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EVALUATION OF HYROCARBON EMISSIONS FROM PETROLEUM LIQUID STORAGE

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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EVALUATION OF HYDROCARBON EMISSIONS FROM PETROLEUM LIQUID STORAGE

by

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ABSTRACT

This study provides an estimate of 1976 nationwide hydrocarbon emissions from storage of petroleum liquids in existing tanks with a capacity greater than 150,000 liters. Numbers and types of existing tanks were determined to estimate these emissions by geographical location, industry sector, and volatility class of the stored products. Projections of emissions are made for 1980 and 1985 assuming only newly constructed tanks meet the requirements of the New Source Performance Standard (NSPS) for the storage of petroleum liquids and then assuming existing fixed roof tanks storing products with a volatility greater than 10.5 kPa are retrofitted with internal floating covers. Other options such as the use of vapor recovery systems for fixed roof tanks and double seals on external floating roof tanks were considered beyond the scope of the study. A nationwide estimate of 1976 emissions by petroleum liquid type stored is presented.

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1.0 SUMMARY

The purpose of this project was to evaluate hydrocarbon (HC) emissions from petroleum storage tanks located in the United States. The evaluation was limited to floating-roof and fixed-roof tanks having capacities greater than 151,000 liters (40,000 gallons). The project required estimating the current, nationwide, annual emissions from the tanks and projecting the emission levels to the years 1980 and 1985. Emphasis of the project was placed on estimating the HC emissions from tanks located at refineries, terminals, tank farms, and pipeline facilities. Tanks at oil production facilities were not included. Emission estimates were then developed for 1980 and 1985 assuming that all existing fixed-roof tanks storing petroleum liquids with a true vapor pressure greater than 10.5 kilopascals (kPa) (1.52 psia) were retrofitted with floating roofs and that all new tanks for these petroleum liquids were external floating-roof tanks. Application of alternative controls system such as vapor recovery systems and double seals on external floating-roof tanks was beyond the scope of this project.

1.1 EMISSION ESTIMATE METHODOLOGY

The numbers of floating-roof and fixed-roof tanks, and subsequently, the annual HC emissions from these tanks were estimated by first compiling a tank data base. For individual tank locations, information was collected about the tank design characteristics, the properties of the petroleum liquid stored, and the tank operations. Primary data sources were state and local air pollution regulatory agencies. Approximately 25,000 tank locations were listed in the compiled tank data base.

Processing of the compiled tank data consisted of sorting the data by various classifications schemes and calculation of the annual HC emissions from each tank location. The emission calculations were performed using the emission equations described in the U.S. Environmental Protection Agency document Compilation of Air Pollution Emission Factors (AP-42).[1] Results for the emission calculations were summed for direct input into the total emission estimates. Also, the results were averaged to obtain tank emission factors. These factors were used to approximate tank HC emissions for refineries, terminals, and pipeline facilities not listed in the compiled tank data base.

Summing the results for the emission calculations plus the emission approximations for locations not listed in the data base yielded the total estimates of annual HC emissions from floating-roof and fixed-roof tanks for the year 1976. Projections of annual HC emissions for the years 1980 and 1985 were made by linear extrapolation of the 1976 estimated emission values. A ratio of future to current domestic refining capacity was used to project upward the 1976 values.

1.2 EMISSION ESTIMATE RESULTS

1.2.1 1976 ANNUAL HYDROCARBON EMISSIONS

For the year 1976, it was estimated there were 40,000 floating-roof and fixed-roof tanks having capacities greater than 151,000 liters. Annual HC emissions from these tanks were estimated to total 8.3×10^8 kilograms per year (kg/yr). (One kilogram equals 2.2 pounds.) Approximately 17% of the emissions were estimated to be emitted from external and internal floating-roof tanks as shown below by the volatility of the petroleum liquid stored in the tank (expressed in kilopascals (kPa), 1.0 kPa equals 0.145 psia).

Volatility of Petroleum Liquid Stored		Number of Tanks	Annual HC Emissions
(kPa)	(psia)		(1,000 kg/yr)
0.0 to 3.5	0.0 to 0.51	1,830	2,002
3.5 to 10.5	0.51 to 1.52	1,310	5,020
10.5 to 35.5	1.52 to 5.0	7,093	64,178
35.5 to 62.7	5.0 to 9.1	3,357	61,464
62.7 to 76.5	9.1 to 11.1	218	9,400
TOTAL		13,808	142,064

The remaining 83% of the emissions were estimated to be emitted from fixed-roof tanks as shown below:

Volatility of Petroleum Liquid Stored		Number of Tanks	Annual HC Emissions
(kPa)	(psia)		(1,000 kg/yr)
0.0 to 3.5	0.0 to 0.51	15,416	34,170
3.5 to 10.5	0.51 to 1.52	3,388	98,787
10.5 to 35.5	1.52 to 5.0	5,840	406,116
35.5 to 62.7	5.0 to 9.1	1,396	134,927
62.7 to 76.5	9.1 to 11.1	49	16,170
TOTAL		26,089	690,170

Tables 1-1 and 1-2 summarize, respectively, the estimated tank numbers and annual HC emissions for the year 1976 by Petroleum Allocation for Defense (PAD) Districts and by industry sectors.

Installing internal floating roofs is one method available to control HC emissions from fixed-roof tanks. For the year 1976, annual HC emissions from fixed-roof tanks were also estimated assuming the retrofitting of internal floating roofs in the fixed-roof tanks storing petroleum liquids having a vapor pressure greater than 10.5 kPa

Table 1-1. SUMMARY OF ESTIMATED TANK NUMBERS FOR THE YEAR 1976

TANK TYPE	PAD DISTRICT					TOTAL
	1	2	3	4	5	
Floating-roof[a]	3,264	4,286	3,535	523	2,200	13,808
Fixed-roof	6,213	7,572	7,117	1,013	4,174	26,089

TANK TYPE	INDUSTRY SECTOR					TOTAL
	Refinery	Terminal	Tank Farm	Pipeline	Other	
Floating-roof[a]	5,482	5,407	579	2,032	308	13,808
Fixed-roof	12,525	8,073	746	2,734	2,011	26,089

[a] External and internal floating-roof tanks

Table 1-2. SUMMARY OF ESTIMATED ANNUAL HC EMISSIONS FOR THE YEAR 1976 CURRENT EMISSION CONTROL STRATEGY (units: 1,000 kg/yr)

TANK TYPE	PAD DISTRICT					TOTAL
	1	2	3	4	5	
Floating-roof[a]	32,754	43,388	43,303	2,978	19,641	142,064
Fixed-roof	142,603	220,468	196,395	12,852	117,852	690,170

TANK TYPE	INDUSTRY SECTOR					TOTAL
	Refinery	Terminal	Tank Farm	Pipeline	Other	
Floating-roof[a]	59,583	52,448	6,638	21,830	1,565	142,064
Fixed-roof	357,732	201,948	31,051	79,701	19,738	690,170

[a] External and internal floating-roof tanks.

(1.52 psia). These estimates showed total annual HC emissions from fixed-roof tanks would be reduced by 77% to 1.6×10^8 kg/yr. A comparison of the 1976 emission estimates for both emission control strategy assumptions is shown in Table 1-3.

1.2.2 1980 AND 1985 ANNUAL HYDROCARBON EMISSIONS

For the year 1980, it was projected there will be 16,900 floating-roof tanks and 29,000 fixed-roof tanks having capacities greater than 151,000 liters. These projections assumed all new tank construction would comply with the current New Source Performance Standards (NSPS) for petroleum storage tanks.[2] All new tanks projected to store petroleum liquids having a vapor pressure greater than 10.5 kPa were counted as external floating-roof tanks.

Total annual HC emissions from floating-roof and fixed-roof tanks for the year 1980 were projected to be 8.8×10^8 kg/yr. A second projection was made assuming all new tank construction would comply with the current NSPS and all existing fixed-roof tanks would be retrofitted with internal floating roofs. Using this alternative control strategy assumption, projected annual 1980 HC emissions were reduced to 3.5×10^8 kg/yr. Table 1-4 compares the 1980 emission projections by stored petroleum liquid volatility class.

An analogous set of projections was made for the year 1985. The numbers of floating-roof tanks and fixed-roof tanks were projected to increase to, respectively, 19,700 tanks and 31,500 tanks assuming current NSPS. Projected annual HC emissions totaled 9.3×10^8 kg/yr. Using the alternative emission control strategy, the projected annual HC emissions decreased to 4.0×10^8 kg/yr. A comparison of the 1985 emission projections is shown in Table 1-5.

Table 1-3. COMPARISON OF ANNUAL HC EMISSION ESTIMATES FOR THE YEAR 1976 (units: 1,000 kg/yr)

CURRENT EMISSION CONTROL STRATEGY

TANK TYPE	VOLATILITY[b] CLASS					TOTAL
	0-3.5	3.5-10.5	10.5-35.5	35.5-62.7	62.7-76.5	
Floating-roof[a]	2,002	5,020	64,178	61,464	9,400	142,064
Fixed-roof	34,170	98,787	406,116	134,927	16,170	690,170

ALTERNATIVE EMISSION CONTROL STRATEGY[c]

TANK TYPE	VOLATILITY[b] CLASS					TOTAL
	0-3.5	3.5-10.5	10.5-35.5	35.5-62.7	62.7-76.5	
Floating-roof[a]	2,002	5,020	64,178	61,464	9,400	142,064
Fixed-roof	34,170	98,787	17,735	7,675	707	159,074

[a] External and internal floating-roof tanks

[b] Volatility of petroleum liquid stored in tank expressed as true vapor pressure in units of kilopascals

[c] Existing fixed-roof tanks storing 10.5 kPa or greater volatility petroleum liquids are retrofitted with internal floating roofs.

Table 1.4. COMPARISON OF ANNUAL HC EMISSION PROJECTIONS FOR THE YEAR 1980
(units: 1,000 kg/yr)

CURRENT EMISSION CONTROL STRATEGY

TANK TYPE	VOLATILITY CLASS					TOTAL
	0-3.5	3.5-10.5	10.5-35.5	35.5-62.7	62.7-76.5	
Floating-roof[a]	2,240	5,612	80,809	74,667	11,200	174,528
Fixed-roof	39,262	113,362	406,116	134,927	16,170	709,837

ALTERNATIVE EMISSION CONTROL STRATEGY

TANK TYPE	VOLATILITY CLASS					TOTAL
	0-3.5	3.5-10.5	10.5-35.5	35.5-62.7	62.7-76.5	
Floating-roof[a]	2,240	5,612	80,809	74,667	11,200	174,528
Fixed-roof	39,262	113,362	17,735	7,675	707	178,741

[a] External and internal floating-roof tanks

[b] Volatility of petroleum liquid stored in tank expressed as true vapor pressure in units of kilopascals

[c] All new tank construction complies with New Source Performance Standards

[d] All new tank construction complies with New Source Performance Standards and existing fixed-roof tanks storing 10.5 kPa or greater volatility petroleum liquids are retro- fitted with internal floating roofs

Table 1-5. COMPARISON OF ANNUAL HC EMISSION PROJECTIONS FOR THE YEAR 1985 (units: 1,000 kg/yr)

CURRENT EMISSION CONTROL STRATEGY

TANK TYPE	VOLATILITY CLASS					TOTAL
	0-3.5	3.5-10.5	10.5-35.5	35.5-62.7	62.7-76.5	
Floating-roof[a]	2,455	6,317	96,890	85,121	12,527	203,310
Fixed-roof	42,672	128,031	406,116	134,927	16,170	727,916

ALTERNATIVE EMISSION CONTROL STRATEGY

TANK TYPE	VOLATILITY CLASS					TOTAL
	0-3.5	3.5-10.5	10.5-35.5	35.5-62.7	62.7-76.5	
Floating-roof[a]	2,455	6,317	96,890	85,121	12,527	203,310
Fixed-roof	42,672	128,031	17,735	7,675	707	196,820

[a] External and internal floating-roof tanks

[b] Volatility of petroleum liquid stored in tank expressed as true vapor pressure in units of kilopascals

[c] All new tank construction complies with New Source Performance Standards

[d] All new tank construction complies with New Source Performance Standards and existing fixed-roof tanks storing 10.5 kPa or greater volatility petroleum liquids are retrofitted with internal floating roofs

2.0 INTRODUCTION

The purpose of this project was to evaluate hydrocarbon (HC) emissions from petroleum storage tanks located in the United States. The evaluation was limited to floating-roof and fixed-roof tanks having capacities greater than 151,000 liters (40,000 gallons). Estimates were made of nationwide, annual HC emissions from the tanks. A complementary task involved compiling economic cost information about the installation of internal floating-roofs in fixed-roof tanks.

2.1 HYDROCARBON EMISSION ESTIMATES

Hydrocarbon emission estimates were made for external and internal floating-roof tanks and fixed-roof tanks. The emphasis of the project was placed on estimating the annual HC emissions from tanks associated with refining, distributing, and marketing of petroleum liquids (tanks located at refineries, at terminals, at tank farms, and along pipelines). Tanks located at oil production facilities were not included in the project. When information about tanks located at petrochemical, power, or industrial plants was readily available, the tanks were included in the emission estimates. However, compiling data about tanks located at these facilities received secondary priority with respect to meeting the project objectives.

The specific objectives of the project were:

1. To estimate the number of existing floating-roof tanks and fixed-roof tanks having capacities greater than 151,000 liters.
2. To estimate the current, annual HC emissions from the existing floating-roof tanks and fixed-roof tanks.

3. To estimate the annual HC emissions from the existing fixed-roof tanks assuming an alternative emission control strategy requiring all existing fixed-roof tanks storing petroleum liquids having a true vapor pressure greater than 10.5 kilopascals (kPa) (1.52 psia) be retrofitted with internal floating-roofs.

4. To project annual HC emissions from floating-roof and fixed-roof tanks for the years 1980 and 1985 assuming current emission control strategy requiring all new tank construction meet New Source Performance Standards.[2]

5. To project annual HC emissions from floating-roof and fixed-roof tanks for the years 1980 and 1985 assuming an alternative emission control strategy requiring all new tank construction meed New Source Performance Standards and all existing fixed-roof tanks storing petroleum liquids having a vapor pressure greater than 10.5 kPa be retrofitted with internal floating roofs.

Use of alternative control systems such as vapor recovery systems and double seals on external floating-roof tanks was beyond the scope of this project.

The methodology used for the HC emission estimates is outlined in Chapter 3. The annual HC emission estimates are presented in Chapter 4.

2.2 TANK COST DATA

The purpose of this task was to compile economic cost information on the installation of internal floating-roofs in fixed-roof tanks. No evaluation of cost effectiveness was made. Chapter 5 presents the cost data.

3.0 EMISSION ESTIMATE METHODOLOGY

Estimation of the number of tanks in the United States and, subsequently, the annual HC emissions from these tanks was performed in five stages. Figure 3-1 outlines the estimation procedures. The methodology used for each stage of the procedure is summarized in Sections 3.1 through 3.5. A detailed description of the calculations upon which the emission estimates were based is presented in Appendix A. Section 3.6 discusses the applicability of the equations used for the emission calculations.

3.1 TANK DATA COMPILATION

The first stage of the estimation procedure involved collecting data for individual tank locations about the tank design characteristics, the properties of the stored petroleum liquid, and the tank operations. To determine the availability of existing tank data, inquiries were made to Federal agencies, air pollution regulatory agencies, tank vendors, and tank owners. State and local air pollution regulatory agencies proved to be the best sources of individual tank data for meeting the study objectives. Supplemental tank data was obtained from the U.S. Environmental Protection Agency (EPA).

The minimum information required about a specific tank location for the tank to be included in the individual tank data base was:

1. Type of tank
2. Capacity of tank
3. Type of petroleum liquid stored in tank

Additional information about the tank design, tank operations, and stored petroleum liquid properties was compiled when available

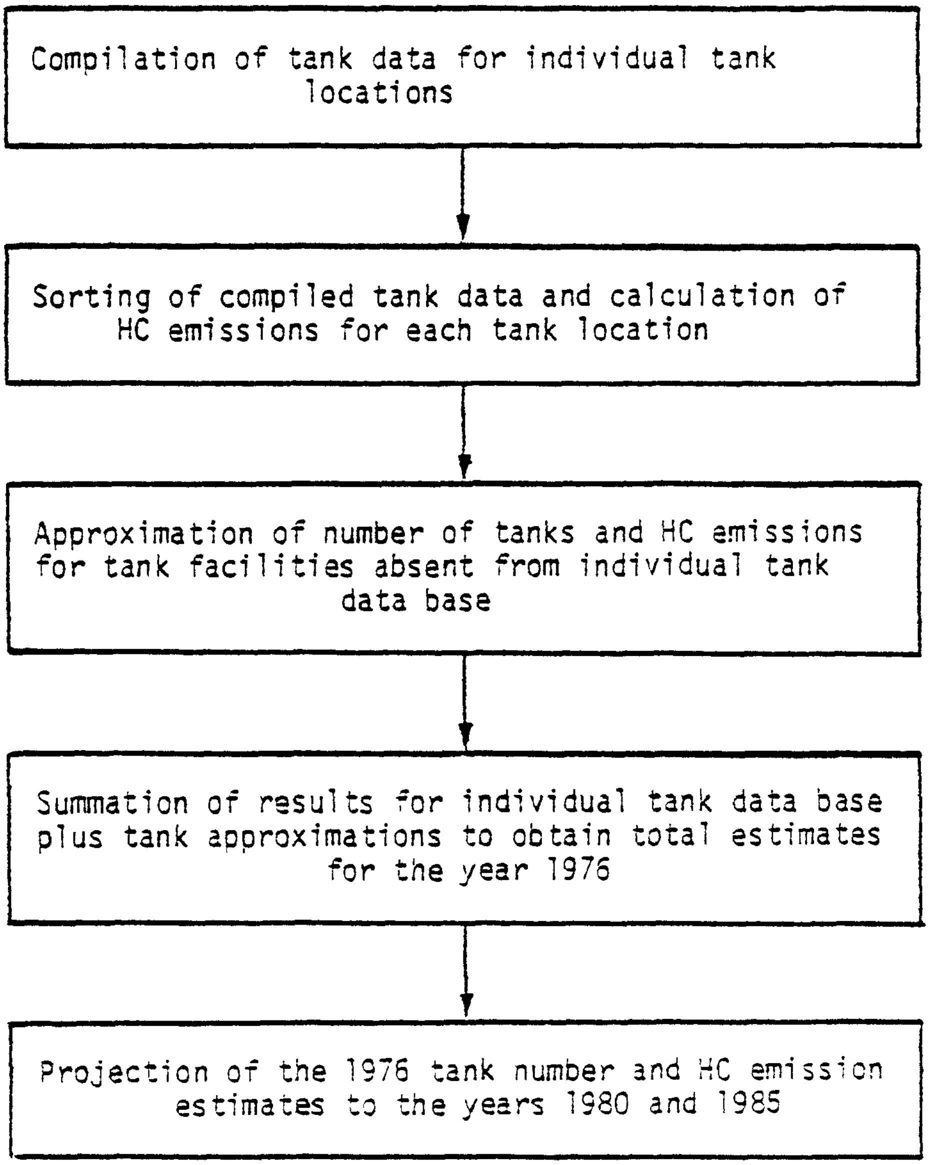

Figure 3-1. Emission Estimate Methodology

for a specific tank location. Approximately 25,000 tank locations were listed in the compiled tank data base.

3.2 TANK DATA PROCESSING

Processing of the individual tank data comprised sorting the data by various classification schemes and calculation of the annual HC emissions from each tank location. To facilitate the data processing, the data for individual tank locations were sorted by state and coded for storage and retrieval from computer data files. Computer programs were used to tabulate the data and perform all emission calculations.

3.2.1 TANK DATA TABULATIONS

The individual tank data were sorted by geographic regions, industry sector location, and the volatility of the stored petroleum liquid. Petroleum Administration for Defense (PAD) Districts were used to tabulate the data by geographic regions (see Figure 3-2). The industry sectors selected to classify the data reflect the project emphasis on tanks located at petroleum refining, distribution, and storage facilities. These sectors are defined in Table 3-1. Tabulations of the data by petroleum liquid volatility was accomplished using vapor pressure ranges provided by the EPA (refer to Table 3-1). The distributions of the compiled individual tank data by the classification schemes are summarized in Appendix B.

3.2.2 EMISSION CALCULATIONS

Annual HC emissions were calculated for each tank listed in the 25,000 tank data base. The results were summed for direct input into the total emission estimates and averaged to develop tank emission factors. These factors were used to approximate HC emissions at tank locations not listed in the tank data files.

Figure 3-2. Petroleum Administration for Defense (PAD) Districts

Table 3.1. TANK DATA CLASSIFICATION CATEGORIES

INDUSTRY SECTOR CATEGORIES

Industry Sector	Definition
Refinery	Refinery location including all tanks used for petroleum liquid storage, processing, and distribution
Terminal	Facilities independent of refineries used primarily for receiving and distributing petroleum liquids
Tank Farm	Facilities independent of refineries used primarily for storage of petroleum liquids
Pipeline	Pipeline pumping stations
Other	Petrochemical, power, and industrial plants

PETROLEUM LIQUID VOLATILITY CATEGORIES

Volatility Class	True Vapor Pressure Range	
	(kilopascals)	(psia)
1	0 to 3.5	0 to 0.51
2	3.5 to 10.5	0.51 to 1.52
3	10.5 to 35.5	1.52 to 5.0
4	35.5 to 62.7	5.0 to 9.1
5	62.7 to 76.5	9.1 to 11.1

The emission calculations were performed using the emission equations described in the EPA document, Compilation of Air Pollution Emission Factors (AP-42)[1] (see Appendix C). Three types of input parameters were required for the emission equations.

1. Meteorological parameters
2. Tank design parameters
3. Petroleum liquid property parameters

Annual average meteorological conditions were used to calculate annual HC emissions. Also, emissions were calculated for winter and summer conditions using, respectively, January and July monthly average meteorological conditions. To account for the variation of meteorological conditions throughout the United States, the country was divided into 121 meteorological districts. The district boundaries were selected so that the general meteorology of each district was characterized by data recorded in the district. The emission calculations were performed using the meteorological data corresponding to the district in which a specific tank was located.

Input for the tank design and petroleum liquid property parameters were obtained from the data compiled about each tank location. If information for a particular parameter was missing, a value for the parameter was assumed in order to allow the calculations to be completed. The assumptions used for the tank design parameters were based on tank design trends identified from data listed in the tank data files. Properties tabulated in AP-42 were used when an assumed value for a petroleum liquid property was required.

3.3 EMISSION APPROXIMATIONS

Tabulation of the calculated emissions for the individual tank data provided an estimate of the annual HC emissions for many but not all refinery, terminal, tank farm, pipeline, and other tank locations throughout the United States. Consequently, a method was devised to approximate the number of tanks and tank emissions for refinery and pipeline pumping station locations not listed in the tank data files. Approximations of the total number of terminal tanks in each state were used to supplement the individual tank calculation results. No approximations were made for tank farm, petrochemical plant, power plant, or industrial plant locations not listed in the tank data files.

