**	**14,000**	....	....	**53,000**	**4,500**	....	....	**6,500**	....	**550**
MONTANA																
Big West Oil Co.—Kevin	5,123	5,500	750	[1]1,250	....	....	[2]1,000	[4]20	....	[1]1,000	....	....	....	325	....	....
Cenex—Laurel	40,400	42,500	14,000	....	[1]11,500	3,000	[8]12,000	....	[5]14,000	[1]10,000	[3]3,000	[4]2,000	....	6,000	....	....
Continental Oil Co.—Billings	52,500	56,000	14,500	....	[1]14,000	7,000	[8]13,500	....	....	[7]39,500	[2]3,800	[4]2,600	....	4,300	....	....
Exxon Co.—Billings	45,000	46,000	18,000	[8]11,500	[1]19,000	15,000	[1]14,500	[1]4,900	....	[2]15,500 [6]20,000	[2]3,400	....	....	13,000	[5]16.7	250
Phillips Petroleum Co.—Great Falls	6,000	NR	2,000	....	[1]1,800	1,200	[8]600	....	....	[1]700 [5]1,000	....	....	....	800	....	....
Tesoro Petroleum Corp.—Wolf Point	2,500	2,700	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Westco Refining Co.—Cut Bank	4,658	5,000	....	[1]2,200	....	....	[2]950	[4]100	....	[1]1,200 [5]1,000						
Total	**156,181**	**164,016**	**49,250**	**14,950**	**46,300**	**26,200**	**42,550**	**5,020**	**14,000**	**89,900**	**10,200**	**4,600**	....	**24,425**	**16.7**	**250**
NEBRASKA																
CRA Inc.—Scottsbluff	5,000	5,500	2,400	....	[1]2,400	500	[1]1,100	....	....	....	....	....	....	....	....	....
Total	**5,000**	**5,500**	**2,400**	....	**2,400**	**500**	**1,100**	....	....	....	....	....	....	....	....	....
NEW JERSEY																
Chevron Oil Co.—Perth Amboy	88,000	NR	50,000	....	[3]30,000	8,000	[2]39,000	....	[2]60,000	[1]39,000 [4]20,000	[1]3,000	....	....	25,000	....	....
Exxon Co.—Linden	265,000	277,000	143,000	....	[1]130,000	20,000	[3]42,000	....	[2]50,000	[1]42,000 [2]14,000 [6]99,000	[1]8,500	....	....	48,000	....	....

[a]Reprinted from The Oil and Gas Journal, 12 March 1976.

TABLE A-1 (continued)[4,a]

Company and location	Crude capacity b/cd	Crude capacity b/sd	Charge capacity—b/sd: Vacuum distillation	Thermal operations	Cat cracking Fresh feed	Cat cracking Recycle	Cat reforming	Cat hydro-cracking	Cat hydro-refining	Cat hydro-treating	Production capacity—b/sd: Alkylation	Aromatics-isomerization	Lubes	Asphalt	Hydrogen (MMcfd)	Coke (t/d)
Mobil Oil Corp.—Paulsboro	98,000	100,500	62,600	[4]23,700	[2]25,000	None	[6]23,500	....	......	[1]23,500 [6]33,000	[2]2,300	....	6,400	....	....	975
Texaco Inc.*—Westville	88,000	NR	29,500	[3]13,000	[1]40,000	NR	[6]13,000	....	......	[1]17,000 [4-6]23,000	[1]3,000	....	....	....	....	....
Total	**539,000**	**562,764**	**286,653**	**38,144**	**229,444**	**40,000**	**118,944**	....	**110,000**	**314,945**	**17,133**	....	**6,400**	**73,000**	....	**975**

*All figures are calendar day. Stream-day figures not reported.

NEW MEXICO

Company and location	Crude capacity b/cd	Crude capacity b/sd	Vacuum distillation	Thermal operations	Cat cracking Fresh feed	Cat cracking Recycle	Cat reforming	Cat hydro-cracking	Cat hydro-refining	Cat hydro-treating	Alkylation	Aromatics-isomerization	Lubes	Asphalt	Hydrogen (MMcfd)	Coke (t/d)
Caribou Four Corners Inc.—Kirtland	2,000	2,500	......	......	......	....	......	....	......	......	....	....	....	....	....	....
Famariss Oil & Refining Co.—Lovington	NR	37,000	......	......	......	....	......	....	......	......	....	....	....	....	....	....
Monument	NR	5,000	......	......	......	....	......	....	......	......	....	....	....	....	....	....
Navajo Refining Co.—Artesia	29,930	NR	4,500	[1]1,250	[6]5,200	NR	[1]1,870	....	......	[1]2,500	[3]1,400	....	....	....	....	....
Plateau Inc.—Bloomfield	8,400	8,800	......	......	......	....	[1]2,250	....	......	[1]2,250	....	....	....	....	....	....
Shell Oil Co.—Ciniza	18,000	19,000	7,900	......	[1]7,200	3,600	[1]6,800	....	......	[6]6,800	[3]1,525	....	....	700	....	....
Thriftway Co.—Bloomfield	6,000	2,500	......	[1]1,000	......	....	......	....	......	......	....	....	....	....	....	....
Total	**104,230**	**106,305**	**12,400**	**2,250**	**12,400**	**5,160**	**10,920**	....	......	**11,550**	**2,925**	....	....	**700**	....	....

