STANDARD SUPPORT
ENVIRONMENTAL IMPACT STATEMENT
FOR CONTROL OF
BENZENE FROM THE GASOLINE MARKETING INDUSTRY

Draft Report

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 2. INDUSTRY DESCRIPTION

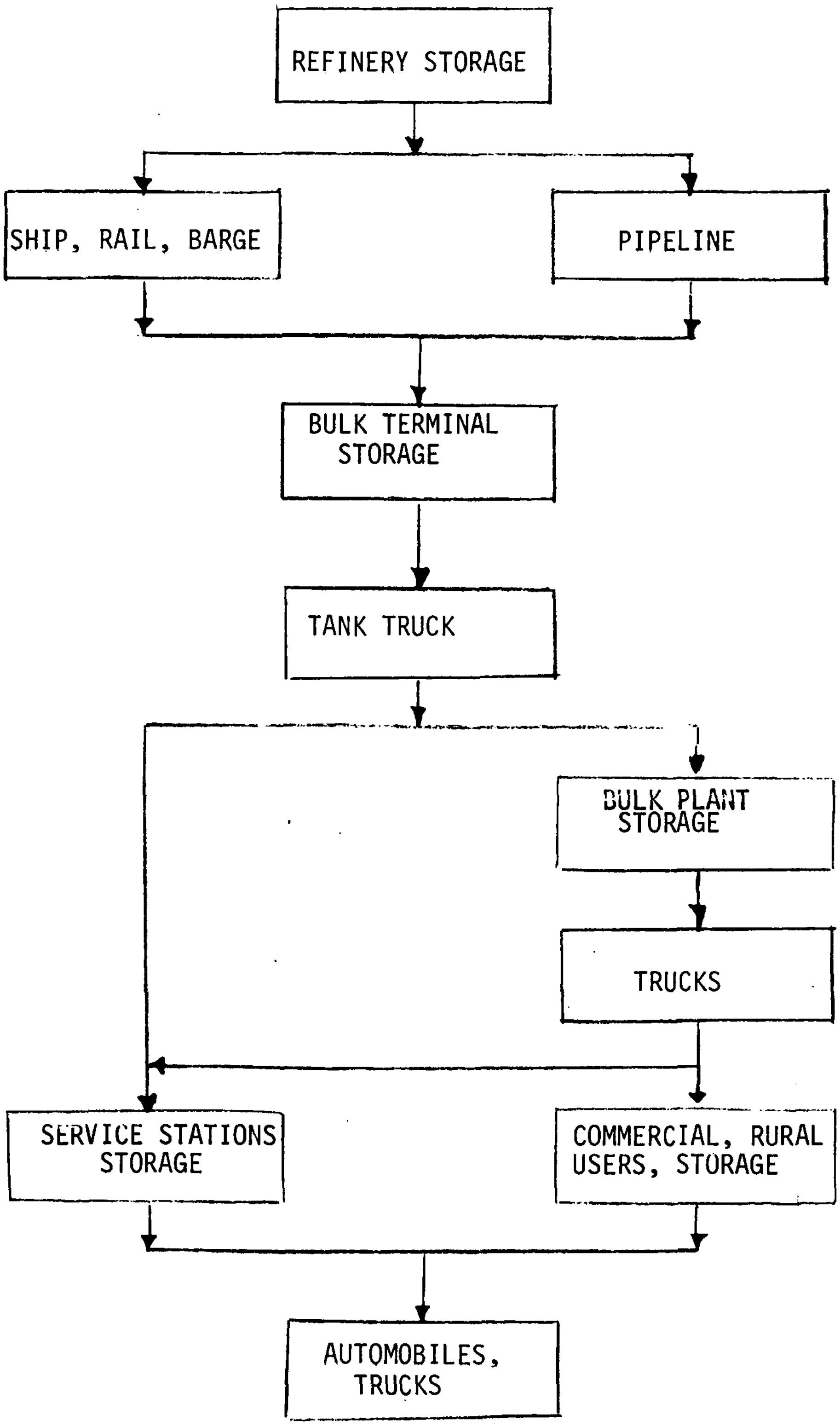
The gasoline marketing network consists of all storage and transportation of gasoline from refinery to motor vehicle fuel tanks. It includes pipelines, ships and barges, trucks and railcars, and storage tanks. Emissions occur as gasoline is stored in or loaded and unloaded from these sources.

This document discusses four of the major benzene source categories in this marketing chain: loading of trucks at bulk plants and terminals and storage at bulk plants and service stations. Motor vehicle loading and bulk terminal storage tanks will be examined in separate studies. Figure 2-1 illustrates the marketing network.

Gasoline is delivered to the terminal from the refinery via pipeline or by ships and barges. Large transport trucks (30,000-36,000 liters or 8000 - 9500 gallon capacity for each cargo trailer) then deliver the gasoline to service stations or intermediate bulk storage areas known as bulk plants. Bulk plants, using 5700-11,000 liter (1500-3000 gallon) capacity delivery trucks primarily service agricultural accounts and certain service stations that are either long distances from terminals or inaccessible to the large transports. In 1977 approximately 60 percent of gasoline delivered to service stations came from terminals and 40 percent came from bulk plants.[1] There has been a trend in recent years for less bulk plant deliveries and more terminal deliveries.

This document uses the term "service stations" to describe both the familiar retail outlets and the non-retail and miscellaneous outlets such as

FIGURE 2-1. THE GASOLINE MARKETING DISTRIBUTION SYSTEM IN THE UNITED STATES



fleet services (rental car agencies and governmental agencies), parking garages, and large agricultural accounts. (All non-retail stations receive less than 50 percent of their revenue from the sale of gasoline.) It does not include about 2.7 million small farms.

2.1 BENZENE CORRELATION TO HYDROCARBON

Data has been collected on the relationship of benzene emissions to total hydrocarbon emissions from gasoline. Previous work in this area has been done by H. E. Runion of Gulf Oil Corporation, and H. J. McDermott and S. E. Killiany of Shell Oil Company.[2,3] EPA has also done limited testing to determine the relative concentration of benzene to hydrocarbon in gasoline emissions.

In his study, Runion conducted laboratory tests on a premium leaded gasoline and two regular leaded gasolines differing in octane levels. The equilibrium vapor phase was formed by injecting 50 ml of fresh gasoline into a 4 ounce bottle equipped with a septum cap and a small wire stirrer. After a suitable period for vapor equilibration at 25^{o}C (77^{o}F), vapor samples were withdrawn and analyzed by gas chromatography. This procedure was repeated on U. S. and European gasolines, and on a series of gasolines spiked with benzene to achieve a broad spectrum of benzene liquid concentrations. These analyses resulted in an approximate linear relationship between liquid volume percent benzene in gasoline and benzene volume percent in the vapors. These data are shown in Figure 2-2 as gm benzene/gm hydrocarbon. The data and interpretation are outlined in Appendix C, Section C.4.

Runion also conducted tests to determine if benzene emission levels might increase during gasoline weathering or evaporation. His conclusion was negative.

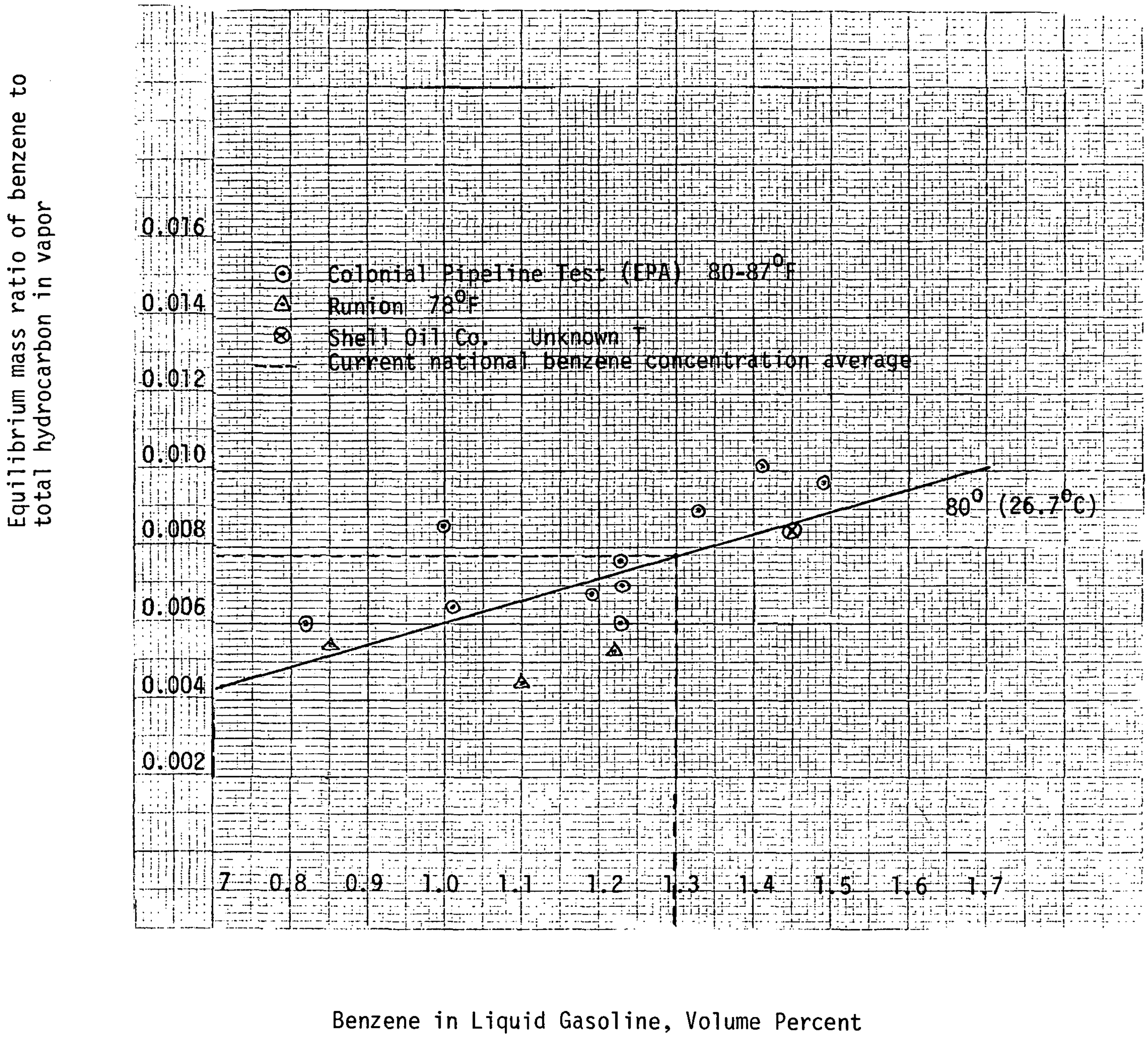
Shell Oil Company addressed the benzene/hydrocarbon relationship in their analysis of 86 gasoline samples of different brands collected for marketing research and process control. The average liquid composition of these samples was about 1 weight percent. The average benzene concentration in the gasoline vapors was about 0.7 volume percent (shown on Figure 2-2. as gm benzene/gm hydrocarbon).

In addition, samples collected from ten gasoline storage tanks at Colonial Pipeline Company, Greensboro, N.C., by EPA have been evaluated. Premium leaded, premium unleaded, regular, and unleaded gasolines were analyzed for liquid and vapor benzene concentrations at 27°C to 31°C (80 to 87°F).[4] These data are presented in Figure 2-2, along with the Shell and Runion data.

Temperature has a major influence on vapor-liquid equilibrium concentrations. The data in Figure 2-2 were obtained at temperatures varying from 25 to 31°C (77 to 87°F). This accounts for some of the irregularities of data on the graph. Any attempt to adjust the data to other temperatures would introduce an indeterminable degree of error. Therefore, this document will use the least squares correlation for 27°C (80°F) without adjustment to determine a benzene/hydrocarbon emission factor for gasoline.

The current national average of benzene content in gasoline is 1.3 liquid volume percent.[5] Figure 2-2 shows about 0.008 gm benzene/gm hydrocarbon in the vapors over gasoline containing 1.3 liquid volume percent benzene at 27°C (80°F). Therefore, this document will use a factor of 0.008 gm benzene/gm hydrocarbon to estimate benzene losses in known amounts of hydrocarbon emissions. (See Appendix C for further details of this correlation.)

FIGURE 2-2. DATA SUMMARY
BENZENE/HYDROCARBON VAPOR RELATIONSHIP



2.2 BULK GASOLINE TERMINALS

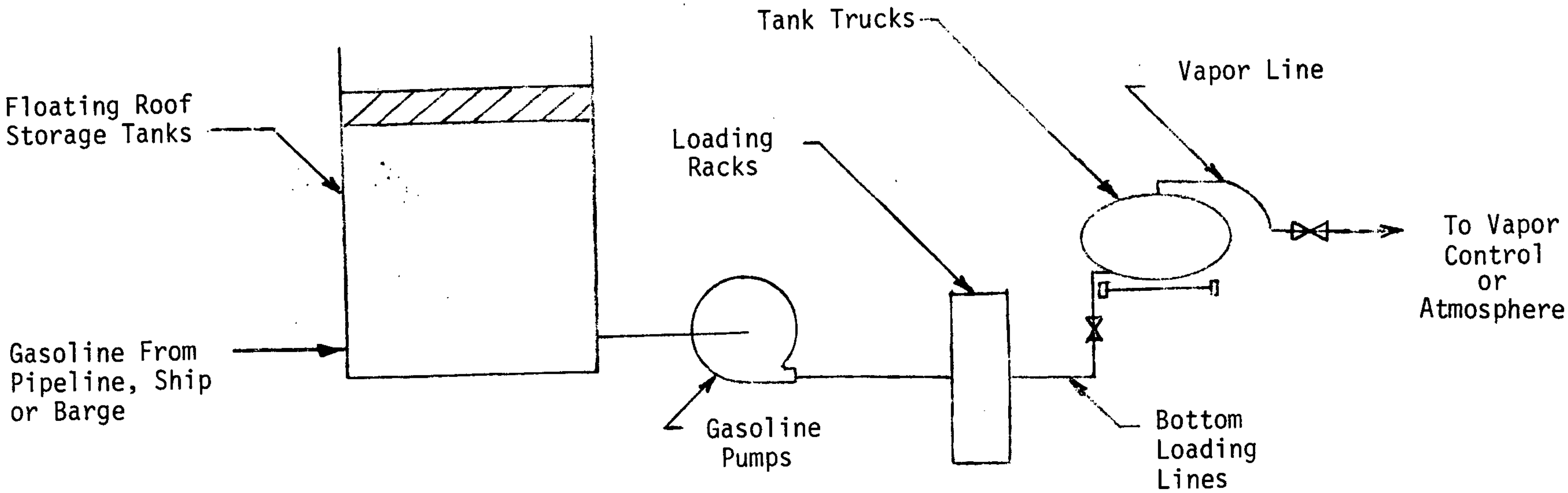
In 1972, the Bureau of the Census totalled the United States terminals as 1,925.[6] They defined a terminal as any bulk gasoline marketing outlet which receives product by pipeline, ship, or barge, or which has a total product storage capacity of 7.95 million liters (2.1 million gallons) or greater. A bulk plant was defined as a wholesale marketer of gasoline having a total product storage capacity less than 7.95 million liters (2.1 million gallons). Further, it was noted that the plant typically received product by rail or truck. Estimates of gasoline throughput for terminals was 413 billion liters (109 billion gallons) in 1977.[7] Throughput is expected to increase until 1980, when there will be a slow decline in gasoline sales due to federally required increases in fuel economy.[8] (For more detail of current industry statistics, see Chapter 6, "Economic Impact." The chapter estimates current bulk terminals at 1511 and bulk plants at 17850.)

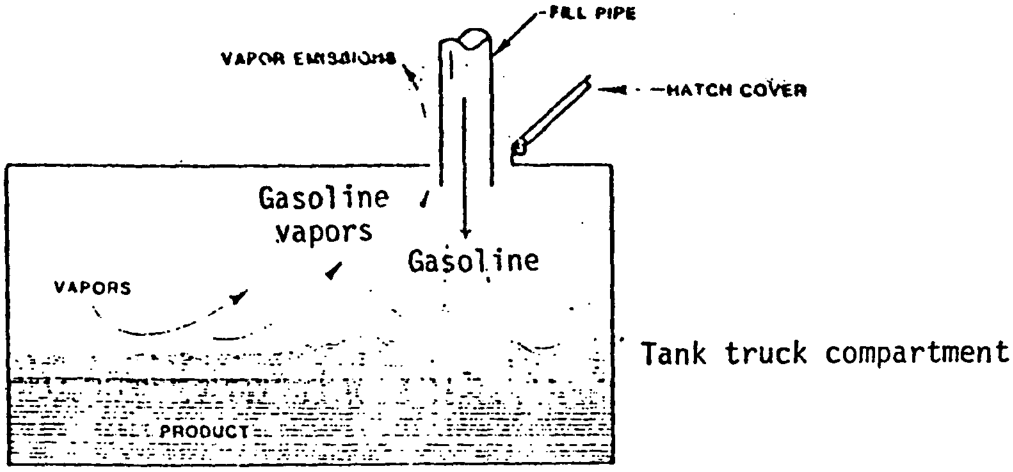
While throughput and storage capacities of terminals are subject to considerable variability, a model existing terminal can be specified as having 950,000 liters (250,000 gallon) per day throughput; three floating roof gasoline storage tanks of 8.74 million liters (55,000 barrels) capacity each; and two loading racks with three top loading, submerged fill arms per rack. There is a trend toward bottom fill in the industry today.[9] Figure 2-3 depicts a simplified schematic of bottom loading at bulk gasoline terminals.

While benzene is emitted from both loading operations and storage at the terminal, the major source - loading operations - will be discussed in this document. As noted above, storage tanks at terminals are generally equipped with floating roofs. Storage tank losses of benzene are relatively small (estimated to be about 20 kg/yr) compared to tank truck loading losses (about 1300 kg/yr for the typical terminal).

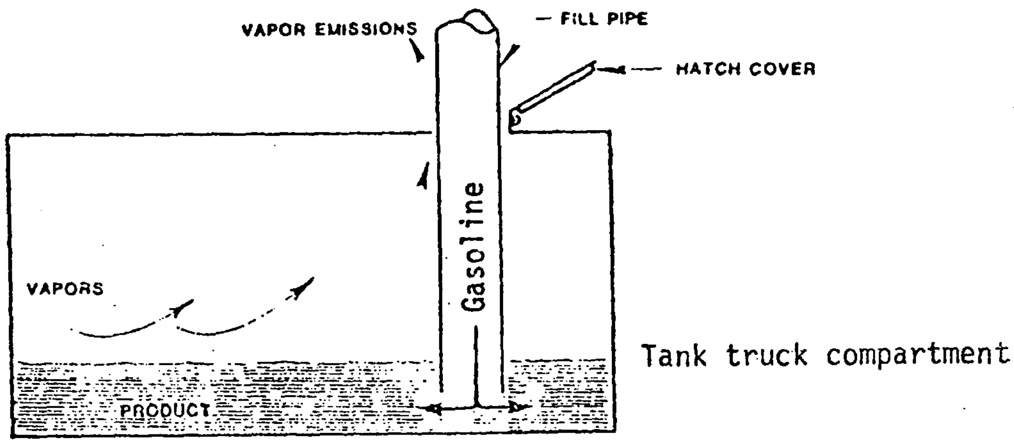
Gasoline is pumped from the large above ground storage tanks at a rate of 1500-2300 liters (400-600 gallons) per minute.[10] (See Figure 2-4).

FIGURE 2-3. SCHEMATIC OF BOTTOM-LOADING TANK TRUCK TERMINAL

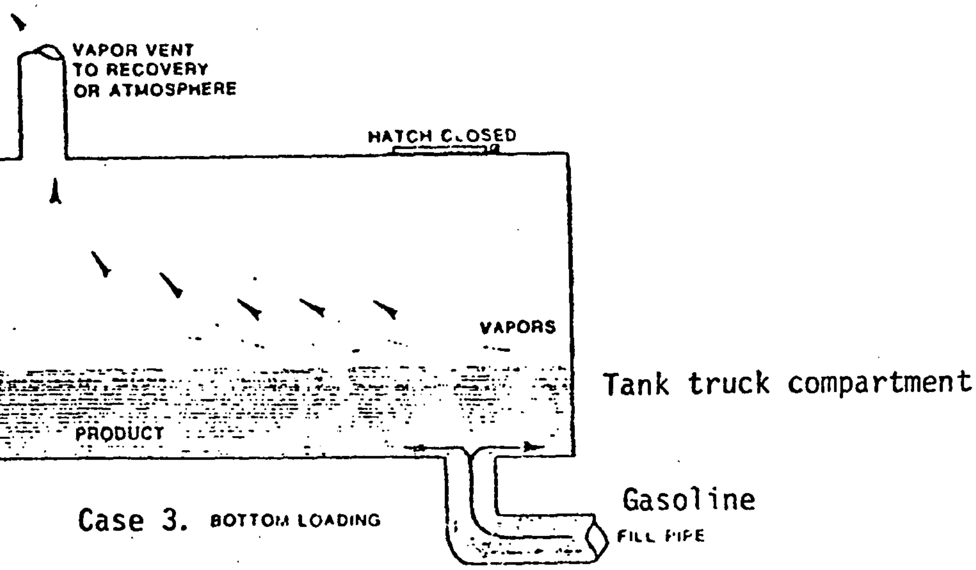




Case 1. SPLASH LOADING METHOD



Case 2. SUBMERGED FILL PIPE



Case 3. BOTTOM LOADING

Figure 2-4. Gasoline Tank Truck Loading Methods

Gasoline is transferred through a 10 centimeter (4 inch) pipe to the top of the truck. The truck contains 4 or 5 compartments, each having an access hatch atop the truck. Gasoline is loaded through these hatches in pipes (loading arms) which are extended to within 15 centimeters (6 inches) of the bottom of the compartment. Assuming each tank truck compartment has 5700-7500 liters (1500-2000 gallons) capacity and the pump rate averages 1900 liters (500 gallons) per minute, it takes 3 to 5 minutes to fill each compartment after the liquid hose is lowered through the hatch into the compartment. A measured amount of gasoline is loaded into the compartment through a preset meter. A liquid level sensor in each compartment is electrically connected to the pump and shuts the pump off should the compartment be overfilled. As an example, a set of 3-5 loading arms, 3-5 pumps, and attendant piping may be collectively known as the loading rack.

As the gasoline is loaded, vapors present in the tank truck are displaced to atmosphere through the hatches. In the typical case of top submerged filling, turbulence in the compartments is minimal. The turbulence of the splash fill operation causes entrainment of gasoline mist and droplets in the vapor space which are subsequently emitted to the atmosphere through the hatches. Economics dictates that submerged fill be installed at terminals that are now equipped with splash fill.

The trend in the industry is to convert trucks to bottom fill. In bottom fill, gasoline is loaded through 10 centimeter (4 inch) diameter couplings on the bottom of each compartment. Hatches remain closed during filling of a truck so equipped. The tank truck compartments are manifolded to a common vent pipe which directs displaced hydrocarbon vapors to atmosphere. An estimated 25 percent of all terminals now have bottom fill.[11]

Emission factors for these three configurations are shown in Table 2-1. Bottom fill and top submerged fill share the same emission factor (4.8 mg of benzene per liter of gasoline loaded), since turbulence is minimal in both. Splash fill has a higher emission factor because of the entrainment of droplets of gasoline (11.2 mg of benzene per liter of gasoline loaded).