3.3.1 REFINERY EMISSION APPROXIMATIONS

Refinery locations not listed in the tank data file were identified using the annual Oil and Gas Journal refining survey.[3] The number of tanks at these refinery locations were approximated on the basis of the rated crude oil refining capacity (expressed as barrels per day). From the tabulated individual tank data, tank factors were developed expressing the average number of refinery floating-roof and fixed-roof tanks per 1000 bbl/day refining capacity. Multiplication of the refining capacities times the tank factors yielded approximations of the number of tanks. Annual HC emissions from the tanks were approximated by multiplying the number of tanks by tank emission factors. These factors expressed the average annual HC emissions from refinery tanks. Separate tank factors and tank emission factors were used for each PAD District to reflect regional variations in refinery operations.

3.3.2 PUMPING STATION EMISSION APPROXIMATIONS

The number of pipeline pumping stations located in each PAD

District which were not listed in the tank data files was determined using pipline maps. Approximations of the number of tanks at these stations were made using a factor of two tanks per pumping station. Tanks located at crude oil pumping stations were arbitrarily designated fixed-roof tanks, and tanks located at refined product pumping stations were designated floating-roof tanks. Emissions from the tanks were approximated using the tank emission factors developed for refinery locations.

3.3.3 TERMINAL EMISSION APPROXIMATIONS

No surveys or maps were available that allowed identification of the terminal locations not listed in the tank data files. Therefore, the total numbers of tanks located at terminals in each state were approximated based on the state populations. This was accomplished using tank factors expressing the average number of terminal floating-roof and fixed-roof tanks per 1000 population. The difference between the approximated total number of terminal tanks and the number of terminal tanks listed in the tank data files indicated the number of additional tanks for which HC emission approximations were to be made. Annual HC emissions were then approximated by multiplying the number of tanks by tank emission factors. These factors expressed the average annual HC emissions from terminal tanks. To reflect regional variations in terminal operations, separate tank factors and tank emission factors were developed for each PAD District.

3.4 1976 EMISSION ESTIMATES

A distribution of the total estimates of tank numbers and annual HC emissions for the year 1976 were required by industry sector, petroleum liquid volatility, and petroleum liquid type.

Tabulations of tank numbers and annual HC emissions from the tank data files were made for all three classification groups. However, approximations of tank numbers and annual HC emissions for tank locations not listed in the tank data files were made only by industry sector. To estimate total tank numbers and annual HC emissions, the results of the data file tabulations and the tank approximations were summed by industry sector. These total values were subsequently redistributed by petroleum liquid volatility and type assuming the same distribution ratios exhibited by the tank data file tabulations shown in Appendix B.

Installing internal floating roofs is one method available to control HC emissions from fixed-roof tanks. The annual HC emissions for the year 1976 were also estimated assuming the retrofit of internal floating roofs in the fixed-roof tanks storing petroleum liquids having a vapor pressure greater than 10.5 kPa (1.52 psia). Annual HC emission calculations were repeated for each fixed-roof tank listed in the tank data files. The emission equations recommended in AP-42 for internal floating-roof tanks were used. Estimates of total emissions were obtained by summing the calculation results and ratioing the values upward by factors of total estimated to tabulated numbers of tanks.

3.5 1980 AND 1985 EMISSION PROJECTIONS

Future petroleum storage tank HC emissions will depend on the number of new tanks constructed in the United States as well as the type of emission controls installed on new and existing tanks. Both factors were considered for the 1980 and 1985 emission projections.

3.5.1 PROJECTED NUMBER OF TANKS

Projections of the total numbers of tanks for the years 1980 and 1985 were made by linear extrapolation of the 1976 estimated tank numbers. A ratio of future to current domestic refining capacity was used to project upward the 1976 values estimated by volatility class and PAD District. The rational for using this ratio is discussed in Appendix A. Projections of the 1980 refining capacity were made by totaling announced refinery expansion and new construction plans. The 1985 refining capacity was projected using an annual growth rate of 2.4%.

The projected tank numbers determined by linear extrapolation of the 1976 values assume the current distribution of the tank numbers by tank type. However, the New Source Performance Standards (NSPS) require all new tanks storing petroleum liquids having a volatility greater than 10.5 kPa (1.52 psia) to be of floating-roof design or have a vapor recovery system.[2] Consequently, the projected numbers of tanks for 1980 and 1985 were re-distributed by tank type to comply with NSPS. This was accomplished by counting all new tanks projected for volatility classes 3, 4, and 5 as external floating-roof tanks.

3.5.2 PROJECTED EMISSIONS

Projections of tank emissions for 1980 and 1985 were made by linear extrapolation of the 1976 estimated HC emissions. A ratio of future to current estimated numbers of tanks was used to project upward the 1976 emission values listed by volatility class and PAD District.

3.6 APPLICABILITY OF EMISSION EQUATIONS

Calculations of annual HC emissions from petroleum storage tanks were performed using the equations described in AP-42. These equations were derived from empirical correlations developed by the American Petroleum Institute (API) for external floating-roof tanks,[4] internal floating-roof tanks,[5] and fixed-roof tanks.[6] The correlations were originally developed to estimate liquid volume evaporation losses from tanks storing gasoline and crude oil.

Although based on test data for gasoline and crude oil storage, the fixed-roof tank equations may be used for all refined products and intermediate refinery stocks.[6] The floating-roof tank equations are applicable to external and internal floating-roof tanks storing petroleum liquids in the true vapor pressure range of 13.8 kPa (2 psia) to 75.8 kPa (11 psia).[4] There is no basis for applying the equations to floating-roof tanks storing fuel oils or other low vapor pressure petroleum liquids. However, because no alternative relationships were available, the AP-42 equations were used to estimate annual HC emissions from the floating-roof tanks placed in volatility classes 1 and 2.

The API equations used to develop the AP-42 equations were based on test data measured primarily during the late 1930's and early 1940's. Field and experimental studies are currently being conducted to re-examine the parameters affecting HC emissions from petroleum storage tanks. Chicago Bridge and Iron Company (CBI) constructed a pilot scale tank to investigate HC emissions from external floating-roof tanks. Under sponsorship of Standard Oil Company (Ohio) and the Western Oil and Gas Association (WOGA), comprehensive studies have been conducted using the test tank to study the performance of different external floating-roof seal types.[7,8] Field studies have also been sponsored by

WOGA to measure HC emissions from floating-roof and fixed-roof tanks located in California.[9,10] These studies compared the measured emissions to quantities estimated using the AP-42 equations. Results from the various studies suggest that under certain conditions the AP-42 equations significantly overestimate HC emissions from floating-roof and fixed-roof tanks. However, interpretation of these results with respect to revising the AP-42 equations was beyond the scope of this project.

The API has initiated a project to update its technical bulletins on methods of estimating HC losses from external and internal floating roof tanks, scheduled for completion in early 1979.[11] A similar project is planned for fixed-roof tanks. Until the revised API bulletins become available, the AP-42 equations remain a conservative but the best available method for estimating HC emission from petroleum storage tanks.

4.0 EMISSION ESTIMATE RESULTS

Annual HC emissions from floating-roof tanks and fixed-roof tanks were estimated for the years 1976 and then projected to the years 1980 and 1985. All of the emission estimates presented in this chapter were made using annual average meteorological conditions. Emission estimates for the year 1976, using January and July meteorological conditions, are shown in Appendix D.

4.1 1976 ANNUAL HYDROCARBON EMISSIONS

4.1.1 ESTIMATED NUMBER OF TANKS

For the year 1976, there were estimated to be 37,600 floating-roof and fixed-roof tanks having capacities greater than 151,000 liters located at refinery, terminal, tank farm, and pipeline facilities. An additional 2,300 tanks were counted at other locations. The distribution of the estimated numbers of floating-roof and fixed-roof tanks by industry sectors is shown in Table 4-1.

The distribution of the estimated tank numbers by petroleum liquid volatility and type are presented in Tables 4-2 and 4-3. The tables show both floating-roof tanks and fixed-roof tanks stored all types of petroleum liquids. However, floating-roof tanks were used primarily for storage of high volatility petroleum liquids. Approximately one-half of the total estimated number of floating-roof tanks stored gasoline. The majority of fixed-roof tanks were used for storage of petroleum liquids having vapor pressures less then 10.5 kPa (volatility classes 1 and 2).

The overall ratio of the estimated fixed-roof tank numbers to floating-roof tank numbers was about 2 to 1. However, one should not assume that the total fixed-roof tank storage capacity was twice the storage capacity for floating-roof tanks. The tank capacities listed in the tank data files were tabulated. These results showed that total floating-roof tank capacity was approximately equal to the total fixed-roof tank capacity (refer to Appendix B, Tables B-4, B-5, and B-6).

4.1.2 CURRENT EMISSION CONTROL STRATEGY

Annual HC emissions from floating-roof and fixed-roof tanks located at refinery, terminal, tank farm, and pipeline facilities were estimated to total 8.1×10^8 kilograms per year (kg/yr). (One kilogram equals 2.2 pounds). Emission estimates for tanks located at other facilities contributed an additional 0.2×10^8 kg/yr. The distribution of the estimated annual HC emissions by industry sector, petroleum liquid volatility, and petroleum liquid type are presented in Tables 4-4 through 4-6.

Approximately 17 percent of the total annual HC emissions were estimated to be emitted from external and internal floating-roof tanks. The remaining 83 percent of the total estimated emissions were emitted from fixed-roof tanks. For both tank types, the majority of the HC emissions were emitted from tanks storing gasoline and crude oil.

4.1.3 ALTERNATIVE EMISSION CONTROL STRATEGY

Installing internal floating-roofs is one method available to control HC emissions from fixed-roof tanks. For the year 1976, annual HC emissions were also estimated assuming the retrofit of internal floating roofs in the fixed-roof tanks storing petroleum liquids having a vapor pressure greater than 10.5 kPa (1.52 psia). Table 4-7 presents the annual HC emission estimates for this control strategy. Total annual HC emissions from floating-roof tanks remained unchanged. However, the total fixed-roof tank emission estimates were reduced by 77 percent from 6.9×10^8 kg/yr to 1.6×10^8 kg/yr.

4.2 1980 AND 1985 ANNUAL HYDROCARBON EMISSIONS

4.2.1 CURRENT EMISSION CONTROL STRATEGY

The New Source Performance Standards require all new tanks storing petroleum liquids which have a volatility greater than 10.5 kPa to be of floating-roof design or have a vapor recovery system.[2] Projections of the numbers of tanks for the years 1980 and 1985 were made assuming all new tanks projected for volatility classes 3, 4, and 5 would be of external floating-roof design. For the year 1980, it was projected that there will be 16,900 floating-roof tanks and 29,000 fixed-roof tanks. The 1985 numbers of floating-roof tanks and fixed-roof tanks were projected to increase to, respectively, 19,700 tanks and 31,500 tanks. Tables 4-8 and 4-9 show the distribution of the tank number projections by volatility classes.

Total annual HC emissions from floating-roof and fixed-roof tanks for the year 1980 were projected to be 8.8×10^8 kg/yr. For the year 1985, the total emission projections increased to 9.3×10^8 kg/yr. The distributions of the 1980 and 1985 projected annual HC emissions by volatility classes are presented in Tables 4-10 and 4-11.

4.2.2 ALTERNATIVE EMISSION CONTROL STRATEGY

Annual HC emissions were also projected for the years 1980 and 1985 assuming an alternative emission control strategy. For this strategy, it was assumed all new tanks would comply with the New Source Performance Standards and existing fixed-roof tanks storing petroleum liquids in volatility classes 3,4, and 5 would be retrofitted with internal floating roofs.

The projected annual HC emissions for the years 1980 and 1985 are shown in Tables 4-12 and 4-13. Using the alternative emission control strategy assumption, projected total 1980 annual HC emissions were reduced to 3.5×10^8 kg/yr. Similarly, the projected annual HC emissions for the year 1985 decreased to 4.0×10^8 kg/yr.

Table 4-1. 1976 TANK NUMBER ESTIMATES BY INDUSTRY SECTOR

FLOATING ROOF TANKS[a]

PAD DISTRICT	INDUSTRY SECTOR					TOTAL
	Refinery	Terminal	Tank Farm	Pipeline	Other	
1	595	2,142	122	368	37	3,264
2	1,266	1,845	93	868	214	4,286
3	2,118	663	202	532	20	3,535
4	277	141	11	94	0	523
5	1,226	616	151	170	37	2,200
TOTAL	5,482	5,407	579	2,032	308	13,308

[a] External and internal floating-roof tanks

FIXED ROOF TANKS

PAD DISTRICT	INDUSTRY SECTOR					TOTAL
	Refinery	Terminal	Tank Farm	Pipeline	Other	
1	1,610	4,111	83	98	311	6,213
2	3,354	2,061	98	995	1,064	7,572
3	4,560	908	228	1,152	269	7,117
4	525	144	11	322	11	1,013
5	2,476	849	326	167	356	4,174
TOTAL	12,525	8,073	746	2,734	2,011	26,089

Table 4-2. 1976 TANK NUMBER ESTIMATES BY VOLATILITY CLASS

F L O A T I N G R O O F T A N K S[a]

PAD DISTRICT	VOLATILITY CLASS 1	2	3	4	5	TOTAL
1	259	248	1,753	938	66	3,264
2	453	336	2,794	648	55	4,286
3	662	244	1,330	1,221	78	3,535
4	32	38	397	56	0	523
5	424	444	819	494	19	2,200
TOTAL	1,830	1,310	7,093	3,357	218	13,808

[a] External and internal floating-roof tanks

F I X E D R O O F T A N K S

PAD DISTRICT	VOLATILITY CLASS 1	2	3	4	5	TOTAL
1	3,697	955	1,305	237	19	6,213
2	4,350	788	2,081	332	21	7,572
3	4,659	381	1,464	606	7	7,117
4	688	142	157	26	0	1,013
5	2,022	1,122	833	195	2	4,174
TOTAL	15,416	3,388	5,840	1,396	49	26,089

Table 4-3. 1976 TANK NUMBER ESTIMATES BY PETROLEUM LIQUID TYPE

PETROLEUM LIQUID TYPE	TANK TYPE	
	Floating Roof[a]	Fixed Roof
Crude oil	2,212	2,223
Gasoline	7,119	3,755
Diesel fuel	248	1,213
Jet fuel, kerosene	265	1,031
Jet fuel, JP-4	515	822
Distillate Fuel oil[b]	882	5,327
Residual fuel oil[c]	160	1,543
Naphtha	474	453
Alkylate	101	68
Medium vapor pressure stocks[d]	844	2,175
Low vapor pressure stocks[c]	324	5,439
Benzene	246	82
Other[f]	418	1,958
TOTAL	13,808	26,089

[a] External and internal floating-roof tanks

[b] Fuel oil grades 1, 2, 3

[c] Fuel oil grades 4, 5, 6

[d] Petroleum liquid vapor pressure greater than 3.4 kPa (.5 psia)

[e] Petroleum liquid vapor pressure less than 3.4 kPa (.5 psia)

[f] Unidentified refined petroleum liquids

TABLE 4-4. 1976 ANNUAL HC EMISSION ESTIMATES BY INDUSTRY SECTOR
(units: 1000 kg/yr)

FLOATING ROOF TANKS[a]

PAD DISTRICT	INDUSTRY SECTOR					TOTAL
	Refinery	Terminal	Tank Farm	Pipeline	Other	
1	7,547	19,340	1,743	3,950	174	32,754
2	14,367	17,261	894	9,746	1,120	43,388
3	23,739	9,959	3,054	6,319	232	43,303
4	1,630	684	77	587	0	2,978
5	12,300	5,204	870	1,228	39	19,641
TOTAL	59,583	52,448	6,638	21,830	1,565	142,064

[a] External and internal floating-roof tanks

FIXED ROOF TANKS

PAD DISTRICT	INDUSTRY SECTOR					TOTAL
	Refinery	Terminal	Tank Farm	Pipeline	Other	
1	43,180	78,650	17,805	1,079	1,389	142,603
2	125,836	53,666	3,713	25,206	11,047	220,468
3	131,496	20,276	5,028	37,549	2,046	196,395
4	6,907	1,985	20	3,777	163	12,852
5	49,313	47,371	4,485	12,090	4,593	117,352
TOTAL	357,732	201,948	31,051	79,701	19,738	690,170

Table 4-5. 1976 ANNUAL HC EMISSION ESTIMATES BY VOLATILITY CLASS (units: 1000 kg/yr)

FLOATING ROOF TANKS[a]

PAD DISTRICT	VOLATILITY CLASS 1	2	3	4	5	TOTAL
1	121	756	15,992	13,966	1,919	32,754
2	247	1,658	26,361	13,499	1,623	43,388
3	1,124	1,087	13,189	24,061	3,842	43,303
4	36	151	2,180	611	0	2,978
5	474	1,368	6,456	9,327	2,016	19,641
TOTAL	2,002	5,020	64,178	61,464	9,400	142,064

[a] External and internal floating-roof tanks

FIXED ROOF TANKS

PAD DISTRICT	VOLATILITY CLASS 1	2	3	4	5	TOTAL
1	5,108	22,144	97,737	15,174	2,440	142,603
2	4,083	18,895	153,536	42,385	1,569	220,468
3	21,042	10,409	97,254	63,914	3,776	196,395
4	521	1,505	9,928	898	0	12,852
5	3,416	45,834	47,661	12,556	8,385	117,852
TOTAL	34,170	98,787	406,116	134,927	16,170	690,170

Table 4-6. 1976 ANNUAL HC EMISSION ESTIMATES
BY PETROLEUM LIQUID TYPE
(units: 1000 kg/yr)

PETROLEUM LIQUID TYPE	TANK TYPE	
	Floating Roof[a]	Fixed Roof
Crude oil	23,719	171,520
Gasoline	97,389	335,322
Diesel fuel	471	3,374
Jet fuel, kerosene	470	5,188
Jet fuel, JP-4	2,059	18,488
Distillate Fuel oil[b]	2,073	17,881
Residual fuel oil[c]	187	4,377
Naphtha	4,936	15,359
Alkylate	1,237	2,533
Medium vapor pressure stocks[d]	4,261	63,369
Low vapor pressure stocks[c]	738	7,647
Benzene	1,026	1,220
Other[f]	3,498	43,392
TOTAL	142,064	690,170

[a] External and internal floating-roof tanks

[b] Fuel oil grades 1, 2, 3

[c] Fuel oil grades 4, 5, 6

[d] Petroleum liquid vapor pressure greater than 3.4 kPa (.5 psia)

[e] Petroleum liquid vapor pressure less than 3.4 kPa (.5 psia)

[f] Unidentified refined petroleum liquids

Table 4-7. 1976 ANNUAL HC EMISSION ESTIMATES ASSUMING ALTERNATIVE EMISSION CONTROL STRATEGY (units: 1000 kg/yr)

FLOATING ROOF TANKS[a]

PAD DISTRICT	VOLATILITY CLASS					TOTAL
	1	2	3	4	5	
1	121	756	15,992	13,966	1,919	32,754
2	247	1,658	26,361	13,499	1,623	43,388
3	1,124	1,087	13,189	24,061	3,842	43,303
4	36	151	2,180	611	0	2,978
5	474	1,368	6,456	9,327	2,016	19,641
TOTAL	2,002	5,020	64,178	61,464	9,400	142,064

[a] External and internal floating-roof tanks

FIXED ROOF TANKS

PAD DISTRICT	VOLATILITY CLASS					TOTAL
	1	2	3	4	5	
1	5,108	22,144	4,786	1,435	148	33,621
2	4,083	18,895	6,728	1,808	180	31,694
3	21,042	10,409	3,859	3,149	185	38,644
4	521	1,505	322	47	0	2,395
5	3,416	45,834	2,040	1,236	194	52,720
TOTAL	34,170	98,787	17,735	7,675	707	159,074

Table 4-8. 1980 TANK NUMBER PROJECTIONS ASSUMING CURRENT EMISSION CONTROL STRATEGY

FLOATING ROOF TANKS[a]

PAD DISTRICT	VOLATILITY CLASS					TOTAL
	1	2	3	4	5	
1	368	352	3,037	1,432	102	5,291
2	456	339	2,830	656	55	4,336
3	745	274	1,677	1,449	89	4,234
4	32	38	397	56	0	523
5	463	485	964	556	21	2,489
TOTAL	2,064	1,488	8,905	4,149	267	16,873

[a] External and internal floating-roof tanks

FIXED ROOF TANKS

PAD DISTRICT	VOLATILITY CLASS					TOTAL
	1	2	3	4	5	
1	5,249	1,356	1,305	237	19	8,166
2	4,382	794	2,081	332	21	7,610
3	5,240	428	1,464	606	7	7,745
4	688	142	157	26	0	1,013
5	2,192	1,216	833	195	2	4,438
TOTAL	17,751	3,936	5,840	1,396	49	28,972

Table 4-9 1985 TANK NUMBER PROJECTIONS ASSUMING CURRENT EMISSION CONTROL STRATEGY

FLOATING ROOF TANKS[a]

PAD DISTRICT	VOLATILITY CLASS					TOTAL
	1	2	3	4	5	
1	406	389	3,488	1,604	114	6,001
2	531	394	3,630	816	69	5,440
3	787	290	1,856	1,565	94	4,592
4	37	44	492	70	0	643
5	533	558	1,233	669	24	3,017
TOTAL	2,294	1,675	10,699	4,724	301	19,693

[a] External and internal floating-roof tanks

FIXED ROOF TANKS

PAD DISTRICT	VOLATILITY CLASS					TOTAL
	1	2	3	4	5	
1	5,792	1,496	1,305	237	19	8,849
2	5,096	923	2,081	332	21	8,453
3	5,538	453	1,464	606	7	8,068
4	807	166	157	26	0	1,156
5	2,518	1,397	833	195	2	4,945
TOTAL	19,751	4,435	5,840	1,396	49	31,471

Table 4-10 1980 ANNUAL HC EMISSION PROJECTIONS ASSUMING CURRENT EMISSION CONTROL STRATEGY (units: 1000 kg/yr)

FLOATING ROOF TANKS[a]

PAD DISTRICT	VOLATILITY CLASS 1	2	3	4	5	TOTAL
1	172	1,073	27,698	21,326	2,965	53,234
2	249	1,673	26,701	13,666	1,623	43,912
3	1,265	1,221	16,631	28,561	4,384	52,062
4	36	151	2,180	611	0	2,978
5	518	1,494	7,599	10,503	2,228	22,342
TOTAL	2,240	5,612	80,809	74,667	11,200	174,528