NEW YORK

Company and location	Crude capacity b/cd	Crude capacity b/sd	Vacuum distillation	Thermal operations	Cat cracking Fresh feed	Cat cracking Recycle	Cat reforming	Cat hydro-cracking	Cat hydro-refining	Cat hydro-treating	Alkylation	Aromatics-isomerization	Lubes	Asphalt	Hydrogen (MMcfd)	Coke (t/d)
Ashland Petroleum Co.—Tonawanda	68,385	70,500	25,000	......	[1]22,000	None	[3]11,500	....	[4]20,000	[3]27,000	....	[1]3,000	....	10,500	....	....
Mobil Oil Corp.—Buffalo	43,000	44,000	18,000	......	[2]19,000	6,000	[3]12,500	....	......	[1]14,500	[1]2,800	....	....	7,500	....	....
Total	**111,385**	**114,500**	**43,000**	......	**41,000**	**6,000**	**24,000**	....	**20,000**	**41,500**	**2,800**	**3,000**	....	**18,000**	....	....

NORTH DAKOTA

Company and location	Crude capacity b/cd	Crude capacity b/sd	Vacuum distillation	Thermal operations	Cat cracking Fresh feed	Cat cracking Recycle	Cat reforming	Cat hydro-cracking	Cat hydro-refining	Cat hydro-treating	Alkylation	Aromatics-isomerization	Lubes	Asphalt	Hydrogen (MMcfd)	Coke (t/d)
Amoco Oil Co.—Mandan	49,000	49,900	......	......	[1]23,000	11,000	[6]8,200	....	......	[1]10,000	[2]2,600	....	....	....	....	....
Northland Oil & Refining Co.—Dickinson	5,000	NR	......	......	......	....	......	....	......	......	....	....	....	....	....	....
Westland Oil Co.—Williston	4,658	5,000	......	[1]1,100	......	....	[2]2,000	....	......	[1]1,600	....	....	....	....	....	....
Total	**58,658**	**60,163**	......	**1,100**	**23,000**	**11,000**	**10,200**	....	......	**11,600**	**2,600**	....	....	....	....	....

OHIO

Company and location	Crude capacity b/cd	Crude capacity b/sd	Vacuum distillation	Thermal operations	Cat cracking Fresh feed	Cat cracking Recycle	Cat reforming	Cat hydro-cracking	Cat hydro-refining	Cat hydro-treating	Alkylation	Aromatics-isomerization	Lubes	Asphalt	Hydrogen (MMcfd)	Coke (t/d)
Ashland Petroleum Co.—Canton	64,000	66,000	33,000	......	[1]24,460	740	[3]11,000	....	[4]22,500 [6]12,000	[1]12,000	[3]7,000	....	....	12,000	....	....
Findlay	20,370	21,000	8,000	......	......	....	......	....	......	......	....	....	....	6,500	....	....
Gulf Oil Co.—Cleves	42,100	43,500	13,000	......	[1]18,000	9,000	10,000	....	[5]5,000	[1]11,000	[4]4,500	....	....	2,900	....	....
Toledo	50,300	51,000	12,500	......	[1]19,800	2,000	11,000	....	[5]5,500	[1]11,000	[3]5,500	....	....	2,000	....	....
Standard Oil Co. of Ohio—Lima	168,000	177,000	51,000	[4]16,000	[1]37,700	7,800	[3]47,000	[4]21,000	......	[1-3]59,000	....	....	2,100	....	....	620
Toledo	120,000	126,000	68,000	[4]12,600	[1]52,500	19,000	[3]42,500	[4]36,000	......	[1-3]37,000	[1]11,300	....	....	7,000	[1]24.0	660
Sun Oil Co. of Pennsylvania—Toledo	125,000	130,000	22,000	......	[1]50,000	7,500	[1]25,000 [3]16,000	[1]26,000	......	[1]27,500	[1]7,000	....	....	...	....	....
Total	**589,770**	**614,500**	**207,500**	**28,600**	**202,460**	**46,040**	**162,500**	**83,000**	**45,000**	**157,500**	**35,300**	....	**2,100**	**30,400**	**24.0**	**1,280**

OKLAHOMA

Company and location	Crude capacity b/cd	Crude capacity b/sd	Vacuum distillation	Thermal operations	Cat cracking Fresh feed	Cat cracking Recycle	Cat reforming	Cat hydro-cracking	Cat hydro-refining	Cat hydro-treating	Alkylation	Aromatics-isomerization	Lubes	Asphalt	Hydrogen (MMcfd)	Coke (t/d)
Allied Materials Corp.—Stroud	NR	5,500	5,500	......	......	....	......	....	......	......	....	....	1,200	1,500	....	....
Apco Oil Corp.—Cyril	14,000	14,274	4,400	......	[1]6,700	1,675	[3]1,125	....	......	[1]1,125	[3]1,700	....	....	1,600	....	....
Champlin Petroleum Co.—Enid	53,800	56,000	18,000	[4]5,000	[1]19,000	300	[3]15,000	....	......	[1]20,400	[2]4,500	[6]6,000	1,100	1,800	....	200
Continental Oil Co.—Ponca City	126,000	131,000	32,000	[4]16,000	[1]44,000	NR	[3]31,000	....	......	[1]31,000 [6]2,700	[3]9,700	[4]4,000	2,000	3,000	....	675

[a]Reprinted from The Oil and Gas Journal, 12 March 1976.