The term "balance service" in Table 2-1 refers to the situation in which transport trucks return to the terminal with the vapor space nearly saturated with hydrocarbons from "balanced" bulk plants or service stations. In effect, the transport truck has exchanged the liquid gasoline for the vapors displaced by filling the gasoline storage tanks at the service station or bulk plant. The benzene emission factor for both splash and submerged loading in "balance service" is 8 mg/liter.[12]

2.3 BULK GASOLINE PLANTS

Bulk gasoline plants are intermediate distributors which receive product primarily by truck. Commonly the bulk plant will have a daily throughput of 15,000 liters (4000 gallons) and will have three above ground fixed roof storage tanks of 38,000-76,000 liter (10,000-20,000 gallon) capacity each, one unloading-loading rack with three overhead arms, and two delivery trucks.[13]

In 1972 there were 23,367 bulk plants in the United States.[14] (Current estimates run closer to 18,000.) Gasoline throughput (bulk plants handle other distillates and often agricultural supplies), was estimated to be 165 million liters (44 billion gallons) per year in 1977.[15] The number of plants is declining due to a trend toward the use of terminals as opposed to plants for distribution. There is an economic

TABLE 2-1. NATIONAL BENZENE EMISSIONS FROM THE GASOLINE MARKETING INDUSTRY

SOURCE	Hydrocarbon mg/l	Benzene mg/l	Throughput liters/yr (1 gallon = 3.8 liters)	National BZ Emissions Metric Tons per/yr - U.S.
Bulk Terminal Loading Trucks				
Top Submerged	600 1/ (1000)2/	4.8 (8)	413 X 10^9 3/	1980
Bottom Fill	600 (1000)	4.8 (8)		
Splash Fill	1400 (1000)	11.2 (8)		
Bulk Plants Storage	600 - Breathing	4.8	165 x 10^9 3/	792
	460 - Emptying	3.7		607
	1150 - Filling	9.2		1518
Loading	1400 - Splash	11.2	165 x 10^9	1848
Service Station Underground Storage Tank				
Filling 4/	880 Submerged	7.0	413 x 10^9	3734
	1380 Splash	11.0		
Breathing 5/	60	0.5		207
Emptying	60	0.5		207
			TOTAL	10,893

1/ Model facility.
2/ Parentheses denote trucks are in balance service at stations. This factor has been rounded off from 960 mg/l.
3/ Does not account for an undetermined amount of gasoline delivered to small farms. The quantity is expected to be small.
4/ About 50 percent of all stations have submerged fill, 50 percent splash.
5/ Breathing and emptying losses are generally estimated together for service stations. For this table it was assumed the two are equal. In reality, breathing losses would likely be much lower than emptying losses.

advantage in delivering gasoline directly to the service station where possible. (For more detail of current industry statistics, see Chapter 6.0, Section 6.2.1, "Bulk Plant Industry Characterization.")

There are two major source areas in bulk plants - storage tanks and loading of delivery trucks at loading racks. Unlike bulk terminals, storage tank losses are significant at the bulk plant. Figure 2-5 depicts the bulk plant and its emission sources.

2.3.1 Gasoline Storage

Gasoline is stored in 38,000-76,000 liter (10,000-20,000 gallon) capacity tanks at the bulk plant. The tanks are generally located above ground and are loaded by pumping gasoline from large transport trucks to the bottom of the 8 meter (26 foot) high storage tank. Ordinarily, a single pump serves for both loading and unloading, but separate pumps are provided for different tanks, especially where different grades of gasoline are stored. Atop each tank is a pressure-vacuum relief valve which vents to atmosphere when the pressure exceeds a preset limit (usually 2600 pascals or 6 oz/in^2 pressure).

Benzene can be emitted with other hydrocarbons during loading and unloading of the tank (working losses) or during normal expansion of vapors due to temperature changes during the day (breathing losses). Table 2-1 shows these emission rates.

Working losses occur during the filling and the emptying of liquid in the tank. As gasoline liquid is pumped into the tank, vapor is displaced to atmosphere (filling loss). As gasoline is pumped out, fresh air is brought into the tank by the vacuum of diminishing liquid volume. This fresh air gradually becomes saturated with vapors, expands, and a vapor laden portion of the volume is emitted (emptying loss). Working losses account for about

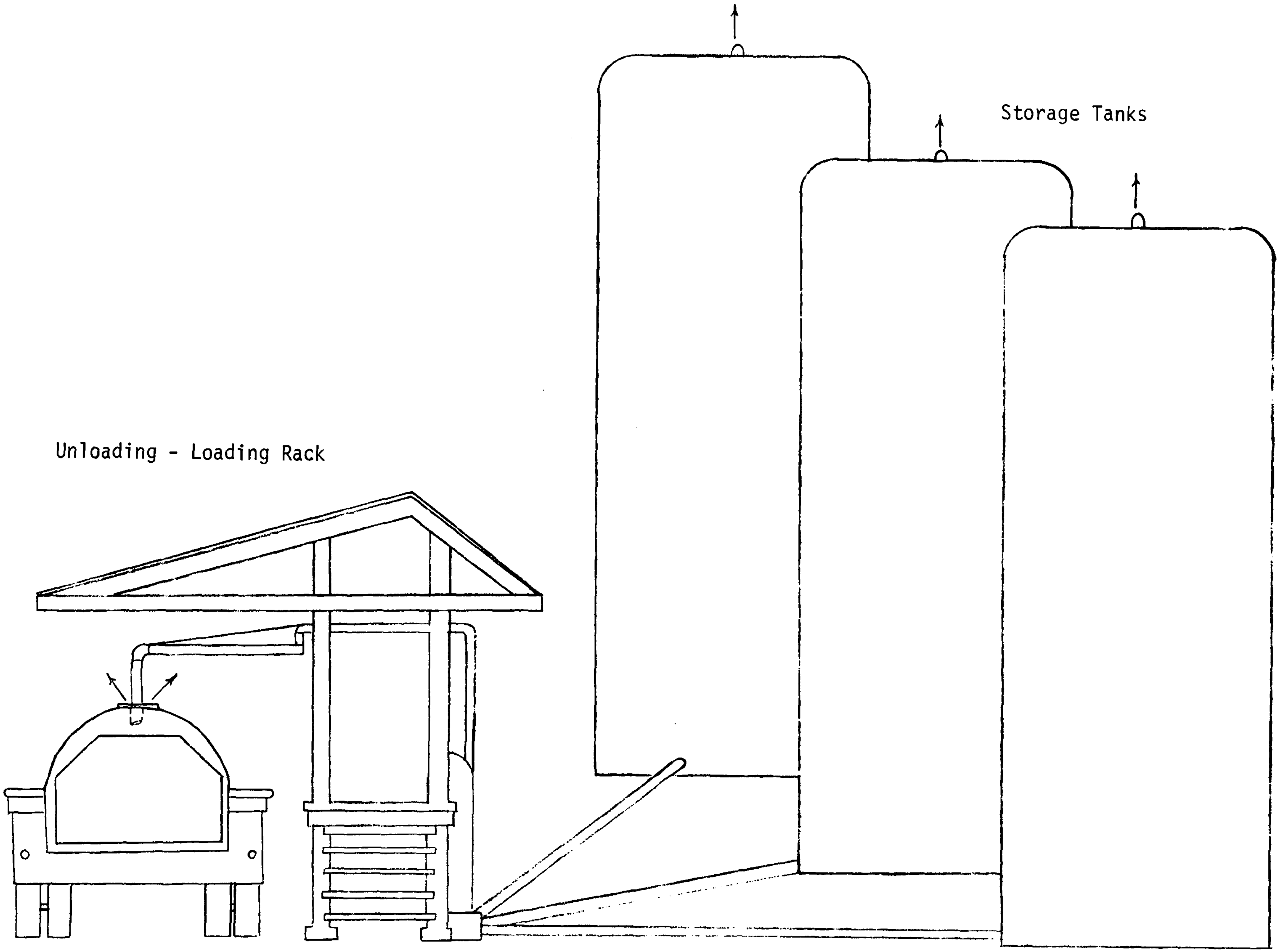


Figure 2-5 Typical Bulk Plant

(delivery truck splash loading)

13 mg of benzene per liter of gasoline pumped.[16] (3.7 mg/l for emptying loss and 9.2 mg/l for filling loss.)

Breathing losses occur due to temperature changes during the day. These diurnal fluctuations cause the vapor volume in the vapor space to expand and contract. As it expands, a portion is vented to atmosphere since the tank has a fixed volume. As it contracts, fresh air is brought in and saturated. The vapor space is expanded and vented - in the same fashion of unloading working losses. Breathing losses are affected by a number of factors including ambient temperature and color and condition of storage tanks. While breathing loss emission rates are difficult to typify, this document uses 4.8 mg of benzene per liter of liquid pumped to define breathing losses for a typical bulk plant having three storage tanks.[17]

2.3.2 Loading of Delivery Trucks

Deliveries of gasoline from the bulk plant are made in small 5700-11,000 liter (1500-3000 gallon) capacity tank trucks. These trucks are generally loaded via the hatches by top splash fill at a pump rate of 380-760 liters (100-200 gallons) per minute.[18] (Top splash fill is accomplished through open hatches atop the truck tank.) Clients of bulk plants include agricultural interests, remote service stations, and service stations in areas inaccessible to large trucks.

Loading losses are given in Table 2-1. Delivery trucks emit 11.2 mg of benzene per liter of gasoline pumped during loading by splash fill.

2.4 SERVICE STATIONS

Service stations, as defined in this document, include all motor vehicle refueling operations. This includes retail outlets, which numbered 178,000 in 1977.[19] A retail outlet receives more than 50 percent of revenue from sales of gasoline. The definition of service station also includes the non-retail and miscellaneous outlets which numbered 243,000 in 1977.[20] Non-retail stations include governmental, commercial, or industrial fleet operations (e.g. the U. S. Post Office, rental car agencies, etc.) Miscellaneous stations include large agricultural accounts, marinas, parking garages and others which obtain less than 50 percent of revenue from gasoline sales. The estimate does not include an estimated 2.7 million small farm accounts.

Total national throughput in 1977 was 413 X 10^9 liters (109 X 10^9 gallons) at service stations.[21] Retail outlets pumped 77 percent of this or 318 X 10^9 liters (84 X 10^9 gallons). A typical retail outlet has a throughput of about 150,000 liters (40,000 gallons) of gasoline per month. It has six to nine nozzles for refueling (about half of retail stations are full service and half have some self service). There are three underground storage tanks of 38,000 liter (10,000 gallon) capacity each.

Non-retail and miscellaneous outlets pump about 23 percent of total gasoline consumed in the United States. Their throughput is generally less than 38,000 liters (10,000 gallons) per month, per facility.[22]

Emissions can occur from two major sources in service stations - the loading of storage tanks (underground) and the refueling of motor vehicles. This document will deal with the former only. Figure 2-6 illustrates the loading of storage tanks at service stations. (Minor sources include breathing and emptying losses from underground storage tanks and spillage.)

The loading of underground storage tanks is accomplished by gravity. The tanks are coupled to the delivery tank truck by flexible ten centimeter (four inch) diameter hoses. On-truck valves are opened and the liquid gasoline is dropped

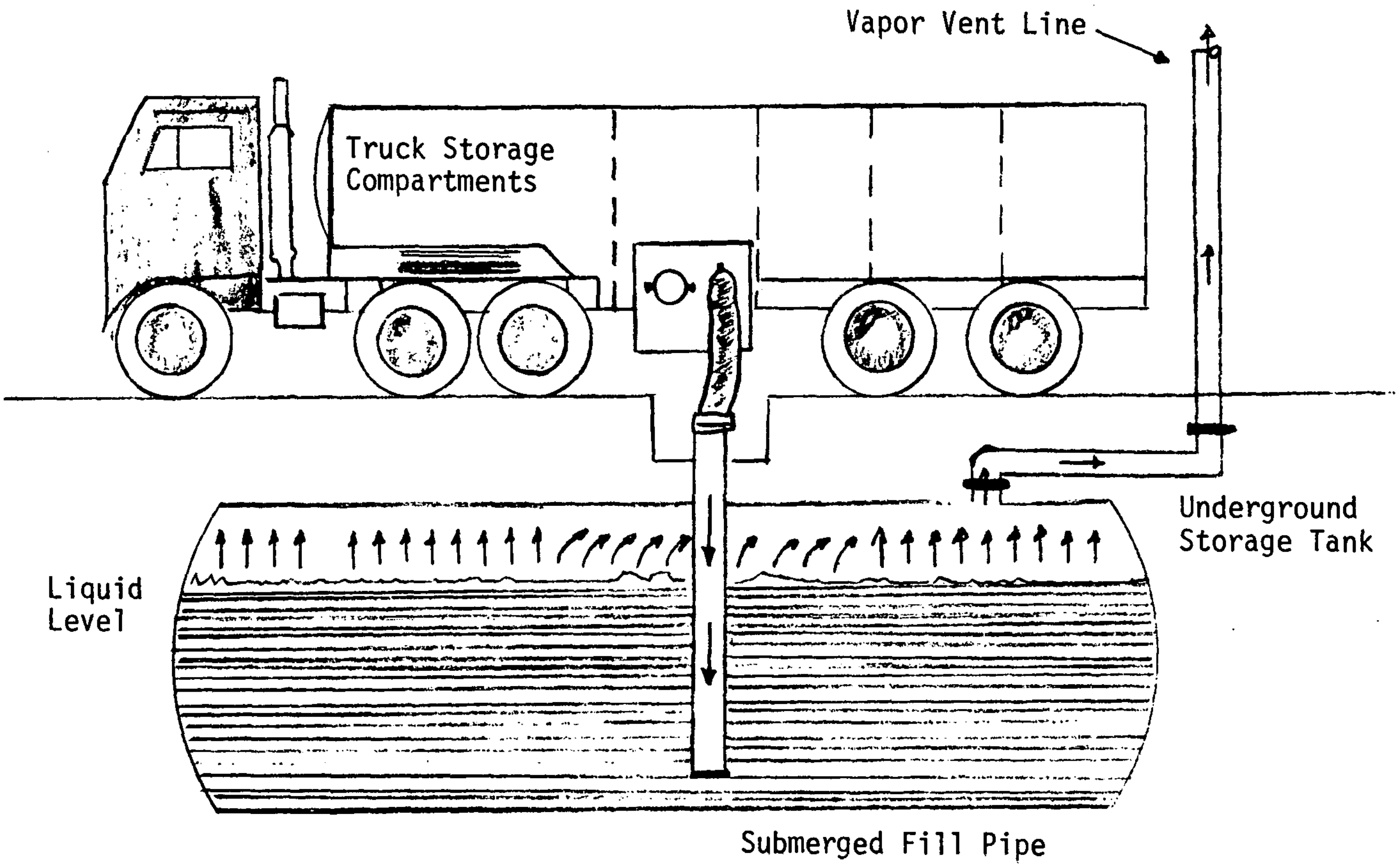


FIGURE 2-6. TANK TRUCK UNLOADING INTO AN UNDERGROUND SERVICE STATION STORAGE TANK

into the storage tank. Displaced vapors (filling losses) are vented to atmosphere via a vent pipe usually located at the rear of the station. Unloading losses (emptying losses) are generated as discussed in Section 2.3. These emptying losses are generally very small. Storage tank losses are shown in Table 2-1. The table shows the difference between splash loading the tank and drop or submerged filling. About 50 percent of stations are currently equipped with submerged fill and the other half have splash fill. A typical emission factor falls in between, therefore, and is 9 mg of benzene per liter of gasoline pumped.[23]

Because a great majority of service station tanks are underground (in compliance with safety regulations) diurnal temperature changes have little effect on emissions. Breathing losses do occur, however, and as Table 2-1 shows, these losses summed with emptying losses are 1.0 mg of benzene per liter of gasoline pumped.[24] Because control technology such as vacuum assist and balance systems used for controlling emissions from the refueling of automobiles also controls emptying and breathing losses, this document shall omit discussion of these two relatively small sources. Breathing and emptying losses will be discussed in an upcoming study of benzene emissions from automobile refueling.

2.5 GASOLINE TANK TRUCKS

Losses from trucks can occur during loading and in transit. Loading losses occur because of vapor displacement and are described below. Transit losses are due to vapor breathing or vapor leaks during transit. There is currently only a limited amount of data on the significance of transit losses from trucks.

2.5.1 Tank Truck Description

There are two basic types of tank trucks used for gasoline delivery; tractor-semi tank trailers and straight tank trucks. Tractor-semi tank trailers range in total capacity from 30,000 to 36,000 liters (8,000-9,500 gallons) with one to six compartments for different grades of gasoline or other products. Straight tank trucks are smaller with a total capacity of 5,700 to 11,000 liters (1500-3000 gallons) and one to six compartments. Each type of tank truck may pull a full trailer in some states of equal or less total storage capacity. Each compartment has a hatch opening, dome cover, pressure-vacuum relief valves and vents. Because tank trucks usually vary only in size and shape, no distinction will be made between the two when discussing the emission sources.

The hatch opening on top of the truck tank is for access in cleaning and maintaining the tank. A dome cover or lid is used to seal the hatch opening during transport and loading-unloading operations. The hatch lid also serves as a pressure relief valve. If extreme pressure or vacuum is built up the hatch lid will lift (normally at 20,000 pascals or 3 psi) to relieve this pressure.

The pressure-vacuum (P-V) valve is completely open at 6900 pascals-- (1 psig) pressure or 2600 pascals (6 ounces) vacuum (required by Department of Transportation) for normal venting during loading-unloading operations and during transfer operations. These P-V valves are normally a spring loaded type valve.

An emergency vent (high capacity vent) is another major relief system for the compartment. These vents are mechanically or air actuated when bottom loading or unloading the tank to relieve pressure or vacuum during the loading-unloading operation. On vapor collection tank trucks, the emergency vent is encased in metal or rubber (hoods) and the vapors are vented through piping to the bottom side of the tank. When top loading without vapor recovery, these emergency vents are not normally used because the hatches are open and vapor escapes around the loading arm.

2.5.2 Sources of Emissions

The major emission sources on tank trucks are the hatch covers, P-V vents, valves and power vents. Losses from truck tanks occur during loading and in transit. Loading losses occur because of vapor displacement and are described in this chapter. Transit losses are due to vapor breathing and vapor leaks during transit. During EPA testing of five terminals the average tank truck leakage was found to range from 46 to 155 mg of hydrocarbons per liter loaded [25] (or 0.37 to 1.2 mg of benzene per liter loaded).

Hatch Covers

A dome or hatch cover is used to seal the hatch opening during transport and bottom loading-unloading operations. The seal around the dome cover and around the base ring where the cover attaches to the tank shell are the most likely locations for leaks to occur when the dome cover is closed. During top loading operations (without vapor collection) the hatch cover is open, therefore these leaks occur only during transit. These leaks can be caused by cracked or worn seals, warped or damaged hatch covers, and cracked or improperly installed dome cover base rings.

P-V Relief Valves

Leaks can also occur at the P-V valves when the dome covers are closed during bottom loading, unloading, and transfer. Emissions occur when the set pressure or vacuum is exceeded, or when they are not properly maintained. The valve seat may become dirty or damaged which would not allow the valve to seal properly. The valve actuating device, such as a spring on a spring loaded valve, may become damaged also allowing improper sealing and cause leakage. Also, many of the P-V vents partially open before the set pressure or vacuum is reached and fully open at the set pressure or vacuum.

Emergency Vents

Emergency vents may leak when closed if the vent is not installed properly or is not maintained properly. The vent seal may become dirty or damaged which would not allow the valve to seal properly. In cases where the vent is encased for vapor collection, seals, hoods, and rubber hoses may become cracked or loose which would allow vapor leakage.

Miscellaneous Sources

Other emission sources may occur from various locations around the tank truck. Improperly installed or damaged hose couplers can be emission sources. The tank shell, if damaged, can produce emission sources from cracks or failures in welds or failure of tank shell itself. These types of leaks occur less frequently than those discussed previously, but may be large emission sources on some truck tanks.

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14. Reference 6, Op. Cit.

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16. "Supplement No. 7 for Compilation of Air Pollutant Emission Factors, Second Edition," U.S. EPA, April, 1977.

17. Reference 13, Op. Cit.

18. Reference 13, Op. Cit.

19. Reference 7, Op. Cit.

20. Reference 7, Op. Cit.

21. Reference 7, Op. Cit.

22. Reference 7, Op. Cit.

23. Reference 16, Op. Cit.

24. Reference 16, Op. Cit.

25. "Control of Hydrocarbons From Tank Truck Gasoline Loading Terminals," EPA-450/2-77-026, October, 1977, Table 3-2, page 3-5.

3.0 EMISSION CONTROL TECHNOLOGY

The purpose of this chapter is to describe available control techniques which can be used to reduce benzene emissions from the gasoline marketing network.

3.1 USE OF CONTROL METHODS

With the exception of reduction of benzene in liquid gasoline at the refinery, all control techniques discussed in this chapter have been applied to hydrocarbon sources in bulk terminals, bulk plants, or service stations. The techniques have been applied to comply with air pollution regulations designed to minimize hydrocarbon emissions in certain Air Quality Control Regions, not because of economic incentives. The source test data developed to support control of hydrocarbon emissions can be used to support control of benzene emissions also. As discussed in Chapter 2, empirical correlations were developed to derive benzene emission factors from hydrocarbon emission factors. Therefore, data derived from control of hydrocarbon emissions are used, in part, as the basis for control of benzene emissions in this study. In addition, EPA has collected data on the effect of controls on benzene specifically. Chapter 2 indicates that for the conditions under which equilibrium data were derived ($27^{o}C$, 1.3 liquid volume percent benzene in gasoline), 0.008 grams of benzene are emitted with every gram of hydrocarbon emitted. This provides an emission factor for benzene in gasoline.

Table 3-1 summarizes hydrocarbon emission data gathered by source tests of various emission control techniques employed at bulk terminals, bulk plants, and service stations. Estimated and measured benzene emissions are included in the table.

3.2 BULK TERMINALS

About 300 vapor control systems have been installed and are in commercial operation at tank truck gasoline loading terminals. Stage I service station controls (balance systems between underground storage tanks and tank trucks) have provided impetus for such installations in Air Quality Control Regions with oxidant problems, since the vapor in trucks must be controlled.

The benzene content of gasoline vapors vented to vapor control systems source tested by EPA at tank truck loading terminals are approximately 4.8 mg/l of gasoline loaded. It should be noted that many trucks in these tests leaked and many were "lean" (only partially saturated), which are both conditions which affect processor efficiency. Benzene test data indicate outlet emissions are in the range of 0.003 to 0.33 mg/l of gasoline loaded. Table 3-1 (tests A through F) summarizes actual EPA hydrocarbon test data (including total hydrocarbon and estimated benzene mass rates in grams per liter of gasoline transferred). Tests G through K summarize actual EPA test data for benzene at terminals.

A brief process description of the types of vapor control systems installed at gasoline tank truck loading terminals and source tested by EPA follows.

TABLE 3-1. SUMMARY OF BENZENE EMISSION TESTS

SOURCE	Test	Date	Control Device	Size of Facility	Processor Outlet Total HC mg/l	Processor Outlet Total Benzene mg/l
Bulk Terminals	A	12/10-12/74	CRA	600,000 l/day	31.2	N/A
Truck Loading	B	12/16-19/76	RF	380,000	37	N/A
	C	9/20-22/76	RF	1,430,000	33.6	N/A
(See References	D	9/23-25/76	CRA	1,190,000	43.3	N/A
1-11)	E	11/18/73-5/2/74	TO	1,100,000	1.3	N/A
	F	11/10-12/76	RF	810,000	62.6	N/A
	G	5/25-27/77	AA	284,000	30	.003 2/
	H	12/16/77	CRA	600,000	41.1	.106 2/
	I	1/10-12/78	TO	1,000,000	34.2	.330 2/
	J	3/7/78	RF	810,000	53.4	.052 2/
	K	3/1-5/78	CRA	1,000,000	-	.080 2/
Bulk Plants Storage Tanks	A	7/76	Balance	64,000 l/day	8.5	0.07 1/
	B	8/76	Balance	13,000 l/day	46	0.37 1/
Delivery Trucks	A	7/76	Balance	64,000 l/day	81	0.65 1/
	B	8/76	Balance	13,000 l/day	75	0.60 1/
Service Stations	A	6/12/74	Balance	~150,000 liters/mo	7.9	0.06 1/
Filling Storage Tanks 3/	B	6/18/74	Balance	~ 75,000 liters/mo	10.6	0.08 1/

1/ Estimated from hydrocarbon test data.