[a] External and internal floating-roof tanks

FIXED ROOF TANKS

PAD DISTRICT	VOLATILITY CLASS 1	2	3	4	5	TOTAL
1	7,253	31,444	97,737	15,174	2,440	154,048
2	4,113	19,039	153,536	42,385	1,569	220,642
3	23,672	11,690	97,254	63,914	3,776	200,306
4	521	1,505	9,928	898	0	12,852
5	3,703	49,684	47,661	12,556	8,385	121,989
TOTAL	39,262	113,362	406,116	134,927	16,170	709,837

Table 4-11. 1985 ANNUAL HC EMISSION PROJECTIONS ASSUMING CURRENT EMISSION CONTROL STRATEGY (units: 1,000 kg/yr)

FLOATING ROOF TANKS[a]

PAD DISTRICT	VOLATILITY CLASS					TOTAL
	1	2	3	4	5	
1	190	1,185	31,824	23,882	3,314	60,395
2	290	1,944	34,249	16,999	2,036	55,518
3	1,337	1,293	18,399	30,847	4,630	56,506
4	42	175	2,701	764	0	3,682
5	596	1,720	9,717	12,629	2,547	27,209
TOTAL	2,455	6,317	96,890	85,121	12,527	203,310

[a] External and internal floating-roof tanks

FIXED ROOF TANKS

PAD DISTRICT	VOLATILITY CLASS					TOTAL
	1	2	3	4	5	
1	8,005	34,700	97,737	15,174	2,440	158,056
2	4,784	22,132	153,536	42,385	1,569	224,406
3	25,019	12,376	97,254	63,914	3,776	202,339
4	611	1,759	9,928	898	0	13,196
5	4,253	57,064	47,661	12,556	8,385	129,919
TOTAL	42,672	128,031	406,116	134,927	16,170	727,916

Table 4-12. 1980 ANNUAL HC EMISSION PROJECTIONS ASSUMING ALTERNATIVE EMISSION CONTROL STRATEGY (units: 1,000 kg/yr)

F L O A T I N G   R O O F   T A N K S[a]

P A D DISTRICT	VOLATILITY CLASS 1	2	3	4	5	T O T A L
1	172	1,073	27,698	21,326	2,965	53,234
2	249	1,673	26,701	13,666	1,623	43,912
3	1,265	1,221	16,631	28,561	4,384	52,062
4	36	151	2,180	611	0	2,978
5	518	1,494	7,599	10,503	2,228	22,342
T O T A L	2,240	5,612	80,809	74,667	11,200	174,528

[a] External and internal floating-roof tanks

F I X E D   R O O F   T A N K S

P A D DISTRICT	VOLATILITY CLASS 1	2	3	4	5	T O T A L
1	7,253	31,444	4,786	1,435	148	45,066
2	4,113	19,039	6,728	1,808	180	31,868
3	23,672	11,690	3,859	3,149	185	42,555
4	521	1,505	322	47	0	2,395
5	3,703	49,684	2,040	1,236	194	56,857
T O T A L	39,262	113,362	17,735	7,675	707	178,741

Table 4-13. 1985 ANNUAL HC EMISSION PROJECTIONS ASSUMING ALTERNATIVE EMISSION CONTROL STRATEGY (units: 1000 kg/yr)

FLOATING ROOF TANKS[a]

PAD DISTRICT	VOLATILITY CLASS					TOTAL
	1	2	3	4	5	
1	190	1,185	31,824	23,882	3,314	60,395
2	290	1,944	34,249	16,999	2,036	55,518
3	1,337	1,293	18,399	30,847	4,630	56,506
4	42	175	2,701	764	0	3,682
5	596	1,720	9,717	12,629	2,547	27,209
TOTAL	2,455	6,317	96,890	85,121	12,527	203,310

[a] External and internal floating-roof tanks

FIXED ROOF TANKS

PAD DISTRICT	VOLATILITY CLASS					TOTAL
	1	2	3	4	5	
1	8,005	34,700	4,786	1,435	148	49,074
2	4,784	22,132	6,728	1,808	180	35,632
3	25,019	12,376	3,859	3,149	185	44,588
4	611	1,759	322	47	0	2,739
5	4,253	57,064	2,040	1,236	194	64,787
TOTAL	42,672	128,031	17,735	7,675	707	196,320

5.0 TANK COST DATA

Economic cost data was compiled about erection of new tanks and installation of internal floating roofs in fixed-roof tanks. No evaluation of cost effectiveness was made. The prices for tanks and internal floating roofs were quoted by vendors for tank capacities expressed in units of barrels. For convenience, the new tank erection costs and internal floating roof installation costs are presented in this chapter by tank capacity expressed in units of barrels (one barrel equals 159 liters).

5.1 NEW TANK ERECTION COSTS

Total costs for erecting a new floating-roof or fixed-roof tank at a specific location include material costs for the tank shell and fittings, costs for preparing the tank foundation, and labor costs. Tank foundation costs vary depending on the soil type at the tank site. Labor costs vary according to the prevailing labor rates for an area.

New tank erection costs were obtained for three basic tank types.

1. Fixed-roof tanks
2. External floating-roof tanks
3. Covered floating-roof tanks

These tank types are briefly described in Appendix C. Additional background information concerning petroleum storage tanks is available in the EPA document Air Pollution Engineering Manual (AP-40).[12]

Table 5-1 presents new tank erection costs as quoted by two major tank vendors[13,14] and an oil company.[16] These costs are presented in units of dollars per barrel of tank capacity. The table shows the cost per barrel decreases as the tank capacity increases. Also, the erection costs quoted by the tank vendors are significantly lower than the cost estimates used by the oil company. For a 100,000 barrel capacity fixed-roof tank, the tank vendor costs are 10 percent to 25 percent lower than the cost estimates used by the oil company. Similarly, the vendor costs for a 100,000 barrel capacity external floating-roof tank are 4 percent to 23 percent below the oil company estimated costs.

5.2 INTERNAL FLOATING ROOF INSTALLATION COSTS

One of the most effective methods available to reduce HC emissions from fixed-roof tanks is the installation of an internal floating-roof to cover the exposed liquid surface. There are three basic types of internal floating-roofs:

1. Aluminum, pontoon type roofs
2. Steel, pan type roofs
3. Plastic, foam type rafts

Fixed-roof tanks with steel, pan type internal floating roofs are termed, "covered floating-roof tanks". If the internal floating roofs are made of a nonferrous material, the tank is termed an "internal floating cover tank".

The internal floating roof type most commonly installed in fixed-roof tanks today is the aluminum pontoon type. This type of roof is preferred because of its strength, light weight, and low cost. The use of steel pan type roofs has declined due to the higher cost and problems with the roof sinking. Plastic foam type rafts also are not widely used because of the possibility of the roof absorbing liquid or inducing static sparking.

Installation costs for installing aluminum, pontoon type, internal floating roofs in fixed-roof tanks were obtained from two vendors.[16,17] These costs are presented in Table 5-2. The table shows the roofs are available for all fixed-roof tank capacities. Prior to installation of the internal floating roof, the tank must be cleaned. The installation costs shown in Table 5-2 do not include tank cleaning costs. These costs vary depending on the condition of the tank and whether the work is performed by a contractor or the tank owner.

Table 5-1. 1977 NEW TANK ERECTION COSTS

Tank Vendor A

Fixed-Roof Tanks		External Floating Roof Tanks		Covered Floating Roof Tanks	
Capacity (barrels)	Costs[a] ($ per barrel)	Capacity (barrels)	Costs[a] ($ per barrel)	Capacity (barrels)	Costs[a] ($ per barrel)
5,000	7.80	20,000	6.75	8,700	8.05
10,000	5.60	25,000	6.20	11,000	7.27
15,000	5.20	30,000	5.50	20,000	6.25
20,000	4.80	35,000	5.29	26,000	5.85
30,000	4.10	45,000	4.78	34,000	5.29
40,000	3.80	55,000	4.45	43,000	5.12
50,000	3.65	67,500	4.15	53,000	4.81
60,000	3.50	80,000	4.00	64,000	4.61
80,000	3.30	95,000	3.79	76,500	4.44
100,000	3.15	100,000	3.75	90,000	4.28
120,000	3.05	110,000	3.64	104,000	4.16
160,000	2.95	120,000	3.54	120,000	4.04
200,000	2.90	130,000	3.46	135,000	3.98
		150,000	3.33	171,000	3.89
		170,000	3.24	207,000	3.63
		220,000	3.10		
		270,000	3.00		

[a]Costs are for Southern California and include costs for fittings but do not include tank foundation costs.

Table 5-1. 1977 NEW TANK ERECTION COSTS (CONTINUED)

Tank Vendor B

Tank Capacity (barrels)	Tank Erection Costs[a] ($ per barrel)		
	Fixed-roof	External Floating Roof	Covered Floating Roof
1,000	21.50	b	b
5,000	6.75	10.75	9.35
10,000	4.55	6.75	6.00
20,000	3.55	5.15	4.75
40,000	2.98	4.00	4.00
60,000	2.81	3.50	3.66
80,000	2.73	3.22	3.44
100,000	2.64	3.00	3.25
125,000	2.62	2.90	3.08
140,000	2.55	2.84	3.04
150,000	2.41	2.80	3.03
200,000	2.34	2.64	3.00
250,000	2.28	2.62	2.98
300,000	2.25	2.56	2.94
400,000	2.17	2.42	2.83

[a]Costs are for Southern California but do not include costs for fittings or the tank foundation.

Cost of fittings - Large tanks 1 to 4% of total cost; small tanks - 5% of total cost.

[b]Not available in this size.

Table 5-1. 1977 NEW TANK ERECTION COSTS (CONCLUDED)

Oil Company[a]

Tank Capacity (barrels)	Tank Erection Costs ($ per barrel)		
	Fixed-Roof Tanks	External Floating Roof Tanks	Covered Floating Roof Tanks
1,000	18.00	--	--
5,000	8.85	--	--
10,000	7.00	11.50	9.50
20,000	5.50	8.00	7.00
40,000	--	5.85	5.60
50,000	--	5.22	--
100,000	3.50	3.90	4.25
200,000	3.25	3.30	3.79

[a]Cost values used by a major oil company to estimate new tank erection costs.

Table 5-2. 1977 COSTS FOR INSTALLATION OF ALUMINUM PONTOON TYPE INTERNAL FLOATING ROOFS

Vendor A

Tank Capacity (barrels)	Tank Diameter (feet)	Tank Height (feet)	Cost Installed[a] ($ per barrel)
1,000	18	20	5.44
5,000	34	30	1.51
10,000	42	40	0.91
20,000	60	40	0.61
40,000	84	40	0.54
60,000	102	40	0.47
80,000	120	48	0.46
100,000	121	48	0.36
125,000	136	48	0.35
140,000	142	48	0.34
160,000	154	48	0.33
200,000	172	48	0.32
250,000	193	48	0.31
300,000	212	48	0.31
400,000	244	48	0.29

[a]Costs are based on materials fabricated at the plant and include the cost of installation with Boilermaker Craft Union personnel. Costs do not include shipping charges, crew travel pay, or tank cleaning costs.

Table 5-2. 1977 COSTS FOR INSTALLATION OF ALUMINUM PONTOON TYPE INTERNAL FLOATING ROOFS (CONCLUDED)

Vendor B

Tank Capacity (barrels)	Tank Diameter (feet)	Tank Height (feet)	Cost Installed[a] ($ per barrel)
4,000	30	30	1.35
9,000	40	40	0.71
14,000	50	40	0.68
20,000	60	40	0.52
27,500	70	40	0.52
35,000	80	40	0.45
55,000	100	40	0.42
70,000	110	40	0.39
80,000	120	40	0.37

[a]Costs are for Southern California and do not include tank cleaning costs or sales tax.

6.0 CONCLUSIONS

The primary goal of this project was to estimate existing annual HC emissions from floating-roof and fixed-roof tanks having capacities greater than 151,000 liters and located at refinery, terminal, tank farm , and pipeline facilities. To estimate emissions, individual tank data were compiled for approximately 25,000 tank locations throughout the United States. The emission calculations were performed using equations described in the EPA document Compilation of Air Pollutant Emission Factors. Results for the emission estimates showed:

1. For the year 1976, total annual HC emissions from floating-roof tanks were on the order of 1.4×10^8 kg/yr.
2. For the year 1976, total annual HC emissions from fixed-roof tanks were on the order of 6.9×10^8 kg/yr.
3. Assuming the retrofit of internal floating roofs in the existing fixed-roof tanks storing petroleum liquids which have a vapor pressure greater than 10.3kPa, existing total annual HC emissions from fixed-roof tanks would be on the order of 1.6×10^8 kg/yr.

The American Petroleum Institute is sponsoring a project to develop new methods for estimating HC emissions from tanks. When these methods become available, a new set of calculations can be performed using the individual tank data base to provide more accurate estimates of HC emissions from fixed-roof and floating-roof tanks.

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APPENDIX A. EMISSION ESTIMATE METHODOLOGY

The estimation of the number of petroleum storage tanks located in the United States and, subsequently, the annual hydrocarbon (HC) emissions from these tanks was performed in five stages.

Stage 1 - Compilation of data about individual tanks located throughout the United States.

Stage 2 - Tabulation of the individual tank data by various classification schemes and calculation of annual HC emissions for each tank location.

Stage 3 - Approximation of the numbers of tanks and HC emissions for refinery, pipeline, and terminal locations not included in the individual tank data base.

Stage 4 - Summation of the results from Stage 2 and Stage 3 to obtain the 1976 HC emission estimates.

Stage 5 - Projection of the 1976 HC emission estimates to the years 1980 and 1985.

The following sections describe in detail the calculations upon which the emission estimates are based, the approximations of tank emissions at locations not included in the individual tank data base, and the projections of 1980 and 1985 tank emissions.

A.1 EMISSION CALCULATIONS

Annual HC emissions were calculated for each tank listed in the 25,000 tank data base. All computations were performed using computer programs. The emission calculation results were summed for direct input into the total emission estimates and averaged to develop tank emissions factors. The emission factors, which will be described in Section A.2, were used to approximate HC emissions at tank locations not listed in the tank data files.

A.1.1 EMISSION EQUATIONS

The emission calculations were performed using the emission equations described in Section 4.3 of Supplement No. 7 for Compilation of Air Pollutant Emission Factors (AP-42).[1] Section 4.3 from AP-42 is reproduced in Appendix C. External floating-roof tank HC emissions were calculated using the "standing storage loss" and "withdrawal loss" equations. The same equations were used with a wind speed of 1.8 m/s (4 mi/hr) for calculating the HC emissions from internal floating-roof tanks. Fixed-roof tank HC emissions were calculated using the "breathing loss" and "working loss" equations.

A.1.2 EMISSION EQUATION INPUT PARAMETERS

The emission equations required three types of input parameters:

1. Meteorological parameters
2. Tank design parameters
3. Petroleum liquid property parameters

Meteorological data was assigned to each tank location. Tank design and petroleum liquid property parameters for each tank location were obtained from the information listed in the tank data files. If information about a specific parameter was absent from the tank data files a value for the parameter was assumed in order to allow the calculations to be completed. Thus, annual HC emissions were calculated for all tank locations listed in the tank data files.

A.1.2.1 Meteorological Parameters

The emission equations required wind speed for the external floating-roof tank equations and diurnal temperature variation for the fixed-roof tank equations. Ambient temperature was used to estimate bulk liquid storage temperature when it was not listed for a specific tank location in the tank data files.

To account for variations of meteorological conditions that occur throughout the United States, the country was divided into meteorological districts. Meteorological data summaries were obtained from the National Climatic Center, Asheville, North Carolina. Each summary comprised a tabulation of meteorological data recorded over a ten-year period at major meteorological stations. Using these data, the country was divided into 121 meteorological districts. The district boundaries were selected so that the data recorded at the station characterized the general meteorology throughout the district.

Each tank listed in the tank data files was assigned a code number designating the meteorological district in which the tank was located. The emission calculations for the tank location were performed using the meteorological data corresponding to the code number. Annual HC emissions were calculated for three different sets of meteorological data:

1. Annual average data
2. Monthly average data for January
3. Monthly average data for July

Annual HC emissions using the January and July meteorological data assumed the monthly conditions occur throughout the year. The reason for including these calculations was to allow the relative comparison of the annual HC emissions based on annual average meteorological conditions with HC emissions for winter and summer meteorological conditions.

A.1.2.2 Tank Design Parameters

Tank design parameters were required for the floating-roof tank and fixed-roof tank emission equations. When information about a tank design parameter was absent from the tank data files, a value for the parameter was assumed. The assumptions used for the calculations are presented in Table A-1. These assumptions were selected by reviewing the data listed in the tank data files and selecting values that were representative of the majority of the tanks.

A.1.2.3 Petroleum Liquid Property Parameters

Information about the petroleum liquid true vapor pressure, density, and vapor molecular weight were required for the emission calculations. These properties can vary significantly depending on the hydrocarbon composition of the petroleum liquids as well as the temperature at which the liquids are stored.

Identifying properties for different types of petroleum liquid posed the greatest challenge to providing input values for the emission equations. For many tank locations listed in the tank data files, no information was available about the petroleum liquid properties. Consequently, assumptions were made for the property values in order to complete the emission calculations. Selection of the assumption values was complicated by the variation of the

Table A-1. TANK DESIGN PARAMETERS

FIXED-ROOF TANKS	
Parameter	**Assumption[a]**
1. Tank height	12.2 m (40 ft)
2. Tank color	white
3. Tank liquid level	50% of the tank rim height
4. Tank roof slope	0.1 m/m
5. Tank turnovers	
a. Tanks storing crude oil	30 per year
b. Tanks storing refined product	13 per year

FLOATING ROOF TANKS	
Parameter	**Assumption[a]**
1. Tank height	
a. Tank capacity $\geq 151 m^3$ and $< 318 m^3$ (2,000 barrels)	6.1 m (20 ft)
b. Tank capacity $\geq 318 m^3$ and $< 1,430 m^3$ (9,000 barrels)	9.1 m (30 ft)
c. Tank capacity $\geq 1,430 m^3$ and $< 3,180 m^3$ (20,000 barrels)	12.2 m (40 ft)
d. Tank capacity $\geq 3,180 m^3$	14.6 m (48 ft)
2. Tank color	white
3. Floating-roof type	
a. External floating-roof tanks	pontoon
b. Internal floating-roof tanks	pan
4. Floating-roof seal	primary
5. Floating-roof seal condition	good
6. Tank construction	welded
7. Tank turnovers	15 per year

[a] Assumptions used for emission calculations only when information about a tank design parameter was absent from tank data files.

property values with temperature as well as the limited amount of data available in the open literature about these properties.

A.1.2.3.1 Storage Temperature

When petroleum liquid storage temperature was not listed in the tank data files for a specific tank location, the temperature was assumed to equal the average ambient temperature for the meteorological district in which the tank was located. A storage temperature of 277°K (40°F) was assumed if the average ambient temperature was less than 277°K.

A.1.2.3.2 Vapor Pressure

The procedure used to input true vapor pressures (TVP) into the emission equations is summarized in Table A-2. Reid vapor pressures (RVP) were first converted to approximate TVP values before being input into the emission equations. When no vapor pressure information about the petroleum liquid stored at a specific tank location was available, a TVP value was assumed. The assumptions used for different refined petroleum liquids are presented in Table A-3.

Crude oil vapor pressures vary over a wide range depending on the crude oil source. When necessary to assume a crude oil vapor pressure, RVP values for hypothetical crude oils were used. The hypothetical crude oils represented composites of the major crude oil types refined in different regions of the United States. The relative quantities of the major crude oils refined in each region were obtained from refinery crude oil slates used for a study about the petroleum refining industry completed by A. D. Little, Inc. (ADL).[2] Reid vapor pressures for the different crude oils listed in each slate were obtained from published

Table A-2. EMISSION EQUATION VAPOR PRESSURE INPUT PROCEDURE

Vapor Pressure	Petroleum Liquids Stored	Input Procedure
True vapor pressure (TVP) listed in tank data files	all petroleum liquids	TVP inputed directly into emission equations
Reid vapor pressure (RVP) listed in tank data files	gasoline	RVP converted to TVP at 289°K (60°F) using nomograph (Figure 4.3-8 in AP-42)
	crude oil	RVP converted to TVP at 289°K (60°F) using nomograph (Figure 4.3-9 in AP-42)
	other petroleum liquids	TVP at 289°K (60°F) estimated from tabulated TVP values (Table 4.3-1 in AP-42)
No vapor pressure listed in tank data files	refined petroleum liquids	TVP at 289°K (60°F) estimated from tabulated TVP values (Table 4.3-1 in AP-42)
	crude oil	RVP assumed based on a regional crude oil composition - RVP converted to TVP at 289°K using nomograph (Figure 4.3-9 in AP-42)

Petroleum Liquid	True Vapor Pressure[e] at 289°K		Vapor Molecular Weight[e] at 289°K	Petroleum Liquid Density[e] at 289°K	
	(kilo pascals)	(psia)	(g/g-mole)	(kg/m^3)	(lb/gal)
Gasoline	36.0	5.2	66	670	5.6
Naphtha	24.0	3.5	68	670	5.6
Alkylate	24.0	3.5	68	670	5.6
Jet Fuel (JP-4)	9.0	1.3	80	770	6.4
Refinery Intermediate[b]	9.0	1.3	80	770	6.4
Benzene	8.3	1.2	78	880	7.4
Commercial Jet Fuel	.059	.0085	130	840	7.0
Kerosene	.059	.0085	130	840	7.0
Gas Oil	.059	.0085	130	840	7.0
Diesel Fuel	.051	.0074	130	850	7.1
Distillate Fuel Oil	.051	.0074	130	850	7.1
Residual Fuel Oil	.003	.00004	190	950	7.9
Low Vapor Pressure Stocks	.003	.00004	190	950	7.9
General Refined Product[c]	9.0	1.3	80	770	6.4
Crude Oil[d]	-	-	50	850	7.1

[a] Assumptions used for emission calculations only when information about parameter was absent from tank data files.

[b] Undefined refinery feedstock

[c] Undefined refined product

[d] Crude oil vapor pressures based on hypothetical crude oils for regions in the United States

[e] Properties based on values tabulated in Table 4.3-1 of AP-42

data.[3,4] A hypothetical crude oil RVP was calculated for each refinery region by first weighting the crude oil RVP values on the basis of the quantity of crude oil refined. These values were then averaged to obtain the hypothetical crude oil RVP. The ADL study did not include refineries located in the Rocky Mountain states. The crude oil RVP used for tank locations in this region was assumed to be that of crude oil produced from Wyoming oil fields. The crude oil RVP assumptions are presented in Table A-4.

The conversion of RVP to TVP is normally accomplished using the nomographs prepared by API. Because of the large volume of individual tank data compiled for the study, converting each RVP value manually proved to be a very time consuming task. Consequently, the conversion procedure was adapted to allow the computer program to perform the conversions. The program converted a given RVP to an approximate TVP value by interpolating the TVP value from a conversion table. The values tabulated in the table were read from the API RVP-TVP conversion nomographs (see AP-42 Figures 4.3-8 and 4.3-9 in Appendix C).