TABLE A-1 (continued)[4,a]

Company and location	Crude capacity b/cd	Crude capacity b/sd	Charge capacity—b/sd: Vacuum distillation	Thermal operations	Cat cracking Fresh feed	Cat cracking Recycle	Cat reforming	Cat hydro-cracking	Cat hydro-refining	Cat hydro-treating	Production capacity—b/sd: Alkyla-tion	Aromatics-isomerization	Lubes	Asphalt	Hydrogen (MMcfd)	Coke (t/d)
Kerr-McGee Corp.—Wynnewood	50,000	51,500	10,000	......	[1]11,500	2,000	[2]7,500	[1]4,500	......	[1]7,500 [7]4,000	[3]3,500	....	....	3,500	[1]9.5	....
Midland Cooperatives Inc.—Cushing	19,000	19,814	7,000	[4]4,000	[1]7,000	3,000	[3]4,500	....	......	[1]4,500 [2]2,000 [6]1,000 [7]1,000	[2]2,000	....	....	....	....	80
OKC Refining Inc.—Okmulgee	25,000	24,000	3,200	......	[8]8,000	2,000	......	....	......	[8]1,500	....	....	....	1,800	....	....
Sun Oil Co.—Duncan	48,500	50,000	17,000	[4]12,000	[1]25,000	10,500	[2]7,800	....	......	[1]7,800	[5]5,800	....	....	....	[1]50.0	400
Tulsa	88,500	90,000	31,500	[4]8,200	[1]30,000	1,400	[2]23,000 [6]7,000	....	......	[1]28,000 [8]8,500	[1]2,600 [2]6,000	[1]2,000 [3]950 [4]2,100	6,800	4,800	....	300
Texaco Inc.*—West Tulsa	50,000	NR	14,500	[1]6,000	[1]18,000	NR	[2]20,000	....	......	[3]8,000 [4-8]17,000	[1]3,000	[4]500	....	....	....	....
Tonkawa Refining Co.—Arnett	NR	5,000	......	......	......	....	......	....	......	......	....	....	....	....	....	....
Vickers Petroleum Corp.—Ardmore	61,000	60,000	30,000	......	[1]20,000	1,000	[2]12,000	....	......	[1]12,000	[2]5,000	....	....	15,000	....	....
Total	**545,775**	**559,719**	**173,863**	**51,866**	**191,200**	**40,475**	**131,147**	**4,500**	......	**160,803**	**44,133**	**15,606**	**11,100**	**33,000**	**59.5**	**1,655**

*All figures are calendar day. Stream-day figures not reported.

OREGON

Company and location	Crude capacity b/cd	Crude capacity b/sd	Vacuum distillation	Thermal operations	Cat cracking Fresh feed	Cat cracking Recycle	Cat reforming	Cat hydro-cracking	Cat hydro-refining	Cat hydro-treating	Alkyla-tion	Aromatics-isomerization	Lubes	Asphalt	Hydrogen (MMcfd)	Coke (t/d)
Standard Oil Co. of California—Portland	14,000	NR	15,000	......	......	....	......	....	......	......	....	....	....	8,600	....	....
Total	**14,000**	**14,737**	**15,000**	......	......	....	......	....	......	......	....	....	....	**8,600**	....	....

PENNSYLVANIA

Company and location	Crude capacity b/cd	Crude capacity b/sd	Vacuum distillation	Thermal operations	Cat cracking Fresh feed	Cat cracking Recycle	Cat reforming	Cat hydro-cracking	Cat hydro-refining	Cat hydro-treating	Alkyla-tion	Aromatics-isomerization	Lubes	Asphalt	Hydrogen (MMcfd)	Coke (t/d)
Atlantic Richfield Co.—Philadelphia	185,000	195,000	106,000	......	......	....	[1]60,000	[1]30,000	[2]20,000 [8]41,000	[1]54,000	...		....	19,500	[1]45.0	....
BP Oil Corp.—Marcus Hook	143,000	150,000	60,000	......	[1]40,000	1,600	[6]46,000	[4]21,000	[4]40,000	[1-3]50,000 [4]20,000 [6]17,000	[2]9,700	[1]600	....	....	....	....
Gulf Oil Co.—Philadelphia	174,300	180,000	65,000	......	[1]80,000	6,500	52,000	....	[6]60,000	[1]52,000	[2]15,000	[1]3,800 [2]1,600	....	....	....	....
Kendall-Amalie Division, Witco Chemical Corp.—Bradford	9,000	9,500	.....	......	......	....	[1]2,000	....	....	[1]2,500	....	....	3,300	....	....	....
Pennzoil Co., Wolf's Head Division—Reno	2,100	2,220	......	......	......	....	......	....	......	......	....	....	500	....	....	....
Rouseville	10,000	10,400	3,328	......	......	....	[1]3,600	[3]2,700	......	[1]4,500	....	....	3,175	....	....	....
Quaker State Oil Refining Corp.—Emlenton	3,320	3,495	1,700	[1]750 [5]600	......	....	[2]1,250	....	......	[1]1,450	....	....	1,700	....	....	....
Farmers Valley	6,500	6,800	2,750	[1]1,400	......	....	[2]1,858	....	....	[1]2,300	....	....	2,500	....	....	....
Sun Oil Co.—Marcus Hook	165,000	180,000	48,000	......	[1]75,000	10,000	[1]29,400 [2]15,600	....	......	[1]35,000 [6]10,000 [7]13,000	[1]12,000	[1]5,300	17,000	12,000	....	....
United Refining Co.—Warren	52,000	52,000	38,000	......	[1]11,000	200	[1]10,000	....	......	[2]15,000 [4]1,500	[2]1,400	....	....	5,000	....	....
Valvoline Oil Co., Division of Ashland Oil Inc.—Freedom	6,800	7,000	3,600	......	......	....	......	....	......	......	....	....	1,400	....	....	....
Total	**757,020**	**796,415**	**328,378**	**2,750**	**206,000**	**18,300**	**221,708**	**53,700**	**161,000**	**278,250**	**38,100**	**11,300**	**29,575**	**36,500**	**45.0**	....

[a]Reprinted from The Oil and Gas Journal, 12 March 1976.