2/ Test data - preliminary results

CRA - Compression-Refrigeration-Absorption
RF - Refrigeration
TO - Thermal Oxidizer
AA - Adsorption-Absorption

3/ Other systems which incorporated treatment of auto refill losses in addition to storage tank filling were tested by EPA. The systems had higher efficiency than the two tests shown here. (See Appendix C)

3.2.1 Refrigeration Systems (RF)

The principle of the straight refrigeration system (RF) is based on the condensation of gasoline vapors by refrigeration at atmospheric pressure. It is estimated that 90 units of this type are in commercial operation.[12] Vapors displaced from the trucks enter a double pass fin-tube condenser where they are cooled to a temperature of about -73°C and condensed. The remaining air containing 3 to 5 percent hydrocarbon is vented to the atmosphere. Because vapors are treated as they are vented from the tank trucks, no vapor holder is required. Condensed gasoline is withdrawn from the condenser and separated from condensed water. Hydrocarbon condensate is returned to premium gasoline storage tanks and water typically passes to a slop tank or oil-water separator. A simplified schematic of a recent model of this type of vapor recovery system is shown in Figure 3-1. A source test for benzene was conducted on a refrigeration unit (Test J). Outlet emissions of benzene from the unit averaged 0.052 mg/l. Inlet vapors to the unit contained an average of 0.99 mg of benzene per liter of gasoline.[13]

3.2.2 Compression-Refrigeration-Absorption Systems (CRA)

The compression-refrigeration-absorption vapor recovery system (CRA) is based on the absorption of gasoline vapors under pressure with chilled gasoline from storage. Incoming vapors are first passed through a saturator where they are sprayed with fuel to ensure that the hydrocarbon concentration is above the explosive level. This is done as a safety measure to reduce the hazards of compressing hydrocarbon vapors.

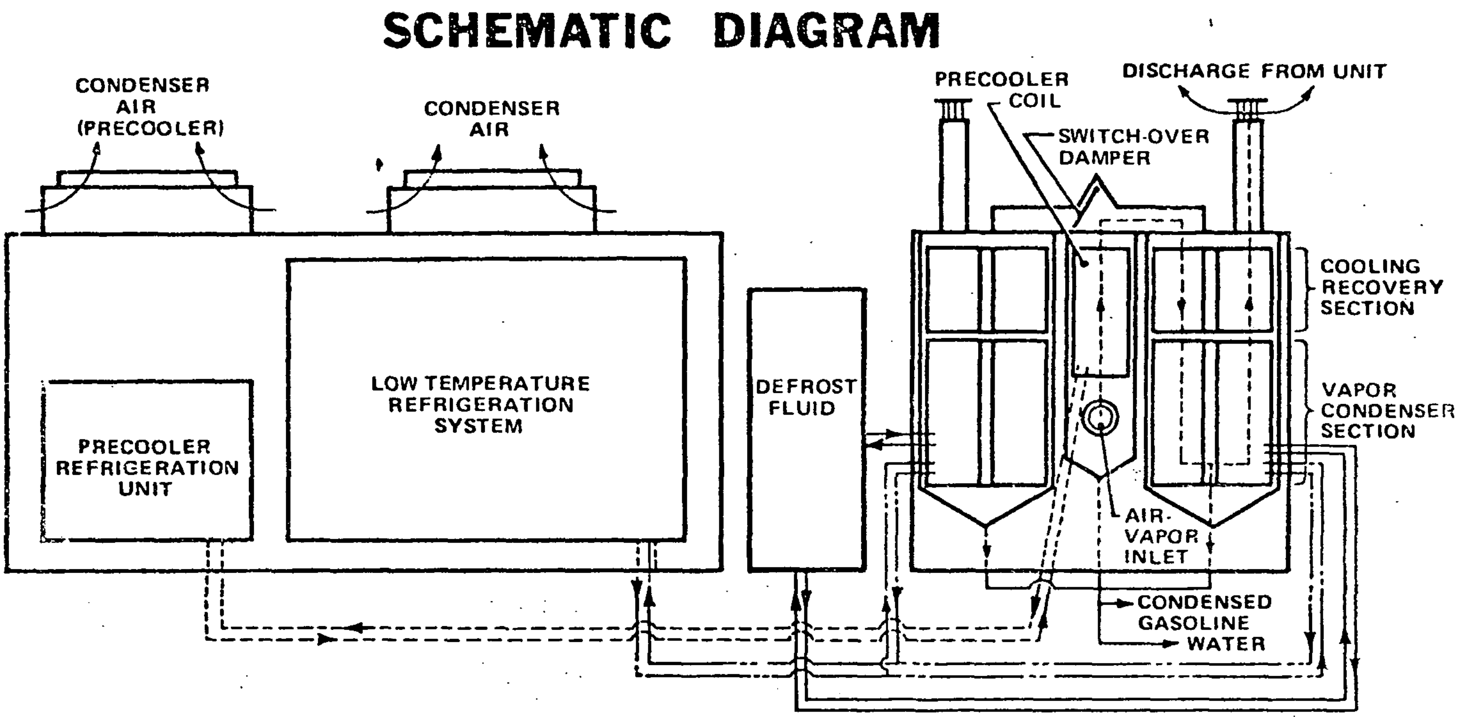


FIGURE 3-1. REFRIGERATION VAPOR RECOVERY UNIT
by Edwards Engineering Corporation

The partially saturated vapors are then compressed and cooled prior to entering the absorber. In the absorber, the cooled, compressed vapors are contacted by chilled gasoline drawn from product storage and are absorbed. The remaining air containing only a small amount of hydrocarbons is vented from the top of the absorber and gasoline enriched with light ends is withdrawn from the bottom of the absorber and returned to the gasoline storage tanks. A schematic of a typical system is shown in Figure 3-2.

One CRA unit test by EPA at a tank truck loading facility averaged benzene outlet emissions of .106 mg/l. The benzene content of the inlet vapors to the unit was approximately 2.45 mg/l.[14] (Test H on Table 3-1.)

3.2.3 Adsorption-Absorption (AA)

A recently developed vapor recovery system is carbon bed adsorption-absorption (AA). This type of system commonly consists of two vertically positioned carbon beds and a vacuum regeneration system. During normal tank truck gasoline loading operations,one carbon bed is in the adsorbing mode and the other carbon bed is in the regeneration mode.

Hydrocarbon vapors collected during the adsorbing mode are stripped from the carbon bed by vacuum during the regeneration cycle. The vapors pass through a gasoline condensing bath which is returned to the supply tanks as liquid gasoline. Water is removed in a separator. The air and any remaining hydrocarbons exiting from the condensing bath are then passed through an absorber utilizing gasoline as the absorbent and exhausted

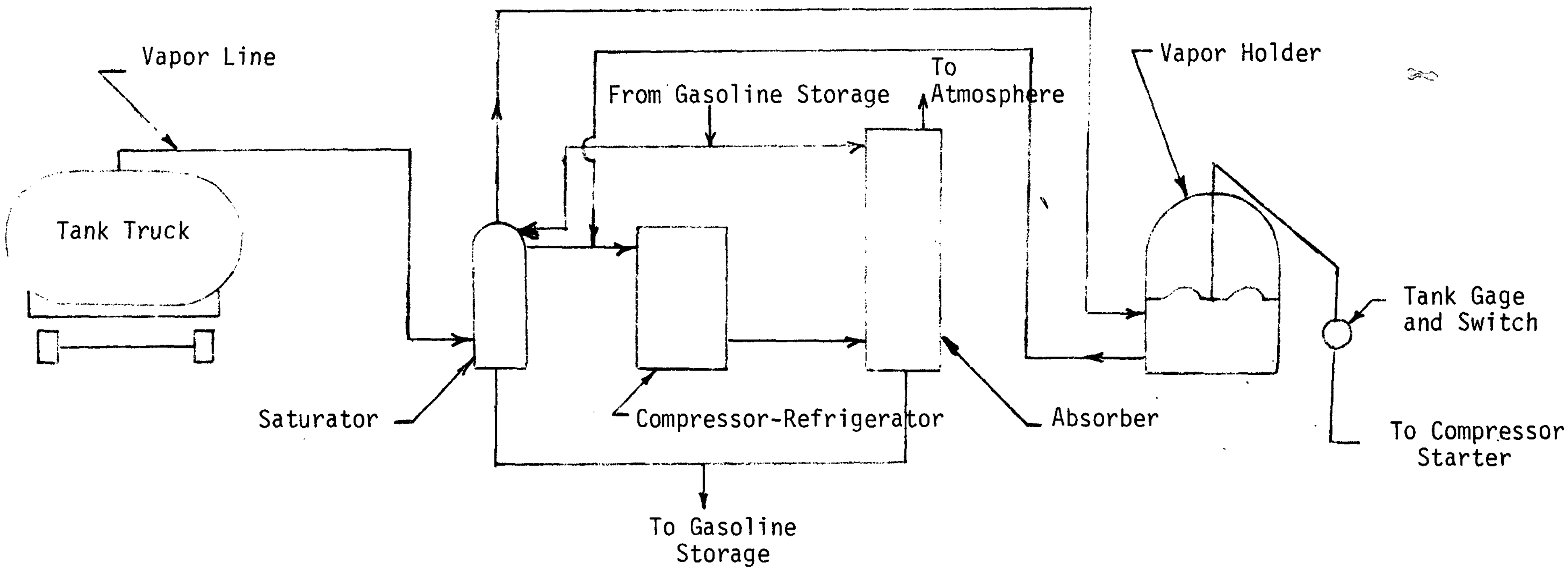


FIGURE 3-2. SCHEMATIC OF COMPRESSOR-REFRIGERATION-ABSORPTION SYSTEM (CRA)

to atmosphere. Thus, during regeneration even when no trucks are being loaded with gasoline some hydrocarbon vapors are vented from the control equipment. A schematic of a typical unit is shown in Figure 3-3.

During a source test of an adsorber-absorber (Test G on Table 3-1), benzene emissions at the outlet of the vapor control equipment averaged .003 mg/l. Inlet vapors to the unit contained an average of 2.5 mg/l of benzene.[15] All tests were performed for a relatively short period of time on a new carbon bed. No data are available on the bed life of the adsorber. Insufficient data are available to determine if bed life is affected by vacuum desorption of the carbon. During desorption heavier compounds cling to the carbon creating a "heel" which eventually builds up on the bed, lowering working capacity.[16] There has been insufficient experience with the design to determine how fast the heel builds up. Other modes of regeneration have not been evaluated for this application.

3.2.4 Oxidation Systems

Table 3-1 indicates that there is not a significant difference between oxidation and vapor recovery in terms of benzene control efficiency. Gasoline vapors from loading operations at one terminal were displaced to a vapor holder as they were generated. The vapors were kept above the upper explosive limit in the vapor holder by injecting propane. When the vapor holder reached its capacity, the gasoline vapors were released to the oxidizer after mixing with a properly metered air stream and there the vapors were combusted. The thermal oxidizer is not a true incinerator, rather it operates in the manner of an enclosed flare. A simplified schematic of the system is shown in Figure 3-4.

Twelve to fifteen oxidizers have reportedly been installed by terminal operators. Later models of this type of control equipment are not equipped with vapor holders; vapors from the tank trucks during loading operations are vented directly to the thermal oxidizer. In a recent EPA test of this type

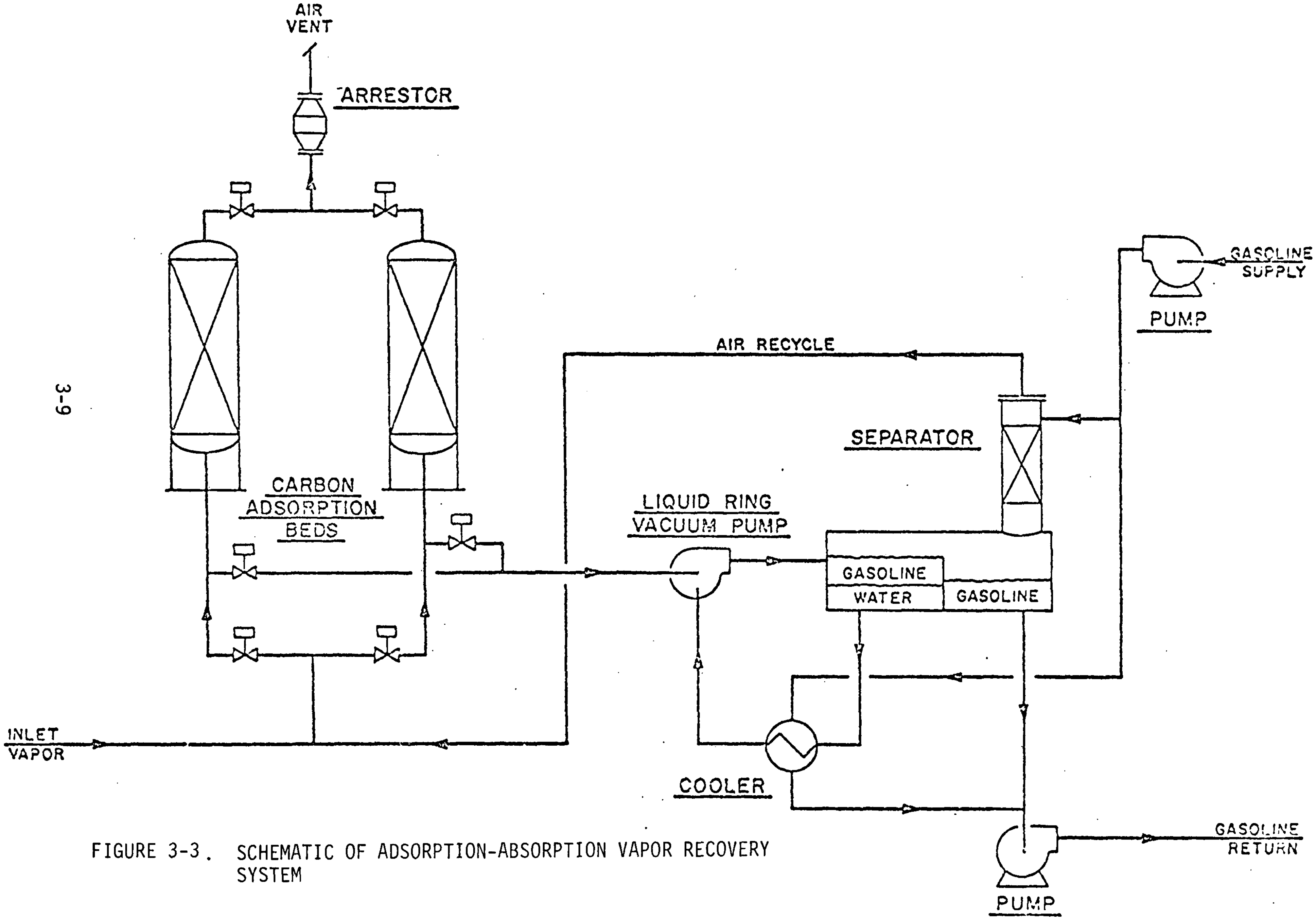


FIGURE 3-3. SCHEMATIC OF ADSORPTION-ABSORPTION VAPOR RECOVERY SYSTEM

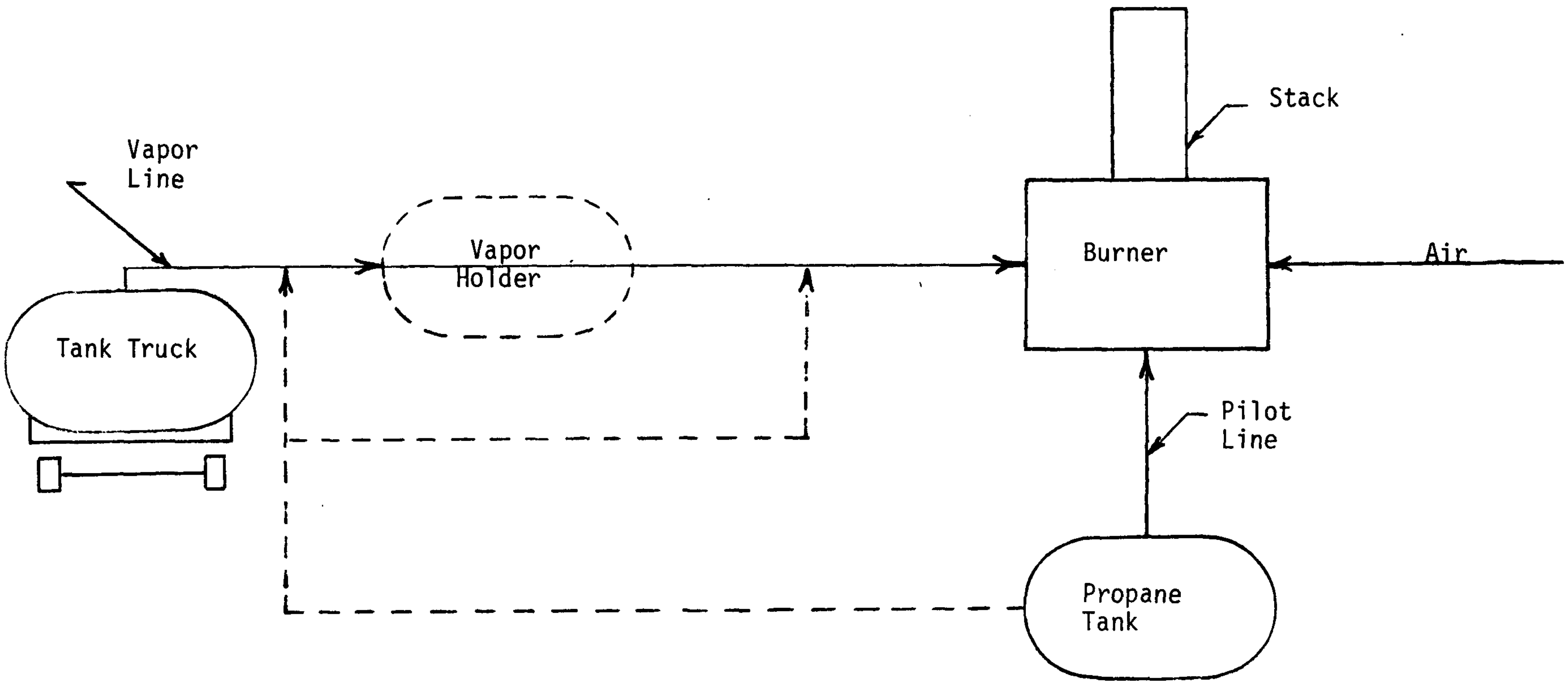


FIGURE 3-4. SCHEMATIC OF THERMAL OXIDATION SYSTEM (TO)

Note: Dotted lines represent optional equipment.

of unit (Test I on Table 3-1), benzene average outlet emissions of .330 mg/l were indicated. Inlet vapors to the unit contained approximately 1.68 mg/l.[17] The system was tested during very cold conditions. Very small amounts of hydrocarbon were vented to the oxidizer (most being condensed in the truck). Consequently, the system did not operate as efficiently as expected. This problem can be remedied with a vapor holder.

Environmental Protection Agency hydrocarbon and benzene source tests for compression-refrigeration-absorption, refrigeration, thermal oxidation, and adsorption-absorption are summarized in Appendix C.

3.3 BULK GASOLINE PLANTS

Control of gasoline working losses resulting from storage and handling of gasoline at bulk plants can be accomplished through submerged fill and balance systems. While vapor processing systems as discussed above for terminals have not been applied to bulk plants, they could be used to control both breathing and working losses from plant sources.

3.3.1 Submerged Fill

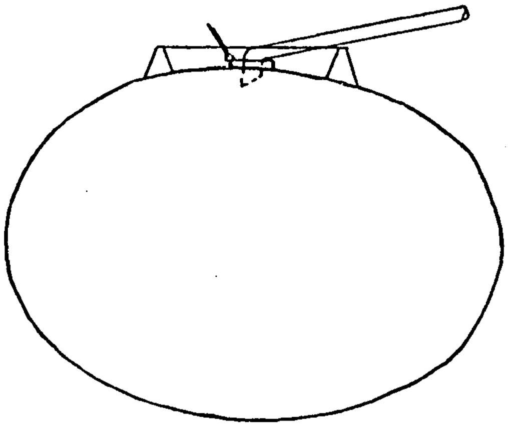
One method for controlling emissions at bulk plants is to reduce the vapors generated during filling of tank trucks and storage tanks by using submerged fill. The reason for this reduction is that submerged fill decreases turbulence and evaporation and eliminates liquid entrainment. (Bulk plant storage is typically equipped with submerged fill.) Submerged loading can be accomplished with a top submerged fill pipe or bottom filling. In the top submerged fill pipe method, the fill pipe descends through an open hatch to within 15 centimeters (6 inches) of the bottom of the compartment. In the bottom filling method, the fixed fill pipe is attached to the tank truck at the bottom of each compartment (on the side of the tank). Changing from splash to submerged loading, benzene vapors generated by filling of tank trucks can be reduced from 11.2 to 4.8 mg/liter transferred.[18]

The following discussion and figures describe three top-submerged fill systems and two bottom loading systems presently being used at gasoline bulk plants to load gasoline tank trucks.

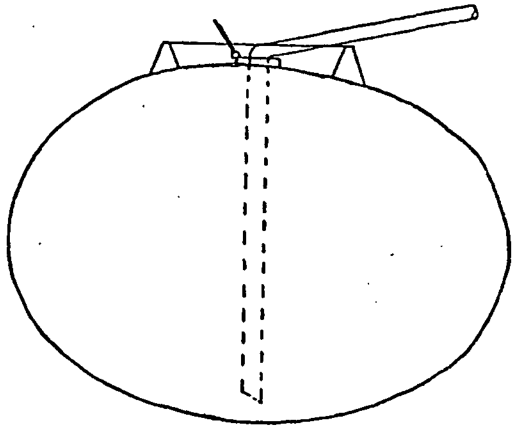
Submerged drop tubes are the simplest type of top-submerged fill system used to reduce generated emissions, but they do not collect vapors, since the hatch remains open during loading operations. Figure 3-5 shows a typical system. To convert the existing top-splash fill arm to a submerged drop tube requires attaching a straight section of pipe or a telescoping pipe onto the top-splash nozzle. The length of pipe required is determined by measuring the distance from the top-splash nozzle to within 15 cm of the bottom of the truck tank. In order to properly align and maneuver the drop tube into the open truck hatch, it may be necessary to install extra swivel joints on the loading arm. No conversion of the tank truck is needed.

The second type of top-submerged fill system is a dry break drop tube system. Figure 3-5 shows a simple schematic of this system. Principal features of the system include (1) minimal modifications to the existing loading rack; (2) the use of dry break, quick-connect connections between the top loading arm and new fill ports on the truck; (3) the use of a single vapor return line which connects to the compartment vapor hoods on the truck; and (4) the discontinued use of filling through existing truck hatches. The system requires some modification to the truck and requires meter pumps or some other overfill protection system.