The RVP values were converted to TVP values at a reference petroleum liquid storage temperature of 289^{o}K (60^{o}F). To account for variations in TVP due to the storage of petroleum liquids at temperatures other than 289^{o}K, simplified relationships between TVP and temperature were used. True vapor pressures for petroleum liquids having a TVP less than 6.9 kPa (1.0 psia) were not adjusted for temperature variation. For these liquids the change in TVP with temperature did not significantly alter the calculated emission values. True vapor pressures for petroleum liquids, having a TVP greater than 6.9 kPa were adjusted assuming TVP varied linearly with storage temperature. Although the variation of TVP with temperature is actually logarithmic, the assumed relationship provided a reasonable approximation of TVP over the general

Table A-4. REGIONAL CRUDE OIL VAPOR PRESSURE ASSUMPTIONS

Region	ADL Cluster Model[a]	Reid Vapor Pressure Assumption	
		(kilo pascals)	(psia)
PAD District 1	East Coast Refinery	27.6	4.0
PAD District 2 (East of Mississippi River)	Large Midwest Refinery	24.8	3.6
PAD District 2 (West of Mississippi River)	Small Midcontinent Refinery	26.9	3.9
PAD District 3 (Alabama, Louisiana, Arkansas, Mississippi)	Louisiana Gulf Refinery	53.8	7.8
PAD District 3 (Texas, New Mexico)	Texas Gulf Refinery	40.7	5.9
PAD District 4	b	13.8[c]	2.0[c]
PAD District 5	West Coast Refinery	22.8	3.3

[a] Source: <u>The Impact of Lead Additive Regulations on the Petroleum Refining Industry</u>, EPA-450/3-76-016, A. D. Little, Inc. May 1976

[b] Crude oil used at refineries in PAD IV assumed to be from Wyoming oil fields.

[c] Lower RVP limit of nomograph - limited data suggests actual RVP lower.

range of storage temperatures in floating-roof and fixed-roof tanks (277°K (40°F) to 305°K (90°F)). The relationships used for the emission calculations are presented in Table A-5. These relationships were derived from the tabulated TVP values versus temperature values listed in AP-42 Table 4.3-1 (see Appendix C). Absence of data precluded developing similar relationships for crude oils. Consequently, crude oil RVP values were converted to RVP values assuming the storage temperature remained at 289°K.

A.1.2.3.3 Other Properties

Petroleum liquid density and vapor molecular weight were required for the emission equations. The values used for the emission calculations were obtained from information listed in the tank data files when available. However, for many tank locations values for density and vapor molecular weight had to be assumed. The assumptions were based on values listed in AP-42 Table 4.3-1 (see Appendix C) and are presented in Table A-3. Gas oil and commercial jet fuel, were assumed to have properties similar to kerosene. Diesel fuel was assumed to have properties similar to distillate fuel. Low vapor pressure stocks (lubricating oils, slop oils, etc.) were assumed to have properties similar to residual fuel. The density and vapor molecular weight of crude oils vary depending on the crude oil source. However, the absence of crude oil property data required assuming for all crude oils a density of 850 kg/m^3 (7.1 lb/gal) and a vapor molecular weight of 50 g/g-mole.

A.2 EMISSION APPROXIMATIONS

The results from the emission calculations were for many but not all refinery, terminal, tank farm, pipeline, and other tank

Table A-5. RELATIONSHIPS USED TO CORRECT TRUE VAPOR PRESSURE WITH STORAGE TEMPERATURE

GENERAL RELATIONSHIP[a]

$$TVP_A = TVP_R + S\ (T_R - T_A)$$

TVP_A = TVP at actual storage temperature

TVP_R = TVP at reference storage temperature

T_A = Actual storage temperature

T_R = Reference storage temperature

S = Change in TVP per degree change in temperature

"S" FACTOR FOR DIFFERENT PETROLEUM LIQUIDS[b]

Petroleum Liquid	"S" FACTOR (pascals per °K)	(psia per °F)
Gasoline		
$TVP_A \geq 41.$ kPa	575	.15
$31.$ kPa $< TVP_A < 41.$ kPa	421	.11
$31.$ kPa $\geq TVP_A$	345	.09
Naphtha	345	.09
Alkylate	345	.09
Jet Fuel (JP-4)	115	.03
Refinery Intermediate	115	.03
Benzene	115	.03

[a] Valid for storage temperature range 280°K to 310°K (40°F to 90°F)
[b] Based on a reference temperature of 289°K (60°F)

locations throughout the United States. The number of tanks and HC emissions were approximated for refinery and pipeline pumping station locations not included in the tank data files. Approximations of the total numbers of tanks at terminals in each state were used to supplement the tabulated numbers of terminal tanks and calculated emissions from the tank data files. No approximations were made for tank farm, petrochemical, power plant, or industrial plant locations not listed in the tank data files.

A.2.1 REFINERY TANK EMISSION APPROXIMATIONS

Refinery tank locations not listed in the tank data files were identified using the Oil and Gas Journal "Refinery Survey."[6] The number of tanks at these locations were approximated on the basis of the rated crude oil refining capacity (expressed as barrels per calendar day (bbl/day). Factors were calculated expressing the average numbers of floating-roof and fixed-roof tanks per 1000 bbl/day rated capacity. These factors were developed by averaging tank factors calculated for specific refinery locations listed in the tank data files. Separate tank factors were calculated for each PAD District in order to reflect regional variations in refinery operations. Multiplication of the rated refining capacity times the tank factors yielded approximations of the number of tanks at a refinery location. The refinery tank factors used for the approximations are listed in Table A-6.

Annual HC emissions from the tanks were determined by multiplying the numbers of tanks by factors expressing the average annual HC emissions per tank. These factors were developed by averaging tank HC emissions calculated for specific refinery locations listed in the tank data files. Separate

Table A-6. TANK APPROXIMATION FACTORS

PAD DISTRICT	TANK APPROXIMATION FACTORS			
	REFINERY Tanks per 1,000 bbl[a] Crude Oil Refining Capacity		TERMINAL Tanks per 1,000 Population	
	Fixed-roof	Floating-roof	Fixed-roof	Floating-roof
1	.8	.4	.06	.03
2	.8	.3	.03	.03
3	.8	.3	.04	.03
4	.8	.4	.02	.02
5	.8	.4	.03	.03

[a] 1,000 barrels = 159,000 liters

tank emission factors were computed for each PAD District and the three meteorological conditions. The refinery tank emission factors are presented in Table A-7.

A.2.2 Pipeline Tank Approximations

No attempt was made to identify the specific pumping station locations not listed in the tank data files. Instead, the total number of pipeline pumping stations located in each state was determined. This was accomplished by counting pumping station locations on crude oil and refined product pipeline maps published by the Oil and Gas Journal. The total number of pumping stations was subtracted from the number of pumping stations listed in the tank data files to determine the number of additional station locations for which tank and HC emissions must be made.

To approximate the number of tanks at these additional pumping stations, a factor of two tanks per station was used. This factor was developed from data listed in the tank data files and represented the nationwide average number of tanks located at pumping stations. Tanks at crude oil pumping stations were arbitrarily designated fixed-roof tanks. Tanks at refined product pumping stations were designated floating-roof tanks. Annual HC emissions from the pipeline tanks were approximated using the refinery tank emission factors.

A.2.3 Terminal Tank Approximations

No surveys or maps were available that allowed identifying the terminal locations not listed in the compiled tank data. Therefore, the total number of tanks located at terminals was

Table A-7. TANK EMISSION APPROXIMATION FACTORS

Tank Type	PAD District	Annual HC Emissions Per Tank (1,000 kg/yr)					
		REFINERY			TERMINAL		
		Annual[a]	January[a]	July[a]	Annual	January	July
External Floating-roof	1	11	12	11	9	8	10
	2	12	11	13	9	10	11
	3	12	12	12	15	14	15
	4	6	5	8	6	5	8
	5	9	7	9	6	5	8
Fixed-roof	1	13	12	14	14	12	19
	2	17	16	29	25	25	32
	3	28	27	29	23	20	24
	4	12	10	15	19	18	20
	5	16	15	16	19	18	20

[a] Meteorological conditions upon which estimation factors are based

approximated for each state. The assumption was made that the number of terminal tanks in a state is related to demand for petroleum products, and demand is related to population. Tank factors were developed expressing the average number of floating-roof and fixed-roof tanks per 1000 population. Factors were calculated for the specific states for which the tank data files were judged to provide a complete inventory of terminal tanks in the state. Averaging of the calculated values yielded terminal tank factors for each PAD District. These factors are presented in Table A-6. Using the populations of each state and the terminal tank factors, the total numbers of terminal tanks in each state were approximated.

The difference between the approximated total number of terminal tanks and the number of terminal tanks listed in the tank data files indicated the number of additional tanks for which HC emission approximations were to be made. Annual HC emissions from these tanks were approximated by multiplying the number of tanks by factors expressing the average annual HC emissions per tank. Like the refinery tank emission factors, these factors were developed by averaging the tank HC emissions calculated for specific terminal locations listed in the tank data files. Separate tank emission factors were computed for each PAD District and the three meteorological conditions. The terminal tank emission factors are presented in Table A-7.

A.3 SAMPLE CALCULATION OF TOTAL TANK EMISSIONS

A simplified sample calculation is presented for a state located in PAD District 2 to illustrate the basic emission estimate methodology. For the state selected for the example, individual tank data was available for terminal and tank farm locations in the state. No individual tank data was available for refinery or pipeline facilities. Table A-8 presents a summary of the data used for the calculations.

The individual tank data was keypunched on computer cards. The cards were used to create a computer data file. Using the computer program developed for the project, emission calculations were performed for each tank location listed in the data files. A sample page of the computer printout is shown in Figure A-1. The printout tabulates the HC emissions from each tank location for the three different sets of meteorological data.

The HC emissions from tanks located at refinery and pipeline facilities in the state were approximated using the procedure outlined in Section A-2. The number of tanks at these facilities were first approximated by using the tank factors presented in Table A-6 and the general data presented in Table A-8. From the approximated number of tanks, emissions were calculated using the factors shown in Table A-7.

The results of the computer calculations and the tank approximation calculations are shown in Table A-9. Summation of these results yielded the total estimates of annual HC emissions from floating-roof and fixed-roof tanks in the state for the year 1976.

A.4 1980 AND 1985 EMISSION PROJECTIONS

Future petroleum storage tank HC emissions will depend on the number of new tanks constructed in the United States as well as the type of emission controls installed on new and existing tanks. Both factors were considered for the 1980 and 1985 emission projections.

Table A-8. SUMMARY OF DATA USED FOR SAMPLE CALCULATION

GENERAL DATA

Location - PAD District 2

1970 state population - 4,418,000

1976 total refinery capacity in state - 45,400 bbl/day

Number of crude oil pipeline pumping stations - 12

Number of refined product pipeline pumping stations - 7

Meteorological condition - annual average

INDIVIDUAL TANK DATA

Individual tank data was compiled for 169 tanks at terminal and tank farm locations in the state.

PACIFIC ENVIRONMENTAL SERVICES, INC. NATIONAL STORAGE TANK INVENTORY

INDIVIDUAL TANK LISTING FOR STATE OF IA, PAD NO. 2

COUNTY	INDUS SECTR	TANK NO.	TANK TYPE	PRODCT STORD	CAPACITY (BBLS)	DIAMETER (FT)	HT (FT)	OUTAGE (FT)	CONSTRC	SL TY	PAINT COLOR	THRUPUT (BBLS/Y)	STORAGE LOSSES (TONS/YR) JAN	JUL	ANN	WITHDRAWALLOSSES (TONS/YR) JAN	JUL	ANN
JOHNSON	TERM	47	FR	GAS-G	17500.0	55.9	40.0	0.0	WELD		WHITE	12500.0	3.8	9.7	5.6	0.01	0.01	0.01
JOHNSON	TERM	48	FR	GAS-G	17500.0	55.9	40.0	0.0	WELD		WHITE	452302.0	3.8	9.7	5.6	0.43	0.43	0.43
LYON	TERM	188	FR	GAS-R	55000.0	90.5	48.0	0.0	WELD		WHITE	442623.0	8.5	23.5	12.2	0.26	0.26	0.26
LYON	TERM	189	FR	GAS-R	55000.0	90.5	48.0	0.0	WELD		WHITE	442623.0	8.5	23.5	12.2	0.26	0.26	0.26
LYON	TERM	190	FR	GAS-R	55000.0	90.5	48.0	0.0	WELD		WHITE	442623.0	8.5	23.5	12.2	0.26	0.26	0.26
LYON	TERM	191	FR	GAS-R	19000.0	58.2	40.0	0.0	WELD		WHITE	64422.0	4.8	12.9	6.7	0.06	0.06	0.06
LYON	TERM	192	FR	GAS-R	20000.0	59.8	40.0	0.0	WELD		WHITE	64422.0	4.9	13.4	7.0	0.06	0.06	0.06
NORTH LIB.	TERM	225	FR	GAS-G	5000.0	34.5	30.0	0.0	WELD		WHITE	76957.0	1.9	3.7	2.6	0.12	0.12	0.12
NORTH LIB.	TERM	226	FR	GAS-G	5000.0	34.5	30.0	0.0	WELD		WHITE	92879.0	1.9	3.7	2.6	0.14	0.14	0.14
NORTH LIB.	TERM	227	FR	GAS-G	10000.0	42.3	40.0	0.0	WELD		WHITE	701748.0	2.6	5.0	3.5	0.87	0.87	0.87
POLK	TERM	4	FX	GAS-G	35800.0	80.0	40.0	21.3	WELD	V3	WHITE	444576.0	4.0	14.9	6.5	4.61	13.07	6.86
POLK	TERM	6	FX	GAS-G	35800.0	80.0	40.0	21.3	WELD	V3	WHITE	427329.0	4.0	14.9	6.5	4.41	12.51	6.56
POLK	TERM	7	FX	GAS-G	35800.0	80.0	40.0	21.3	WELD	V3	WHITE	442779.0	4.0	14.9	6.5	4.57	12.96	6.80
POLK	TERM	16	FX	GAS-G	40000.0	84.5	40.0	21.4	WELD	V3	WHITE	506200.0	4.5	16.5	7.1	5.22	14.82	7.77
POLK	TERM	27	FR	GAS-G	17500.0	55.9	40.0	0.0	WELD		WHITE	262500.0	4.3	12.5	6.2	0.25	0.25	0.25
POLK	TERM	28	FR	GAS-G	17500.0	55.9	40.0	0.0	WELD		WHITE	231886.0	4.3	12.5	6.2	0.22	0.22	0.22
POLK	TERM	29	FR	GAS-G	17500.0	55.9	40.0	0.0	WELD		WHITE	258962.0	4.3	12.5	6.2	0.24	0.24	0.24
POLK	TERM	32	FR	GAS-G	30000.0	44.8	48.0	0.0	WELD		WHITE	374226.0	5.6	16.4	8.1	0.30	0.30	0.30
POLK	TERM	33	FR	GAS-G	30000.0	44.8	48.0	0.0	WELD		WHITE	438419.0	5.6	16.4	8.1	0.35	0.35	0.35
POLK	TERM	35	FR	GAS-G	30000.0	44.8	48.0	0.0	WELD		WHITE	355150.0	5.6	16.4	8.1	0.28	0.28	0.28
POLK	TERM	36	FR	GAS-G	37500.0	74.7	48.0	0.0	WELD		WHITE	467781.0	6.4	19.4	9.6	0.33	0.33	0.33
POLK	TERM	38	FR	GAS-G	37500.0	74.7	48.0	0.0	WELD		WHITE	451442.0	6.6	19.4	9.6	0.32	0.32	0.32
POLK	TERM	39	FR	GAS-G	80000.0	109.1	48.0	0.0	WELD		WHITE	997930.0	11.6	34.2	17.0	0.48	0.48	0.48
POLK	TERM	40	FR	GAS-G	80000.0	109.1	48.0	0.0	WELD		WHITE	1169142.0	11.6	34.2	17.0	0.56	0.56	0.56
POLK	TERM	41	FXIFR	GAS-G	77299.9	107.3	48.0	0.0	WELD		WHITE	1129662.0	5.2	17.4	7.6	0.55	0.55	0.55
POLK	TERM	42	FXIFR	GAS-G	77299.9	107.3	48.0	0.0	WELD		WHITE	926828.0	5.2	17.4	7.6	0.46	0.46	0.46
POLK	TERM	43	FXIFR	GAS-G	77299.9	107.3	48.0	0.0	WELD		WHITE	1012209.0	5.2	17.4	7.6	0.50	0.50	0.50
POLK	TERM	214	FR	GAS-G	5900.0	37.5	30.0	0.0	WELD		WHITE	229921.0	2.3	5.0	3.0	0.32	0.32	0.32
POLK	TERM	216	FR	GAS-G	75500.0	106.0	48.0	0.0	WELD		WHITE	1066368.0	10.8	24.0	14.5	0.53	0.53	0.53
POLK	TERM	217	FR	GAS-G	52100.0	88.1	48.0	0.0	WELD		WHITE	741035.0	8.2	18.1	11.0	0.44	0.44	0.44
POLK	TERM	222	FXIFR	GAS-G	39300.0	76.5	48.0	0.0	WELD		WHITE	163320.0	3.3	8.1	4.4	0.11	0.11	0.11
POTTAWATTA	TERM	161	FX	GAS-G	55900.0	99.9	40.0	21.7	WELD	V3	WHITE	1134205.0	6.6	23.0	11.3	11.70	32.47	18.43
POTTAWATTA	TERM	168	FX	GAS-G	6410.0	33.8	40.0	20.6	WELD		WHITE	41248.0	9.9	34.4	16.8	4.25	11.81	6.70
POTTAWATTA	TERM	171	FX	GAS-G	17500.0	55.9	40.0	20.9	WELD		WHITE	342880.0	23.8	82.8	40.5	35.36	98.14	55.72
POTTAWATTA	TERM	174	FX	GAS-G	29400.0	72.7	40.0	21.2	WELD		WHITE	193419.0	37.8	131.4	64.3	19.95	55.36	31.43
POTTAWATTA	TERM	175	FX	GAS-G	29400.0	72.7	40.0	21.2	WELD		WHITE	342881.0	37.8	131.4	64.3	35.36	98.14	55.72
SCOTT	TERM	178	FX	GAS-G	40000.0	84.5	40.0	21.4	WELD	V3	WHITE	118764.0	5.0	16.5	8.0	1.34	3.48	1.98
SCOTT	TERM	179	FX	GAS-G	9900.0	42.0	40.0	20.7	WELD		WHITE	51128.0	13.1	34.3	19.6	5.10	11.84	7.12
SCOTT	TERM	181	FX	GAS-G	9900.0	42.0	40.0	20.7	WELD		WHITE	11672.0	13.1	34.3	19.6	1.16	2.70	1.63
SCOTT	TERM	182	FX	GAS-G	78599.9	118.5	40.0	22.0	WELD	V3	WHITE	683641.0	8.1	21.2	12.1	6.82	15.83	9.52
SCOTT	TERM	195	FR	GAS-G	33000.0	70.1	48.0	0.0	WELD		WHITE	532791.0	5.6	10.7	7.4	0.40	0.40	0.40
SCOTT	TERM	196	FR	GAS-G	13000.0	48.2	40.0	0.0	WELD		WHITE	116727.0	3.2	6.1	4.2	0.13	0.13	0.13

FIGURE A-1 SAMPLE EMISSION CALCULATIONS COMPUTER PRINTOUT

Table A-9. SAMPLE CALCULATION OF TOTAL TANK HC EMISSIONS FOR A STATE IN PAD DISTRICT 2

TERMINALS AND TANK FARMS

Individual tank data was compiled for terminal and tank farm facilities located in the state. Annual HC emissions from each tank location were calculated using a computer program. The summed results of the calculations assuming annual average meteorological conditions were:

Tank Type	Number of Tanks	Total Annual HC Emissions (10^3 kg/yr)
Floating-roof	98	647,000
Fixed-roof	71	2,307,000

REFINERIES

No individual tank data was compiled for refineries in the state. Total annual HC emissions were approximated usi tne general data presented in Table A-8 and the appropriate factors from Tables A-6 and A-7.

Floating-roof tanks

(45,400 bbl/day)(0.0003 tanks/bbl/day) = 14 tanks

(14 tanks)(12,000 kg/yr/tank) = 168,000 kg/yr

Fixed-roof tanks

(45,400 bbl/day)(0.0008 tanks/bbl/day) = 37 tanks

(37 tanks)(17,000 kg/yr/tank) = 629,000 kg/yr

PIPELINE PUMPING STATIONS

No individual tank data was compiled for pipeline pumping stations in the state. Total annual HC emissions were approximated using the general data presented in Table A-8 and the procedure outline in Section A.2.2.

Floating-roof tanks

(7 stations)(2 tanks/station) = 14 tanks

(14 tanks)(12,000 kg/yr/tank) = 168,000 kg/yr

Fixed-roof tanks

(12 stations)(2 tanks/station) = 24 tanks

(24 tanks)(17,000 kg/yr/tank) = 408,000 kg/yr

TOTAL ANNUAL HC EMISSIONS

Floating-roof tanks

647,000 kg/yr + 168,000 kg/yr + 168,000 kg/yr = 983,000 kg/yr

Fixes-roof tanks

2,307,000 kg/yr + 629,000 kg/yr + 408,000 kg/yr = 3,344,000 kg/yr

A.4.1 PROJECTED NUMBER OF TANKS

Projections of total numbers of tanks in 1980 and 1985 were made by linear extrapolation of the 1976 estimated tank numbers. A ratio of future to current total storage capacity was used to project upward the 1976 estimated tank numbers by volatility class and PAD District. The basic equations used for the projections are shown below.

$$(\text{1980 No. of Tanks}) = \left\{ \frac{(\text{1980 Capacity})}{(\text{1976 Capacity})} \right\} \times (\text{1976 No. of Tanks})$$

$$(\text{1985 No. of Tanks}) = \left\{ \frac{(\text{1985 Capacity})}{(\text{1976 Capacity})} \right\} \times (\text{1976 No. of Tanks})$$

A.4.1.1 Projected Total Tank Storage Capacity

Total tank storage capacity in the United States is a function of the demand for petroleum liquids. Prior to 1973, petroleum demand projections could be based on historical trends. However, uncertainties about the availability of crude oil supplies as well as changes in national energy policies have increased the complexity of petroleum demand forecasting. Future petroleum demand has been the subject of recent studies.[6,7] However, these projections did not lend themselves directly to estimating future tank storage capacity. Elaborate projections of future petroleum demand are beyond the scope of this study. Furthermore, since the tank projections were based on the relative increase in future storage capacity compared to current storage capacity, a simplified approach was adopted to estimate total storage capacity.