TABLE A-1 (continued)[4],[a]

Company and location	Crude capacity b/cd	Crude capacity b/sd	Charge capacity—b/sd Vacuum distillation	Thermal operations	Cat cracking Fresh feed	Cat cracking Recycle	Cat reforming	Cat hydro-cracking	Cat hydro-refining	Cat hydro-treating	Production capacity—b/sd Alkyla-tion	Aromatics-isomerization	Lubes	Asphalt	Hydrogen (MMcfd)	Coke (t/d)
TENNESSEE																
Delta Refining Co.—Memphis	43,900	44,800	15,000	......	[8]13,500	None	[8]10,000	....	......	[1]11,000	[4]4,000	....	....	8,000	....	....
Total	**43,900**	**44,800**	**15,000**	......	**13,500**	....	**10,000**	....	......	**11,000**	**4,000**	....	....	**8,000**	....	....
TEXAS																
American Petrofina Inc.—Mt. Pleasant	26,000	NR	15,000	......	[8]9,600	2,200	[8]3,500	....	[4-5]6,000	[1-3]3,500	[3]2,200	....	....	8,000	....	....
Port Arthur	84,000	NR	28,000	[1]10,000	[1]30,000	2,000	[8]22,000	....	[5]30,000	[1-3]22,000	[1]2,500	[1]3,000 [3]1,600	....	....	....	....
Amoco Oil Co.—Texas City	333,000	347,000	164,000	[4]22,600	[1]157,000	47,000	[4]131,000	[1]40,000	......	[1]130,500	[1]30,000	[1]37,500	....	5,300	....	1,030
Atlantic Richfield Co.—Houston	213,000	233,500	70,000	[4]27,000	[1]69,000	5,000	[1]100,000	[4]4,500	[5]35,000	[1]100,000 [5]6,000 [6]8,000	[1]9,000	[1]10,400	6,500	....	....	1,300
Champlin Petroleum Co.—Corpus Christi	67,700	68,800	10,000	......	[1]13,000	105	[8]6,300 [6]25,000	....	......	[1]27,000 [5]6,300	[3]3,300	[1]2,100 [3]1,600 [6]7,510	....	....	....	....
Charter International Oil Co.—Houston	64,000	70,000	22,000	[3]10,000	[1]24,000	5,000	[1]13,500	....	[5]29,500	[1]15,000	[1]4,500	[1]7,900	....	4,000	....	....
Chevron Oil Co.—El Paso	71,000	NR	24,000	......	[1]22,000	8,000	[8]25,000	....	[4]14,000 [5]4,000	[1]25,000	[1]5,000	[4]1,500	....	5,000	....	....
Coastal States Petrochemical Co.—Corpus Christi	185,000	NR	45,000	[4]12,000	[1]19,000	600	[1]15,000 [6]20,000	....	[3]25,000	[1]30,000 [4]10,000 [6]10,000	[3]2,500	[1]5,500 [3]5,000	....	500	....	500
Cosden Oil & Chemical Co.—Big Spring	65,000	NR	25,000	[1]10,000	[1]24,000	1,000	[8]20,000	....	[5]8,000	[1-3]25,000	[5]6,000	[1]4,500 [3]2,000 [3]800	....	8,000	....	....
Crown Central Petroleum Corp.—Houston	100,000	103,000	38,000	[4]9,500	[1]43,000	9,000	[1]8,000 [3]14,000	....	......	[1]22,000	[3]10,000	[1]2,000 [3]2,000	....	....	....	300
Crystal Oil Co.—La Blanca	5,462	5,600	......	......	......	....	......	....	......	......	....	....	....	....	....	....
Longview	8,318	8,650	......	......	......	....	[4]1,500	....	......	......	....	....	....	....	....	....
Diamond Shamrock Oil & Gas Co.—Sunray	51,500	53,500	16,500	[1]2,500	[2]11,500 [3]11,500	2,000 2,000	[4]14,000	....	......	[1]14,000 [3]1,500 [7]4,500	[1]8,700	[4]1,400	....	[1]2,500	....	....
Dorchester Gas Producing Co.—White Deer	1,000	1,000	......	......	......	....	[8]980	....	......	......	....	....	....	....	....	....
Eddy Refining Co.—Houston	2,800	NR	......	......	......	....	......	....	......	......	....	....	....	....	....	....
Exxon Co.—Baytown	390,000	405,000	[1]180,000	......	[1]125,000	21,000	[1]88,000	[1]20,000	[3]78,000 [5]30,000	[1]90,000 [3]15,000 [5]109,000 [6]41,000 [7]8,500	[1]26,000	....	31,800	12,000	....	....
Flint Chemical Co.—San Antonio	1,200	1,400	......	......	......	....	......	....	......	......	....	....	....	....	....	....
Gulf Oil Co.—Port Arthur	312,100	319,000	147,400	[4]30,000	[1]120,000	6,000	65,000	[1]15,000	[4]65,000	[1]65,000 [3]1,200 [6]13,900	[1]5,500 [3]14,500	[1]2,700 [3]2,500 [5]7,200	13,200	....	[1]28.0	1,390
Gulf States Oil & Refining Co.—Quitman	NR	4,400	......	......	......	....	......	....	......	......	....	....	....	....	....	....
Howell Hydrocarbons Inc.—San Antonio	NR	3,600	......	......	......	....	[1]750	....	......	......	....	....	....	....	....	....
J & W Refining Inc.—Tucker	9,700	10,000	......	......	......	....	......	....	......	......	....	....	....	....	....	....
La Gloria Oil & Gas Co.—Tyler	29,300	29,700	......	[1]3,000 [4]12,000	[1]10,000	5,000	[8]9,500	....	......	[1]7,000	[1]3,000	....	....	....	....	80
Marathon Oil Co.—Texas City	64,000	66,000	20,000	......	[1]28,500	4,500	[1]8,000	....	......	......	[3]11,000	[1]2,000	....	....	....	....
Mid-Tex Refiner—Hearne	2,600	3,000	......	......	......	....	......	....	......	......	....	...	....	....	....	....

[a]Reprinted from The Oil and Gas Journal, 12 March 1976.