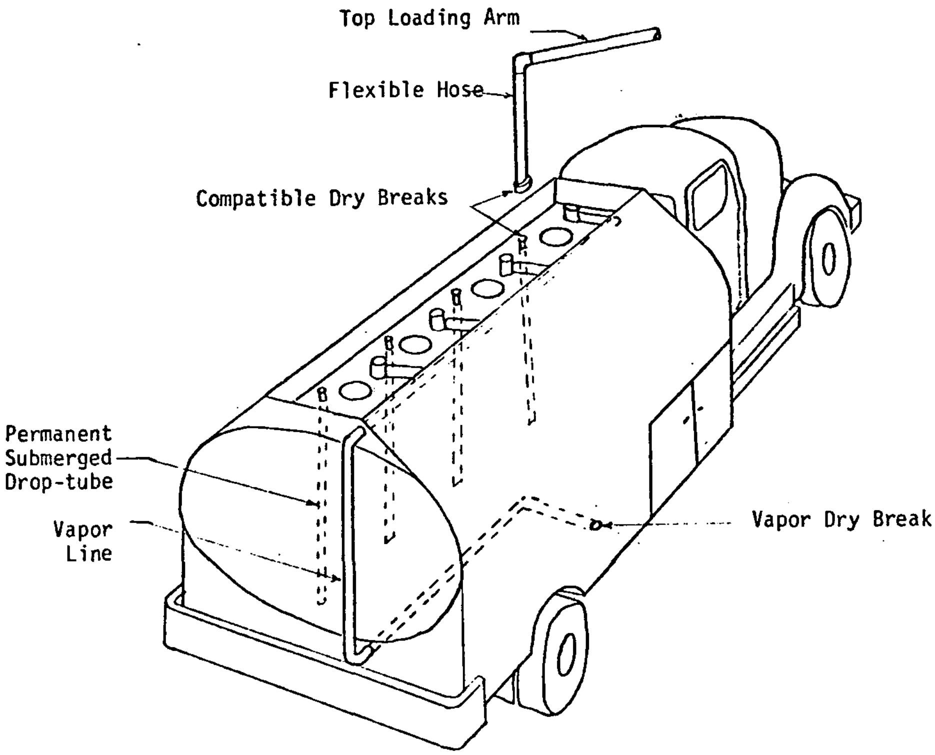
Top loading vapor heads are a third type of top-submerged fill system. Figure 3-6 shows a simple schematic of this system. Top vapor head arms consist of a splash or submerged loading nozzle fitted with a head which



TOP-SPLASH FILL
No vapor collection



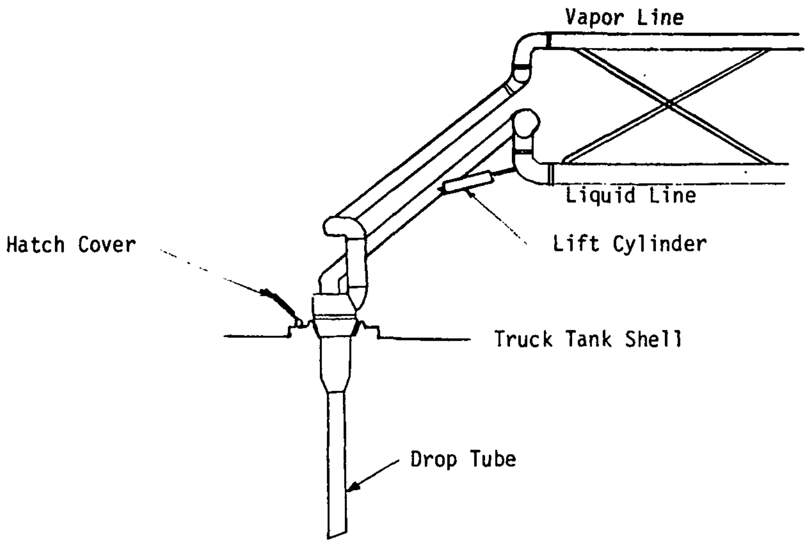
TOP-SUBMERGED FILL
No vapor collection



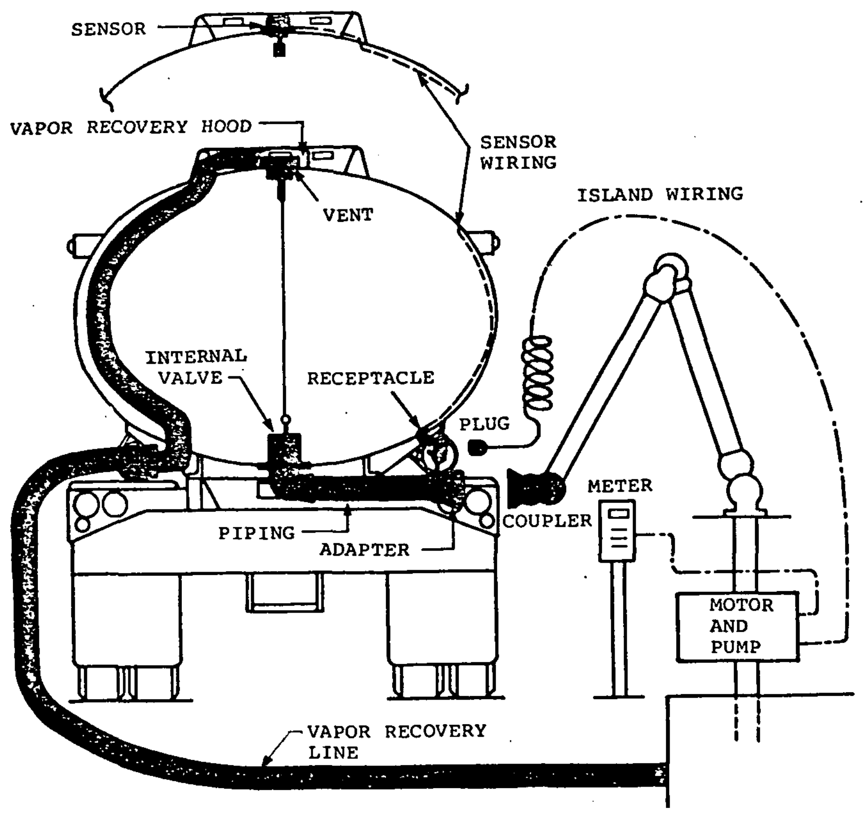
DRY BREAK DROP TUBE SYSTEM

FIGURE 3-5. TOP-LOADING SYSTEMS AT BULK PLANTS seals tightly against the hatch opening. Liquid flow is possible as long as a positive seal is maintained (pneumatically or mechanically) between the vapor recovery head and the hatch opening. Liquid is loaded through a central channel in the nozzle and the displaced vapors flow into an annular vapor space surrounding the central channel. The vapors flow into a hose on the loading arm. Since the vapor line is incapable of handling liquid overflows and the liquid level is no longer visible through the open hatch, a safety shutoff valve is included in the nozzle. Truck conversion is not necessary for the loading operation at the plant. The principal limitation to the use of this vapor recovery head at any existing top loading rack arm is its weight. The existing loading arm and rack supports must be modified to hold the vapor head. With a few types of vapor heads there must be a supply of air pressure to operate the heavy loading arm.

Bottom loading is a ground-level facility, as opposed to the elevated platform used for top loading. Here the truck is filled through adapters at the bottom of the tank. Figure 3-6 shows a simple schematic of this system. There are two major types of bottom load systems used at bulk plants, the normal type used at bulk terminals and the Wiggins system adapted specifically for use at bulk plants. Both types of bottom loading systems use the same principles of operation. Both types of bottom fill systems have several variations but a basic bottom loading system consists of: (1) an adapter, the device which permits coupling of the loading rack liquid hose to the tank truck piping; (2) liquid level sensors which prevent overfilling by shutting down the rack pumps or closing the internal valve system; and (3) a vapor collection system which collects vapors from the compartments and routes them through a common vapor manifold that terminates at a dry break on the side of the truck.



TOP LOADING VAPOR HEAD SYSTEM



Bottom Loading

FIGURE 3-6. TOP AND BOTTOM LOADING SYSTEMS

An overfill protection system is needed for loading of tank trucks when the hatches are closed. The four basic types of overfill protection systems are preset meters, meters, liquid level sensing devices, and float rods.

Most vapor controlled facilities use a preset meter on the loading rack to provide primary overfill control. The driver selects the amount of product to be loaded and when the preset volume has passed through the meter, the pump is automatically shut down. Meters without preset equipment are also used. The driver simply loads the desired amount, and shuts off the pump manually.

Liquid level sensing devices are commonly used with preset meters to provide a secondary control system in the event of a meter failure or incorrect meter setting. Liquid level sensing devices can also be used as the primary overfill protection system. There are two basic types of sensor systems commonly used for bottom loading. The most common type in use today is an electrical system in which the tank level sensor sends an electrical signal to the loading rack to shut down the pump when the tank is full. Figure 3-6 (bottom loading) shows a simple schematic of this system. The other type of system is completely self-contained on the truck and closes the tank inlet valve when the sensor determines that the tank is full. The loading rack pump is then shut off manually.

Floats and level rods are being used at bulk plants with the dry break drop tube system discussed earlier. As the liquid level reaches the float, the graduated rod rises and the liquid level is visually determined. Rubber o-rings are installed to seal around the rod to eliminate the escape of vapors. When not being used, a cap is placed over the fitting. If the rod is in the full position, the rod is simply pushed down and the cap installed.

3.3.2 Balance System

The displacement, or vapor balance system, operates by transferring vapors displaced from the receiving container to the container being unloaded. A vapor line between the truck and storage tanks essentially creates a closed system permitting the vapor spaces of the two vessels to balance with each other. (See Figure 3-7). Balance systems are applicable to both above and below ground facilities.

Vapor balancing of incoming transport trucks displaces vapor from storage tanks to truck tank compartments; emissions can be ultimately treated at the terminal with secondary recovery control systems. EPA-sponsored source tests at two bulk plants have shown that a control efficiency greater than 90 percent for hydrocarbon filling losses is attainable with vapor balancing of incoming trucks and storage tanks.[19] Benzene reductions would be equivalent. (The 10 percent loss is due to a small amount of vapor growth in the returned vapors.)

Vapor balancing of storage tanks and delivery trucks also reduces account truck hydrocarbon filling losses by greater than 90 percent.[20] Also, balance systems on delivery truck filling virtually eliminate emptying losses from storage tanks, since displaced air is saturated or nearly saturated with hydrocarbons. The efficiency attainable in loading delivery trucks is significantly affected by tightness of the truck compartments, i.e. condition of hatches, pressure-vacuum relief valves and seals, and the care exercised in making line connections.

Assuming the lost vapors from the vapor balance system are ideal gases, the benzene vapors will be emitted in proportion to the hydrocarbon vapors. Therefore, a benzene efficiency greater than 90 percent is also

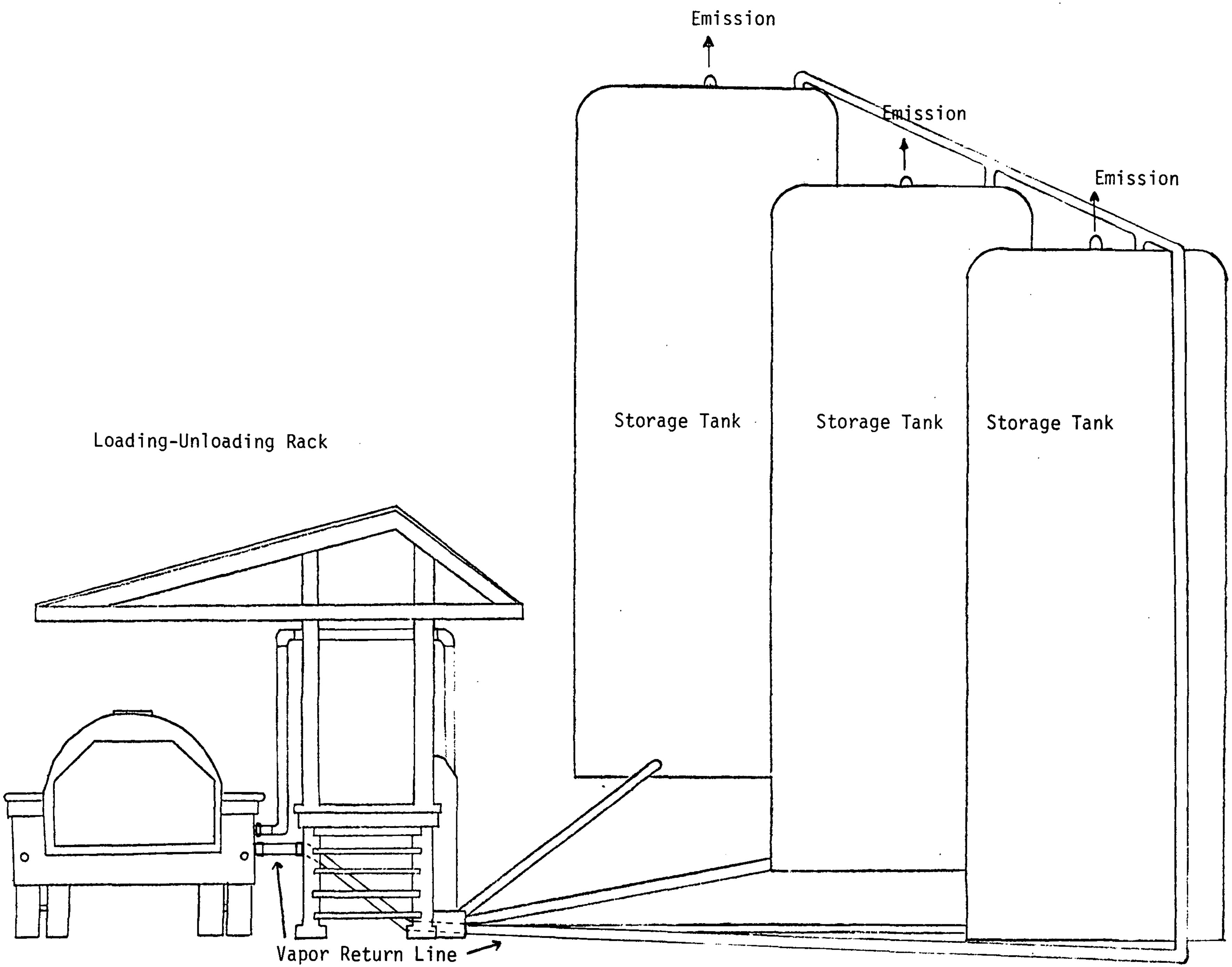


FIGURE 3-7. VAPOR BALANCE SYSTEM
(Bottom Fill)

attainable with a vapor balance system for filling and emptying losses. Breathing losses are not controlled by the balance system. Accounting for breathing losses, the balance system achieves about 70 percent efficiency for the entire plant.

The following criteria should be met to attain 90 percent or greater efficiency for all bulk plant sources except storage breathing loss.

(1) Storage Tanks

(a) Above and below ground storage tanks should have submerged fill in order to reduce generated emissions from the loading of storage tanks (this is typically done on plants at present).

(b) Pressure-vacuum relief valves should be set as high as possible and in accordance with the current National Fire Protection Association Pamphlet No. 30, "Flammable Combustion Liquids Code."

(c) Vapor return line piping and storage tank manifold piping should be leak tight and of sufficient size to allow efficient transfer of vapors to the tank trucks. The vapor return piping is generally 5 to 8 cm (2 - 3 inches) in diameter.

(2) Loading-unloading rack

A dry break fitting is needed on the rack end of the vapor return piping. A dry break is required to prevent ground level gasoline vapor emissions when gasoline transfer is not being made. This fitting keeps the storage tanks sealed until the vapor hose is connected.

(3) Tank Trucks

(a) Tank trucks should be submerge filled to reduce emissions generated during loading operations.

(b) Tank Trucks must be modified to recover all vapors during loading and unloading at the bulk plant, and to recover vapors at balanced customer tanks (service stations).

(c) A dry break closure is required on the end of the tank truck's vapor return line to prevent ground-level gasoline vapor emissions. These emissions would occur as a result of failure to connect the vapor return line to the tank truck's vapor return line.

(d) Tank truck vapor tightness - if truck hatches or relief valves leak during balancing, they either vent the recovered vapors or draw in air. It is necessary to ensure that trucks are vapor tight during the loading and unloading operation in order to assure proper balancing. Many plant owners check the liquid level in the truck compartments before and after loading to ensure they are receiving the desired volume of gasoline. This procedure is acceptable as long as the hatches are secured during loading and unloading.

3.3.3 Vapor Recovery and Oxidation Processing Systems

Vapor recovery (CRA, RF or AA) and oxidation systems can be used to process all the vapors displaced from the storage tanks and the tank trucks during loading. Such systems have been applied to bulk terminal truck loading losses, but have not been applied in bulk plants. These systems will yield a higher control than vapor balance systems when applied to the loading-unloading rack and storage tanks, since breathing losses are also controlled by "add-on" equipment. See Section 3.2 for discussion of these systems.

3.4 SERVICE STATIONS

As explained in Chapter 2, benzene is emitted from underground storage tanks during loading and emptying of the tank (working losses) and during the day as temperatures fluctuate (breathing losses). This document discusses only those systems applicable to the control of loading losses (breathing and emptying loss controls are deferred to another study).

In gasoline service stations, balancing has been used to control hydrocarbon emissions from both automobiles and storage tanks (the two major sources). The technique is equally effective in reducing benzene emissions from these sources.

In the service station balance system, vapors are vented by displacement to the transport or delivery truck which unloads gasoline. The truck transfers the vapors to the terminal or plant for ultimate treatment at the terminal. The system for underground storage tanks is detailed below. (Figure 3-8 illustrates balancing at service stations.)

3.4.1 Balance System Description

Gasoline is delivered in large (30,000-36,000 liter or 8000-9500 gallon capacity) transport trucks. The gasoline is loaded by gravity into the underground storage tanks via a flexible hose. Liquid gasoline displaces a nearly equal volume of partially saturated gasoline vapors. The vapor is vented through a pipe and flexible hose connected to a vapor collection system (simply a manifolded pipe) on the transport truck. Liquid transfer creates a slight pressure in the storage tank and a slight vacuum in the truck compartment. These pressure differences effectively cause the transfer of more than 95 percent of displaced vapor to the truck. Because of a phenomenon known as vapor growth caused by liquid temperature differences, the truck volume cannot always accomodate all of the vapors. Any excess vapor is released through the vapor vent line shown in Figure 3-8.

The following scenario depicts how the whole process could take place:

(1) The tank truck arrives loaded with gasoline. The station operator has ordered about 10,000 liters of premium and regular leaded gasolines (2 compartments of the 4 compartment truck).

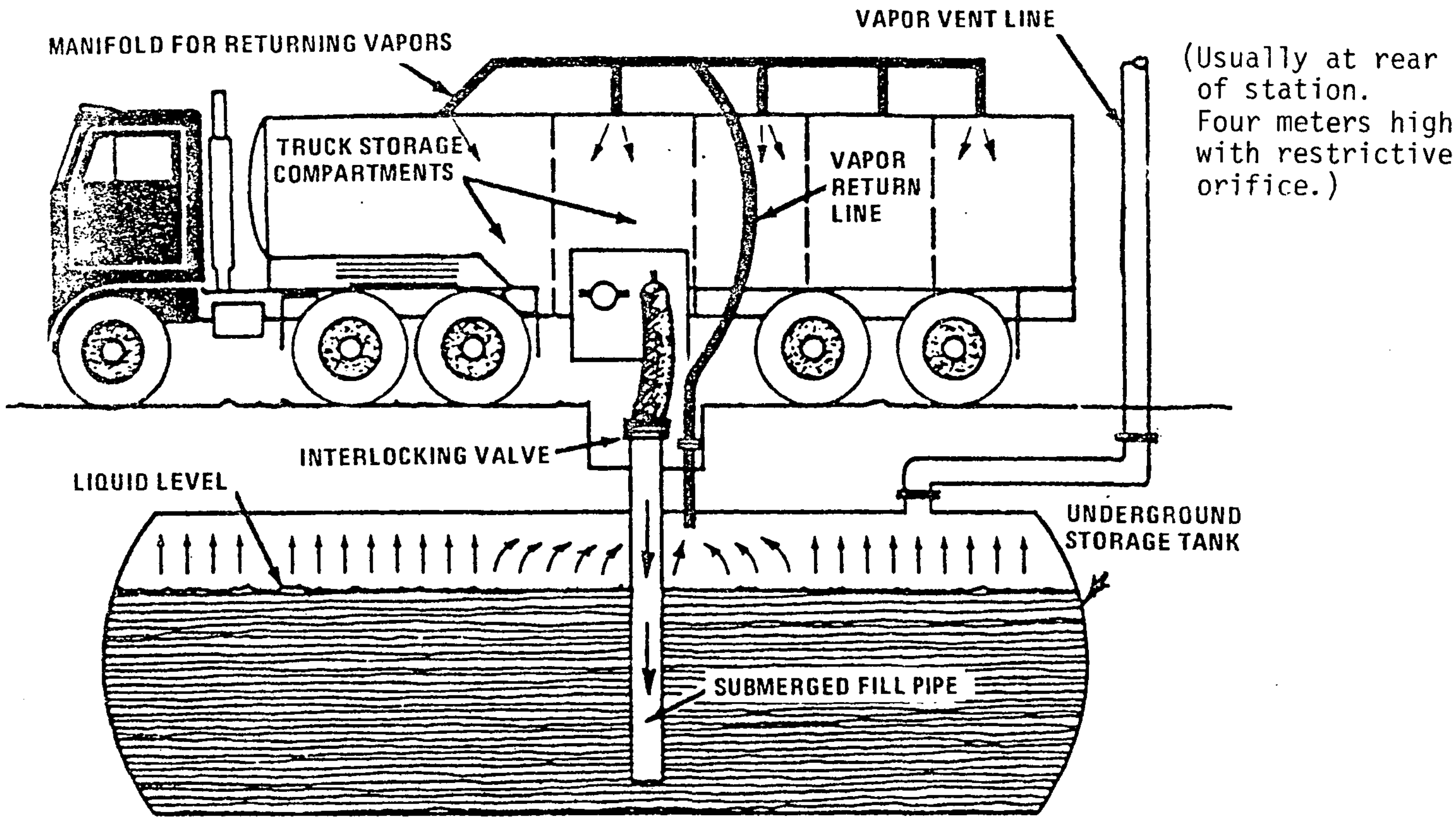


FIGURE 3-8. VAPOR BALANCE SYSTEM AT A SERVICE STATION

(2) As the station operator opens the storage tank liquid fill cap, the truck driver unwinds and lays out the two flexible hoses (liquid and vapor) which he carries on the truck.

(3) The station operator dips a pole into the tank, measures the liquid level, and calculates the amount in the tank (to ensure against overfill). He climbs atop the truck, opens the two compartment hatches, checks that the compartments are full and closes the hatches.

(4) The driver connects the liquid fill and vapor hoses to his truck and then to the storage tank. He opens the valve for one compartment and the gasoline flows by gravity to the underground tank.

(5) As the first "drop" is completed, the truck driver "milks" the liquid line, then disconnects the hoses at the tank.

(6) He disconnects the liquid line at the truck and puts the liquid hose on the second compartment. He then repeats steps 4 and 5.

(7) The station operator climbs atop the truck, opens the hatches, and assures that all gasoline has been delivered from the compartments. He secures the hatches and the driver leaves (after he has disconnected his two hoses). The driver may return to the bulk terminal/bulk plant or may proceed to another station to empty his other compartments of gasoline. The driver may also unload more than one compartment at a time. Manifolded storage tank vapor return lines or multiple vapor couplings on the truck are necessary to do this.

The effectiveness of the system is adversely affected by leaks. Truck hatches should be closed and hose connections should be tight during loading. Tests demonstrate balance systems to be greater than 95 percent efficient for reducing underground storage tank filling losses.[21,22] Note that breathing and emptying losses are not controlled by this method. These two losses account for about five percent of total station losses. Certain controls for automobile refueling emissions control these two sources.

3.4.2 Necessary Criteria for the Balance System

A November, 1975, EPA report entitled, "Design Criteria for Stage I Vapor Control Systems - Gasoline Service Stations," specified the necessary components of the vapor balance system as applied to underground storage tanks at service stations.

As stated in the document there are at least four objectives of detailing equipment for the system.

(a) Assure that the vapor return line will be connected during tank filling,

(b) assure that there are no significant leaks in the system or tank truck which reduce vacuum in the truck or otherwise inhibit vapor transfer,

(c) assure that the vapor return line and connectors are of sufficient size and sufficiently free of restrictions to allow transfer of vapor to the truck tank and achieve the desired recovery,

and (d) assure that gasoline is discharged below the gasoline surface in the storage tanks.

All test data submitted to EPA were obtained from systems which met these four objectives. If the balance system's efficiency is to be duplicated on other service stations, these objectives must also be met.

The following details specific equipment necessary:

1. <u>Drop Tube</u> - a tube which extends from the tank fill neck to below the liquid level in the tank is necessary. This tube is called a "drop tube" and tanks so equipped are "submerge filled." Generally, if the tube extends within 15 centimeters (6 inches) of the tank bottom, it will be submerged in gasoline since tanks are not pumped dry.

2. <u>Gauge well</u> - operators gauge the amount of liquid in their tanks by use of a long marked pole or "dip stick." The pole is generally inserted through the fill neck and dropped to the bottom. The liquid level is indicated by wetting of the pole. As long as the fill pipe is submerged (see 1), this creates no problem. Some stations are equipped with a separate gauge well. If left uncapped during filling, vapors are displaced through this opening rather than to the tank truck. The gauge well should be equipped with a drop tube to prevent this.

3. <u>Vapor hose return</u> - typically, gasoline is gravity fed into the storage tank from the truck by the 10 cm (4 inches) diameter drop tube at a rate around 1500 liters (400 gallons) per minute. An 8 cm vapor return hose (3 inches) will accomodate the volume of vapor generated by such a "drop."

4. <u>Vapor line connections</u> - vapor lines from two or more tanks may be manifolded to a common vapor hose connector. This can be advantageous to the operator who fills more than one tank at a time. A general rule is to provide a vapor return hose cross sectional area of at least half of the cross sectional areas of all fill hoses which displace vapors to the hose.

5. <u>Liquid fill connection</u> - the liquid fill connector should be equipped with a vapor tight cap. Gaskets and similar sealing devices can ensure this closure as can "cam-lock" and "dry break" closures.

6. Tank truck vapor tightness - If truck hatches or relief valves leak during balancing, they either vent the recovered vapors or draw in air. It is necessary to ensure that trucks are vapor tight during the unloading operation in order to assure proper balancing. Many station owners check the liquid level in the truck compartments before and after loading to ensure they are receiving the desired volume of gasoline. This procedure is acceptable as long as the hatches are secured during loading.