Total tank storage capacity was estimated assuming:

1. Demand for refined products in the United States is satisfied by domestic refinery output.
2. Total tank storage capacity is a function of total crude oil refined capacity (expressed in barrels per day).

Based on these assumptions the following equation was devised.

$$\begin{bmatrix}\text{Total Tank}\\ \text{Storage}\\ \text{Capacity}\end{bmatrix} = \begin{bmatrix}\text{Crude Oil}\\ \text{Refining Capacity}\\ \text{(CORC)}\end{bmatrix} \times \begin{bmatrix}\text{Crude Oil}\\ \text{Storage Period}\\ \text{(COSP)}\end{bmatrix} + \begin{bmatrix}\text{Product to}\\ \text{Crude Oil}\\ \text{Ratio}\\ \text{(PCOR)}\end{bmatrix} \times \begin{bmatrix}\text{Crude Oil}\\ \text{Refining Capacity}\\ \text{(CORC)}\end{bmatrix} \times \begin{bmatrix}\text{Product}\\ \text{Storage}\\ \text{Period}\\ \text{(PSP)}\end{bmatrix}$$

The crude oil and product storage periods represent the number of days of storage capacity a refinery has to maintain operation flexibility and to provide for seasonal demand variations. The product to crude oil ratio represents the amount of refined product produced per barrel of crude oil.

To determine the ratio of 1980 to 1976 total tank storage capacity, the following equation was used.

$$\frac{\text{(1980 Capacity)}}{\text{(1976 Capacity)}} = \frac{\left\{\text{(1980 COSP)} + \left[\text{(1980 PCOR)} \times \text{(1980 PSP)}\right]\right\} \times \text{(1980 CORC)}}{\left\{\text{(1976 COSP)} + \left[\text{(1976 PCOR)} \times \text{(1976 PSP)}\right]\right\} \times \text{(1976 CORC)}}$$

To further simplify the equation, the following assumptions were made.

1. The crude oil and product storage periods are equal.
2. The crude oil storage period remains constant through 1980.
3. The product to crude oil ratio remains constant through 1980.

These assumptions allowed the projections to be made using the equation shown below.

$$\frac{(1980\ \text{Capacity})}{(1976\ \text{Capacity})} = \frac{(1980\ \text{CORC})}{(1976\ \text{CORC})}$$

Using an identical approach, the ratio of 1985 to 1976 total tank storage capacity was calculated by the following equation.

$$\frac{(1985\ \text{Capacity})}{(1976\ \text{Capacity})} = \frac{(1985\ \text{CORC})}{(1976\ \text{CORC})}$$

A.4.1.2 Projected Crude Oil Refining Capacity

Projections of 1980 and 1985 crude oil refining capacities were made for each PAD District using the 1976 domestic refining capacity as the baseline. The Oil and Gas Journal "Annual Refinery Survey"[5] was the source for the 1976 baseline refining capacities.

The increase in total domestic refining capacity for 1980 was projected by totaling announced refinery expansion and new construction plans. It was assumed all planned refinery construction would be completed on schedule. Table A-10 lists the refinery expansion and new construction plans used for the calculations.

No specific refinery expansion or new construction information was available for the period 1980 to 1985. Consequently, the increase in total domestic refining capacity for 1985 was determined by projecting the total 1976 refining capacity to 1985.

Table A-10. ANNOUNCED REFINERY EXPANSION AND NEW CONSTRUCTION PLANS

Company And Location[8,9]	Type	PAD District	Refinery Process Capacity (Barrels Per Day)
1977			
Steuart Petroleum Company (Piney Point) Maryland	N	1	100,000
Mallard Exploration, Incorporated (Atmor) Florida	N	1	7,000
Midland Corporation (Cushing) Arkansas	E	3	16,000
Shell Oil Company (Woodriver) Illinois	E	2	30,000
Tenneco (Chalmette) Louisiana	E	3	30,000
Gulf Oil (Luling) Texas	N	3	30,000
Exxon (Baytown) Texas	E	3	250,000
Energy Company of Alaska (Fairbanks) Alaska	N	5	25,000
California Oil Purification (Ventura) California	E	5	15,000
Standard Oil of California (Perth Amboy) New Jersey	E	1	30,000
1978			
Crown Central Petroleum Corporation (Baltimore) Maryland	E	L	200,000
Hampton Roads Energy Company (Portsmouth) Virginia	N	1	184,000
Oddesa Refining, Incorporated (Mobile) Alabama	N	3	120,000
Dow Chemical Company (Freeport) Texas	N	3	200,000
Hudson Oil Refining (Bayport) Texas	N	3	200,000
1979			
Pittston Company (Eastport) Maine	N	1	250,000
Cascade Energy Resources (Rainier) Oregon	N	5	200,000

E - Expansion at existing refinery
N - New refinery to be constructed

Using an annual growth rate of 2.4 percent, the total refining capacity for the United States in the year 1985 was projected to be 20 million barrels per day. The 2.4 percent factor is a projected growth rate of future petroleum product demand in the United States obtained from Reference 8. To distribute the projected total 1985 refining capacity, the individual 1976 state refining capacities were used as a baseline. First, the refinery expansions and new construction listed in Table A-10 were added to the 1976 state refining capacities for the appropriate states. The 1976 state refining capacities for the states for which no specific refinery expansion or construction data were available were then increased by a constant factor to obtain the total projected capacity of 20 million barrels per day. The resulting distribution of the 1985 refining capacity by states is shown in Table A-11. Summation of these results by PAD District yield the 1985 refining capacities.

Table A-12 shows by PAD District the 1976 baseline refining capacities and the 1980 and 1985 projected refining capacities.

A.4.1.3 Major Proposed Terminal Projects

Additional consideration was given to major seaport crude oil terminal projects being planned. A terminal is expected to be built on the West Coast to handle Alaskan oil. Oil transported through this terminal will be used at refineries in PAD District 5 as well as distributed to refineries in PAD Districts 2 and 3. Alaskan oil fields have been estimated to produce 1.7×10^6 barrels per day of oil by 1980 and 2.4×10^6 barrels per day by 1985.[7] To estimate the number of tanks required to handle this oil, it was assumed all of the tanks would be external floating-roof tanks with capacities of 650,000 barrels.

Table 11. DISTRIBUTION OF TOTAL 1985 PROJECTED REFINING CAPACITY BY STATE

State	1976 Refining Capacity[5] (barrels per day)	1985 Refining Capacity (barrels per day)	State	1976 Refining Capacity[5] (barrels per day)	1985 Refining Capacity (barrels per day)
Alabama	49,375	169,375	Montana	156,181	182,943
Alaska	73,000	98,000	Nebraska	5,000	5,857
Arizona	4,000	4,685	New Hampshire	13,000	15,227
Arkansas	60,400	76,400	New Jersey	645,000	755,524
California	2,297,385	2,691,055	New Mexico	119,020	139,415
Colorado	64,200	75,201	New York	107,000	125,335
Delaware	140,000	164,000	North Dakota	58,658	68,709
Florida	5,700	12,700	Ohio	589,950	691,041
Georgia	19,750	23,134	Oklahoma	546,825	640,526
Hawaii	99,000	115,964	Oregon	14,000	214,000
Illinois	1,181,550	1,384,015	Pennsylvania	804,920	942,847
Indiana	561,650	657,892	Tennessee	43,900	51,422
Kansas	453,918	531,699	Texas	4,193,072	4,911,578
Kentucky	164,470	192,653	Utah	158,425	185,572
Louisiana	2,036,950	2,385,992	Virginia	53,000	237,000
Maine	0	250,000	Washington	366,900	429,770
Maryland	28,500	328,500	West Virginia	19,450	22,782
Michigan	150,050	175,762	Wisconsin	45,400	53,179
Minnesota	216,800	253,950	Wyoming	188,630	220,953
Mississippi	328,541	384,838			
Missouri	107,000	125,335	Total	16,170,570	19,994,830

Table A-12. DOMESTIC REFINING CAPACITY BY PAD DISTRICT

	REFINING CAPACITY (barrels/day)		
PAD District	Baseline 1976[5]	Projected 1980	Projected 1985
1	1,836,320	2,607,320	2,877,049
2	4,125,171	4,155,171	4,832,040
3	6,787,358	7,633,358	8,067,598
4	567,436	567,436	664,669
5	2,854,285	3,094,285	3,553,474
Total	16,170,570	18,057,570	19,994,830

Using a 7 day storage factor, it was calculated that 18 tanks would be required in 1980 and 26 tanks in 1975. These tank numbers were added to the 1980 and 1985 projected number of tanks for PAD District 5. The only other announced major terminal project is the Louisiana Off-Shore Oil Port (LOOP) located in PAD District 3. However, storage at this terminal is to be underground in salt domes.

A.4.1.4 Tank Type Distribution

The projected numbers of tanks determined by linear extrapolation of the 1976 values assume the current distribution of the tank numbers by tank type. However, the New Source Performance Standards (NSPS) require all new tanks storing petroleum liquids having a volatility greater than 10.5kPa (1.52 psia) to be of floating-roof design or have a vapor recovery system.[10] Consequently, the projected numbers of tanks for 1980 and 1985 were re-distributed by tank type to comply with NSPS. The projected total numbers of new tanks in volatility classes 3, 4 and 5 were counted as external floating-roof tanks.

A.4.2 PROJECTED HC EMISSIONS

Projections of storage tank HC emissions for 1980 and 1985 were made by linear extrapolation of the 1976 estimated HC emissions. A ratio of future to current numbers of tanks was used to project upward the 1976 emission values by volatility class and PAD District. The basic equations used for the projections are shown below.

$$(1980\ \text{Emissions}) = \left[\frac{(1980\ \text{No. of Tanks})}{(1976\ \text{No. of Tanks})}\right] \text{X}\ (1976\ \text{Emissions})$$

$$(1985\ \text{Emissions}) = \left[\frac{(1985\ \text{No. of Tanks})}{(1976\ \text{No. of Tanks})}\right] \text{X}\ (1976\ \text{Emissions})$$

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APPENDIX B

TANK DATA FILE SUMMARY

Data for approximately 25,000 tank locations were listed in the tank data files. Processing of the data comprised sorting the tank data by various classification schemes and calculating the annual HC emission for each tank location. The following series of tables summarizes the distribution of tanks listed in the tank data files and the results of the emission calculations.

Total Number of Tanks

Total Tank Capacities

Tank Design Characteristics

Annual HC Emissions

Table B-1. TABULATED NUMBER OF TANKS BY INDUSTRY SECTOR

F L O A T I N G R O O F T A N K S[a]

P A D DISTRICT	INDUSTRY SECTOR					T O T A L
	Refinery	Terminal	Tank Farm	Pipeline	Other	
1	539	851	122	28	37	1,577
2	928	718	93	166	214	2,119
3	1,541	314	202	97	20	2,174
4	177	41	11	2	0	231
5	1,226	553	151	117	37	2,084
T O T A L	4,411	2,477	579	410	308	8,185

[a] External and internal floating-roof tanks

F I X E D R O O F T A N K S

P A D DISTRICT	INDUSTRY SECTOR					T O T A L
	Refinery	Terminal	Tank Farm	Pipeline	Other	
1	1,501	1,440	83	22	311	3,357
2	2,518	1,107	98	257	1,064	5,044
3	3,024	463	228	46	269	4,030
4	325	44	11	2	11	393
5	2,476	786	326	155	356	4,099
T O T A L	9,844	3,840	746	482	2,011	16,923

Table B-2. TABULATED NUMBER OF TANKS BY VOLATILITY CLASS

F L O A T I N G R O O F T A N K S[a]

PAD DISTRICT	VOLATILITY CLASS					TOTAL
	1	2	3	4	5	
1	125	120	847	453	32	1,577
2	223	166	1,382	321	27	2,119
3	407	150	818	751	48	2,174
4	14	17	175	25	0	231
5	402	421	775	468	18	2,084
TOTAL	1,171	874	3,997	2,018	125	8,185

[a] External and internal floating-roof tanks

F I X E D R O O F T A N K S

PAD DISTRICT	VOLATILITY CLASS					TOTAL
	1	2	3	4	5	
1	1,998	516	705	128	10	3,357
2	2,898	525	1,386	221	14	5,044
3	2,638	216	829	343	4	4,030
4	267	55	61	10	0	393
5	1,986	1,102	818	191	2	4,099
TOTAL	9,787	2,414	3,799	893	30	16,923

Table B-3. TABULATED NUMBER OF TANKS BY PETROLEUM LIQUID TYPE

PETROLEUM LIQUID TYPE	TANK TYPE		
	External Floating Roof	Internal Floating Roof	Fixed Roof
Crude Oil	1,233	78	1,442
Gasoline	3,795	425	2,436
Diesel fuel	125	22	787
Jet fuel, kerosene	143	14	669
Jet fuel, JP-4	290	15	533
Distillate fuel oil[a]	479	44	3,455
Residual fuel oil[b]	83	12	1,001
Naphtha	238	43	294
Alkylate	57	3	44
Medium vapor pressure stocks[c]	450	50	1,411
Low vapor pressure stocks[d]	105	87	3,528
Benzene	119	27	53
Other[e]	231	17	1,270
TOTAL	7,348	837	16,923

[a]Fuel oil grades 1, 2, 3

[b]Fuel oil grades 4, 5, 6

[c]Petroleum liquid vapor pressure greater than 3.4 kPa (.5 psia)

[d]Petroleum liquid vapor pressure less than 3.4 kPa (.5 psia)

[e]Unidentified refined petroleum liquids

Table B-4. TABULATED TOTAL EXTERNAL FLOATING ROOF TANK CAPACITY (units: barrels)[a]

PAD DISTRICT	VOLATILITY CLASS					TOTAL
	1	2	3	4	5	
1	4,860,623	4,602,363	56,888,538	26,639,995	2,005,832	94,997,351
2	11,072,939	7,088,409	91,881,901	22,025,610	975,395	133,044,254
3	20,984,052	7,922,329	69,464,782	51,784,554	3,859,944	154,015,661
4	702,243	1,310,598	4,944,308	913,497	0	7,870,646
5	31,725,937	15,780,141	48,664,827	41,354,877	3,339,000	140,864,782
TOTAL	69,345,794	36,703,840	271,844,356	142,718,533	10,180,171	530,792,694

[a] 1 barrel = 159 liters

Table B-5. TABULATED TOTAL INTERNAL FLOATING-ROOF TANK CAPACITY (units: barrels)[a]

PAD DISTRICT	VOLATILITY CLASS					TOTAL
	1	2	3	4	5	
1	733,738	381,096	6,392,372	2,280,772	180,099	9,968,077
2	1,055,790	194,297	5,185,898	384,596	166,000	6,986,581
3	3,276,013	365,021	3,649,092	550,072	0	7,840,198
4	0	40,000	106,395	51,394	0	197,789
5	1,426,190	2,629,061	5,713,184	3,480,167	42,599	13,291,201
TOTAL	6,491,731	3,609,475	21,046,941	6,747,001	388,698	38,283,846

[a] 1 barrel = 159 liters

Table B-6. TABULATED TOTAL FIXED-ROOF TANK CAPACITY
(units: barrels)[a]

PAD DISTRICT	VOLATILITY CLASS					TOTAL
	1	2	3	4	5	
1	67,169,791	12,382,250	26,272,148	3,937,961	99,984	109,862,134
2	75,269,301	15,058,155	62,874,715	9,979,014	165,368	163,346,553
3	77,946,088	7,232,707	28,285,388	9,092,234	139,198	122,695,615
4	3,813,287	861,624	1,226,496	71,886	0	5,973,293
5	55,353,847	48,888,446	25,566,702	8,797,799	688,297	139,295,091
TOTAL	279,552,314	84,423,182	144,225,449	31,878,894	1,092,847	541,172,686

[a] 1 barrel = 159 liters

Table B-7. TABULATED NUMBER OF FLOATING-ROOF TANKS[a] BY TANK CAPACITY

PAD DISTRICT	TANK CAPACITY RANGE in units of 1,000 barrels[a]												
	.95 to 10	10 to 20	20 to 30	30 to 40	40 to 50	50 to 60	60 to 70	70 to 80	80 to 90	90 to 100	100 to 150	150 to 200	>200
1	178	180	168	146	106	140	81	75	101	84	163	100	55
2	256	311	291	128	91	196	85	173	193	78	137	62	118
3	238	249	223	143	47	178	117	114	184	52	338	166	125
4	38	30	25	43	12	17	2	12	20	10	20	2	0
5	366	225	187	149	84	115	87	128	150	50	271	120	152
TOTAL	1,076	995	894	609	340	646	372	502	648	274	929	450	450

[a] External and internal floating-roof tanks

[b] 1 barrel = 159 liters

Table B-8. TABULATED NUMBER OF FIXED-ROOF TANKS BY TANK CAPACITY

P A D DISTRICT	T A N K C A P A C I T Y R A N G E in units of 1,000 barrels[a]												
	.95 to 10	10 to 20	20 to 30	30 to 40	40 to 50	50 to 60	60 to 70	70 to 80	80 to 90	90 to 100	100 to 150	150 to 200	>200
1	1,391	541	423	162	102	204	54	62	133	65	77	68	75
2	2,455	754	389	252	176	318	53	155	150	51	123	38	130
3	1,595	824	383	163	37	321	88	175	194	64	153	12	21
4	181	103	41	19	11	9	10	2	8	7	2	0	0
5	2,085	598	253	217	92	162	51	143	168	33	143	70	84
T O T A L	7,707	2,820	1,489	813	418	1,014	256	537	653	220	498	188	310

[a] 1 barrel = 159 liters

Table B-9. TABULATED NUMBER OF TANKS BY TANK CONSTRUCTION

PAD District	Type of Tank Construction		
	Welded	Riveted	Not Identified
1	377	75	4,482
2	354	216	6,593
3	184	150	5,870
4	39	0	585
5	952	712	4,519
T O T A L	1,906	1,153	22,049

Table B-10. TABULATED NUMBER OF FLOATING-ROOF TANKS BY ROOF TYPE

PAD DISTRICT	FLOATING ROOF TYPE					TOTAL
	Pan	Pontoon	Double Deck	Internal Floater	Not Identified	
1	27	156	17	192	1,185	1,577
2	54	185	65	176	1,639	2,119
3	102	126	1	247	1,698	2,174
4	0	5	0	28	198	231
5	69	311	188	194	1,322	2,084
TOTAL	252	783	271	837	6,042	8,185

Table B-11. TABULATED NUMBER OF FLOATING-ROOF TANKS BY ROOF SEAL TYPE

PAD DISTRICT	FLOATING ROOF SEAL TYPE 1s	1t	2s	2t	Not identified	TOTAL
1	142	62	5	17	1,351	1,577
2	198	0	0	0	1,921	2,119
3	265	2	1	0	1,906	2,174
4	12	0	0	0	219	231
5	154	81	2	11	1,836	2,084
TOTAL	771	145	8	28	7,233	8,185

1s: Primary seal, mechanical type

1t: Primary seal, resilient type

2s: Primary seal, mechanical type and secondary seal

2t: Primary seal, resilient type and secondary seal

Table B-12. TABULATED ANNUAL HC EMISSIONS BY INDUSTRY AREA

Annual Average Meteorological Conditions

(units: 1,000 kg/yr)

F L O A T I N G   R O O F   T A N K S[a]

P A D DISTRICT	INDUSTRY SECTOR					T O T A L
	Refinery	Terminal	Tank Farm	Pipeline	Other	
1	6,937	7,616	1,743	289	174	16,759
2	10,377	7,028	894	1,460	1,120	20,879
3	16,928	4,572	3,054	1,184	232	25,970
4	994	48	77	2	0	1,121
5	12,300	4,804	870	747	39	18,760
T O T A L	47,536	24,068	6,638	3,682	1,565	83,489

[a] External and internal floating-roof tanks

F I X E D   R O O F   T A N K S

P A D DISTRICT	INDUSTRY SECTOR					T O T A L
	Refinery	Terminal	Tank Farm	Pipeline	Other	
1	41,794	32,980	17,805	113	1,889	94,581
2	112,413	30,278	3,713	12,474	11,047	169,925
3	88,866	10,174	5,028	5,413	2,046	111,527
4	4,546	78	20	0	163	4,807
5	49,313	46,170	4,485	11,894	4,593	116,455
T O T A L	296,932	119,680	31,051	29,894	19,738	497,295

Table B-12. TABULATED ANNUAL HC EMISSIONS BY INDUSTRY AREA (Continued)

January Meteorological Conditions

(units: 1,000 kg/yr)

F L O A T I N G R O O F T A N K S[a]

PAD DISTRICT	INDUSTRY SECTOR					TOTAL
	Refinery	Terminal	Tank Farm	Pipeline	Other	
1	6,685	6,201	1,837	196	173	15,092
2	9,192	6,563	881	1,388	871	18,895
3	16,823	4,343	3,143	1,129	222	25,660
4	888	36	56	2	0	982
5	10,837	3,717	629	578	37	15,798
TOTAL	44,425	20,860	6,546	3,293	1,303	76,427

[a] External and internal floating-roof tanks

F I X E D R O O F T A N K S

PAD DISTRICT	INDUSTRY SECTOR					TOTAL
	Refinery	Terminal	Tank Farm	Pipeline	Other	
1	31,519	27,238	12,108	112	1,545	72,522
2	81,066	25,093	3,112	10,052	7,701	127,024
3	85,283	9,206	4,464	4,783	1,413	105,149
4	3,761	57	14	0	114	3,946
5	45,362	43,655	4,034	11,105	4,132	108,288
TOTAL	246,991	105,249	23,732	26,052	14,905	416,929

Table B-12. TABULATED ANNUAL HC EMISSIONS BY INDUSTRY AREA
(Concluded)

July Meteorological Conditions

(units: 1,000 kg/yr)

F L O A T I N G R O O F T A N K S[a]

P A D DISTRICT	INDUSTRY SECTOR					T O T A L
	Refinery	Terminal	Tank Farm	Pipeline	Other	
1	7,328	8,635	2,436	382	172	18,953
2	11,629	7,890	901	1,638	1,507	23,565
3	16,332	4,569	2,734	1,160	235	25,030
4	1,319	76	130	2	0	1,527
5	12,710	5,790	1,127	903	39	20,569
T O T A L	49,318	26,960	7,328	4,085	1,953	89,644

[a] External and internal floating-roof tanks

F I X E D R O O F T A N K S

P A D DISTRICT	INDUSTRY SECTOR					T O T A L
	Refinery	Terminal	Tank Farm	Pipeline	Other	
1	57,616	42,683	25,066	109	2,367	127,841
2	165,201	40,086	4,738	20,485	16,961	247,471
3	91,653	11,005	5,607	5,972	2,714	116,951
4	7,298	126	34	0	292	7,750
5	52,878	51,389	5,302	12,719	4,869	127,157
T O T A L	374,646	145,289	40,747	39,285	27,203	627,170