TABLE A-1 (continued)[4,a]

Company and location	Crude capacity b/cd	Crude capacity b/sd	Charge capacity—b/sd: Vacuum distillation	Thermal operations	Cat cracking Fresh feed	Cat cracking Recycle	Cat reforming	Cat hydro-cracking	Cat hydro-refining	Cat hydro-treating	Production capacity—b/sd: Alkylation	Aromatics-isomerization	Lubes	Asphalt	Hydrogen (MMcfd)	Coke (t/d)
Mobil Oil Corp.—Beaumont	325,000	335,000	103,000	[4]33,000	[1]84,000 [3]24,000	NR NR	[1]45,000 [4]49,000	[1]29,000	......	[1]83,000 [6]42,000	[1]12,000	[5]21,000	8,800	....	[1]60.0	1,200
Phillips Petroleum Co.—Borger	99,000	NR	......	......	[1]55,000	15,000	[1]26,000	....	......	[3]25,000 [4]26,000 [7]12,000	[3]14,500	[2]2,900 [4]8,000 [5]12,000	....	....	....	....
Sweeny	85,000	NR	17,000	....	[1]30,000	5,000	[1]32,000	....	....	[1]52,000	[2]9,000	[1]2,600 [3]3,600 [5]9,000	....	....	....	....
Pride Refining Inc.—Abilene	36,500	37,960	......	......	......	....	......	....	....	......	....	....	....	....	....	....
Quintana-Howell Joint Venture—Corpus Christi	NR	44,500									....	....	....	....	....	....
Shell Oil Co.—Deer Park	294,000	305,000	125,000	[1]70,000 [2]20,000	[1]70,000	NR	[1]15,000 [2]20,000 [4]42,000	[1]25,000	[4]50,000	[2]71,000 [3]17,500 [6]7,000 [7]85,000	[1]7,850	[1]13,800	7,900	4,200	[1]71.0	....
Odessa	32,000	34,000	10,000	......	[1]10,500	5,500	[1]11,000	....	......	[2]11,000	[1]2,600	[1]750	....	....	....	....
South Hampton Co.—Silsbee	18,100	NR	......	......	......	....	[1]4,000	....	......	[2]4,000	....	....	....	....	....	....
Southwestern Refining Co. Inc.—Corpus Christi	120,000	124,000	24,000	......	[1]9,500	2,500	[2]15,000	....	......	[1]15,000	[2]2,400	[1]6,000	....	....	....	....
Suntide Refining Co.—Corpus Christi	57,000	60,000	10,000	[4]7,700	[1]20,000	6,500	[1]13,000 [2]11,000	....	......	[1]15,500	[2]3,200	[1]4,500 [2]1,300	....	....	....	235
Tesoro Petroleum Corp.—Carrizo Springs	28,000	29,250	.....	......	......	....	[2]3,000	....	....	[1]3,000	....	..	....	....	....	....
Texaco Inc.*—Amarillo	20,000	NR	......	[4]4,000	[1]8,000	NR	[2]5,000	....	......	[1]5,000	[1]1,500	....	....	....	....	100
El Paso	17,000	NR	......	[4]4,000	[1]7,000	NR	[2]3,500	....	......	[1]3,500	[1]1,500	[4]500	....	....	....	100
Port Arthur	406,000	NR	142,000	[1]18,000	[1]135,000	NR	[2]60,000	[1]15,000	......	[1]60,000 [4]37,000 [6]18,000	[1]15,000	....	20,000	....	....	....
Port Neches	47,000	NR	26,000	......	......	....	......	....	......	......	....	..	....	9,000	....	....
Texas Asphalt & Refining Co.—Euless	6,000	6,000	......	......	......	....	......	....	......	......	....	....	....	....	....	....
Texas City Refining Inc.—Texas City	76,500	80,000	27,500	[2]9,000	[1]27,000	1,000	[2]11,000	....	......	[1]11,000	[2]3,500	....	....	....	....	....
Three Rivers Refining Inc.—Three Rivers	NR	5,000	3,000	......	......	....	......	....	......	......	....	....	....	....	....	....
Union Oil Co. of California—Nederland	120,000	NR	43,000	......	[1]40,000	4,000	[2]37,500	...	......	[1]37,500 [4]6,500 [7]5,500	[1]4,000	[1]2,400 [2]2,100	3,500	5,400	...	....
Union Texas Petroleum, Division of Allied Chemical Co.—Winnie	9,425	10,000	.....	......	......	....	[1]6,200	[1-2]3,000	......	[2]270	....	[1]300	....	....	....	....
Wickett Refining Co.—Wickett	8,500	NR	......	......	......	....	......	....	......	[7]250	....	....	....	....	....	....
Winston Refining Co.—Fort Worth	20,000	20,500	3,500	......	[1]3,400	2,600	[1]1,700	....	......	......	....	....	....	....	....	....
Total	**3,966,330**	**4,144,778**	**1,348,241**	**317,188**	**1,257,166**	**270,405**	**1,009,542**	**153,167**	**374,500**	**1,478,143**	**222,751**	**201,516**	**93,922**	**64,900**	**159.0**	**6,257**

*All figures are calendar day. Stream-day figures not reported.