7. Closures or interlocks on underground tank vapor hose connectors and on the tank truck - (optional to ensure 95 percent)

Closures and interlocks ensure that vapor hoses are connected to the tank truck and to the underground tank. If the vapor hose is not connected, no gasoline can be dropped into the storage tank. Further, they ensure that the storage tank is sealed unless the vapor hose is connected.

8. Vent line restrictions - (optional) Vent line restrictions which reduce the the vent line diameter from about 5 centimeters to about 2 cm (2 to 0.75 inches) assure that gasoline vapor goes to the tank truck and not through the tank vent pipe to atmosphere. Further the restriction helps assure that the vapor hose is properly attached. If it is not, then the flow of gasoline into the tank is significantly slowed because of the back pressure caused by the vent pipe restriction.

A pressure vacuum relief valve set to open at 3450 Pascals (8 oz. per square inch) or greater pressure and 1725 Pascals (4 oz. per square inch) or greater vacuum will accomplish the same end. Fire regulations differ in different areas of the country and more or less stringent settings may be required by local fire marshalls.

3.5 GASOLINE TANK TRUCKS

As explained in Chapter 2, benzene vapors are emitted from the truck tank's hatch seals, P-V vents, and emergency vent hoods. Limited data are available at this time to quantify typical emission rates or potential emission reductions. Many of these leaks can be found through visual inspections or heard during the loading operations of the tank. These leakage points can be controlled through good maintenance procedures and schedules. In many instances, replacement of worn or damaged parts may be the only logical and long term method for ensuring the truck tank will stay leak tight. EPA will have more data on control methods by the end of September, 1978.

3.6 REDUCTION OF BENZENE CONTENT OF GASOLINE

The purpose of this section is to discuss another option for controlling emissions from the marketing industry by reducing the level of benzene in motor gasoline.

3.6.1 Assessment of Benzene Content of 1981 Gasoline Pool

Results from an EPA contract study conducted by A. D. Little, Inc., (ADL) indicate that the average U.S. gasoline pool in 1981 will contain about 1.37 volume percent benzene.[23] The average was based on determining the blending component composition of the 1981 pool and the benzene contents of each of these components as shown in Table 3-2.

In a similar manner the average benzene content of the 1977 U.S. gasoline pool was determined to be 1.30 volume percent. This average is in good agreement with the 1.24 and 1.25 volume percent reported by NIOSH and Gulf Oil[24,25] respectively. It is somewhat higher than the 1.0 volume percent weighted average of the samples reported in a DuPont, June, 1977, survey.[26]

3.6.2 Control Options for Removal of Benzene from Reformates and FCC Gasolines

Reformates and fluid catalytic cracked gasolines comprise 64.5 percent of the gasoline pool and contribute 86 percent of the pool benzene. The study focused on these two major contributors and determined it would be feasible to remove 94.5 percent of their benzene content (82 percent removal of benzene from the pool) using the following selected processing routes:

Reformates

1. Fractionate the total (full boiling range) reformate produced in the gasoline reformers in a new tower (deisohexanizer) to remove isohexane and lighter in the overhead stream and the benzene and heavier paraffins and aromatics in the bottoms. The benzene free overhead from the deisohexanizer is sent to gasoline blending.

2. Fractionate the bottoms stream in a second new distillation tower (C_6 fractionator) to remove a C_6 overhead stream (C_6 heart cut) which would contain 95 percent of the benzene contained in the reformer gasoline and the other C_6 paraffins. The heavier aromatics and C_7 paraffins bottoms are sent to gasoline blending.

3. The C_6 heart cut which contains 15 volume percent benzene is sent to a benzene extraction plant where 99 percent of the benzene is removed as commercial grade benzene and the raffinate (essentially free of benzene) sent to gasoline blending. The sulfolane process is assumed used for benzene extraction. As shown in Figure 3-9, reduction of benzene in reformate would lower the average total U.S. gasoline pool level by 62 percent to a pool level of 0.52 volume percent.

FIGURE 3-9. CUMULATIVE REDUCTION IN BENZENE CONTENT OF GASOLINE (Extracting 94.5 percent of benzene from gasoline blending components)

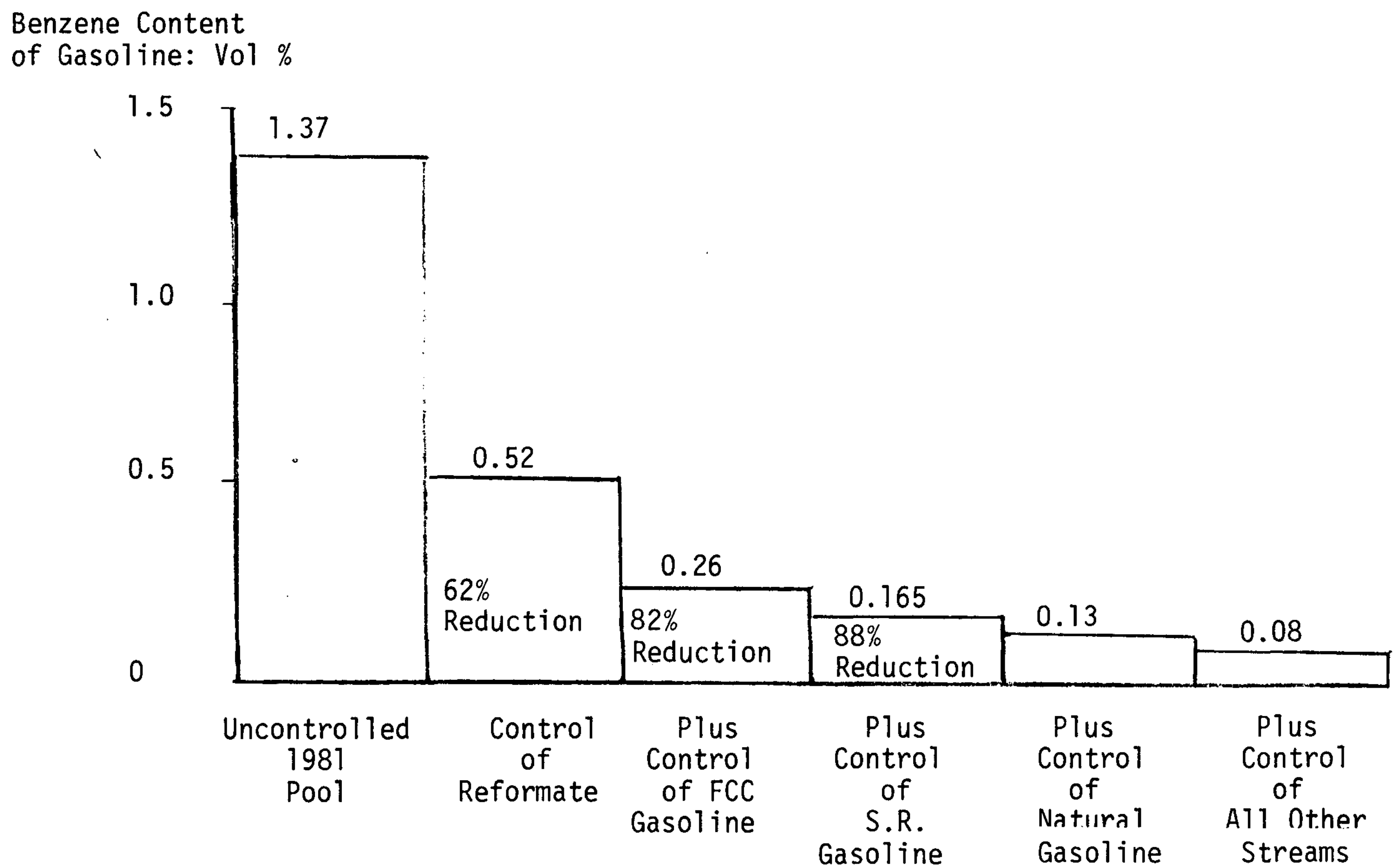


TABLE 3-2. AVERAGE BENZENE CONTENT OF 1981 U.S. GASOLINE POOL

(Volume %)

	Pool Component Composition			Blending Component	
	Thousand Barrels/Day	%	Benzene Vol %	BZ Contribution to Pool Vol %	% of Pool Benzene
Reformate	2235	30.0	3.0	0.90	65.7
FCC Gasoline	2571	34.5	0.8	0.28	20.4
S.R. Naphtha	536	7.2	1.4	0.10	7.3
Natural Gasoline	186	2.5	1.5	0.04	2.9
Hydrocrackate	134	1.8	1.1	0.02	1.5
Coker Gasoline	89	1.2	1.4	0.02	1.5
Isomerate	104	1.4	0.4	< 0.1	0.4
Raffinate	104	1.4	0.2	< 0.1	0.32
Alkylate	1014	13.6	0	0	0
Butane	477	6.4	0	0	0
Gasoline Pool	7450	100		1.37	100

FCC Gasoline

A C_6 heart cut is first fractionated from the full range FCC gasoline in a manner identical to the two fractionation steps for reformates. Two new additional towers are required.

1. FCC gasolines contain olefins and diolefins boiling in the benzene range. Reformates are free of olefins. It has not been commercially demonstrated that aromatics can be extracted from C_6 heart cut containing these olefins without causing operational problems in the extraction plant.

2. This requires that the C_6 heart cut be hydrogenated in a new hydrogenation plant to saturate the olefins to paraffins. Paraffins are much lower in octane that the olefins and the octane of the C_6 heart cut which represents about 15 percent of total FCC gasoline is reduced by 20 octane numbers.

3. The hydrogenated C_6 heart cut containing 15 volume percent benzene and 95 percent of the benzene in the FCC gasoline is sent to a benzene extraction plant where 99 percent of the benzene is removed as commercial grade benzene.

3.6.3 Benzene Removal From Other Gasoline Blending Components

Reduction of the benzene content of straight run naphtha is also feasible and would further reduce the benzene content by a nominal 7 percent for a total of 88 percent reduction from the pool. The process for benzene removal would be similar to that for FCC gasoline, but requires only mild hydrogenation to remove the sulfur in the S.R. naphtha. The benzene content of SR naphthas are directly dependent on the benzene in each crude oil. A detailed analysis of this variability to accurately determine removal costs was beyond the scope of the ADL study.

A variety of other gasoline blending components such as isomerate, hydrocrackate, and natural gasoline contribute to 12 percent of the benzene in the pool. Although it is probably feasible to reduce their benzene content in a similar manner, the complexity of analysis of removal options was not considered warranted in this study.

3.7 SUMMARY

This chapter has shown that controls can be applied to bulk terminals, bulk plants and service stations which reduce benzene emissions significantly. Recovery or oxidation systems at terminals reduce truck loading emissions by as much as 97 percent. Balance systems at bulk plants can reduce total plant emissions by about 70 percent while "add-on" equipment can reduce the plant emissions by over 90 percent. Service stations employing balance systems can cut benzene emissions from the loading of storage tanks by 95 percent. It was estimated that reduction of benzene from liquid gasoline at the refinery could reduce benzene emissions from terminals, plants, and service stations by over 80 percent.

Table 3-3 summarizes these reductions for the individual sources within the facilities.

TABLE 3-3. EFFECT OF CONTROL TECHNIQUES ON BENZENE EMISSIONS

SECTOR	SOURCE	Typical BZ Emission Factor with Current Controls (mg/l)	Control Technique	Controlled BZ Emission Factor mg/l
Bulk Terminal	Loading of trucks	4.8	RF	0.3
			CRA	0.3
			AA	0.3
			TO	0.3
			BZ reduction in gasoline 3/	0.96
Bulk Plant	Storage Tanks	17.7	Balance ST 1/	9.4
			Balance ST & T 2/	5.7
			Add-on Controls	1.7
			BZ reduction in gasoline 3/	3.54
	Loading of trucks	11.2	Submerged fill	4.8
			Balance system w/submerged fill	.48
			Add-on Controls w/splash fill	1.1
			BZ reduction in gasoline 3/	2.24
Service Station	Storage Tank Loading	9.0	Balance	.45
			BZ reduction in gasoline 3/	1.8

1/Balance ST = storage tanks only are balanced to transport trucks

2/Balance ST & T = storage tanks are balanced to transport trucks, delivery trucks are balanced to storage tanks

RF - Refrigeration CRA - Compression-Refrigeration-Absorption
AA - Adsorption-Absorption TO - Thermal Oxidizer

3/At 94.5% extraction from 86% of pool (reformate and FCC gasoline)

3.8 REFERENCES

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4.0 ALTERNATIVE CONTROL LEVELS

This chapter presents control alternatives for the gasoline marketing industry and shows the relative impacts on national benzene emissions for each. Table 4-1 summarizes the options and Table 4-2 outlines emission levels.

As described in Chapter 2 the United States marketing network consists of bulk terminals, which typically have top submerged or bottom fill on transport trucks; bulk plants, which have no controls on delivery trucks and are generally equipped with bottom fill on storage tanks; and service stations, of which about half have splash loaded underground storage tanks and the other half utilize submerged fill.

Controls for terminals are well demonstrated in that 300 or so of the 1500 terminals currently employ some sort of VOC recovery or oxidation device on loading facilities (described in Chapter 3.0). These devices include refrigeration (RF), compression-refrigeration-absorption (CRA), adsorption (AA), and incineration (TO). Tests indicate that a high benzene removal efficiency is expected from the use of each of the systems.[1,2,3,4,5]

Bulk plants can install submerged fill on delivery trucks and balance storage tanks to transport trucks. This is a relatively inexpensive method of reducing total plant emissions by about 50 percent (from 28.9 mg/l to 14.2 mg/l). A balance system installed on the entire plant (trucks and tanks) can reduce emissions by over 70 percent (from 28.9 mg/l to 6.2 mg/l). Finally, "add-on" controls, similar to those described for terminals, applied to tanks and trucks at plants can reduce benzene emissions by at least 90 percent. (The difference between the efficiency of add-on controls and the efficiency of the total plant balance system is that add-on controls reduce breathing losses, which are unaffected by balancing.)

Filling losses from underground storage tanks at service stations can be reduced over 95 percent by use of a balance system. The shortcoming of this approach is that unless the truck delivering gasoline to the station is controlled at the terminal or bulk plant,the truck's benzene vapors are emitted to atmosphere anyway. As will be seen in the discussion, this is a possibility with Option 1.

Reducing benzene content in gasoline at the refinery will not only reduce benzene emissions at terminals, plants and service stations by 80 percent, but may also reduce emissions from significant benzene sources such as storage tanks, automobile refueling operations and auto tailpipes. Smaller sources such as marine operations, spills and consumer equipment would also be controlled. This added impact must be weighed into consideration when comparing the options listed here. (note: EPA is still developing data on the effect of benzene content in gasoline on auto tailpipe emissions. Because these studies have not been completed as yet, this document does not estimate the total benzene control, if any, attributable to reduction of benzene in gasoline.)

Four options are presented in this chapter which combine different control strategies at each segment. For example, in Option 1, the least effective alternative for reducing benzene, high efficiency add-on controls at terminals are combined with balance of transport trucks and storage tanks at bulk plants (with submerged fill for delivery trucks) and with balance systems at service stations.

The options are presented in increasing effectiveness of benzene reduction. (Refer to Tables 4-1 and 4-2.)

4.1 OPTION 1

Option 1 reduces the benzene emissions the least of all the options. Bulk terminal operators are required to install refrigeration, adsorption-absorption, incineration or equivalent systems on loading facilities. All of these devices are well demonstrated on operating terminals in the United States. They are considered to be the most effective control methods in current use and test data indicate several systems have the capability of reducing benzene by 95 percent.

Bulk plants under Option 1 would be required to install submerged fill on delivery trucks and to balance storage tanks with incoming transport trucks. This effectively means that 50 percent of the plant is uncontrolled. It also means that those service stations which are serviced by bulk plants would be uncontrolled since the delivery trucks would not be equipped to recover vapor.

Under Option 1, service stations serviced by bulk terminals would be required to install balance systems for the filling of their underground storage tanks. Those serviced by bulk plants would be exempted from balancing (since the delivery trucks from bulk plants would not be equipped to handle the vapor), but would still be required to install submerged fill. It has been estimated that about 40 percent of all station gasoline throughput comes from bulk plants.[6]

The balance system is very effective in handling gasoline vapors. Those stations installing balance could expect a 95 percent reduction in benzene emissions from filling the underground storage tanks.[7]

Overall efficiency of Option 1 is about 60 percent. National benzene emissions from the marketing network sources discussed in this document would drop from about 10,500 to 4050 metric tons per year.

4.2 OPTION 2

Option 2 involves the reduction of benzene from liquid gasoline at the refinery. Estimates have been made of possible reductions of benzene from the gasoline pool (see Chapter 3).[8] Reductions of 80 percent appear to be possible. It is expected that an 80 percent reduction in benzene from the liquid gasoline would mean an approximate 80 percent reduction in the benzene in gasoline vapor. Using this factor, an 80 percent reduction in benzene emissions can be expected with Option 2. National emissions from the sources discussed here would drop from about 10,500 to 2100 metric tons per year.

This technology would also remove benzene from other significant sources of the pollutant. Emissions from sources such as automobile refueling operations, and gasoline storage may be reduced by as much as 80 percent.

4.3 OPTION 3

Option 3 represents a more effective alternative for the marketing network. Bulk terminals would be required to apply the same effective controls as listed in Option 1, (e.g. absorption, refrigeration, oxidation, adsorption or equivalent). Reduction at bulk terminals is the same in Option 3 as in Option 1 (about 95 percent).

The bulk plant, under Option 3, would be required to install a full balance system on both delivery trucks and storage tanks. Note, in Table 4-2, the effect of applying the balance system to delivery trucks on emptying losses in the storage tank. As the tank is emptied, the increased volume of the vapor space is taken up by nearly saturated vapors from the delivery trucks and not by fresh air. If the delivery truck vapors are close to saturation (as would be expected from trucks returning from balanced service stations), emptying losses would approach zero. For Table 4-2, it was assumed that the trucks would return saturated and emptying losses are zero.

Service stations would be required to apply the highly effective balance systems. In this case, all service stations would balance to incoming trucks. The filling losses would be ultimately carried by truck back to the terminal.

Overall efficiency of Option 3 is about 86 percent. Benzene emissions from the marketing network would decrease from about 10,500 to 1400 metric tons per year.

4.4 OPTION 4

The fourth and last option represents the highest emission reduction possible for the gasoline marketing network with current technology. It differs from Options 1 and 3 only in that all of the significant losses from bulk plants are controlled.

For bulk terminals, the add on controls (absorption, refrigeration, oxidation, adsorption, etc.) are required. Bulk plants are required to install similar controls on both storage tanks and loading racks. This would result in at least 90 percent control of breathing, emptying and filling losses from the plant. Losses may be reduced by as much as 95 percent. Since no "add-on" controls have been applied to bulk plants, however, a conservative 90 percent has been assumed. All service stations would be required to install balance systems. The balanced vapors would be returned to the terminal or plant for disposal.

Overall efficiency of Option 4 is about 93 percent. National benzene emissions from these sources would be reduced from about 10,500 to 760 metric tons per year.

TABLE 4-1. GASOLINE MARKETING NETWORK CONTROL OPTIONS

Source	Base Case	Option 1	Option 2	Option 3	Option 4
A. Terminals Loading Racks	Top Submerged or Bottom Fill on Trucks	Vapor Recovery or Oxidation	Reduction of Benzene in Gasoline	Vapor Recovery or Oxidation	Vapor Recovery or Oxidation
B. Bulk Plants Storage			Reduction of Benzene in in Gasoline		All sources Vapor Recovery or Oxidation
Breathing	No control	No control		No control	
Emptying	No control	No control		100% control	
Filling	Bottom fill	Balance to transport		Balance to transport	
Loading Rack Filling	Splash fill	Submerged fill		Balance to storage	
C. Service Station Underground /1 storage tank loading only	50% splash load 50% submerged	Balance w/submerged fill /2	Reduction of Benzene in gasoline	Balance with submerged fill	Balance w/submerged fill

/1 Breathing & emptying losses to be discussed with refueling operations in a separate study.

/2 Those stations serviced by terminals would be balanced.
Those stations serviced by bulk plants would not be balanced (would have submerged fill).

TABLE 4-2. GASOLINE MARKETING CONTROL OPTIONS - NATIONAL EMISSIONS

	Throughput liters/yr	HC Base Emission Factors (mg/l)	gm BZ / gm HC	National Base metric tons/yr BZ	Option 1 metric tons/yr BZ	Option 2 metric tons/yr BZ	Option 3 metric tons/yr BZ	Option 4 metric tons/yr BZ
Terminals								
Loading	413×10^9	600	0.008	1980	100	396	100	100
Bulk Plants								
Storage	165×10^9	600 Breathing	0.008	792	792	158	792	79
		460 Emptying	0.008	607	607	120	0	60
		1150 Filling	0.008	1518	152	304	152	152
Loading	165×10^9	1400	0.008	1848	792	370	185	185
Service Stations								
Underground Storage Tank Loading Only /1	413×10^9	1130	0.008	3734	1605	747	187	187
	TOTAL			10,479	4048	2095	1416	763
	PERCENT REDUCTION			0	61	80	86	93

/1 Breathing and emptying losses to be discussed with refueling operations.

4.5 REFERENCES

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5.0 ENVIRONMENTAL IMPACTS OF APPLYING THE TECHNOLOGY

This chapter will assess the environmental and energy impacts of applying the control technology discussed in Chapter 3 and the control options outlined in Chapter 4.

5.1 IMPACT ON BENZENE EMISSIONS

In order to determine emission reductions which would occur as a result of using each technique, it is necessary to examine air pollution control requirements of existing State and local regulations.

There are currently no State regulations which control benzene emissions from the gasoline marketing network. There are, however, regulations covering hydrocarbons in a few areas and these need to be examined in order to develop the typically controlled network. Controls for benzene and hydrocarbons are identical in terms of equipment.

Appendix E outlines the States which regulate sources under consideration here and also indicates the hydrocarbon emissions standards which apply.

It can be seen that the typical terminal of 950,000 liters (250,000 gallons) per day throughput is required to have top submerged or bottom loading on loading racks. A few Air Quality Control Regions have required vapor recovery, but it is estimated that less than 20 percent of all United States terminals are affected by these regulations.[1]

The typical bulk plant of 15,000 liters (4000 gallons) per day throughput is generally required to have bottom loaded storage tanks, but there are virtually no controls required for loading operations.

It is assumed that about one-half of the retail service stations in the United States are equipped with "drop tubes."[2] The others use splash fill. A few areas (about 15 ACQR's) require balance systems on retail stations. These stations represent about 16 percent of all retail stations in the United States[3] (or about 12 percent of all retail station throughput). The typical retail service station has a throughput of about 150,000 liters (40,000 gallons) per month. Non-retail stations have a throughput of about 38,000 liters (10,000 gallons) per month (represent about 25 percent of throughput and over 50 percent of stations).

5.1.1 Bulk Terminal Controls

It was shown in Chapter 3 that the four add-on controls source tested for bulk terminal loading losses are approximately of equal efficiency in reducing benzene emissions. Compression-refrigeration-absorption, refrigeration, adsorption-absorption, and oxidation systems all achieve about 95 percent control of benzene. In terms of mass reduction, this means that the typical terminal can reduce annual benzene emissions from 1300 to 65 kg by use of these controls. (See Table 5-1. Data in the table have been derived in Chapters 3 and 4.) Reducing the amount of benzene in liquid gasoline at the refinery can reduce the terminal losses by 80 percent. The typical terminal benzene emissions would go from 1300 kg/yr to 260 kg/yr by use of this method.

5.1.2 Bulk Plant Controls

The bulk plant has two major source areas: the vent from storage tanks emitting filling, emptying and breathing losses; and delivery trucks which emit benzene along with other hydrocarbons during loading.

Table 5-1 shows that losses from storage tanks could be reduced from 76 to 24 kg/yr with use of the balance system; losses are reduced to 8 kg/yr with add-on controls; and losses drop to 15 kg/yr with benzene reduction in gasoline. Note that balancing the total plant reduces losses even further than balancing the storage tank only. This is because emptying losses and delivery truck filling losses are controlled with total plant balancing.

Losses from filling delivery trucks can be reduced from 48 kg/yr to 5 kg/yr by use of add-on controls. Other options reduce the kg/yr emission level to 2 for balancing, 10 for benzene reduction in gasoline, and 20 for submerged fill only.