Table B-13. TABULATED ANNUAL HC EMISSIONS BY VOLATILITY CLASS

Annual Average Meteorological Conditions
(units: 1,000 kg/yr)

F L O A T I N G R O O F T A N K S[a]

PAD DISTRICT	VOLATILITY CLASS 1	2	3	4	5	TOTAL
1	65	1,087	8,053	6,523	1,031	16,759
2	119	799	12,684	6,496	781	20,879
3	673	653	7,910	14,430	2,304	25,970
4	14	57	819	231	0	1,121
5	454	1,307	6,166	8,908	1,925	18,760
TOTAL	1,325	3,903	35,632	36,588	6,041	83,489

[a] External and internal floating-roof tanks

F I X E D R O O F T A N K S

PAD DISTRICT	VOLATILITY CLASS 1	2	3	4	5	TOTAL
1	2,970	14,656	64,685	10,042	1,613	93,966
2	3,157	14,604	118,659	32,759	1,212	170,391
3	11,951	5,911	55,228	36,293	2,144	111,527
4	197	567	3,720	339	0	4,823
5	3,296	45,323	47,130	12,415	8,291	116,455
TOTAL	21,571	81,061	289,422	91,848	13,260	497,162

Table B-13. TABULATED ANNUAL HC EMISSIONS BY VOLATILITY CLASS (Continued)

January Meteorological Conditions

(units: 1,000 kg/yr)

FLOATING ROOF TANKS[a]

PAD DISTRICT	VOLATILITY CLASS					TOTAL
	1	2	3	4	5	
1	63	356	6,586	7,031	1,056	15,092
2	126	501	10,910	6,532	826	18,895
3	670	656	7,770	14,250	2,314	25,660
4	8	54	702	218	0	982
5	424	1,034	4,933	7,420	1,987	15,798
TOTAL	1,291	2,601	30,901	35,451	6,183	76,427

[a] External and internal floating-roof tanks

FIXED ROOF TANKS

PAD DISTRICT	VOLATILITY CLASS					TOTAL
	1	2	3	4	5	
1	3,270	9,784	48,249	9,722	1,534	72,559
2	3,003	9,352	88,289	23,385	1,156	126,185
3	11,631	5,710	51,463	34,325	2,020	105,149
4	192	504	2,936	314	0	3,946
5	2,975	36,399	36,508	7,048	6,621	90,051
TOTAL	21,071	62,749	227,445	75,294	11,331	397,390

Table B-13. TABULATED ANNUAL HC EMISSIONS BY VOLATILITY CLASS (Concluded)

July Meteorological Conditions

(units: 1,000 kg/yr)

F L O A T I N G R O O F T A N K S[a]

PAD DISTRICT	VOLATILITY CLASS 1	2	3	4	5	TOTAL
1	60	443	10,322	7,234	894	18,953
2	113	658	16,174	5,971	676	23,592
3	628	622	7,667	13,911	2,202	25,030
4	9	58	1,220	240	0	1,527
5	448	1,391	6,611	10,348	1,771	20,569
TOTAL	1,258	3,172	41,994	37,704	5,543	89,671

[a] External and internal floating-roof tanks

F I X E D R O O F T A N K S

PAD DISTRICT	VOLATILITY CLASS 1	2	3	4	5	TOTAL
1	3,402	19,871	92,648	10,276	1,644	127,841
2	3,250	21,152	177,004	42,816	1,203	245,425
3	12,100	6,070	58,532	37,999	2,250	116,951
4	231	697	6,469	353	0	7,750
5	3,169	48,400	53,328	13,493	8,767	127,157
TOTAL	22,152	96,190	387,981	104,937	13,864	625,124

Table 8-14. TABULATED ANNUAL HC EMISSIONS BY PETROLEUM LIQUID TYPE

Annual Average Meteorological Conditions

(units: 1000 kg/yr)

PETROLEUM LIQUID TYPE	TANK TYPE		
	External Floating Roof	Internal Floating Roof	Fixed Roof
Crude Oil	13,586	353	123,587
Gasoline	54,913	2,321	241,613
Diesel fuel	244	33	2,431
Jet fuel, kerosene	259	17	3,738
Jet fuel, JP-4	1,126	84	13,321
Distillate fuel oil[a]	1,176	42	12,884
Residual fuel oil[b]	107	3	3,154
Naphtha	2,722	179	11,067
Alkylate	713	14	1,825
Medium vapor pressure stocks[c]	2,411	93	45,660
Low vapor pressure stocks[d]	433	1	5,510
Benzene	569	34	879
Other[e]	2,025	31	31,626
TOTAL	80,284	3,205	497,295

[a]Fuel oil grades 1, 2, 3

[b]Fuel oil grades 4, 5, 6

[c]Petroleum liquid vapor pressure greater than 3.4 kPa (.5 psia)

[d]Petroleum liquid vapor pressure less than 3.4 kPa (.5 psia)

[e]Unidentified refined petroleum liquids

Table B-14. TABULATED ANNUAL HC EMISSIONS BY PETROLEUM LIQUID TYPE (Continued)

<u>January Meteorological Conditions</u>

(units: 1000 kg/yr)

PETROLEUM LIQUID TYPE	TANK TYPE		
	External Floating Roof	Internal Floating Roof	Fixed Roof
Crude Oil	13,668	353	122,420
Gasoline	49,529	2,024	161,120
Diesel fuel	237	33	2,392
Jet fuel, kerosene	254	17	3,726
Jet fuel, JP-4	999	84	11,182
Distillate fuel oil[a]	1,162	42	12,712
Residual fuel oil[b]	102	3	3,087
Naphtha	2,599	155	8,271
Alkylate	684	14	1,487
Medium vapor pressure stocks[c]	2,281	13	37,198
Low vapor pressure stocks[d]	415	1	5,536
Benzene	561	32	702
Other[e]	1,138	27	28,057
TOTAL	73,629	2,798	397,890

[a]Fuel oil grades 1, 2, 3

[b]Fuel oil grades 4, 5, 6

[c]Petroleum liquid vapor pressure greater than 3.4 kPa (.5 psia)

[d]Petroleum liquid vapor pressure less than 3.4 kPa (.5 psia)

[e]Unidentified refined petroleum liquids

Table B-14. TABULATED ANNUAL HC EMISSIONS BY PETROLEUM LIQUID TYPE

(Concluded)

July Meteorological Conditions

(units: 1000 kg/yr)

PETROLEUM LIQUID TYPE	TANK TYPE External Floating Roof	Internal Floating Roof	Fixed Roof
Crude Oil	12,605	353	123,960
Gasoline	62,622	2,827	333,603
Diesel fuel	232	33	2,423
Jet fuel, kerosene	247	17	3,643
Jet fuel, JP-4	1,180	85	28,156
Distillate fuel oil[a]	1,107	42	12,811
Residual fuel oil[b]	105	3	3,140
Naphtha	2,723	204	14,845
Alkylate	703	13	2,290
Medium vapor pressure stocks[c]	2,409	151	56,613
Low vapor pressure stocks[d]	420	1	5,444
Benzene	537	36	1,079
Other[e]	976	35	37,117
TOTAL	85,871	3,800	625,124

[a]Fuel oil grades 1, 2, 3

[b]Fuel oil grades 4, 5, 6

[c]Petroleum liquid vapor pressure greater than 3.4 kPa (.5 psia)

[d]Petroleum liquid vapor pressure less than 3.4 kPa (.5 psia)

[e]Unidentified refined petroleum liquids

APPENDIX C
EMISSION EQUATIONS

The emission calculations were performed using the emission equations described in Supplement No. 7 for Compilation of Air Pollutant Emission Factor, AP-42, U.S. Environmental Protection Agency, April 1977. The following pages are a reproduction of Section 3.4, "Storage of Petroleum Liquids."

4.3 STORAGE OF PETROLEUM LIQUIDS[1]

by Charles C. Masser

Fundamentally, the petroleum industry consists of three operations: (1) petroleum production and transportation, (2) petroleum refining, and (3) transportation and marketing of finished petroleum products. All three operations require some type of storage for petroleum liquids. Storage tanks for both crude and finished products can be sources of evaporative emissions. Figure 4.3-1 presents a schematic of the petroleum industry and its points of emissions from storage operations.

4.3.1 Process Description

Four basic tank designs are used for petroleum storage vessels: fixed roof, floating roof (open type and covered type), variable vapor space, and pressure (low and high).

4.3.1.1 Fixed Roof Tanks[2] - The minimum accepted standard for storage of volatile liquids is the fixed roof tank (Figure 4.3-2). It is usually the least expensive tank design to construct. Fixed roof tanks basically consist of a cylindrical steel shell topped by a coned roof having a minimum slope of 3/4 inches in 12 inches. Fixed roof tanks are generally equipped with a pressure/vacuum vent designed to contain minor vapor volume changes. For large fixed roof tanks, the recommended maximum operating pressure/vacuum is +0.03 psig/-0.03 psig (+2.1 g/cm^2/-2.1 g/cm^2).

4.3.1.2 Floating Roof Tanks[3] - Floating roof tanks reduce evaporative storage losses by minimizing vapor spaces. The tank consists of a welded or riveted cylindrical steel wall, equipped with a deck or roof which is free to float on the surface of the stored liquid. The roof then rises and falls according to the depth of stored liquid. To ensure that the liquid surface is completely covered, the roof is equipped with a sliding seal which fits against the tank wall. Sliding seals are also provided at support columns and at all other points where tank appurtenances pass through the floating roof.

Until recent years, the most commonly used floating roof tank was the conventional open-type tank. The open-type floating roof tank exposes the roof deck to the weather; provisions must be made for rain water drainage, snow removal, and sliding seal dirt protection. Floating roof decks are of three general types: pan, pontoon, and double deck. The pan-type roof consists of a flat metal plate with a vertical rim and sufficient stiffening braces to maintain rigidity (Figure 4.3-3). The single metal plate roof in contact with the liquid readily conducts solar heat, resulting in higher vaporization losses than other floating roof decks. The roof is equipped with automatic vents for pressure and vacuum release. The pontoon roof is a pan-type floating roof with pontoon sections added to the top of the deck around the rim. The pontoons are arranged to provide floating stability under heavy loads of water and snow. Evaporation losses due to solar heating are about the same as for pan-type roofs. Pressure/vacuum vents are required on pontoon roof tanks. The double deck roof is similar to a pan-type floating roof, but consists of a hollow double deck covering the entire surface of the roof (Figure 4.3-4). The double deck adds rigidity, and the dead air space between the upper and lower deck provides significant insulation from solar heating. Pressure/vacuum vents are also required.

The covered-type floating roof tank is essentially a fixed-roof tank with a floating roof deck inside the tank (Figure 4.3-5). The American Petroleum Institute has designated the term "covered floating" roof to describe a fixed roof tank with an internal steel pan-type floating roof. The term "internal floating cover" has been chosen by the API to describe internal covers constructed of materials other than steel. Floating roofs and covers can be installed inside existing fixed roof tanks. The fixed roof protects the floating roof from the weather, and no provision is necessary for rain or snow removal, or for seal

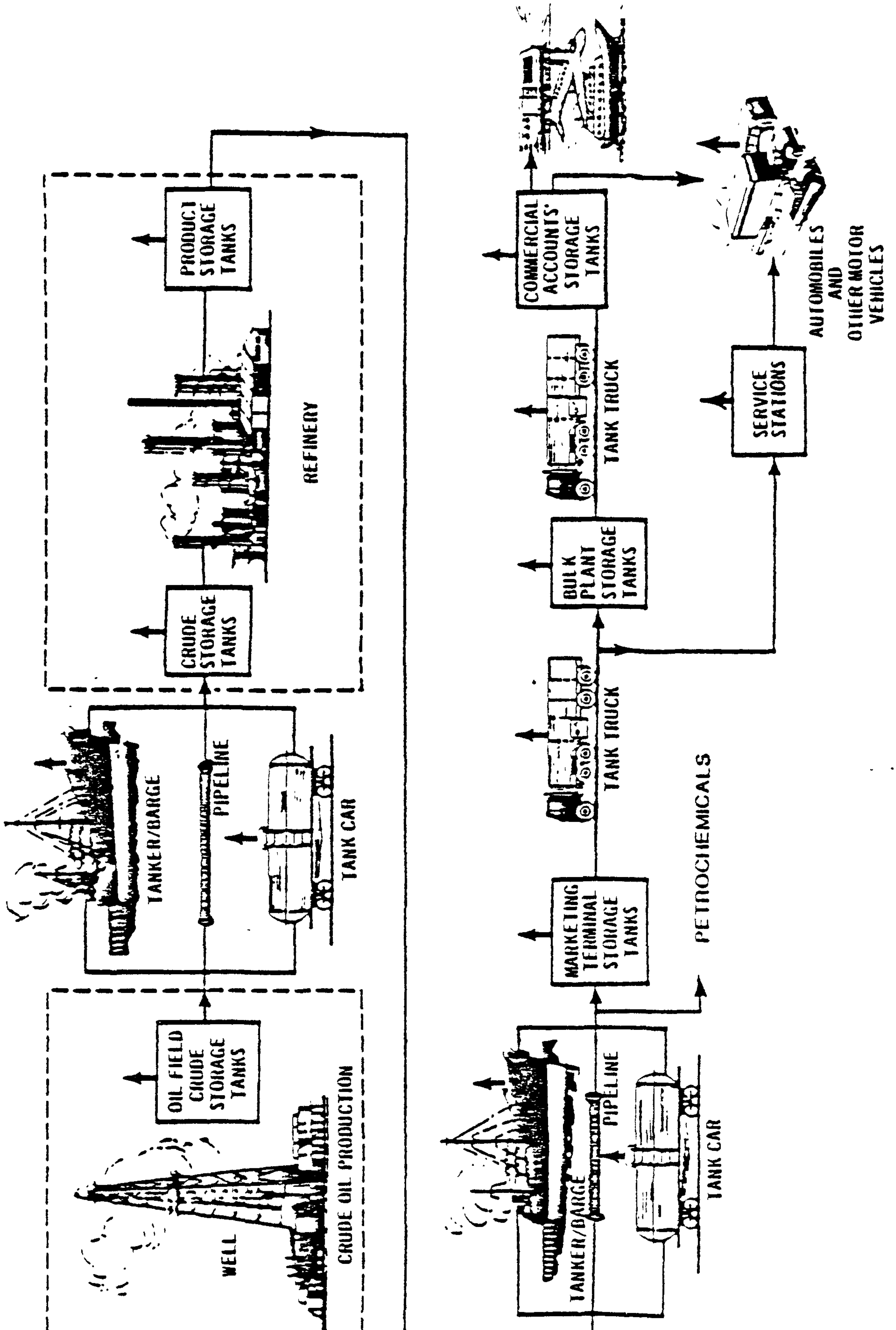

Figure 4.3-1. Flowsheet of petroleum production, refining, and distribution systems. (Sources of organic evaporative emissions are indicated by vertical arrows.)

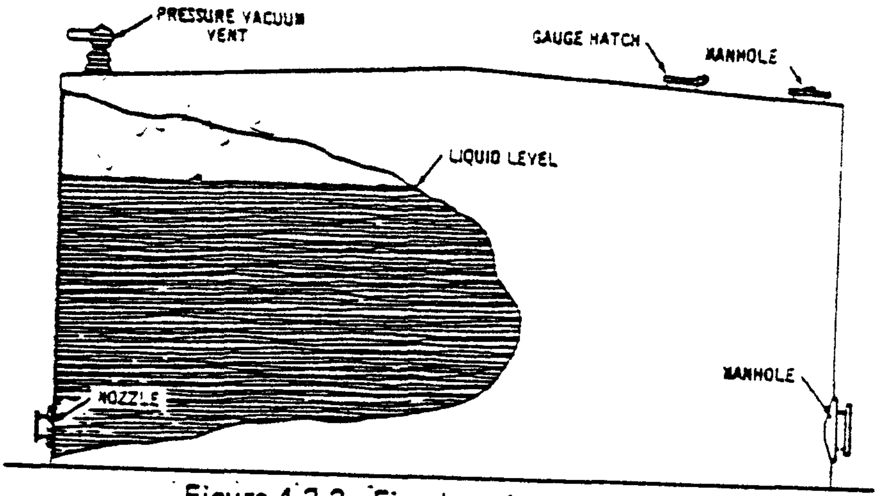

Figure 4.3-2. Fixed roof storage tank.

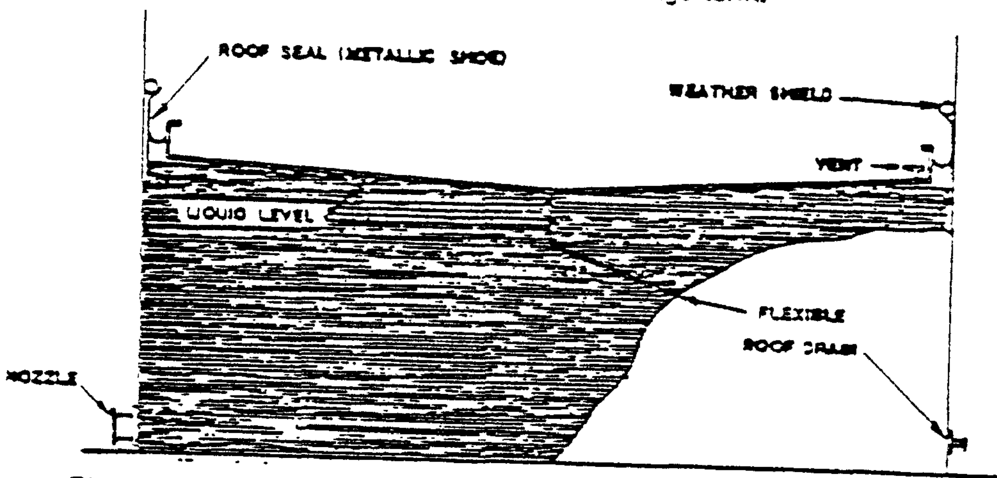

Figure 4.3-3. Pan-type floating roof storage tank (metallic seals).

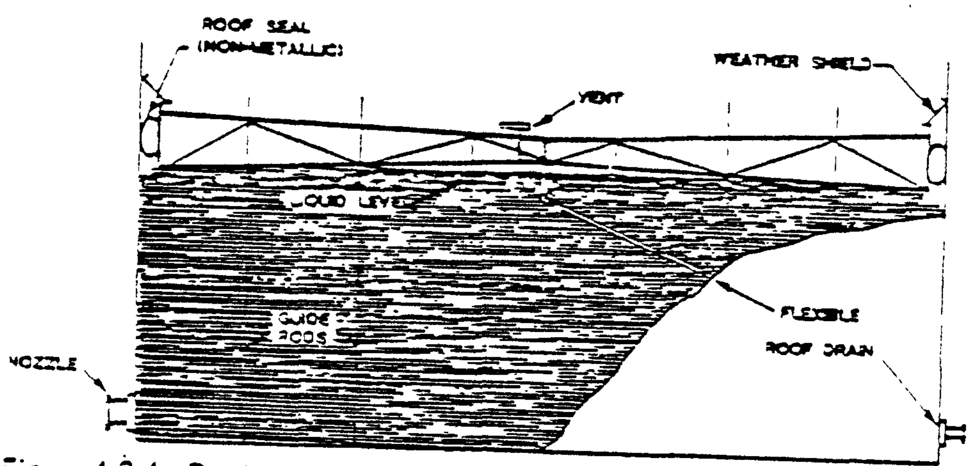

Figure 4.3-4. Double deck floating roof storage tank (non-metallic seals).

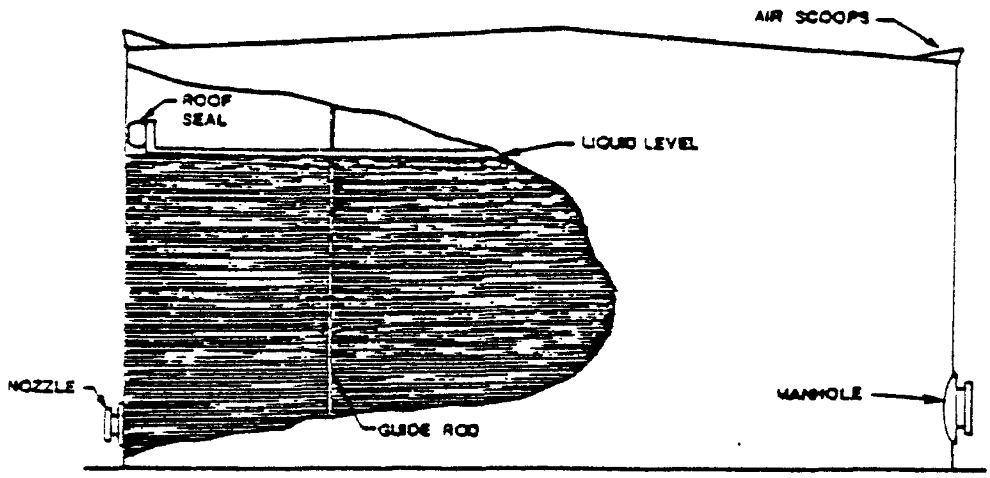

Figure 4.3-5. Covered floating roof storage tank.

protection. Antirotational guides must be provided to maintain roof alignment, and the space between the fixed and floating roofs must be vented to prevent the possible formation of a flammable mixture.

4.3.1.3 Variable Vapor Space Tanks[4] - Variable vapor space tanks are equipped with expandable vapor reservoirs to accommodate vapor volume fluctuations attributable to temperature and barometric pressure changes. Although variable vapor space tanks are sometimes used independently, they are normally connected to the vapor spaces of one or more fixed roof tanks. The two most common types of variable vapor space tanks are lifter roof tanks and flexible diaphragm tanks.

Lifter roof tanks have a telescoping roof that fits loosely around the outside of the main tank wall. The space between the roof and the wall is closed by either a wet seal, which consists of a trough filled with liquid, or a dry seal, which employs a flexible coated fabric in place of the trough (Figure 4.3-6).