UTAH

Company and location	Crude capacity b/cd	Crude capacity b/sd	Charge capacity—b/sd: Vacuum distillation	Thermal operations	Cat cracking Fresh feed	Cat cracking Recycle	Cat reforming	Cat hydro-cracking	Cat hydro-refining	Cat hydro-treating	Production capacity—b/sd: Alkylation	Aromatics-isomerization	Lubes	Asphalt	Hydrogen (MMcfd)	Coke (t/d)
Amoco Oil Co.—Salt Lake City	*39,000*	*40,400*	....	......	[1]18,000	4,000	*[2]6,000*	....	......	[1]6,000	[1]3,750	[4]1,800	....	2,500	....	....
Caribou Four Corners Inc.—Woods Cross	5,000	5,500	1,000	......	......	....	[1]1,800	[1]1,000	......	......	....	....	....	....	....	....
Chevron Oil Co.—Salt Lake City	45,000	NR	35,500	[4]8,500	[1]10,000 [3]8,000	1,000 5,000	[2]5,500	....	[6]5,500	[1]5,500	[2]4,300	[4]750	....	....	....	350
Husky Oil Co.—North Salt Lake	23,000	24,000	3,800	......	[2]4,400	2,500	[1]1,000 [2]5,000	....	......	[1]6,000	[2]800	....	....	....	....	....
Plateau Inc.—Roosevelt	7,000	7,400	.....	.....	[1]5,200	NR	......	....	......	......	....	....	....	....	....	....
Phillips Petroleum Co.—Woods Cross	23,000	NR	3,000	......	[2]8,000	2,500	[4]4,500	....	......	[1]10,500 [3]1,500	[2]1,600	....	....	2,200	....	....

[a]Reprinted from The Oil and Gas Journal, 12 March 1976.

TABLE A-1 (continued)[a]

Company and location	Crude capacity b/cd	Crude capacity b/sd	Charge capacity—b/sd: Vacuum distillation	Thermal operations	Cat cracking Fresh feed	Cat cracking Recycle	Cat reforming	Cat hydro-cracking	Cat hydro-refining	Cat hydro-treating	Production capacity—b/sd: Alkyla-tion	Aromatics-isomerization	Lubes	Asphalt	Hydrogen (MMcfd)	Coke (t/d)
Western Refining Co.—Woods Cross	10,000	10,000	750	[1]10,000	....	....	....	....	....	....	....	....	....	....	....	....
Total	**152,000**	**158,878**	**44,050**	**18,500**	**53,600**	**16,560**	**23,800**	**1,000**	**5,500**	**29,500**	**10,450**	**2,550**	....	**4,700**	....	**350**
VIRGINIA																
Amoco Oil Co.—Yorktown	53,000	55,000	28,000	[4]14,000	[1]27,000	5,000	[8]9,000	....	....	[1]9,000 [7]15,000	....	....	....	....	....	710
Total	**53,000**	**55,000**	**28,000**	**14,000**	**27,000**	**5,000**	**9,000**	....	....	**24,000**	....	....	....	....	....	**710**
WASHINGTON																
Atlantic Richfield Co.—Cherry Point, Ferndale	96,000	100,000	55,000	[1]29,000	....	....	[4]35,000	[1]35,000	[5]12,000	[1]27,000	....	....	....	....	[1]60.0	1,500
Mobil Oil Corp.—Ferndale	71,500	75,000	7,000	[2]7,000	[2]25,500	2,000	[4]13,000	....	....	[1]13,000 [6]21,000	[5]5,900	....	....	....	....	....
Shell Oil Co.—Anacortes	91,000	94,000	33,000	....	[1]36,000	17,000	[2]20,000	....	[4]8,500	[2]24,000 [7]21,000	[1]12,100	[4]2,900	....	....	....	....
Sound Refining Inc.—Tacoma	4,500	NR	4,500	....	....	....	....	....	....	....	....	....	1,900	2,600	....	....
Standard Oil Co. of California—Richmond Beach	4,500	NR	5,000	....	....	....	....	....	....	....	....	....	....	4,000	....	....
Texaco Inc.*—Anacortes	78,000	NR	25,000	....	[1]27,000	NR	[2]20,000	....	....	[4]25,000 [4-5]17,000	[1]6,600	....	....	....	....	....
U.S. Oil & Refining Co.—Tacoma	21,400	NR	4,800	....	....	....	[3]3,000	....	....	[1]3,000	....	....	....	....	....	....
Total	**366,900**	**383,105**	**135,616**	**36,000**	**91,500**	**27,100**	**93,222**	**35,000**	**20,500**	**155,667**	**25,333**	**2,900**	**1,900**	**6,600**	**60.0**	**1,500**
WEST VIRGINIA																
Pennzoil Co., Elk Refining Division—Falling Rock	4,900	5,200	2,500	....	....	....	[1]2,000	....	....	[1]2,500 [3]500	....	....	1,400	....	....	....
Quaker State Oil Refining Corp.—Newell	9,700	10,000	4,000	....	....	....	[2]2,860	....	[6]4,440	[1]3,060	....	....	3,600	....	[1]1.2	....
St. Marys	4,850	5,000	2,175	....	....	....	[2]1,300	....	....	[1]1,450	....	....	1,700	....	....	....
Total	**19,450**	**20,200**	**8,675**	....	....	....	**6,160**	....	**4,440**	**7,510**	....	....	**6,700**	....	**1.2**	....
WISCONSIN																
Murphy Oil Corp.—Superior	45,400	46,800	15,500	....	[1]9,700	1,000	[8]10,000	....	[5]5,800	[1]10,000	[2]1,200	....	....	12,000	....	....
Total	**45,400**	**46,800**	**15,500**	....	**9,700**	**1,000**	**10,000**	....	**5,800**	**10,000**	**1,200**	..	....	**12,000**	....	....
WYOMING																
Amoco Oil Co.—Casper	43,000	44,500	13,800	....	[1]9,500	1,500	[5]5,200	....	....	[1]6,600	[1]1,190		1,470	1,550	....	....
Husky Oil Co.—Cheyenne	23,600	24,600	14,000	....	[1]10,000	2,500	[1]1,000 [5]5,200	....	....	[1]6,200 [4]4,900	[2]2,750	[4]1,500	....	3,000	....	....
Cody	10,800	11,300	6,500	....	[1]3,300	1,000	[2]1,500	....	....	[1]1,500 [4]1,800	[2]800	....	....	4,000	....	....
Little America Refining Co.—Casper	24,500	NR	5,800	....	[6]6,500	4,000	[1]3,750	....	....	[5]5,000 [3]3,750	....	....	....	2,000	....	....
Mountaineer Refining Co. Inc.—La Barge	700	800	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Pasco Inc.—Sinclair	49,000	50,000	16,100	....	[1]17,700	1,200	[1]9,700	....	[4]12,200	[1]13,000 [4]12,000	[1]2,200	....	....	2,600	....	....