5.1.3 Service Station Controls

Service station underground tank filling losses can be controlled by one of two ways. A balance system can be installed to vent filling losses to the truck delivering liquid gasoline or benzene can be reduced at the refinery. In the first case, Table 5-1 shows the effect as reducing benzene from 16 to less than 1 kg/yr. The second case reduces benzene to 3 kg/yr.

Station balance systems are only effective if the delivery or transport truck is equipped to transfer the vapors ultimately to the terminal for disposal.

TABLE 5-1. ESTIMATED IMPACT ON BENZENE EMISSIONS FOR MODEL FACILITIES

SOURCE	Throughput	Estimated BZ Emission Rate mg/l	Typical Annual Emission Rate kg/yr	Control Method	Controlled Rate kg/yr *
Bulk Terminal Loading	950,000 liters/day	4.8	1300	with CRA, R, Ad, OX	65
				BZ reduction in gasoline	260
Bulk Plant Storage	15,000 liters/day	17.7	76	Balance 1 1/	40
				Balance 2 2/	24
				R, OX	8
				BZ reduction	15
Loading	15,000 liters/day	11.2	48	Submerged fill	20
				Balance 1 1/	2
				Add-on (R, OX)	5
				BZ reduction	10
Service Station Filling Underground Storage Tank	150,000 liters/mo	9	16	Balance	0.8
				BZ reduction	3.3

* 286 days/yr

1/ Balance only incoming trucks

2/ Balance entire plant

5.1.4 Control Options

Table 5-2 contains the same control options discussed in Chapter 4. The table sums the individual source emissions into a national emission reduction for each option. Option 1 reduces marketing benzene emissions nationally from 10,500 to 4050 metric tons per year. Option 2 reduces the benzene emissions to 2100, Option 3 to 1400, and Option 4 to 760 metric tons per year.

5.2 OTHER AIR IMPACTS

There are air impacts directly associated with some control technology. Incinerators, for instance, emit small amounts of NO_X, CO and particulate. All of the control options presented here, except for reduction of benzene at the refinery, reduce hydrocarbon losses.

There are other components in gasoline vapor which have been implicated in health problems. These include the additives ethylene dichloride and ethylene dibromide which are suspected carcinogens and xylene which is similar in structure to benzene and also suspect. All controls in the marketing industry would control these suspected toxics except reduction of benzene at the refinery.

This section will discuss direct air impacts for each individual method (other than benzene removal) and then will sum the impacts for each control option. Table 5-3 summarizes this section.

5.2.1 Bulk Terminals

The add-on controls discussed for bulk terminals generally have no adverse impacts on air emissions. CRA, refrigeration, adsorption and oxidation minimize emissions of benzene and other hydrocarbons to the

TABLE 5-2. GASOLINE MARKETING CONTROL OPTIONS - ESTIMATED NATIONAL EMISSIONS

	Throughput liters/yr	HC Base Emission Factors (mg/l)	gm BZ / gm HC	National Base metric tons/yr BZ	Option 1 metric tons/yr BZ	Option 2 metric tons/yr BZ	Option 3 metric tons/yr BZ	Option 4 metric tons/yr BZ
Terminals								
Loading	413 x 10^9	600	0.008	1980	100	396	100	100
Bulk Plants								
Storage	165 x 10^9	600 Breathing	0.008	792	792	158	792	79
		460 Emptying	0.008	607	607	120	0	60
		1150 Filling	0.008	1518	152	304	152	152
Loading	165 x 10^9	1400 Filling	0.008	1848	792	370	185	185
Service Stations								
Underground Storage Tank Loading Only 1/	413 x 10^9	1130	0.008	3734	1605	747	187	187
	TOTAL			10479	4048	2095	1416	763

1/ Breathing and emptying losses to be discussed with refueling operations.

2/ Under Option 1, 40 percent of service station throughput is uncontrolled.

atmosphere. Oxidizers, however, vent small amounts of hydrocarbon as well as secondary pollutants as products of combustion. Table 5-3 shows the estimated quantity of secondary pollutants emitted in the effluent of the control device.

The table also shows the effect of each control technique on hydrocarbon emissions from the typically uncontrolled source. As can be seen, significant quantities of hydrocarbon are controlled by add-on controls. Benzene reduction at the refinery has no effect on hydrocarbon losses.

5.2.2 Bulk Plants

The balance system does not increase other air contaminants to the atmosphere. It does, however, significantly reduce hydrocarbon and suspected toxic substance emissions.

Add-on controls provide the same adverse and positive impacts on emissions to the atmosphere as shown for bulk terminals, except in smaller quantities (because of a lower throughput).

5.2.3 Service Stations

The balance system reduces hydrocarbons and suspected toxic substances to the atmosphere with no effect on other contaminants.

5.2.4 National Impacts for Options

Table 5-4 shows the national impact of Options 1-4 on other air contaminants. It is shown that Option 4 would the largest negative impact because of the widespread use of add-on controls.

TABLE 5-3. OTHER AIR IMPACTS FOR MODEL FACILITIES ESTIMATED FROM TEST DATA - kg/yr

SOURCE	Control Technique	Particulate	CO	NO_X	HC 1/	EDC 2/	EDB 2/
Bulk Terminal Loading	CRA	0	0	0	(140,000)	(Unk)	(Unk)
	Ref	0	0	0	(140,000)	(Unk)	(Unk)
	Ad	0	0	0	(140,000)	(Unk)	(Unk)
	OX	Negligible	17,000	4800	(140,000)	(Unk)	(Unk)
	Reduction at refinery				See Table 5-4		
Bulk Plant Storage	Balance - Incoming	0	0	0	(4,500)	(90%)	(90% reduction)
	Balance - Incoming/ Outgoing	0	0	0	(6,500)	(90%)	(90% reduction)
	Ref	0	0	0	(7,600)	(Unk)	(Unk)
	OX	Negligible	367	108	(7,600)	(Unk)	(Unk)
	BZ reduction at refinery				See Table 5-4		
Loading	Balance	0	0	0	(5,700)	(90%)	(90%)
	Submerged fill	0	0	0	(3,500)	(57%)	(57%)
	Ref	0	0	0	(5,400)	(Unk)	(Unk)
	OX	Negligible	232	68	(5,400)	(Unk)	(Unk)
	BZ reduction at refinery				See Table 5-4		
Service Station	Balance	0	0	0	(1,865)	(95%)	(95%)
	BZ reduction at refinery				See Table 5-4		

1/ Parentheses indicate reduction in pollutant from typical facility

2/ Unknown uncontrolled emission rate - controls will reduce toxics ethylene dichloride and ethylene dibromide

TABLE 5-4. ESTIMATED NATIONAL AIR IMPACTS OTHER THAN BENZENE - WORST CASES
(thousands of metric tons/yr)

POLLUTANT	OPTION 1	OPTION 2	OPTION 3	OPTION 4
Particulate	Negligible	4.5	Neg	Neg
NO_X	8 *	31.8	8 *	12 *
CO	30 *	2.45	30 *	40 *
HC	(936) *	.7	(1200) *	(1300) *
EDC	(Unknown)	No effect	(Unknown)	(Unknown)
EDB	(Unknown)	No effect	(Unknown)	(Unknown)

* 1750 terminals and 17,850 bulk plants using oxidation systems - worst case
Parentheses indicate reduction of pollutant

5.3 WATER POLLUTION IMPACT

No control option discussed here uses water (the adsorber is vacuum regenerated). Water is present, however, in treated vapors and for all add-on systems it is recovered with the gasoline, separated, and disposed of.

Table 5-5 estimates the impact that add-on controls have on wastewater. The estimates are based on analysis of water samples taken during EPA tests. National emissions are extrapolated for each control option.

The amount of water will vary, depending on the temperature and relative humidity of the atmosphere. It is suspected that the removal of benzene from liquid gasoline at the refinery will place an additional burden on refinery waste water. This burden has not been quantified.

5.4. IMPACT ON SOLID WASTE

The disposal of discarded carbon is the only major source of solid waste for the marketing network control methods. Table 5-6 estimates the impact for a single terminal and bulk plant and extrapolates to national impacts for the four control options.

Assumptions made include a conservative estimate of carbon life (3-5 years), a mass of carbon necessary, and total industry use of carbon. It is further conservatively assumed that the carbon cannot be regenerated, but would be disposed of.

TABLE 5-5. WATER IMPACT - WORST CASES

Control Method	Source	Estimated Quantity of water disposed of	ppm HC	Estimated National Mass Rate - kg/yr - HC in waste water			
				Option 1	Option 2	Option 3	Option 4
R, CRA, AA	Bulk terminals	∿ 20 l/day	0-57	570		570	570
OX		0	0				
R	Bulk Plants	1 l/day	0-57				293
OX		0	0				0
Balance		0	0	0		0	0
Balance	Service Station	0	0	0		0	0
			Total	570 2/	Unknown	570 2/	863 3/

1/ Trace benzene in water samples

2/ Assumes no terminal uses oxidation

3/ All plants and terminals use refrigeration

TABLE 5-6. SOLID WASTE IMPACT - WORST CASE

Control Method	Source	Estimated Quantity of Carbon	Estimated National Mass Rate (10^6 kg/yr)			
			Option 1	Option 2	Option 3	Option 4
Adsorption	Bulk terminals	4500 kg	2.2	0	2.2	2.2
	Bulk plants	0	0	0	0	0
	Service Stations	0	0	0	0	0
		TOTAL	2.2	0	2.2	2.2

ASSUMPTION: All terminals use adsorption-absorption.
Bed life is 4 years.
Carbon cannot be regenerated.

5.5 IMPACT ON ENERGY

All control methods discussed here, except balance systems and submerged fill, require energy. The amounts of energy vary. This section estimates the energy requirements for each method and then sums the impacts for each option. Table 5-7 summarizes the estimates.

Add-on controls require energy to operate. Integral parts of refrigeration, AA, and CRA units are the electrically powered pumps and compressors. In the case of these controls, however, there is an energy credit in the form of recovered gasoline. The recovery credit has been added into the penalty for the net requirement. Oxidation units require electrically powered blowers and auxiliary fuel in some cases. Recent model oxidizers use auxiliary fuel for pilot flame only. The energy requirements for all of these sources are small compared to the energy consumption of removing benzene from gasoline to the 80 percent level discussed in this document.

Table 5-7 shows the energy consumption for each technique. The table also estimates the national consumption for each option.

5.6 AIR QUALITY IMPACT

Estimates are being made using dispersion analysis of the impact of the controls on ambient air levels of benzene. The results will be tabulated in similar fashion to Table 5-8.

The base case and subsequent optional controls consider the total benzene emissions from the facility and not just the sources discussed in this document. Thus, bulk terminal concentration estimates include

TABLE 5-7 ENERGY IMPACTS OF CONTROL METHODS 1/

SOURCE	Control Method	Estimated Energy Required per facility 10^6 Joules/day	Estimated National Energy Required Option 1 10^{12} J/yr	Option 2 10^{12} J/yr	Option 3 10^{12} J/yr	Option 4 10^{12} J/yr
Terminals	CRA 2/	(48,300)	(5220)	See Total	Same as Option 1	(3220)
	Ref 2/	(47,300)	(5220)			(3110)
	Ad 2/	(48,500)	(5220)			(3250)
	OX 2/	1,860	200			200
	Reduction of BZ	-	-		-	-
Bulk Plants	Ref 3/	(820)	NA	See Total	NA	(2100)
	OX 3/	150	NA		NA	383
	Reduction of BZ	-	-		-	-
	Submerged fill/balance		(2720)		(3141)	
Service Stations	Balance/submerged fill	-	(5180)	See Total	(5180)	(5180)
	Reduction of benzene	-			-	
		TOTAL 4/	(23,270)	330,000 or 54,100,000 barrels of oil	)23,700)	(16,277)

1/ Parentheses indicate energy credits from recovered gasoline.

2/ Assumes each type of control method installed at 25 percent of terminals

3/ Assumes each type control method installed at 50 percent of bulk plants

4/ One liter of gasoline equals 3.6×10^7 Joules. 6.1 billion Joules per barrel of oil.

TABLE 5-8. AIR QUALITY IMPACT
(ppb BZ - meters from fenceline)

FACILITY	Base Case	Option 1	Option 2	Option 3	Option 4
Terminal					
Bulk Plant Rural Urban					
Service Station					

emissions from storage tanks and service station estimates include refueling operations.

5.7 OTHER ENVIRONMENTAL CONCERNS

Other concerns to be considered include space requirements, availability of resources, and noise. All of these are considered insignificant. Estimates are made in Table 5-9 of the impacts of individual controls.

Reduction of benzene at the refinery will also reduce benzene emissions from sources other than those discussed in this document. These sources are ships and barges, storage tanks at terminals, and automobile refueling operations. It is suspected that the reduction of benzene in gasoline will also reduce automobile tailpipe emissions, but no data are currently available to confirm this. (EPA is accumulating the data in a research project.) Tailpipe benzene emissions may occur as a result of the combustion process in the auto engine, thus the effect of reducing benzene in gasoline may not necessarily be linear to tailpipe benzene emissions.

Auto tailpipe benzene emissions are significant. A recent study [4] estimated that benzene from automobiles totaled 169,500 metric tons in 1976. This compares to 10,500 metric tons emitted from the marketing sources discussed in this document. Tailpipe benzene losses account for about 65 percent of all benzene sources. Because of decreasing gasoline consumption and lowered hydrocarbon emissions from new cars, tailpipe benzene emissions in 1985 are predicted to be much lower than in 1976--down to 27,730 metric tons per year. The effect of reducing benzene content in liquid gasoline on these levels is unknown at this time.

TABLE 5-9. OTHER ENVIRONMENTAL IMPACTS

SOURCE	Control Technique	Approximated Space Requirements Sq Meters	Noise Level - db 1/	Estimated Availability of Resources (months)
Bulk Terminals	CRA	50	< 70 @ 7 meters	6 - 12
	Ref	30	< 70 @ 7 meters	6 - 12
	Ad	30	< 70 @ 7 meters	6 - 12
	OX	30	< 70 @ 7 meters	6 - 12
	OX w/vapor holder	50	< 70 @ 7 meters	6 - 12
Bulk Plants	Ref	30	< 70 @ 7 meters	6 - 12
	OX	30	< 70 @ 7 meters	6 - 12
	Balance	Neg	0	6 - 12
Service Stations	Balance	Neg	0	6 - 12

1/ A CRA unit, which created significantly more noise to the unprotected ear than any other system encountered, was tested for noise levels by a trained analyst. The system registered less than 70 db at 7 meters from the compressor (the noise source).

5.8 REFERENCES

1. A. D. Little, Inc., "The Economic Impact of Vapor Control on the Bulk Storage Industry," prepared for EPA, July, 1978, Draft report.

2. Radian Corporation, "Control of Hydrocarbon Emissions From Petroleum Liquids," EPA-600/2-75-042, September, 1975.

3. EPA, OAQPS, "Review and Analysis of Comments Received in Response to EPA's November, 1976, Proposed Stage II Vapor Recovery Regulations," April 18, 1977.

4. PEDCo Environmental, Inc., "Atmospheric Benzene Emissions," EPA-450/3-77-029, October, 1977.

6. ECONOMIC IMPACT ANALYSIS

6.1 BULK TERMINALS

6.1.1 Bulk Terminal Industry Characterization

6.1.1.1 Introduction

Bulk terminals are primary storage facilities which receive petroleum products from domestic and offshore refineries for market distribution. Output from domestic refiners moves to market via pipeline terminals and marine terminals; imported product moves via marine terminals (Figure 6-1) Most terminals load all of the product they receive into truck transports at the terminal's loading racks. These truck transports have capacities between 30 and 34 M^3 (8,000 and 9,000 gallons) and deliver gasoline to service stations and bulk plants for further distribution. Some large terminals, however, distribute only a portion of their products at the loading rack and move the remaining volumes to secondary storage facilities via pipeline, barge or coastal tanker.

6.1.1.2 Operations and Market Environment

For more than a quarter of a century until about 1970, the production of domestic and foreign crude contributed the most significant portion of total corporate earnings at integrated oil companies. The function of marketing then was to increase the demand for petroleum products thereby generating greater profits from increased crude production. To assure a high demand for products, prices were set at levels which encouraged consumption but which did not fully recover the true costs associated with refining and marketing. These activities were, in effect, subsidized by the profitability of crude production.

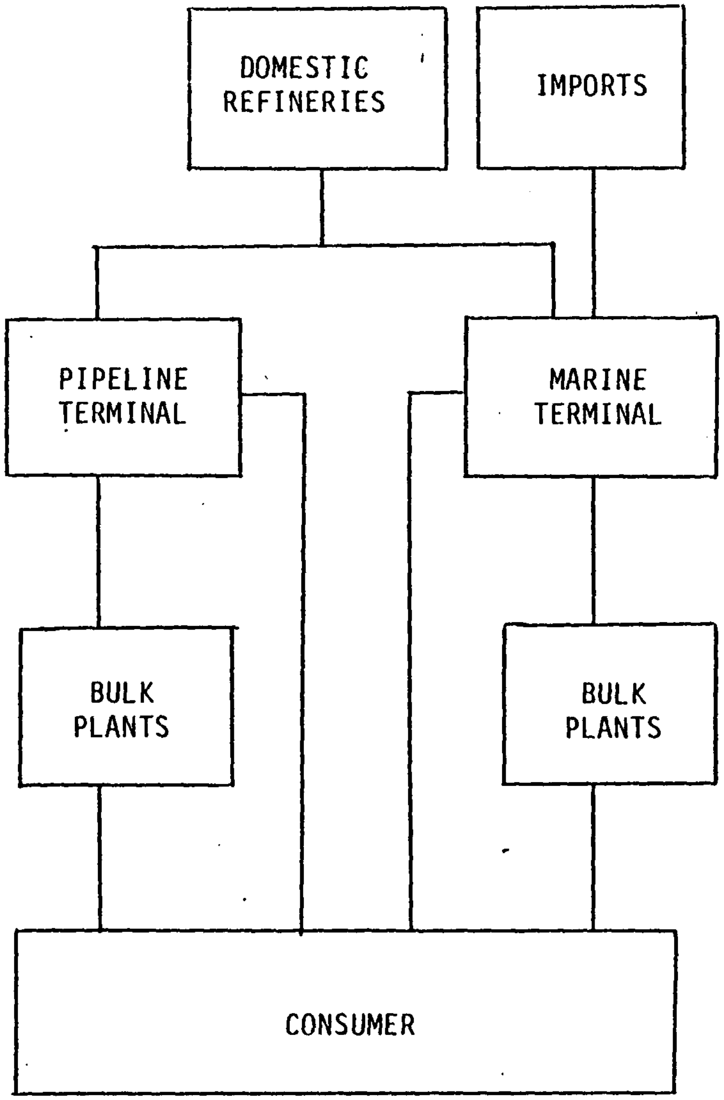

FIGURE 6-1 PRODUCT FLOW DIAGRAM

Beginning around 1970, oil companies began to view their refining and marketing operations as separate profit centers to be judged on "stand alone" economics. No longer would marketing activities, including bulk storage operations, be subsidized by crude production. Terminals were now expected to recover all operating expenses as well as provide an acceptable return on capital. Facilities unable to operate profitably were forced to close. This trend, which was well underway in 1973, was accelerated by the Oil Embargo of 1973-1974.

"Stand alone" economics has caused petroleum marketers, both majors and independents, to review their marketing strengths and to re-evaluate overall strategies. This has led to discussions to close many uneconomic or marginal facilities. Due to this "market rationalization," some marketers are withdrawing from selected regions of the country as part of an overall corporate strategy. Terminals in these markets will either be consolidated, sold or closed.

The cost of transporting petroleum products by pipeline are significantly less expensive than by either tanker or barge. Most product pipelines are currently operating at full capacity thereby making pipeline terminals the most financially attractive type of bulk storage. Pipeline terminals do not compete directly with each other because of their well-defined locus of operation. Marine terminals, however, transport the marginal barrel of product and may compete among themselves whenever several facilities operate within the same area. Marine terminals of equal size compete with each other but none realize a competitive advantage if they are equally efficient. If the competing terminals are not equal in size, the largest, and presumably the most efficient, facility will gain a competitive edge over the smaller and less efficient marine terminals. This competitive disadvantage may initiate or accelerate a marketer's decision to cease marketing operations in selected areas.

6.1.1.3 Bulk Terminal Population

The total number of bulk terminals has declined from 1,925 in 1972 to 1,751 in 1978, a decrease of 9 percent (Table 6-1). This decline has been the result of "stand alone" economics and the rationalization process of petroleum marketers. An estimated 1,511 or 86 percent of all terminals, store some amount of gasoline. Terminals not storing gasoline may specialize in residual fuels, distillates, bunker fuels or chemicals. Many terminals which only store home heating fuel are located in the Northern states.

Most terminals are located in PADD's I and II (Figure 6-2). PADD I has 43 percent of all bulk terminals and 43 percent of the gasoline terminals, i.e. those facilities having some gasoline storage. PADD II has 24 percent of all terminals and 23 percent of all gasoline terminals. The large number of terminals in these two PADD's reflects the regions' lack of refinery self-sufficiency and their reliance on shipments from other parts of the U.S. and from foreign countries in order to meet their local product demand. PADD I received 88 percent of all petroleum products imported into the U.S. in 1976 and 90 percent of all imported gasoline (Tables 6-2 and 6-3). Together, PADD's I and II received almost all of the inter PADD shipments originating in PADD III.

While the total number of terminals in the U.S. decreased 9 percent since 1972, total storage increased 30 percent to 122.5 million M^3 (770.7 million barrels) (Table 6-1). Gasoline storage is estimated to be 47.1 million M^3 (296.3 million barrels), or 38 percent of total terminal storage.

TABLE 6-1

BULK TERMINAL POPULATION*[1]

PADD	ALL TERMINALS: Terminals	% Total	Total Storage Capacity: 000 M^3	(000 Bbl)	% Total	TERMINALS STORING GASOLINE: Terminals	% Total	Gasoline Storage Capacity: 000 M^3	(000 Bbl)	% Total
I	745	43%	64,172	(403,633)	52%	657	43%	23,815	(149,792)	51%
II	429	24%	25,155	(158,219)	21%	343	23%	9,875	(62,115)	21%
III	276	16%	20,068	(126,223)	16%	234	15%	8,228	(51,753)	17%
IV	39	2%	1,151	(7,238)	1%	39	3%	674	(4,240)	1%
V	262	15%	11,988	(75,403)	10%	238	16%	4,517	(28,408)	10%
Total	1,751	100%	122,534	(770,716)	100%	1,511	100%	47,109	(296,308)	100%

* Does not include product storage at refineries.

Source: Bureau of Census, 1972 Census of Wholesale Trade; U.S. Army Corps of Engineers, Port Series; National Petroleum News, Factbook (1972-1978); Independent Liquid Terminals Association, 1978 Director - Bulk Liquid Terminals and Storage Facilities; Industry contacts; ADL estimates.