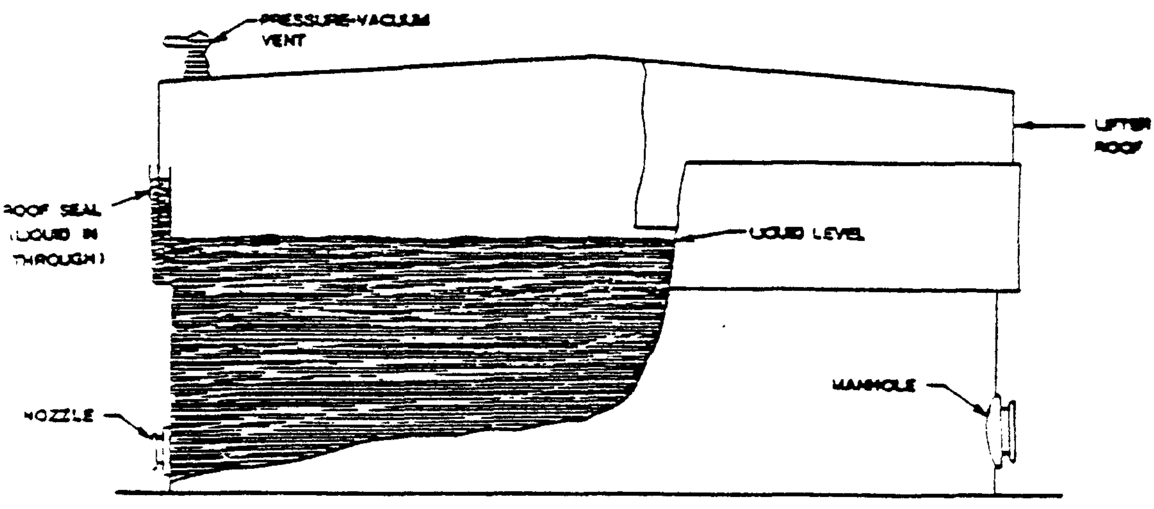

Figure 4.3-6. Lifter roof storage tank (wet seal).

Flexible diaphragm tanks utilize flexible membranes to provide the expandable volume. They may be separate gasholder type units, or integral units mounted atop fixed roof tanks (Figure 4.3-7).

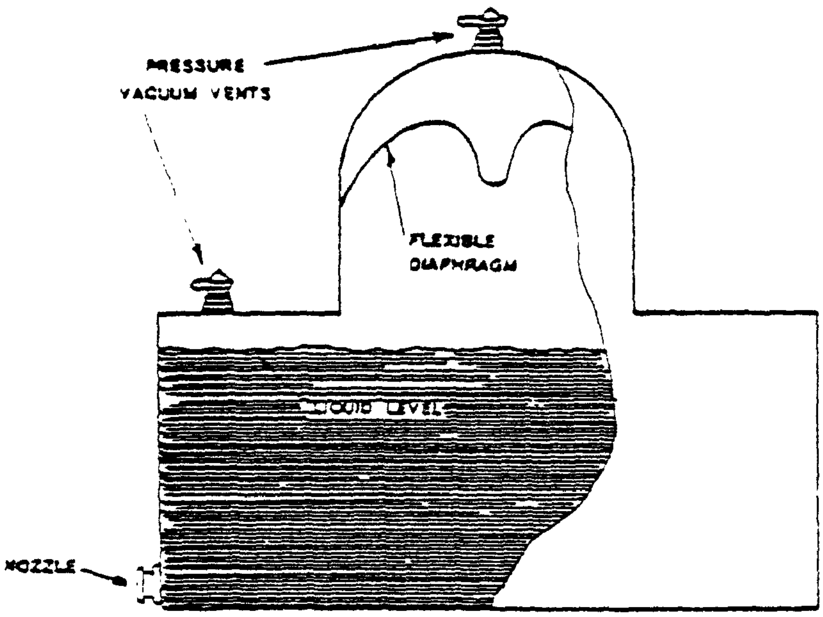

Figure 4.3-7. Flexible diaphragm tank (integral unit).

4.3.1.4 Pressure Tanks[5] - Pressure tanks are designed to withstand relatively large pressure variations without incurring a loss. They are generally used for storage of high volatility stocks, and they are constructed in many sizes and shapes, depending on the operating range. The noded spheroid and noded hemispheroid shapes are generally used as low-pressure tanks (17 to 30 psia or 12 to 21 mg/m^2), while the horizontal cylinder and spheroid shapes are generally used as high-pressure tanks (up to 265 psia or 186 mg/m^2).

4.3.2 Emissions and Controls

There are six sources of emissions from petroleum liquids in storage: fixed roof breathing losses, fixed roof working losses, floating roof standing storage losses, floating roof withdrawal losses, variable vapor space filling losses, and pressure tank losses.[1]

Fixed roof breathing losses consist of vapor expelled from a tank because of the thermal expansion of existing vapors, vapor expansion caused by barometric pressure changes, and/or an increase in the amount of vapor due to added vaporization in the absence of a liquid-level change.

Fixed roof working losses consist of vapor expelled from a tank as a result of filling and emptying operations. Filling loss is the result of vapor displacement by the input of liquid. Emptying loss is the expulsion of vapors subsequent to product withdrawal, and is attributable to vapor growth as the newly inhaled air is saturated with hydrocarbons.

Floating roof standing storage losses result from causes other than breathing or changes in liquid level. The largest potential source of this loss is attributable to an improper fit of the seal and shoe to the shell, which exposes some liquid surface to the atmosphere. A small amount of vapor may escape between the flexible membrane seal and the roof.

Floating roof withdrawal losses result from evaporation of stock which wets the tank wall as the roof descends during emptying operations. This loss is small in comparison to other types of losses.

Variable vapor space filling losses result when vapor is displaced by the liquid input during filling operations. Since the variable vapor space tank has an expandable vapor storage capacity, this loss is not as large as the filling loss associated with fixed roof tanks. Loss of vapor occurs only when the vapor storage capacity of the tank is exceeded.

Pressure tank losses occur when the pressure inside the tank exceeds the design pressure of the tank, which results in relief vent opening. This happens only when the tank is filled improperly, or when abnormal vapor expansion occurs. These are not regularly occurring events, and pressure tanks are not a significant source of loss under normal operating conditions.

The total amount of evaporation loss from storage tanks depends upon the rate of loss and the period of time involved. Factors affecting the rate of loss include:

1. True vapor pressure of the liquid stored.
2. Temperature changes in the tank.
3. Height of the vapor space (tank outage).
4. Tank diameter.
5. Schedule of tank filling and emptying.
6. Mechanical condition of tank and seals.
7. Type of tank and type of paint applied to outer surface.

The American Petroleum Institute has developed empirical formulae, based on field testing, that correlate evaporative losses with the above factors and other specific storage factors.

4.3.2.1 Fixed Roof Tanks[2,7] - Fixed roof breathing losses can be estimated from:

$$L_B = 2.21 \times 10^{-4} M \left[\frac{P}{14.7 - P}\right]^{0.68} D^{1.73} H^{0.51} \Delta T^{0.50} F_p C K_c \quad (1)$$

where: L_B = Fixed roof breathing loss (lb/day).

M = Molecular weight of vapor in storage tank (lb/lb mole). (see Table 4.3-1).

P = True vapor pressure at bulk liquid conditions (psia); see Figures 4.3-8, 4.3-9, or Table 4.3-1.

D = Tank diameter (ft).

H = Average vapor space height, including roof volume correction (ft); see note (1).

ΔT = Average ambient temperature change from day to night (°F).

F_p = Paint factor (dimensionless); see Table 4.3-2.

C = Adjustment factor for small diameter tanks (dimensionless); see Figure 4.3-10.

K_c = Crude oil factor (dimensionless); see note (2).

Note: (1) The vapor space in a cone roof is equivalent in volume to a cylinder which has the same base diameter as the cone and is one-third the height of the cone.

(2) K_c = (0.65) for crude oil, K_c = (1.0) for gasoline and all other liquids.

API reports that calculated breathing loss from Equation (1) may deviate in the order of ± 10 percent from actual breathing loss.

Table 4.3-1. PHYSICAL PROPERTIES OF HYDROCARBONS [7,9]

Hydrocarbon	Vapor molecular weight @ 60°F	Product density (d), lb/gal @ 60°F	Condensed vapor density (w), lb/gal @ 60°F	Vapor pressure in psia at:						
				40°F	50°F	60°F	70°F	80°F	90°F	100°F
Fuels										
Gasoline RVP 13	62	5.6	4.9	4.7	5.7	6.9	8.3	9.9	11.7	13.8
Gasoline RVP 10	66	5.6	5.1	3.4	4.2	5.2	6.2	7.4	8.8	10.5
Gasoline RVP 7	68	5.6	5.2	2.3	2.9	3.5	4.3	5.2	6.2	7.4
Crude oil RVP 5	50	7.1	4.5	1.8	2.3	2.8	3.4	4.0	4.8	5.7
Jet naphtha (JP 4)	80	6.4	5.4	0.8	1.0	1.3	1.6	1.9	2.4	2.7
Jet kerosene	130	7.0	6.1	0.0041	0.0060	0.0085	0.011	0.015	0.021	0.029
Distillate fuel No. 2	130	7.1	6.1	0.0031	0.0045	0.0074	0.0090	0.012	0.016	0.022
Residual oil No. 6	190	7.9	6.4	0.00002	0.00003	0.00004	0.00006	0.00009	0.00013	0.00019
Petrochemicals										
Acetone	58	6.6	6.6	1.7	2.2	2.9	3.7	4.7	5.9	7.3
Acrylonitrile	53	6.8	6.8	0.8	1.0	1.4	1.8	2.4	3.1	4.0
Benzene	78	7.4	7.4	0.6	0.9	1.2	1.5	2.0	2.6	3.3
Carbon disulfide	76	10.6	10.6	3.0	3.9	4.8	6.0	7.4	9.2	11.2
Carbon tetrachloride	154	13.4	13.4	0.8	1.1	1.4	1.8	2.3	3.0	3.8
Chloroform	119	12.5	12.5	1.5	1.9	2.5	3.2	4.1	5.2	6.3
Cyclohexane	84	6.5	6.5	0.7	0.9	1.2	1.6	2.1	2.6	3.2
1, 2 - Dichlorethane	99	10.5	10.5	0.6	0.8	1.0	1.4	1.7	2.2	2.8
Ethylacetate	88	7.6	7.6	0.6	0.8	1.1	1.5	1.9	2.5	3.2
Ethyl alcohol	46	6.6	6.6	0.2	0.4	0.6	0.9	1.2	1.7	2.3
Isopropyl alcohol	60	6.6	6.6	0.2	0.3	0.5	0.7	0.9	1.3	1.8
Methyl alcohol	32	6.6	6.6	0.7	1.0	1.4	2.0	2.6	3.5	4.5
Methylene chloride	85	11.1	11.1	3.1	4.3	5.4	6.8	8.7	10.3	13.3
Methyl ethyl ketone	72	6.7	6.7	0.7	0.9	1.2	1.5	2.1	2.7	3.3
Methyl methacrylate	100	7.9	7.9	0.1	0.2	0.3	0.5	0.8	1.1	1.4
1, 1, 1 - Trichloroethane	133	11.2	11.2	0.9	1.2	1.6	2.0	2.6	3.3	4.2
Trichloroethylene	131	12.3	12.3	0.5	0.7	0.9	1.2	1.5	2.0	2.6
Toluene	92	7.3	7.3	0.2	0.2	0.3	0.4	0.6	0.8	1.0
Vinylacetate	86	7.8	7.8	0.7	1.0	1.3	1.7	2.3	3.1	4.0

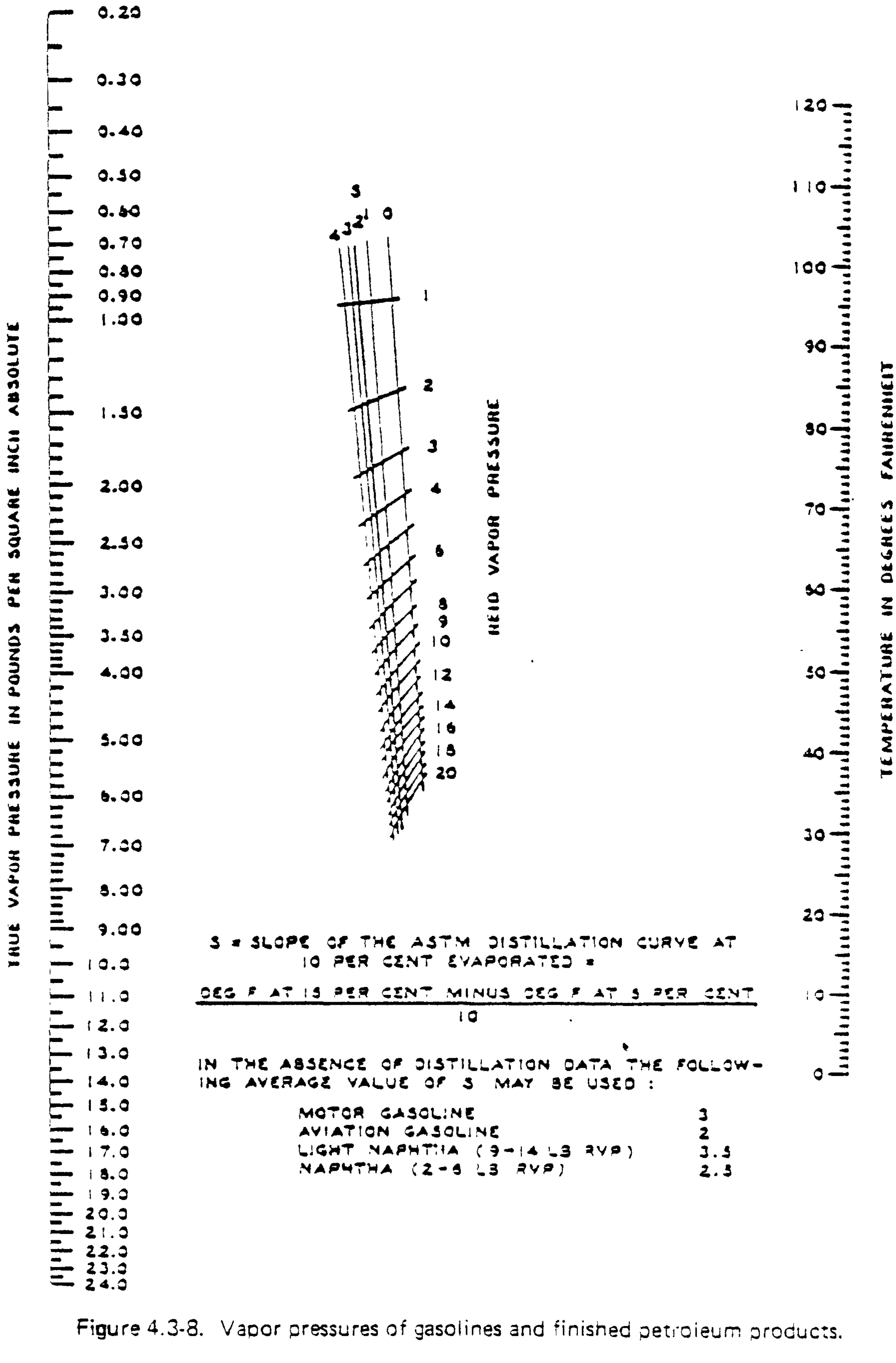

Figure 4.3-8. Vapor pressures of gasolines and finished petroleum products.

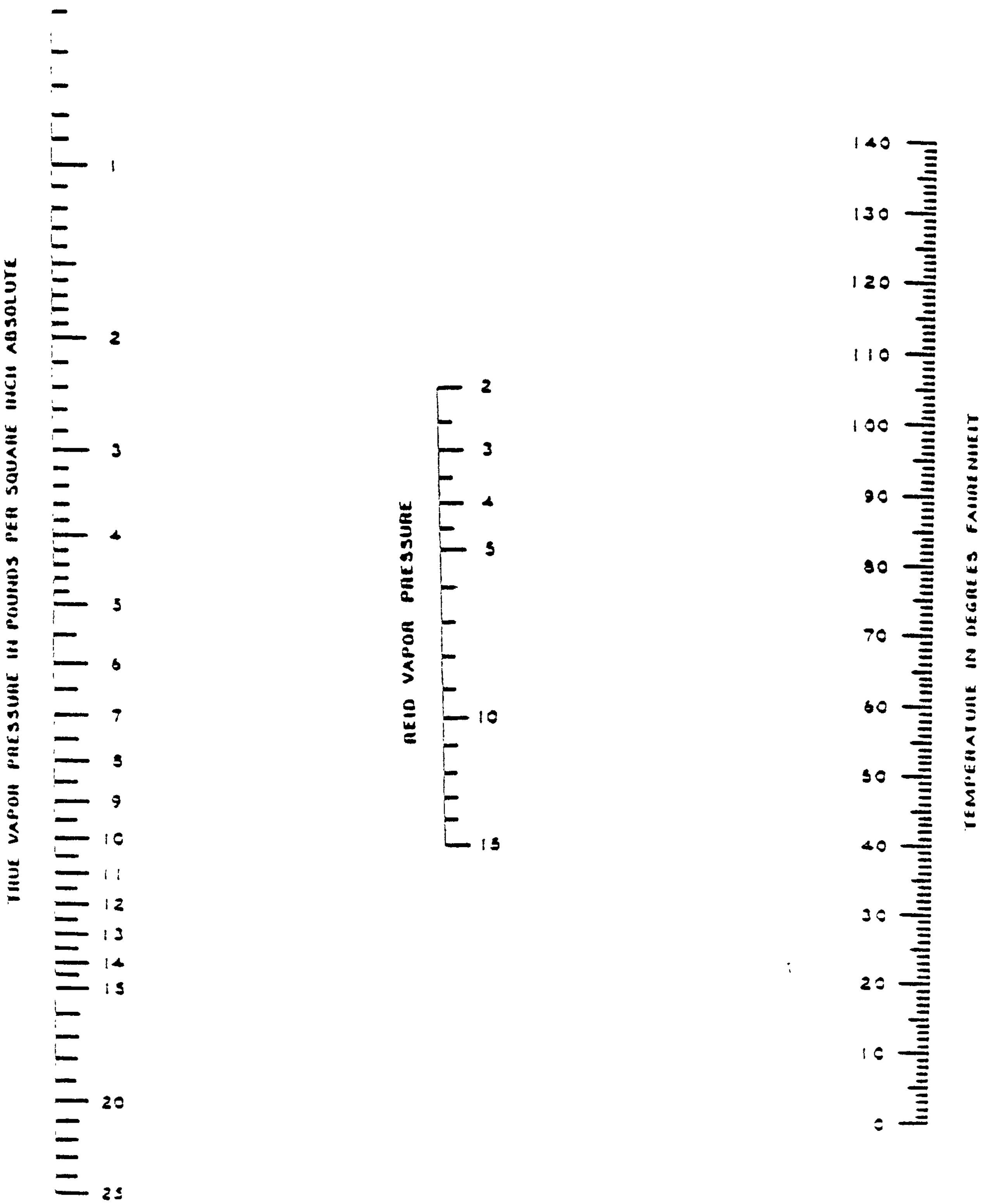

Figure 4.3-9. Vapor pressures of crude oil.

Table 4.3-2. PAINT FACTORS FOR FIXED ROOF TANKS[2]

Tank color		Paint factors (F_p)	
		Paint condition	
Roof	Shell	Good	Poor
White	White	1.00	1.15
Aluminum (specular)	White	1.04	1.18
White	Aluminum (specular)	1.16	1.24
Aluminum (specular)	Aluminum (specular)	1.20	1.29
White	Aluminum (diffuse)	1.30	1.38
Aluminum (diffuse)	Aluminum (diffuse)	1.39	1.46
White	Gray	1.30	1.38
Light gray	Light gray	1.33	1.44[a]
Medium gray	Medium gray	1.40	1.58[a]

[a]Estimated from the ratios of the seven preceding paint factors.

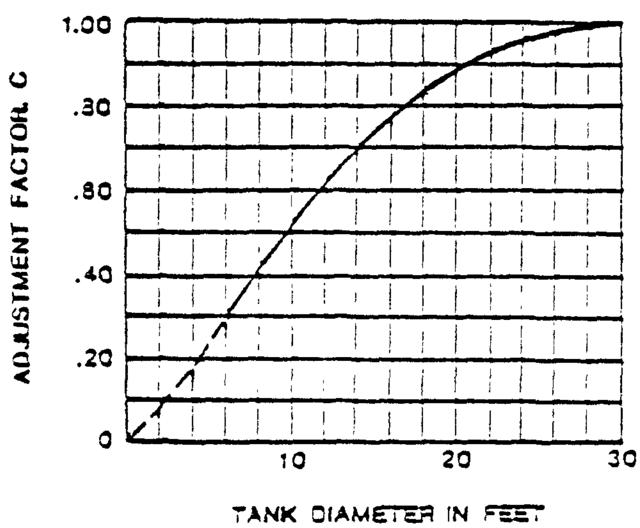

Figure 4.3-10. Adjustment factor (C) for small diameter tanks.

Fixed roof working losses can be estimated from:

$$L_W = 2.40 \times 10^{-2} \, M \, P \, K_N \, K_c \quad (2)$$

where: L_W = Fixed roof working loss (lb/10^3 gal throughput).

M = Molecular weight of vapor in storage tank (lb/lb mole). see Table 4.3-1.

P = True vapor pressure at bulk liquid conditions (psia); see Figures 4.3-8, 4.3-9, or Table 4.3-1.

K_N = Turnover factor (dimensionless); see Figure 4.3-11.

K_c = Crude oil factor (dimensionless); see note.

Note: K_c = (0.84) for crude oil. K_c = (1.0) for gasoline and all other liquids.

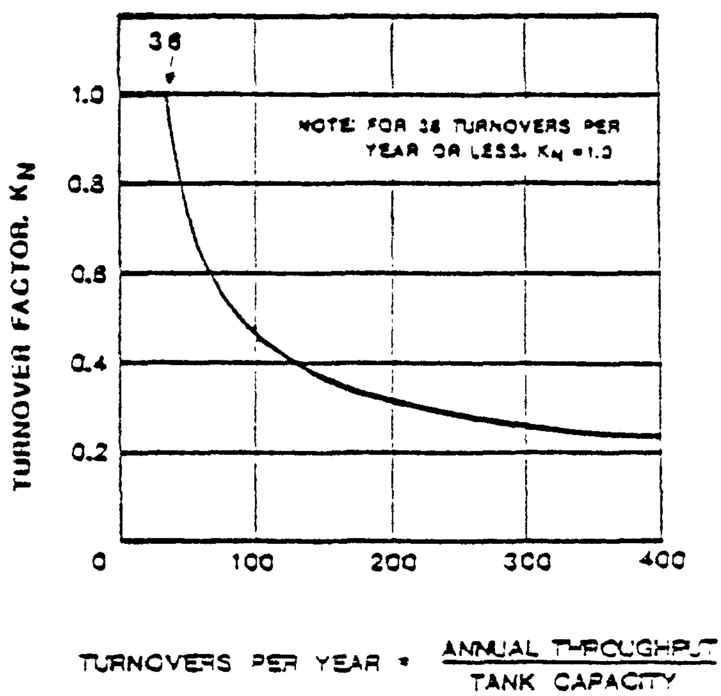

Figure 4.3-11. Turnover factor (K_N) for fixed roof tanks.

The fixed roof working loss (Lw) is the sum of the loading and unloading loss. API reports that special tank operating conditions may result in actual losses which are significantly greater or lower than the estimates provided by Equation (2).