[a]Reprinted from The Oil and Gas Journal, 12 March 1976.

TABLE A-1 (continued)[4,a]

Company and location	Crude capacity b/cd	Crude capacity b/sd	Charge capacity—b/sd: Vacuum distillation	Thermal operations	Cat cracking: Fresh feed	Cat cracking: Recycle	Cat reforming	Cat hydro-cracking	Cat hydro-refining	Cat hydro-treating	Production capacity—b/sd: Alkylation	Aromatics-Isomerization	Lubes	Asphalt	Hydrogen (MMcfd)	Coke (t/d)
Sage Creek Refining Co.—Cowley ...	NR	1,200	......	......	......	....	......	....	......	......	....	....	....	....	....	....
Southwestern Refining Co.—LaBarge	3,100	NR	......	......	......	....	......	....	......	......	....	....	....	....	....	....
Tesoro Petroleum Corp.—Newcastle	10,500	11,000	......	......	[2]4,000	3,000	......	....	......	......	[2]900	....	....	....	....	....
Texaco Inc.*—Casper	21,000	NR	10,000	[5]4,000	[1]7,000	NR	[2]4,000	....	[4]4,000	[1]4,000	....	....	....	1,500	....	125
V-1 Oil Co.—																
Glenrock ..... (possible start up this spring at 1,000 b/cd)																
Total	187,340	194,557	66,726	4,444	58,778	15,300	30,794	....	18,644	59,194	7,840	1,500	1,470	14,817	....	139

*All figures are calendar day. Stream-day figures not reported.

[a]Reprinted from The Oil and Gas Journal, 12 March 1976.

APPENDIX B

NUMBER OF MISCELLANEOUS SOURCES FOR SOME REFINERIES AND REFINERY OPERATIONS

Tables B-1, B-2, and B-3 summarize available information on number of miscellaneous sources by processing unit along with the unit feed rate. Pumps and compressors are shown divided based on liquid and gaseous service. The number of pumps and compressors with packed seals is shown in parentheses where data were available. The accuracy of the data in Tables B-1, B-2, and B-3 could not be determined. In addition to data in Tables B-1 through B-3, one rough estimate of 900 pumps, 65 compressors, and 15 to 20 valves per pump or compressor was obtained from Refinery D, which has 0.309 m^3/s (168,000 bbl/d) crude capacity.

TABLE B-1. QUANTITY OF PUMPS AND COMPRESSORS, ATMOSPHERE-VENTED PRESSURE RELIEF VALVES, AND VALVES FOR REFINERY A

Unit	Pumps and compressors		Pressure relief valves release to atmosphere	Unit Feed Rate[a]	
	Liquid service	Liquid service		m^3/s	(bbl/d)
No. 1 crude unit	33	1	2	0.099	(53.900)
No. 2 crude unit	35	1	2	0.015	(8,100)
No. 3 crude unit	10	0	[b]	0.010	(5,500)
No. 1 vacuum unit	5	0	[b]	0.015	(8,300)
No. 2 vacuum unit	4	0	[b]	0.006	(3,500)
Nos. 1 and 2 light end fractionation unit	11	0	[b]	0.024	(12,975)
No. 3 hydrodesulfurizer unit and No. 1 reformer unit	16	3	[b]	0.014	(7,827)
No. 2 reformer	5	3	[b]	0.003	(1,380)
Fluid catalytic cracking unit	67	9	12	0.032	(17,580)
Cumene unit	22	0	[b]	0.003	(1,500)
HF alkylation unit	19	0	[b]	0.006	(3,405)
Sulfolane extractor unit	13	0	[b]	0.012	(6,340)
BTX fractionation unit	11	0	[b]	0.010	(5,540)
No. 1 hydeal unit	12	8	[b]	0.0003	(140)
No. 2 hydeal unit	15	2	[b]	0.006	(3,200)
No. 4 crude unit	19	1	[b]	0.126	(68,380)
No. 4 vacuum unit	7	0	[b]	0.039	(21,375)
Hydrobon and No. 4 reformer unit	24	2	[b]	0.029	(15,650)
Kerosene HDS unit	6	1	[b]	0.013	(6,870)
Diesel HDS unit	6	1	[b]	0.018	(9,610)
Gas-oil HDS unit	17	2	[b]	0.029	(15,808)
Delayed coking unit	22	1	[b]	0.015	(8,140)
Cat gasoline merox unit	7	0	[b]	0.002	(1,190)
No. 2 light ends unit and light ends merox units	7	0	[b]	0.013	(7,050)
Fuel gas amine absorber unit	[b]	[b]	[b]	[b]	[b]
Amine regenerator column	[b]	[b]	[b]	[b]	[b]
Sour water stripper unit	[b]	[b]	[b]	[b]	[b]
Sulfur recovery unit	[b]	[b]	[b]	[b]	[b]

[a]Crude capacity, 0.340 m^3/s (185,000 bbl/d).

[b]Not available.