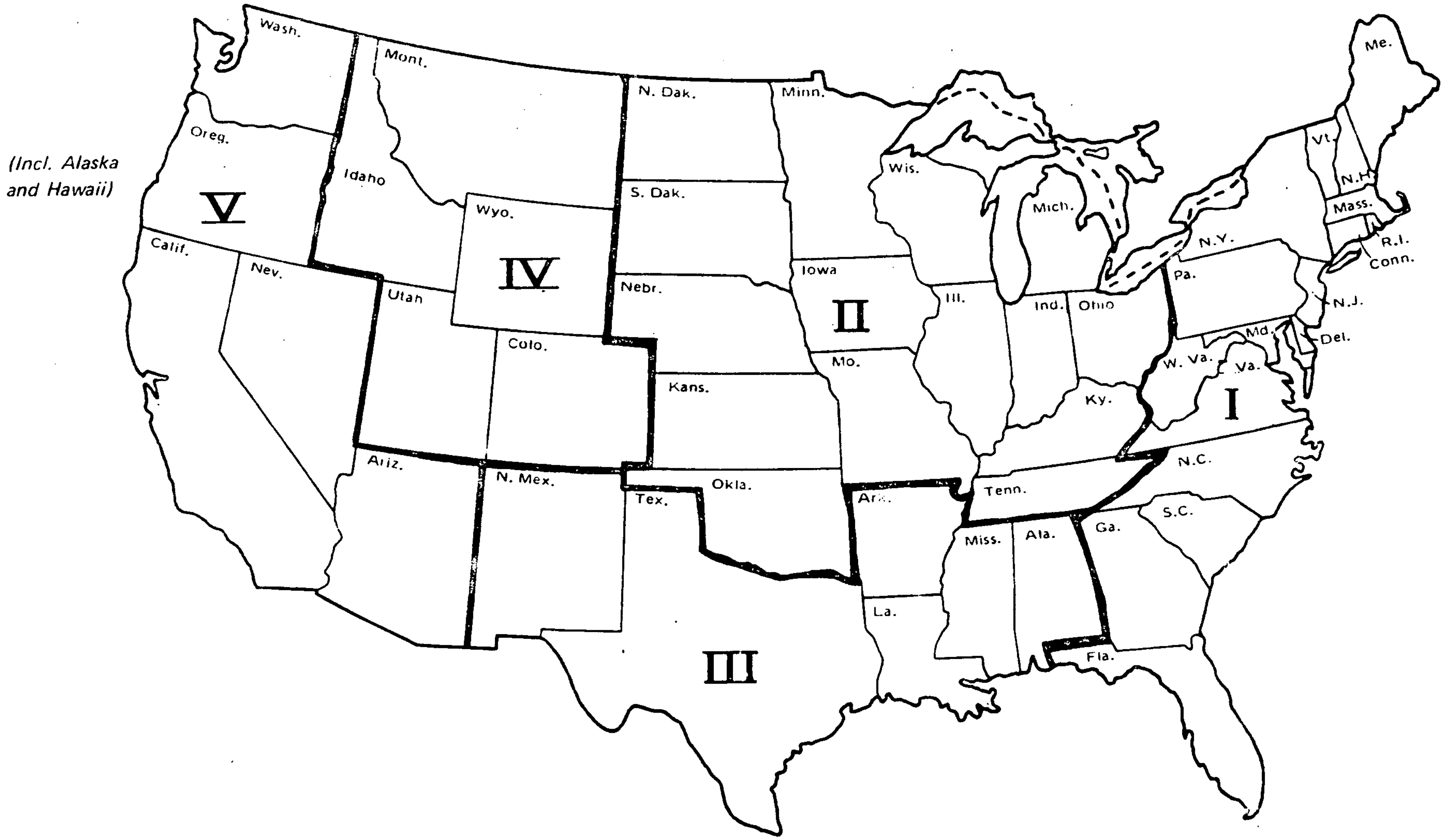

FIGURE 6-2

PETROLEUM ADMINISTRATION FOR DEFENSE DISTRICTS

TABLE 6-2

REGIONAL PRODUCT SUPPLY/DEMAND - 1976

000 M^3/Day (000 Bbl/Day)

			INTER PADD SHIPMENTS						
PADD	DEMAND	REFINERY OUTPUT	FROM I	FROM II	FROM III	FROM IV	FROM V	IMPORTS	OTHER
I	1,032 (6,488)	270 (1,700)	--	18 (111)	491 (3,089)	--	--	269 (1,691)	13 (80)
II	768 (4,828)	597 (3,757)	29 (183)	--	111 (696)	4 (26)	--	15 (94)	57 (356)
III	517 (3,253)	927 (5,832)	--	17 (110)	--	--	- (1)	6 (37)	180 (1,134)
IV	84 (531)	73 (459)	--	10 (63)	--	--	3 (18)	3 (16)	10 (62)
V	375 (2,359)	344 (2,166)	--	--	12 (76)	10 (61)	--	14 (89)	2 (14)
Total	2,776 (17,459)	2,212 (13,914)						306 (1,927)	257 (1,618)

Source: U.S. Department of Energy, Monthly Petroleum Statement

TABLE 6-3

REGIONAL GASOLINE SUPPLY/DEMAND - 1976

000 M^3/Day (000 Bbl/Day)

PADD	DEMAND	REFINERY OUTPUT	INTER PADD SHIPMENTS FROM I	FROM II	FROM III	FROM IV	FROM V	IMPORTS	OTHER
I	381 (2,396)	119 (750)	--	7 (41)	255 (1,606)	--	--	19 (119)	3 (20)
II	380 (2,388)	300 (1,887)	22 (140)	--	41 (260)	2 (15)	--	- (1)	35 (218)
III	150 (945)	371 (2,331)	--	9 (56)	--	--	--	1 (6)	72 (455)
IV	36 (227)	32 (203)	--	6 (36)	--	--	1 (9)	- (0)	5 (29)
V	162 (1,022)	144 (904)	--	--	6 (37)	6 (35)	--	1 (4)	8 (51)
Total	1,109 (6,978)	966 (6,075)						21 (130)	123 (773)

Source: U.S. Department of Energy, Monthly Petroleum Statement

Because of the large number of terminals in this area, PADD's I and II account for most of the total terminal storage and most of the total gasoline storage. PADD I has 52 percent of all storage and 51 percent of the gasoline storage while PADD II has 21 percent of total storage and 21 percent of the total gasoline storage.

6.1.1.4 Bulk Terminal Size

Small facilities comprise the largest portion of the bulk terminal population. Almost half of all bulk terminals have less than 32,000 M^3 (200,000 barrels) of storage capacity (Table 6-4). Another 30 percent have capacities between 32,000 and 95,000 M^3 (200,000 and 600,000 barrels); 22 percent have storage greater than 95 M^3 (600,000 barrels). Similarly, 50 percent of gasoline terminals have total storage capacity less than 32,000 M^3 (200,000 barrels); 28 percent have capacities between 32,000 and 95,000 M^3 (200,000 and 600,000 barrels); and 22 percent have a storage capacity greater than 95,000 M^3 (600,000 barrels).

The distribution of terminals by throughput is fairly even across the selected throughput ranges (Table 6-5). Approximately 36 percent of all terminals have total product throughput less than 636 M^3/day (168,000 gallon/day); 27 percent have a throughput between 636 and 2544 M^3/day (168,000 and 672,000 gallon/day); and 37 percent have a total product throughput greater than 2544 M^3/day (672,000 gallon/day). Almost half of the gasoline terminals, 48 percent, have a gasoline throughput less than 754 M^3/day (200,000 gallon/day); 27 percent have a gasoline throughput between 759 and 1514 M^3/day (200,000 and 400,000 gallons/day); and 25 percent have a gasoline throughput greater than 1514 M^3/day (400,000 gallon/day).

TABLE 6-4

BULK TERMINAL STORAGE DISTRIBUTION[2]

TOTAL STORAGE CAPACITY	ALL TERMINALS		TERMINALS STORING GASOLINE	
000 M^3 (000 Bbl)	NUMBER OF TERMINALS	% TOTAL	NUMBER OF TERMINALS	% TOTAL
<32(200	834	48%	764	50%
32(200) - 95(600)	534	30%	423	28%
95(600) - 159(1000)	215	12%	192	13%
>159(1000)	168	10%	132	9%
Total	1,751	100%	1,511	100%

Source: Bureau of Census, 1972 Census of Wholesale Trade; U.S. Army Corps of Engineers, Port Series; National Petroleum News, Factbook (1972-1978); Independent Liquid Terminals Association, 1978 Directory - Bulk Liquid Terminals and Storage Facilities; Industry contacts; ADL estimates.

TABLE 6-5

BULK TERMINAL THROUGHPUT DISTRIBUTION[3]

ALL TERMINALS			TERMINALS STORING GASOLINE		
AVERAGE PRODUCT THROUGHPUT M^3/Day (000 Gal/Day)	NUMBER OF TERMINALS	% TOTAL	AVERAGE GASOLINE THROUGHPUT M^3/Day (000 Gal/Day)	NUMBER OF TERMINALS	% TOTAL
$<$ 636(168)	626	36%	$<$ 754(200)	728	48%
636(168)-2,544(672)	475	27%	754(200)-1,514(400)	401	27%
2,544(672)-6,995(1,848)	375	21%	1,514(400)-2,271(600)	312	21%
$>$ 6,995(1,848)	275	16%	$>$ 2,271(600)	70	5%
Total		100%			100%

Source: Bureau of Census, 1972 Census of Wholesale Trade; Industry contacts; ADL estimates.

6.1.1.5 Ownership

Major oil companies* own most of the bulk terminals. Major oil companies own 67 percent of all terminals and 72 percent of the gasoline terminals (Table 6-6). Independents, which includes wholesale/marketers, jobbers** and bulk liquid warehousers,*** own 33 percent of all facilities and 28 percent of those handling gasoline.

The majors own the greatest number of bulk terminals within each gasoline throughput range (Table 6-7). The majors also own a disproportionately greater number of the largest bulk terminals. While the majors own 72 percent of all gasoline terminals, they own 77 percent of the terminals having a storage capacity between 95,000 and 159,000 M^3 (600,000 and 1 million barrels) and 78 percent of the facilities with greater than 159,000 M^3 (1 million barrels) of storage capacity but only 60 percent of the smallest terminals having less than 32,000 M^3 (200,000 barrels). The independents, which own 28 percent of all gasoline bulk terminals, own 42 percent of the smallest terminals, i.e., total storage less than 32,000 M^3 (200,000 barrels), and only 22 percent of the largest facilities, i.e., storage greater than 95,000 M^3 (600,000 barrels).

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*Includes regional refiner/marketers. Majors are defined as a fully-integrated company which markets in at least 21 states. A regional refiner/marketer is a semi-integrated comany with at least one refinery which generally markets in less than 21 states.

**A jobber is a petroleum distributor who purchases refined product from a refiner or terminal operator for the purpose of reselling to retail outlets, commercial accounts or reselling through his own retail outlets.

***Bulk liquid warehousers only store products at their facilities for a fee ($/gallon) and do not engage in any marketing activity.

TABLE 6-6

BULK TERMINAL OWNERSHIP[4]

OWNERSHIP SEGMENT	ALL TERMINALS: NUMBER OF TERMINALS	ALL TERMINALS: % TOTAL	TERMINALS STORING GASOLINE: NUMBER OF TERMINALS	TERMINALS STORING GASOLINE: % TOTAL
Majors*	1,170	67%	1,086	72%
Independents	581	33%	425	28%
Total	1,751	100%	1,511	100%

*Includes Regional Refiner/Marketers

Source: U.S. Army Corps of Engineers, Port Series; National Petroleum News, Factbook (1972-1978); Independent Liquid Terminals Association, 1978 Directory - Bulk Liquid Terminals and Storage Facilities; Industry contacts; ADL estimates.

TABLE 6-7

GASOLINE TERMINAL DISTRIBUTION BY SIZE AND OWNERSHIP [5]

TOTAL STORAGE CAPACITY 000 M^3 (000 Bbl)	% OF TOTAL TERMINALS STORING GASOLINE: MAJORS*	INDEPENDENTS	% TOTAL	TOTAL NUMBER OF TERMINALS STORING GASOLINE
<32(200)	30%	21%	50%	764
32(200 - 95(600)	25%	3%	28%	423
96(600) - 159(1,000)	10%	3%	13%	192
>159(1,000)	7%	2%	9%	132
% Total	72%	28%	100%	
Total Number of Gasoline Terminals	1,086	425		1,511

* Includes Regional Refiner/Marketers

Source: Bureau of Census, 1972 Census of Wholesale Trade; U.S. Army Corps of Engineers, Port Series; National Petroleum News, Factbook (1972-1978); Independent Liquid Terminals Association, 1978 Directory - Bulk Liquid Terminals and Storage Facilities; Industry contacts; ADL estimates.

6.1.1.6 Employment

Employment at all bulk terminals declined from 40,222 in 1972 to 35,700 in 1978, a decrease of 11 percent (Table 6-8). Employment at gasoline terminals was estimated to be 30,830 in 1978. PADD I accounts for 55 percent of the total employment at all terminals and 56 percent of the employment at gasoline facilities. PADD II accounts for 22 percent of employment at all terminals and 20 percent of the employment at terminals storing gasoline. Overall, employment is expected to decline as non-competitive facilities close and more terminals install more automated equipment in order to reduce labor costs and to increase plant efficiencies.

6.1.1.7 Future Trends

Recent demand forecasts have indicated that only a modest growth in gasoline consumption is likely through 1979. Demand is then expected to level off or even begin to decline in the early 1980's. These forecasts indicate that no significant increase in additional gasoline storage will be necessary. No new gasoline terminals are expected to be built in the near future.

"Stand alone" economics and the rationalization of marketers will continue to exert closure pressure on marginal facilities. Most bulk terminal closures have already occurred in the bulk terminal market and only 3 percent or 20 of the smallest gasoline terminals, i.e. gasoline throughput less than 200,000 gallons/day, are expected to close by 1983. These closures represent less than 1 percent of the 1978 bulk terminal population.

TABLE 6-8

BULK TERMINAL EMPLOYMENT[6]

PADD	ALL TERMINALS EMPLOYMENT	ALL TERMINALS % TOTAL	TERMINALS STORING GASOLINE EMPLOYMENT	TERMINALS STORING GASOLINE % TOTAL
I	19,280	55%	17,000	56%
II	7,850	22%	6,280	20%
III	4,460	12%	3,770	12%
IV	440	1%	440	1%
V	3,670	10%	3,340	11%
Total	35,700	100%	30,830	100%

Source: Bureau of Census, 1972 Census of Wholesale Trade; U.S. Army Corps of Engineers, Port Series; National Petroleum News, Factbook, (1972-1978); Industry contacts; ADL estimates.

6.1.2 Bulk Terminal Costs

6.1.2.1 Introduction

Estimates of total installed cost and total annualized costs are developed for the bulk terminal vapor control systems discussed earlier in Section 3.2. These systems include refrigeration (RF), compression-refrigeration-absorption (CRA), and adsorption-absorption (AA) vapor recovery and incineration by thermal oxidation (OX). Costs are included for the option of providing both a primary and back-up control system at terminals.

The cost analysis relies upon the use of model terminals and considers those costs associated with the control of benzene emissions directly resulting from the loading of gasoline into tank trucks. Model terminal sizes analyzed are gasoline loading rates of 950 m^3/day (250,000 gallons/day) and 1900 m^3/day (500,000 gallons/day). Cost estimates are provided for both existing and new terminals and are based upon a combination of vendor equipment prices and design information, and installation and operating cost information supplied by actual terminals that have installed vapor control systems. Wherever possible model terminal costs estimated by EPA are compared to actual costs and possible reasons are cited for significant discrepancies.

Control costs incurred to comply with the proposed NESHAP standard are calculated assuming no controls are required due to SIP requirements Terminals located in states requiring vapor recovery (Appendix E) are expected to incur costs for monitoring and possibly a stand-by control system.

A portion of the analysis focuses upon the estimated cost-effectiveness of the various control systems and options considered. This cost-effectiveness is determined in each case by dividing the total annualized control cost by the estimated annual reduction in emissions.

6.1.2.2 Model Terminal Parameters

The model plant approach utilized in this cost analysis required that various technical assumptions be made once the average daily gasoline loading rate was established for a particular model. As mentioned earlier, the two sizes considered were gasoline loading rates of 950 m^3/day (250,000 gallons/day) and 1900 m^3/day (500,000 gallons/day). Table 6-9 summarizes technical parameters and assumptions which served as bases for sizing vapor control systems and analyzing costs and cost-effectiveness. In sizing vapor control systems it appears that two critical design factors include peak hour and maximum instantaneous loading rates at the terminal. As evidenced in Table 6-9, these design factors are not directly linked to the average daily loading rates. This point should be kept in mind later when comparing capital costs for vapor control systems at various daily loading rates.

6.1.2.3 Bases for Capital and Annualized Cost Estimates

The installed capital cost estimates are intended to represent the total investment required to purchase and install a particular control system. All capital costs are intended to reflect first quarter 1978 dollars. Purchase costs for the control systems considered were obtained from vendors for the design factors provided in Table 6-9. Total installed costs were developed from major equipment purchase costs by

Table 6-9. MODEL TERMINAL PARAMETERS

Average Daily Loading Rate:		
m^3/day	950	1,900
gallons/day	250,000	500,000
DESIGN FACTORS		
(a) Number of rack positions	2	4
(b) Number of loading arms per position	3	3
(c) Method of loading	Submerged (top or bottom)	Submerged (top or bottom)
(d) Pumps (each)	1.9 m^3/min (500 gpm)	1.9 m^3/min (500 gpm)
(e) Tank truck capacities	30 m^3 (8,000 gallons)	30 m^3 (8,000 gallons)
(f) Tank truck loading time (total)	20 minutes/truck	20 minutes/truck
(g) Peak hour loading (e) ÷ (f) x 60 x (a)	180 m^3/hr (48,000 gph)	360 m^3/hr (96,000 gph)
(h) Maximum instantaneous loading (a) x (b) x (d)	11 m^3/min (3,000 gpm)	22 m^3/min (6,000 gpm)
EMISSION FACTORS		
Uncontrolled:		
Total hydrocarbon	960 mg/liter	960 mg/liter
Benzene	8 mg/liter	8 mg/liter
Controlled[a]:		
Total hydrocarbon	80 mg/liter	80 mg/liter
Benzene (95% reduction)	0.4 mg/liter	0.4 mg/liter
TERMINAL OPERATING SCHEDULE	300 days/year	300 days/year)

[a]Assumes 100 percent vapor collection at rack during loading and no losses in vapor collection system.

estimating total system installation costs as a percentage of purchase cost. A factor of 100 percent was used for retrofitted terminals while a factor of 70 percent was considered for new terminals. These total installation costs are intended to include sales tax, freight, engineering, unit installation, ancillary equipment and piping and contingencies. Installation cost factors were estimated on the basis of actual installed cost information available to EPA. In most cases these actual installations converted existing top loading racks to bottom loading prior to or in conjunction with hydrocarbon control system installation. EPA model terminal costs do not include this conversion for top loading terminals since EPA feels that this modification is more directly related to operational and personnel safety considerations. Capital costs, however, should adequately reflect higher vapor collection costs for these terminals.

Capital costs for monitoring are not included in the model terminal costs developed. It is estimated that a gas chromatograph monitoring system would cost about $20,000 installed.

Annualized cost estimates include utilities, operating labor, maintenance labor and materials, credits for gasoline recovery, and capital charges for interest, depreciation, administrative overhead, property taxes and insurance. Table 6-10 summarizes all annualized cost factors used in this analysis. All annualized costs are intended to reflect current estimates.

Table 6-10. COST FACTORS USED IN DEVELOPING ANNUALIZED COST ESTIMATES FOR MODEL TERMINALS

Utilities:	
- Electricity	$.017/$10^6$ joules ($.06/Kw-hr)[a]
- Propane	$.10/liter ($.40/gallon)
Operating Labor	$10/man-hour
Maintenance (percent of equipment cost)	
- RF vapor recovery	6 percent[b]
- CRA vapor recovery	4 percent[c]
- AA vapor recovery	4 percent[d] (carbon replacement additional)
- Oxidizer	4 percent[e]
Capital charges (percent of capital cost):	
- Interest and depreciation, plus	16 percent[f]
- Property taxes, insurance and administrative overhead	4 percent
Gasoline value (recovered) FOB terminal before tax:	$.10/liter ($.40/gallon)[g]
Carbon for AA unit (replacement cost)	$21/Kg ($.90/lb)

[a]Reference 7

[b]Reference 7

[c]Based upon actual maintenance costs reported to EPA

[d]Assumed to be comparable to CRA

[e]Reference 8

[f]Calculated using capital recovery factor formula assuming 10 year equipment life and 10 percent interest rate.

[g]Oil Daily - March 1978.

6.1.2.4 Cost Estimates for Emission Controls at Model Existing Terminals

6.1.2.4.1 Single System

As discussed earlier, control options considered in Chapter Four for the gasoline marketing network will require the use of a vapor control system at terminals during tank truck loading operations. Table 6-11 presents estimates of capital and annualized costs for the individual control systems at two daily loading throughputs.

Regarding capital costs presented in Table 6-11 it appears that when compared to vapor recovery systems (RF, CRA, AA) incineration control systems (OX) require the lowest capital investment. For the recovery systems considered refrigeration (RF) capital costs appear to be the lowest. The CRA system cost includes a vapor holder sized to accomodate peak hour loading considering the design vapor flow rate of the CRA unit. Costs can vary slightly depending on the vapor holder and CRA unit size combination selected. The AA system costs are recent vendor budget quotes where installation costs were estimated to be comparable to other vapor recovery systems.

Reviewing annualized costs in Table 6-11 indicates that utilities and maintenance costs appear to be the significant operating costs for all control systems analyzed. Overall, operating costs appear lowest for incineration (OX) and highest for recovery systems if gasoline recovery credits are not included. The capital charges included

Table 6-11. ESTIMATED CONTROL COSTS FOR MODEL EXISTING TERMINALS
Single Vapor Control System Alternative

Gasoline Loaded:	950 m^3/day (250,000 gallons/day)				1900 m^3/day (500,000 gallons/day)			
Vapor Control System:	AA	CRA	OX	RF	AA	CRA	OX	RF
Investment ($000)								
Purchase Cost (FOB factory)[a]	120	128[b]	72	102	155	164[b]	95	153
Total Installed Cost	240	256	144	204	310	328	190	306
Annualized Cost(credit)($000/yr)								
Electricity[c]	3.9	5.1	2.9	9.9	7.8	8.3	5.8	19.8
Propane(pilot)[d]	--	--	1.0	--	--	--	1.0	--
Maintenance	4.8	5.1	2.9	6.1	6.2	6.6	3.8	9.2
Operating labor[e]	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
Carbon Replacement[f]	2.4	--	--	--	4.7	--	--	--
Subtotal (Direct operating costs)	12.6	11.7	8.3	17.5	20.2	16.4	12.1	30.5
Capital Charges	48.0	51.2	28.8	40.8	62.0	65.6	38.0	61.2
Gasoline Recovery(credit)[g]	(39.2)	(39.2)	--	(39.2)	(78.4)	(78.4)	--	(78.4)
Net Annualized Cost(credit)	21.4	23.7	37.1	19.1	3.8	3.6	50.1	13.3

[a]Vendor quotes (see references 9, 10, 11, 12)

[b]Includes vapor holder

[c]All systems except CRA calculated at 12 hours/day of vendor estimated nominal Kw draw - CRA hours based upon design flow rate.

[d]Estimated at .72 gal/hour operation (Reference 11)

[e]Inspections at .5 man-hr/day.

[f]Estimated based upon three year carbon life (Reference 9)

[g]Calculated at 16°C (60°F) and 100% vapor collection at rack.

in annualized costs for the control systems analyzed have been defined earlier in Table 6-10. These charges appear to be three to four times greater than average operating costs for the control systems. Hence, their impact on annualized costs is significant. Equally significant, however, appears to be the effect of gasoline credits on the net annualized cost of vapor recovery units and the relative impact these recovery credits have when comparing net annualized costs for vapor recovery and incineration systems. Based upon the technical assumptions used to estimate gasoline recovery credits, i.e., 100 percent vapor collection at the rack and tank truck compartments saturated with hydrocarbon vapors prior to loading, gasoline recoveries appear to be substantial. However, these annual recovery credit estimates have not been supported by actual terminal data submitted to EPA. Actual recovery information is provided later in the discussion of actual cost information.

6.1.2.4.2 Back-up Controls

An additional consideration analyzed for terminals is the requirement that no tank truck loading be performed unless control units are operating continuously and effectively. In the event the primary control system could not provide the required level of control the terminal would have to either switch to a back-up system or cease loading operations. For purposes of cost analysis three alternatives were considered: (1) Back-up vapor control system, (2) Vapor storage capacity (minimum five day vapor generation capacity),[5] (3) Shutdown of loading operations during

Table 6-12. ESTIMATED CONTROL COSTS FOR MODEL EXISTING TERMINALS
Stand-by Control System Alternative

Gasoline Loaded:	950 m^3/day (250,000 gallons/day)			1900 m^3/day (500,000 gallons/day)		
		(Primary/Stand-by)			(Primary/Stand-by)	
	Stand-by (OX)[a]	(RF/OX)	(OX/OX)	Stand-by (OX)[a]	(AA/OX)	(OX/OX)
Total Installed Capital Cost ($000)	95	299	239	126	436	316
Direct Operating Costs ($000/yr):						
Utilities	Footnote b	9.9	3.9	Footnote b	17.8	6.8
Maintenance and Labor and materials	2.9	10.5	7.3	3.8	16.2	9.1
Capital Charges ($000/yr)	19.0	59.8	47.8	25.2	87.2	63.2
Gasoline (credit)($000/yr)	--	(37.2)[c]	--	--	(74.5)[c]	--
Net Annualized Cost(credit)($000/yr)	21.9	43	59.0	29.0	36.7	79.1

[a]Stand-by system costs are shown separately for those terminals that have already installed vapor controls to comply with existing SIP requirements for hydrocarbons.