The API recommends the use of these storage loss equations only for cases in which the stored petroleum liquids exhibit vapor pressures in the same range as gasolines. However, in the absence of any correlation developed specifically for naphthas, kerosenes, and fuel oils, it is recommended that these storage loss equations also be used for the storage of these heavier fuels.

The method most commonly used to control emissions from fixed roof tanks is a vapor recovery system that collects emissions from the storage vessels and converts them to liquid product. To recover vapor, one or a combination of four methods may be used: vapor/liquid absorption, vapor compression, vapor cooling, and vapor/solid adsorption. Overall control efficiencies of vapor recovery systems vary from 90 to 95 percent, depending on the method used, the design of the unit, the composition of vapors recovered, and the mechanical condition of the system.

Emissions from fixed roof tanks can also be controlled by the addition of an internal floating cover or covered floating roof to the existing fixed roof tank. API reports that this can result in an average loss reduction of 90 percent of the total evaporation loss sustained from a fixed roof tank.[8]

Evaporative emissions can be minimized by reducing tank heat input with water sprays, mechanical cooling, underground storage, tank insulation, and optimum scheduling of tank turnovers.

4.3.2.2 Floating Roof Tanks[3,7] - Floating roof standing storage losses can be estimated from:

$$L_S = 9.21 \times 10^{-3} M \left[\frac{P}{14.7 - P}\right]^{0.7} D^{1.5} V_w^{0.7} K_t K_s K_p K_c \qquad (3)$$

where: L_S = Floating roof standing storage loss (lb/day).

M = Molecular weight of vapor in storage tank (lb/lb mole); see Table 4.3-1.

P = True vapor pressure at bulk liquid conditions (psia); see Figures 4.3-8, 4.3-9, or Table 4.3-1.

D = Tank diameter (ft); see note (1).

V_w = Average wind velocity (mi/hr); see note (2).

K_t = Tank type factor (dimensionless); see Table 4.3-3.

K_s = Seal factor (dimensionless); see Table 4.3-3.

K_p = Paint factor (dimensionless); see Table 4.3-3.

K_c = Crude oil factor (dimensionless); see note (3).

Note: (1) For $D \geq 150$, use $D\sqrt{150}$ instead of $D^{1.5}$

(2) API correlation was derived for minimum wind velocity of 4 mph. If $V_w \leq 4$ mph, use V_w = 4mph.

(3) K_c = (0.84) for crude oil, K_c = (1.0) for all other liquids.

API reports that standing storage losses from gasoline and crude oil storage calculated from Equation (3) will not deviate from the actual losses by more than ±25 percent for tanks in good condition under normal operation. However, losses may exceed the calculated amount if the seals are in poor condition. Although the API recommends the use of these correlations only for petroleum liquids exhibiting vapor pressures in the range of gasoline and crude oils, in the absence of better correlations, these correlations are also recommended with caution for use with heavier naphthas, kerosenes, and fuel oils.

Table 4.3-3. TANK, TYPE, SEAL, AND PAINT FACTORS FOR FLOATING ROOF TANKS[2]

Tank type	K_t
Welded tank with pan or pontoon roof, single or double seal	0.045
Riveted tank with pontoon roof, double seal	0.11
Riveted tank with pontoon roof, single seal	0.13
Riveted tank with pan roof, double seal	0.13
Riveted tank with pan roof, single seal	0.14

Seal type	K_s
Tight fitting (typical of modern metallic and non-metallic seals)	1.00
Loose fitting (typical of seals built prior to 1942)	1.33

Paint color of shell and roof	K_p
Light gray or aluminum	1.0
White	0.9

API has developed a correlation based on laboratory data for calculating floating roof withdrawal loss for gasoline storage.[5] Floating roof withdrawal loss for gasoline can be estimated from:

$$L_{WD} = \frac{22.4\, d\, C_F}{D} \tag{4}$$

where: L_{WD} = Floating roof gasoline withdrawal loss (lb/10^3 gal throughput).

d = Density of stored liquid at bulk liquid conditions (lb/gal); see Table 4.3-1.

C_F = Tank construction factor (dimensionless); see note.

D = Tank diameter (ft).

Note: C_F = (0.02) for steel tanks. C_F = (1.0) for gunite-lined tanks.

Because Equation (4) was derived from gasoline data, its applicability to other stored liquids is uncertain. No estimate of accuracy of Equation (4) has been given.

API has not presented any correlations that specifically pertain to internal floating covers or covered floating roofs. Currently, API recommends the use of Equations (3) and (4) with a wind speed of 4 mph for calculating the losses from internal floating covers and covered floating roofs.

Evaporative emissions from floating roof tanks can be minimized by reducing tank heat input.

4.3.2.3 Variable Vapor Space Systems[4,7] - Variable vapor space system filling losses can be estimated from:

$$L_V = (2.40 \times 10^{-2}) \frac{M\,P}{V_1} \left[(V_1) - (0.25\, V_2\, N)\right] \tag{5}$$

where: L_V = Variable vapor space filling loss (lb/10^3 gal throughput).

M = Molecular weight of vapor in storage tank (lb/lb mole); see Table 4.3-1.

P = True vapor pressure at bulk liquid conditions (psia); see Figures 4.3-8, 4.3-9, or Table 4.3-1.

V_1 = Volume of liquid pumped into system: throughput (bbl).

V_2 = Volume expansion capacity of system (bbl); see note (1).

N = Number of transfers into system (dimensionless); see note (2).

Note: (1) V is the volume expansion capacity of the variable vapor space achieved by roof-lifting or diaphragm-flexing.

(2) N is the number of transfers into the system during the time period that corresponds to a throughput of V_1.

The accuracy of Equation (5) is not documented; however, API reports that special tank operating conditions may result in actual losses which are significantly different from the estimates provided by Equation (5). It should also be noted that, although not developed for use with heavier petroleum liquids such as kerosenes and fuel oils, Equation (5) is recommended for use with heavier petroleum liquids in the absence of better data.

Evaporative emissions from variable vapor space tanks are negligible and can be minimized by optimum scheduling of tank turnovers and by reducing tank heat input. Vapor recovery systems can be used with variable vapor space systems to collect and recover filling losses.

Vapor recovery systems capture hydrocarbon vapors displaced during filling operations and recover the hydrocarbon vapors by the use of refrigeration, absorption, adsorption, and/or compression. Control efficiencies range from 90 to 98 percent, depending on the nature of the vapors and the recovery equipment used.

4.3.2.4 Pressure Tanks - Pressure tanks incur vapor losses when excessive internal pressures result in relief valve venting. In some pressure tanks vapor venting is a design characteristic, and the vented vapors must be routed to a vapor recovery system. However, for most pressure tanks vapor venting is not a normal occurrence, and the tanks can be considered closed systems. Fugitive losses are also associated with pressure tanks and their equipment, but with proper system maintenance they are insignificant. Correlations do not exist for estimating vapor losses from pressure tanks.

4.3.3 Emission Factors

Equations (1) through (5) can be used to estimate evaporative losses, provided the respective parameters are known. For those cases where such parameters are unknown, Table 4.3-4 provides emission factors for the typical systems and conditions. It should be emphasized that these emission factors are rough estimates at best for storage of liquids other than gasoline and crude oil, and for storage conditions other than the ones they are based upon. In areas where storage sources contribute a substantial portion of the total evaporative emissions or where they are major factors affecting the air quality, it is advisable to obtain the necessary parameters and to calculate emission estimates using Equations (1) through (5).

Table 4.3-4. EVAPORATIVE EMISSION FACTORS FOR STORAGE TANKS WITHOUT CONTROLS[2-4,6,7]

Product Stored	Fixed roof tanks – Breathing loss – "New tank" conditions lb/day 10³ gal	kg/day 10³ liter	"Old tank" conditions lb/day 10³ gal	kg/day 10³ liter	Working loss lb/10³ gal throughput	kg/10³ liter throughput	Floating roof tanks – Standing storage loss – "New tank" conditions lb/day 10³ gal	kg/day 10³ liter	"Old tank" conditions lb/day 10³ gal	kg/day 10³ liter	Withdrawal loss lb/10³ gal throughput	kg/10³ liter throughput	Variable vapor space tanks – 10,600 bbl – Filling loss lb/10³ gal throughput	kg/10³ liter throughput
Fuels 67,000 bbl tanks														
1 Gasoline RVP 13	0.30	0.036	0.34	0.041	10.0	1.2	0.044	0.0052	0.10	0.012	0.023	0.0028	9.8	1.2
2 Gasoline RVP 10	0.23	0.028	0.26	0.031	8.2	0.99	0.033	0.0040	0.078	0.0094	0.023	0.0028	7.7	0.93
3 Gasoline RVP 7	0.16	0.019	0.18	0.022	6.7	0.80	0.023	0.0028	0.055	0.0066	0.023	0.0028	5.4	0.65
4 Crude oil RVP 5	0.064	0.0077	0.073	0.0088	2.8	0.34	0.012	0.0014	0.028	0.0034			Not used	Not used
5 Jet naphtha (JP 4)	0.086	0.010	0.098	0.011	2.6	0.30	0.012	0.0014	0.028	0.0034			2.3	0.28
6 Jet kerosene	0.0043	0.00052	0.0049	0.00059	0.027	0.0032	0.00054	0.000065	0.0013	0.00016			0.026	0.0030
7 Distillate fuel no. 2	0.0039	0.00047	0.0044	0.00053	0.023	0.0028	0.00049	0.000058	0.0011	0.00014			0.022	0.0026
8 Residual oil no. 6	0.00016	0.000019	0.00018	0.000022	0.00018	0.000022	0.000018	0.0000022	0.000043	0.0000062			0.00017	0.000020
Fuels 260,000 bbl tanks														
9 Gasoline RVP 13	0.22	0.026	0.25	0.030	10.0	1.2	0.025	0.0030	0.057	0.0068	0.013	0.0015	Not used	Not used
10 Gasoline RVP 10	0.17	0.020	0.19	0.023	8.2	0.99	0.019	0.0023	0.044	0.0053	0.013	0.0015	Not used	Not used
11 Gasoline RVP 7	0.12	0.014	0.13	0.016	5.7	0.80	0.013	0.0016	0.031	0.0037	0.013	0.0015	Not used	Not used
12 Crude oil RVP 5	0.048	0.0058	0.052	0.0062	2.8	0.34	0.0077	0.00092	0.018	0.0022			Not used	Not used
13 Jet naphtha (JP 4)	0.062	0.0074	0.071	0.0085	2.5	0.30	0.0068	0.00082	0.016	0.0019			Not used	Not used
14 Jet kerosene	0.0031	0.00037	0.0035	0.00042	0.027	0.0032	0.00031	0.000037	0.00074	0.000089			Not used	Not used
15 Distillate fuel no. 2	0.0028	0.00034	0.0032	0.00038	0.023	0.0028	0.00028	0.000034	0.00068	0.000082			Not used	Not used
16 Residual fuel no. 6	0.000012	0.0000014	0.000014	0.0000017	0.00018	0.000022	0.000010	0.0000012	0.000024	0.0000029			Not used	Not used
Petrochemicals* 67,000 bbl tanks														
17 Acetone	0.12	0.014	0.14	0.018	4.0	0.48	0.017	0.0020	0.039	0.0047			3.8	0.45
18 Acrylonitrile	0.060	0.0072	0.068	0.0082	1.8	0.21	0.0084	0.0010	0.020	0.0024			1.7	0.20
19 Benzene	0.070	0.0084	0.090	0.011	2.2	0.27	0.011	0.0013	0.026	0.0031			2.1	0.25
20 Carbon disulfide	0.24	0.029	0.28	0.033	8.8	1.1	0.036	0.0042	0.083	0.0099			8.2	0.98
21 Carbon tetrachloride	0.17	0.021	0.20	0.024	5.2	0.62	0.024	0.0029	0.056	0.0069			4.8	0.58
22 Chloroform	0.21	0.025	0.24	0.029	7.1	0.86	0.030	0.0036	0.071	0.0085			6.7	0.80
23 Cyclohexane	0.086	0.010	0.098	0.012	2.4	0.29	0.012	0.0014	0.028	0.0034			2.3	0.27
24 1,2 Dichloroethane	0.087	0.010	0.10	0.012	2.4	0.28	0.012	0.0014	0.029	0.0034			2.2	0.27
25 Ethyl acetate	0.083	0.010	0.095	0.011	2.3	0.28	0.012	0.0014	0.027	0.0033			2.2	0.26
26 Ethyl alcohol	0.028	0.0034	0.032	0.0038	0.66	0.079	0.0039	0.00046	0.0091	0.0011			0.62	0.074
27 Isopropyl alcohol	0.031	0.0038	0.036	0.0043	0.72	0.086	0.0043	0.00052	0.010	0.0012			0.68	0.082
28 Methyl alcohol	0.036	0.0044	0.042	0.0050	1.1	0.13	0.0051	0.00061	0.012	0.0014			1.0	0.12
29 Methylene chloride	0.31	0.037	0.35	0.042	11.0	1.3	0.044	0.0053	0.10	0.012			10.0	1.2
30 Methyl ethyl ketone	0.073	0.0087	0.083	0.0099	2.1	0.25	0.010	0.0012	0.024	0.0029			1.9	0.23
31 Methyl methacrylate	0.038	0.0046	0.043	0.0052	0.72	0.086	0.0051	0.00061	0.012	0.0015			0.68	0.082
32 1,1,1 Trichloroethane	0.17	0.020	0.19	0.023	5.1	0.61	0.023	0.0028	0.055	0.0066			4.8	0.58
33 Trichloroethylene	0.11	0.013	0.12	0.014	2.8	0.34	0.015	0.0018	0.035	0.0042			2.6	0.31
34 Toluene	0.035	0.0042	0.040	0.0048	0.66	0.079	0.0048	0.00058	0.011	0.0014			0.62	0.074
35 Vinyl acetate	0.092	0.011	0.10	0.013	2.7	0.32	0.013	0.0016	0.030	0.0037			2.5	0.30

*Due to safety and health regulations, toxicity, and value of these petrochemicals, they are normally stored in tanks with vapor recovery controls which are 90 to 98 percent efficient.

Emission factors based on the following parameters:

Ambient conditions
- Storage temperature: 60°F (15.6°C)
- Daily ambient temperature change: 15°F (8.3°C)
- Wind velocity: 10 mi/hr (4.5 m/sec)

Typical fixed roof tanks
- Outage: 50 percent of tank height
- Turnovers per year (N): 30 for crude, 13 for all other liquids
- Paint factor (F_p): New tank white paint 1.00; Old tank white/aluminum paint 1.14

For 67,000 bbl tankage (10.7×10^6 liter)
- Height: 48 ft (14.6m)
- Diameter: 110 ft (33.5m)

For 250,000 bbl tankage (39.7×10^6 liter)
- Height: 44 ft (13.4m)
- Diameter: 200 ft (60.8m)

Emission factors based on the following parameters:

Typical floating roof tanks
- Paint factor (K_p): New tank white paint 0.090; Old tank white/aluminum paint 0.95
- Seal factor (K_s): New tank modern seals 1.00; Old tank 60 percent old seals 1.14
- Tank type factor (Kt): New tank welded 0.045; Old tank 50 percent riveted 0.088

Typical variable space tank
- Diameter: 50 ft (15.2m)
- Height: 30 ft (9.1m)
- Capacity: 10,500 bbl (1.67×10^6 liter)
- Turnovers per year (N): 6
- Volume expansion capacity: one fourth of liquid capacity 2625 bbl (0.42×10^6 liter)

4.3.3.1 **Sample Calculation** - Breathing losses from a fixed roof storage tank would be calculated as follows, using Equation (1).

Design basis:

Tank capacity - 100,000 bbl.
Tank diameter - 125 ft.
Tank height - 46 ft.
Average diurnal temperature change - 15°F.
Gasoline RVP - 9 psia.
Gasoline temperature - 70°F.
Specular aluminum painted tank.
Roof slope is 0.1 ft/ft.

Fixed roof tank breathing loss equation:

$$L_B = 2.21 \times 10^{-4} M \left[\frac{P}{14.7 - P}\right]^{0.68} D^{1.73}\ H^{0.51}\ \Delta T^{0.50}\ F_p\ C\ K_c$$

where: M = Molecular weight of gasoline vapors (see Table 4.3-1) = 66.

P = True vapor of gasoline (see Figure 4.3-8) = 5.6 psia.

D = Tank diameter = 125 ft.

ΔT = average diurnal temperature change = 15°F.

F_p = paint factor (see Table 4.3-2) = 1.20.

C = tank diameter adjustment factor (see Figure 4.3-10) = 1.0.

K_c = crude oil factor (see note for equation (1)) = 1.0.

H = average vapor space height. For a tank which is filled completely and emptied, the average liquid level is 1/2 the tank rim height, or 23 ft. The effective cone height is 1/3 of the cone height. The roof slope is 0.1 ft/ft and the tank radius is 62.5 ft. Effective cone height = (62.5 ft) (0.1 ft/ft) (1/3) = 2.08 ft.

H = average vapor space height = 23 ft + 2 ft = 25 ft.

Therefore:

$$L_B = 2.21 \times 10^{-4} (66) \left[\frac{5.6}{14.7 - 5.6}\right]^{0.68} (125)^{1.73} (25)^{0.51} (15)^{0.50} (1.2)(1.0)(1.0)$$

$$L_B = 1068 \text{ lb/day}$$

References for Section 4.3

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APPENDIX D
EMISSION ESTIMATES USING JANUARY AND JULY METEOROLOGICAL CONDITIONS

Hydrocarbon emissions from floating-roof tanks and fixed-roof tanks were estimated for the year 1976 using January and July meteorological conditions. Tables D-1 and D-2 present average monthly HC emissions for January and July by industry sectors and volatility classes.

Table D-1. 1976 JANUARY HC EMISSION ESTIMATES
(units: 1000 kg/month)

F L O A T I N G R O O F T A N K S[a]

P A D DISTRICT	I N D U S T R Y S E C T O R					T O T A L
	Refinery	Terminal	Tank Farm	Pipeline	Other	
1	613	1,377	153	356	15	2,514
2	1,076	1,486	73	759	73	3,467
3	1,959	769	262	529	19	3,538
4	116	45	5	39	0	205
5	903	336	52	79	4	1,374
T O T A L	4,667	4,013	545	1,762	111	11,098

[a] External and internal floating-roof tanks

F I X E D R O O F T A N K S

P A D DISTRICT	I N D U S T R Y S E C T O R					T O T A L
	Refinery	Terminal	Tank Farm	Pipeline	Other	
1	2,736	4,940	1,009	85	129	8,899
2	7,870	4,079	259	1,822	642	14,672
3	10,563	1,509	372	2,887	118	15,449
4	480	155	2	266	10	913
5	3,781	3,732	336	940	337	9,126
T O T A L	25,430	14,415	1,978	6,000	1,236	49,059

Table D-1. 1976 JANUARY HC EMISSION ESTIMATES (Concluded)
(units: 1000 kg/month)

FLOATING ROOF TANKS[a]

PAD DISTRICT	VOLATILITY CLASS					TOTAL
	1	2	3	4	5	
1	10	59	1,097	1,172	176	2,514
2	23	92	2,002	1,199	152	3,468
3	93	90	1,071	1,965	319	3,538
4	2	12	145	45	0	204
5	37	90	429	645	173	1,374
TOTAL	165	343	4,744	5,026	820	11,098

[a] External and internal floating-roof tanks

FIXED ROOF TANKS

PAD DISTRICT	VOLATILITY CLASS					TOTAL
	1	2	3	4	5	
1	401	1,200	5,918	1,192	188	8,899
2	337	1,106	10,044	3,052	133	14,672
3	1,709	839	7,561	5,043	297	15,449
4	44	117	679	73	0	913
5	294	3,649	3,607	922	654	9,126
TOTAL	2,785	6,911	27,809	10,282	1,272	49,059

Table D-2. 1976 JULY HC EMISSION ESTIMATES
(units: 1000 kg/month)

FLOATING ROOF TANKS[a]

PAD DISTRICT	INDUSTRY SECTOR					TOTAL
	Refinery	Terminal	Tank Farm	Pipeline	Other	
1	662	1,795	203	344	14	3,018
2	1,335	1,691	74	897	126	4,123
3	1,916	817	228	532	20	3,513
4	175	73	11	62	0	321
5	1,059	525	94	115	3	1,796
TOTAL	5,147	4,901	610	1,950	163	12,771

[a] External and internal floating-roof tanks

FIXED ROOF TANKS

PAD DISTRICT	INDUSTRY SECTOR					TOTAL
	Refinery	Terminal	Tank Farm	Pipeline	Other	
1	4,929	7,786	2,089	98	197	15,099
2	15,786	5,885	395	3,491	1,413	26,970
3	11,349	1,807	467	3,171	226	17,020
4	859	177	3	400	24	1,463
5	4,406	4,387	142	1,076	406	10,717
TOTAL	37,329	20,042	3,396	8,236	2,266	71,269

Table D-2. 1976 JULY HC EMISSION ESTIMATES (Concluded)
(units: 1000 kg/month)

F L O A T I N G R O O F T A N K S[a]

PAD DISTRICT	VOLATILITY CLASS					TOTAL
	1	2	3	4	5	
1	10	70	1,644	1,152	142	3,018
2	20	115	2,827	1,043	118	4,123
3	88	87	1,076	1,953	309	3,513
4	2	12	257	50	0	321
5	39	121	577	904	155	1,796
TOTAL	159	405	6,381	5,102	724	12,771

[a] External and internal floating-roof tanks

F I X E D R O O F T A N K S

PAD DISTRICT	VOLATILITY CLASS					TOTAL
	1	2	3	4	5	
1	402	2,347	10,942	1,214	194	15,099
2	358	2,332	19,778	4,371	131	26,970
3	1,761	883	8,519	5,530	327	17,020
4	43	132	1,221	67	0	1,463
5	267	4,079	4,495	1,137	739	10,717
TOTAL	2,831	9,773	44,955	12,319	1,391	71,269

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16. ABSTRACT

This study provides an estimate of 1976 nationwide hydrocarbon emissions from storage of petroleum liquids in existing tanks with a capacity greater than 150,000 liters. Numbers and types of existing tanks were determined to estimate these emissions by geographical location, industry sector, and volatility class of the stored products. Projections of emissions are made for 1980 and 1985 assuming only newly constructed tanks meet the requirements of the New Source Performance Standard (NSPS) for the storage of petroleum liquids and then assuming existing fixed roof tanks storing products with a volatility greater than 10.5 kPa are retrofitted with internal floating covers. Other options such as the use of vapor recovery systems for fixed roof tanks and double seals on external floating roof tanks were considered beyond the scope of the study. A nationwide estimate of 1976 emissions by petroleum liquid type stored is presented.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Storage Tanks NSPS for the Storage of Petroleum Liquids Hydrocarbon Emissions Storage of Petroleum Liquids	Fixed Roof Tank External Floating Roof Tanks Internal Floating Roof Tanks	

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