TABLE B-2. QUANTITY OF PUMPS AND COMPRESSORS, ATMOSPHERE-VENTED PRESSURE RELIEF VALVES, AND VALVES FOR REFINERY B

Unit	Pumps and compressors: Liquid service (packed seals)	Pumps and compressors: Gaseous service (packed seals)	Pressure relief valves release to atmosphere	Unit feed rate[a]: m^3/s	Unit feed rate[a]: (bbl/d)
Nos. 1, 2, and 3 crude units	48 (22)	0 (0)	9	0.110	(59,800)
Vacuum unit	5 (4)	0	1	0.022	(11,700)
Fluid catalytic cracking unit	20 (12)	3 (0)	7	0.018	(9,600)
No. 4 unifiner unit	5 (0)	2 (0)	_b	0.032	(17,300)
No. 4 platformer unit	5 (0)	2 (0)	5	0.032	(17,200)
No. 3 unifiner unit	3 (3)	2 (0)	_b	0.017	(9,200)
No. 3 platformer unit	3 (1)	2 (0)	_b	0.016	(8,400)
BTX unit	16 (6)	0	_b	0.019	(10,100)
HF alkylation unit	11 (0)	0	_b	0.007	(3,800)
Light ends unit	3 (2)	0	_b	0.002	(1,000)
Butane splitter	3 (1)	0	_b	0.002	(1,100)
Hydrar unit	9 (0)	2 (0)	_b	0.012	(6,700)
Kerosene merox unit	_b	_b	_b	_b	_b

[a]Crude capacity, 0.340 m^3/s (185,000 bbl/d).

[b]Not available.

TABLE B-3. QUANTITY OF PUMPS AND COMPRESSORS, ATMOSPHERE-VENTED PRESSURE RELIEF VALVES, AND VALVES FOR REFINERY C

Unit	Pumps and compressors: Liquid service (packed seals)		Pumps and compressors: Gaseous service (packed seals)		Pressure relief valves release to atmosphere	Number of valves	Unit feed rate[a] m^3/s	Unit feed rate[a] (bbl/d)
Old crude and vacuum units	43	(5)	1	(0)	0	_b	0.099	(54,000)
New crude and vacuum units	45	(0)	1	(0)	2	_b	0.105	(57,000)
Fluid catalytic cracking unit	30	(10)	4	(0)	0	_b	0.022	(12,000)
Unifiner unit	8	(0)	0		0	_b	0.032	(17,200)
Platformer unit	10	(0)	1	(0)	0	_b	0.031	(17,000)
Sulfolane (aromatics) unit	38	(0)	0		0	_b	0.014	(7,700)
HF alkylation unit	8	(0)	0		0	650	0.008	(4,100)
Light ends unit	8	(0)	0		0	_b	0.005	(2,900)

[a]Crude capacity, 0.340 m^3/s (185,000 bbl/d).

[b]Not available.

APPENDIX C

REGULATIONS FOR THE STATE OF COLORADO, MISCELLANEOUS SOURCE EMISSIONS

1. WATER SEPARATION FROM PETROLEUM PRODUCTS

Single or multiple compartment oil and effluent water separation equipment which receives effluent water containing 200 gallons (760 liters) or more a day of any petroleum product or mixture of petroleum products from any equipment used for processing, refining, treating, storing, or handling of petroleum products having a Reid vapor pressure of 0.5 pound or greater, shall be equipped with one or more of the following vapor loss control devices, properly installed, in good working order, and properly maintained:

- A solid cover with all openings sealed and the liquid contents totally enclosed. All gauging and sampling devices shall be vapor-tight except when gauging or sampling is taking place.

- A pontoon-type or double deck-type floating roof, or internal floating cover, resting on the surface of the contents and equipped with a closure seal or seals to close the space between the roof edge and container wall. All gauging and sampling devices shall be vapor-tight except when gauging or sampling is taking place.

- A vapor recovery system consisting of a vapor gathering system capable of collecting the hydrocarbon vapors discharged and a vapor disposal system capable of processing such hydrocarbon vapors so as to prevent their emission to the atmosphere. All container gauging and sampling devices shall be vapor-tight, except when gauging or sampling is taking place.
- Other equipment of equal or greater efficiency, provided the design and effectiveness of such equipment as documented is submitted to and approved by the Division.

2. PUMPS AND COMPRESSORS

No person may build, install, or permit the building or installation of any rotating pump or compressor handling any type of petroleum distillate unless said pump or compressor is equipped with mechanical seals or other equipment of equal efficiency. If reciprocating-type pumps and compressors are used, they shall be equipped with packing glands properly installed, in good working order, and properly maintained so no emissions occur from the drain recovery systems.

3. WASTE GAS DISPOSAL

Any waste gas stream containing hydrocarbon compounds from a polymer synthesis process emission source shall be burned at 1,300°F (704°C) for 0.3 second or longer, in a direct flame afterburner or an equally effective device. The emissions of hydrocarbon vapors from a vapor blowdown system or emergency relief shall be burned in smokeless flares, or equipment of equal efficiency, provided the design and effectiveness of equipment, as documented, is submitted to and approved by the Division.

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16. ABSTRACT

Background information on miscellaneous sources of hydrocarbons in the petroleum refineries is summarized. The information is used to estimate the expected atmospheric emission reduction of potential new source performance standards (NSPS) for the petroleum refining industry. Miscellaneous sources of emissions included in the study were pipeline valves and flanges, pressure relief valves, blowdown systems, pump and compressor seals, and process drains. Additionally, the background information includes a general review of the petroleum refining industry, a discussion of pertinent emission control methods, and a summary of pertinent available air pollution regulations.

New source performance standards requiring application of best available control technology will result in an estimated 1985 hydrocarbon emission level of 750 Gg/yr, a reduction of 67% from 1985 emissions estimates for a condition of no controls and a reduction of 41% from 1985 emissions estimated under application of existing state regulations to both new and existing sources.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Air Pollution Control Equipment Hydrocarbons Petroleum Refining Blowdown Systems Pump and Compressor Seals Process Drains and Wastewater Separators Pressure Relief Valves Pipeline Valves and Flanges	Air Pollution Control Stationary Sources Hydrocarbon Emission Controls	13 B 14 B 07 C 13 H

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