[b]These will vary but should not significantly effect net operating costs of primary/stand-by combination.

[c]Recovery reductions will vary but are estimated at 5 percent or 15 days down time on primary system.

malfunction. Costs were estimated for Alternatives (1) and (2) at the two model gasoline loading throughputs. Developing costs for Alternative (3) above was considered beyond the scope of this analysis although it may be a viable option for the terminal.

Since a back-up control system at terminals (Alternative (1)) would hopefully see minimal service, additional gasoline recovery potential is expected to be negligible. Based upon Table 6-11 costs it appears that a stand-by incinerator would represent the lowest capital investment and operating costs. Additionally, because the oxidizer could be linked to the primary system at the knockout tank for the latter, total installed costs would be slightly lower than those included in Table 6-11. Costs are presented separately in Table 6-12 for a stand-by incineration system. This is an approximate cost incurred by terminals that presently operate control systems because of SIP requirements for gasoline loading. This incremental cost is then added to primary system costs for RF, AA and OX systems to depict an expected range of cost impacts resulting from this dual-system alternative.

Although costs were analyzed for Alternative (2) i.e., vapor storage capacity for five day vapor generation at the loading throughput rate, these costs appear extremely high when compared to the stand-by OX system costs. As an example, five-day vapor storage capacity for the 950 m^3/day terminal is estimated to cost \$241,000 installed[9] with annualized costs of approximately \$45,000. This is based upon installation of a new vapor holder with 4730 m^3 (170,000 ft^3) vapor storage capacity. Vapor holders sized to handle reduced loading rates during primary system malfunction may be a more viable alternative from a cost standpoint at terminals.

6.1.2.4.3 Cost-Effectiveness

Based upon the annualized control costs presented in Tables 6-11 and 6-12 and estimates of annual reductions in total hydrocarbon and benzene emissions, cost-effectiveness (C/E) is summarized in Table 6-13 for both the single and dual systems analyzed. The emission reduction estimates were developed from parameters included in Table 6-9 and reflect control levels that EPA considers attainable by all control systems considered.

Cost-effectiveness estimates appear to indicate that recovery is more cost-effective than incineration for the single system. This is basically a result of the substantial gasoline recovery credits estimated for the vapor recovery units.

For terminals installing both a primary and back-up control system, a recovery unit and oxidizer unit, respectively, appears to be the most cost-effective combination. This may change as the annual operating time for the back-up oxidizer unit increases. Finally, when compared to a single control unit, installing dual systems will generally double costs per kilogram of benzene controlled. This assumes that stand-by units are sized to handle the same loading rate as primary systems.

6.1.2.4.4 Comparison to Actual Costs

As mentioned earlier in Section 3.2, as a result of SIP hydrocarbon controls, an estimated 300 control systems are presently installed at

Table 6-13. COST EFFECTIVENESS FOR MODEL EXISTING BATTERIES

Gasoline Loaded:	950 m^3/day (250,000 gallons/day)						1900 m^3/day (500,000 gallons/day)					
	Single System				Dual System (Primary/Standby)		Single System				Dual System (Primary/Standby)	
	(AA)	(CRA)	(OX)	(RF)	(RF/OX)	(OX/OX)	(AA)	(CRA)	(OX)	(RF)	(AA/OX)	(OX/OX)
Net Annualized Cost(credit) ($/yr)	21,400	23,700	37,100	19,100	43,000	59,000	3,800	3,600	50,100	13,300	36,700	79,100
Total Hydrocarbon Controlled[a,b,c] (Mg/yr)[d]	250	250	250	250	250	250	500	500	500	500	500	500
Benzene Controlled[a,c] (10^3 Kg/yr)	2	2	2	2	2	2	4	4	4	4	4	4
Cost-Effectiveness HC ($/Mg)	90	90	150	80	170	240	10	10	100	30	70	160
Cost-Effectiveness Benzene ($/Kg)	11	12	19	10	22	30	1	1	13	3	9	20

[a]Assuming control equipment always operating during gasoline loading
[b]Equivalent to 92 percent reduction in hydrocarbon emissions.
[c]Equivalent to 95 percent reduction in benzene emissions
[d]Mg = megagram = 1000 Kg

bulk terminals to control loading emissions from tank trucks. Costs associated with the installation, operation and maintenance of RF, CRA and OX units were provided by several terminal operators. Since many installations were completed as much as four or five years ago, equipment costs were escalated to current estimates by using the Chemical Engineering Index for Fabricated Equipment. Reported costs and escalated estimates are summarized in Table 6-14. EPA and actual capital costs are then compared graphically in Figure 6-2.

When comparing actual capital costs to the model estimates, it is important to consider such factors as the number of racks, vapor storage capabilities (where applicable) and control unit design rate. An additional consideration for actual terminals is that almost all control system installations were done in conjunction with conversions at racks from top to bottom loading. This work is not always done concurrently. Hence, it appears that some vapor piping and installation costs closely linked with the rack conversion work could not be broken out by actual terminals. Taking all the above into consideration, it is felt that the installed capital costs for model and actual facilities compare reasonably well.

Although actual operating cost information was reported by terminals operating control systems, these costs are reported for hydrocarbon concentrations to the control unit that are generally lower than those assumed for model plants. Additionally, unit costs for utilities were not provided with monthly estimates. For these reasons direct comparisons of actual and model annual operating costs and gasoline recovery credits appear

Table 6-14. SUMMARY OF HYDROCARBON CONTROL SYSTEM COSTS FOR ACTUAL TERMINALS

Average Gasoline Loading Throughput m^3/day	Average Gasoline Loading Throughput 10^3 gpd	No. of Rack Positions	Control Unit	Design Rate	Installation Date	Purchase Cost (PC) ($000)	Total Installed Cost ($000)	Total Installed Cost % of PC	Escalated Installed Cost (1st Quarter 1978) ($000)
450	119	2	OX	300 cfm[a]	6/75	65	95	173	115
630	167	2	OX	250 cfm[a]	5/75	65	99	170	119
1010	267	3	OX	800 cfm[a]	3/75	NA	200	NA	240
490	129	2	RF	250,000 gpd	7/75	NA	116	NA	140
600	159	1	RF	250,000 gpd	12/74	45[b]	112	248	150
1930	510	3	RF	800,000 gpd	4/76	128	250	195	287
NA	---	NA	RF	800,000 gpd	1/74	107	173	161	280
NA	---	NA	RF	800,000 gpd	5/74	119	190	160	285
NA	---	NA	RF	800,000 gpd	5/74	119	164	137	250
1230	325	4	CRA	160 cfm	10/75	115[c]	165	143	215
1700	450	3	CRA	225 cfm	12/72	115[c]	195	170	317

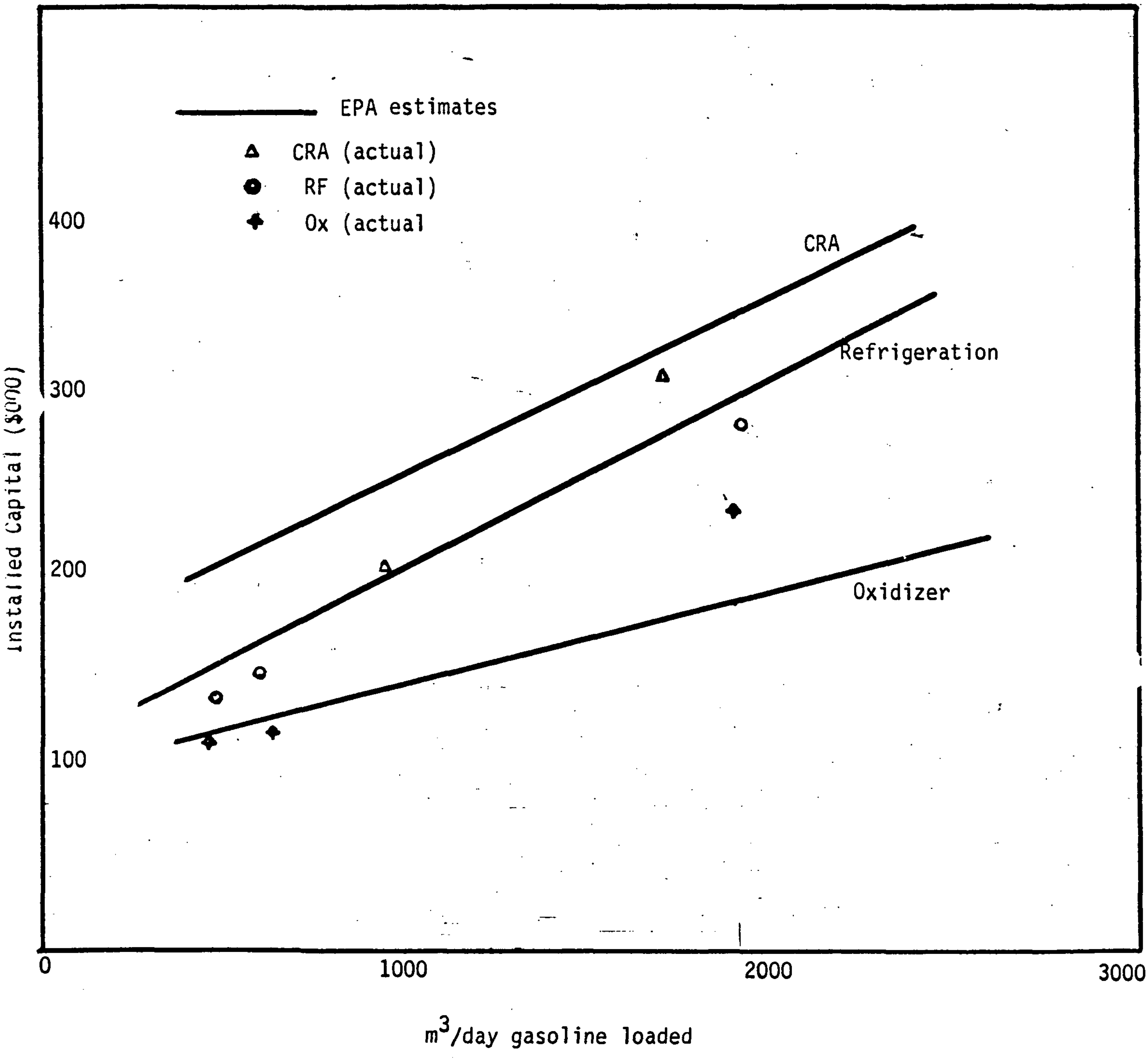
NA - Not available

[a]For comparison to design bases in Table 6.1.2-1, an approximate conversion from cfm to gpm gasoline loaded is 7.5 gal/cf vapor (no vapor growth)

[b]Prototype unit

[c]Cost includes vapor holder

Figure 6-2. Comparison of Installed Capital Costs for Benzene Control Systems



Note: 1 m^3 = 1000 liters = 264 gallons inconclusive. Nevertheless, wherever possible actual operating cost information was factored into the model estimates. This is reflected in several of the maintenance factors, operating labor requirements and electrical requirements used in calculating the respective costs associated with these operating cost factors.

Gasoline recoveries reported by terminals were significantly lower than those estimated for model terminals. Specifically, recoveries ranges from about 0.03 percent to 0.07 percent of the volume of gasoline loaded for actual facilities while EPA estimates correspond to a 0.13 percent recovery.

Low recoveries at actual terminals may be attributable to: (a) loading into "vapor lean" tank trucks that return from areas not requiring Stage I vapor recovery; (b) inefficient vapor collection or control unit operation; (c) the affect of seasonal influences on loading emissions and gasoline recoveries; (d) some combination of these factors.

6.1.2.5 Cost Estimates for Emission Controls at Model New Terminals

Installed capital and annualized costs for the control systems and options considered for model existing terminals have been provided in the preceeding section. For the purpose of estimating costs for new terminals it has been assumed that installation costs will be slightly lower than retrofit situations. This is based upon information indicating that vapor piping installations at existing rack positions often require concrete and structural modifications that could more economically be included in the design of the rack during initial installation time.[~~10~~] → 15 Other physical constraints at existing terminals often affect vapor piping

Table 6-15. ESTIMATED CONTROL COSTS AND COST EFFECTIVENESS FOR MODEL NEW TERMINALS

Gasoline Loaded:	950 m^3/day (250,000 gallons/day)							1900 m^3/day (500,000 gallons/day)						
	Single				Back-up	Dual		Single				Back-up	Dual	
Control Unit(s)	AA	CRA	OX	RF	OX	RF/OX	OX/OX	AA	CRA	OX	RF	OX	AA/OX	OX/OX
Total Installed Cost ($000)	204	218	122	173	88	261	210	264	279	161	260	114	378	275
Direct Operating Costs ($000/yr)	12.6	11.7	8.3	17.5	2.9	20.4	11.2	20.2	16.4	12.1	30.5	3.8	24.0	15.9
Capital Charges ($000/yr)	40.8	43.5	24.5	34.7	17.6	52.3	42.1	52.8	55.8	32.2	52.0	22.8	75.6	55.0
Gasoline Recovery(credit)($000/yr)	(39.2)	(39.2)	--	(39.2)	--	(37.2)	--	(78.4)	(78.4)	--	(78.4)	--	(74.5)	--
Net Annualized Cost(credit)($000/yr)	14.2	16.0	32.8	13.0	20.5	35.5	53.3	(5.4)	(6.2)	44.3	4.1	26.6	25.1	70.9
Total Hydrocarbon Controlled (Mg/yr)	250	250	250	250	*	250	250	500	500	500	500	*	500	500
Benzene Controlled (Mg/yr)	2	2	2	2	*	2	2	4	4	4	4	*	4	4
Cost-Effectiveness HC ($/Mg)	60	60	130	50	*	140	210	(10)	(10)	90	10	*	50	140
Cost-Effectivensss Benzene ($/Mg)	7,100	8,000	16,400	6,500	*	17,700	26,600	(1350)	(1550)	11,100	1,000	*	6,300	17,700

runs and other ancillary costs. Net annualized costs for new terminals are assumed to be impacted only by the slightly lower capital charges associated with lower investments for control system installations.

Considering the foregoing, model costs for new terminals will exhibit cost and cost-effectiveness results that are relatively consistent with those presented earlier for existing terminals. For this reason costs are summarized only in Table 6-15 for new terminals and the reader is advised to refer back to the discussions of existing cost tables for detailed coverage of cost considerations and analyses.

6.1.2.6 Cost Estimates for Tank Truck Vapor Recovery

As discussed earlier in this section, costs for converting terminals to bottom loading are not assumed to be attributable to the proposed EPA regulations. Hence, only those costs associated with providing vapor recovery equipment on tank trucks are considered here. For existing four compartment transports, retrofit capital costs are estimated at $21,000/transport and total annualized costs (including maintenance) are estimated at $780/year. A slight savings (less than 10 percent) is projected when installing vapor recovery on new transports. These estimates were developed from information reported by Reference 7.

6.1.3 Bulk Terminal Impacts

6.1.3.1 Introduction

The principal economic impacts of the proposed vapor control strategy which would reduce the amount of benzene emitted into the atmosphere by bulk terminals are:

- the number of potential bulk terminal closures;*
- the employment displaced by these closures;*
- the total cost of installing vapor control at terminals;
- the total cost of installing vapor control on gasoline tank trailers.

Most terminal operators own gasoline tank trailers, however, a significant number of trailers are also owned by common carrier. Because the cost of converting the trailer fleet to vapor control will not be borne entirely by the bulk terminal industry, its cost will be treated separately.

6.1.3.2 Closure Methodology

Bulk terminals may be forced to close due to vapor control economics because of either of the following reasons:

- Terminals operators are unable to obtain the capital necessary to install vapor control equipment.
- Terminals would fail to achieve a sufficient or acceptible level of profitability if vapor control were installed.

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*The monetary costs of these impacts have not been calculated.

Terminals having no gasoline throughput would be exempt from proposed vapor control program and hence, would not be subject to possible closure. Similarly, the gasoline terminals which are expected to close anyway within the next five years due to competitive economics or market rationalization are not included with the closures caused by vapor control.

The control technologies which will be analyzed in determining bulk terminal impacts are a refrigeration system with an incineration stand-by unit (refrigeration/incineration) and an incineration system with an incineration stand-by unit (incineration/incineration). These two technologies were selected from the various control systems described in Section 6.1.2 because they have the least capital requirement of any of the model systems and they are also the most common technologies currently used by the bulk terminal industry. Stand-by units are required to assure the continuous and efficient control of hydrocarbon vapors during gasoline handling operations. The incineration stand-by unit has the least capital cost of any of the back-up systems evaluated.

Because it would be impossible to determine the number of terminals which would close due to vapor control by examining the entire terminal population on an individual basis, several bulk terminal prototypes were developed to facilitate this analysis. These prototypes, taken collectively, are representative of the bulk terminal industry. Changes in the operational and financial profiles of these facilities which are caused by either of the above two control systems will be translated into potential closures in the actual terminal population. Separate marine and pipeline prototypes were developed for this analysis since these are the two primary modes of product receipt at bulk terminals. For both the marine and pipeline terminals, a large and small prototype was created having the same gasoline throughput as the model vapor control systems discussed in Section 6.1.2, i.e. 950 and 1900 M^4/day (250,000 and 500,000 gallons/day).

The incremental cost of vapor control will impact bulk terminals to varying degrees depending upon the terminal's ability to pass through the costs of vapor control. The most efficient terminals will be able to pass through the full cost of vapor control to their customers in the form of tariff increases. The less efficient terminals, however, will be limited to only passing through, at most, the same unit cost as the more efficient facilities or the market price-setters. Because pipeline terminals are the most financially attractive type of bulk storage, both large and small facilities are assumed to be able to pass through the full cost of vapor control. In the case of marine terminals, which handle the marginal barrel of product, full pass through is limited to the large terminals, while the smaller marine terminals are limited to the same unit cost as the larger facilities.

6.1.3.2.1 Availability of Capital

While over two-thirds of the bulk terminals are owned by major oil companies and regional refiners, who have very good access to capital, each terminal was considered as a separate profit center in order to determine its ability to secure the necessary funds for vapor control equipment. Since no financial assistance was available from a parent corporation or from ancillary marketing operations, the necessary capital would probably be obtained from a commercial lender. A commercial lender is most interested in the terminal's ability to repay the full amount of the loan, i.e. principal as well as interest. If the terminal operator can demonstrate satisfactorily that the loan can be comfortably repaid while still meeting all other current liabilities, e.g., salaries, operating expenses, other loan payments, the capital will most probably be made available. If, however, the proposed loan strains the terminal's debt capacity and hence, jeopordizes the terminal's ability to repay the entire obligation, the capital may not be available. Such a decision would depend upon the lender's perception of the risks and his risk threshold. Cash flows were projected for the bulk terminal prototypes assuming that the vapor control was installed. Based on the cash flow available to service the incremental debt obligation and operating expense, in addition to all pre-control expenses, potential closures in the bulk terminal population were calculated.

6.1.3.2.2 Insufficient Profitability

Bulk terminals unable to pass through the full cost of vapor control would be forced to absorb all remaining control costs. This could cause some facilities, which were just breaking even or marginally profitable in a pre-control case, to now operate at a loss. For each of the bulk terminal prototypes, the gasoline throughput necessary to meet all current liabilities was calculated. Vapor control costs, i.e. operating expense and debt obligations, would increase this breakeven throughput in facilities unable to pass through the full costs of vapor control. Using the increase in breakeven throughput caused by vapor control costs, the number of terminals which once operated above the pre-control breakeven throughput but which now operate below the adjusted breakeven throughput was calculated.

6.1.3.3 Bulk Terminal Closures

An estimated 45-50 bulk terminals are expected to close if refrigeration/incineration or incineration/incineration systems are installed at all gasoline terminals (Table 6-16). Approximately 46 closures would occur due to the cost of an incineration/incineration system while 61 closures are expected because of the cost of a refrigeration/incineration system. No closures are likely due to an inability to obtain the necessary capital; all are expected to be the results of terminals failing to achieve a sufficient or acceptable profitability.

Using the less expensive incineration/incineration system, approximately 30 of the terminal closures are expected at facilities owned by majors or regional refiners while the remaining 16 will be at independents' facilities. All of these closures are expected to be small marine terminals that are unable to pass through the full cost of vapor control. The impact of these closures upon the U.S. gasoline marketing network would be minimal as each of these terminals has an average gasoline throughput which is less than 150,000 gallons/day.

6.1.3.4 Employment Displaced by Terminal Closures

Between 640 and 710 workers are employed at the terminals which are assumed to close due to vapor control (Table 6-17). These workers represent approximately 2 percent of all bulk terminal employees, excluding drivers. Two-thirds of the impacted work force or 430 workers, are employed at terminals owned by majors and regional refiners. The remaining 210 workers are employed at independents' facilities.

TABLE 6-16

BULK TERMINAL CLOSURES DUE TO VAPOR CONTROL ECONOMICS[16]

	REFRIGERATION/ INCINERATION	INCINERATION/ INCINERATION
Terminal Population Subject to Vapor Control	1131	1131
Terminal Closures Due to Inaccessibility of Capital	0	0
Terminal Closures Due to Insufficient Profitability	46	61
Terminals Installing Vapor Control	1085	1080

TABLE 6-17

VAPOR CONTROL EMPLOYMENT AND COSTS IMPACTS AT BULK TERMINALS [17]

	REFRIGERATION/ INCINERATION	INCINERATION/ INCINERATION
Terminals Closed Due to Vapor Control Economics	46	51
Estimated Employment at Closed Terminal	640	710
Terminals Installing Vapor Control	1085	1080
Total Vapor Control Cost (Million 1978 Dollars)	473.2	580.4

6.1.3.5 Vapor Control Costs - Bulk Terminals

The total cost of installing vapor control at all gasoline bulk terminals is $580.4 million using the cost of a refrigeration/incineration system and $473.2 million using the cost of an incineration/incineration system. These figures include the cost of installing incineration stand-by units at all terminals which presently have a primary vapor control system. The total figure is the sum of the capital charges, financing costs and operating expenses less any applicable recovery credits over the 10 year life of the control equipment (Table 6-18). All costs are expressed in constant 1978 dollars; future cash streams have been discounted to present value using a discount rate of 10%.

Majors and regional refiners will bear most of the dollar cost of vapor control. Using the total cost of the incineration/incineration system which has the smaller capital requirement of the two model control systems evaluated, the cost of vapor control to the majors is calculated to be $369.1 million or 78 percent of the total cost of $473.2 million. Independents' are expected to bear the remaining $104.1 million cost, or 28 percent of the total.

6.1.3.6 Vapor Control Costs - Tank Trailer Fleet

There are an estimated 24,800 gasoline tank trailers in operation today, of which 7,400 or 30% are already equipped with vapor control (Table 6-19). Of the remaining trailers, 7300 are expected to be retrofitted while the remaining 10,000 would have vapor control installed as they are replaced. Because gasoline demand is not expected to increase significantly during the next 5 years, no new tank trailers are expected to be built other than those needed to replace existing trailers. Based

TABLE 6-18

VAPOR CONTROL COSTS* AT BULK TERMINALS[18]

(Million 1978 Dollars)

	REFRIGERATION/ INCINERATION	INCINERATION/ INCINERATION
Capital Investment	364.3	280.5
Financing (8 years)	110.8	85.3
Operating Expense (10 years)	250.0	151.8
Recovery Credit (10 years)	(314.7)	--
Capital Investment**	37.0	37.0
Financing (8 years)	9.8	9.8
Operating Expense (10 years)	16.0	16.0
Total Vapor Control Cost	473.2	580.4

* Future cash streams discounted to present value. Discount rate = 10%.

** Cost of incineration stand-by unit for terminals with existing vapor control.

TABLE 6-19

GASOLINE TRAILER POPULATION [19]

Estimated 1978 Gasoline Tank Trailer Fleet	24,760
Gasoline Trailers Vapor Control	(7,440)
Trailers to be Replaced over Next 5 Years*	(10,060)
Retrofit Market	7,260
New Trailers to Replace Existing Fleet	10,060
New Trailers Necessary Due to Increased Gasoline Demand	0
New Trailer Market	10,060
Total Number of Trailers Installing Vapor Control	17,320

* Estimated trailer lifetime of 12.3 years.

on the above population estimate and the capital requirement and operating expense described in Section 6.1.2, the total cost of installing vapor control on the tank trailer fleet is $79.5 million (Table 6-20). This cost includes the capital requirement, financing costs and operating expenses expressed in constant 1978 dollars.

TABLE 6-20

TOTAL COST TO INSTALL VAPOR CONTROL ON THE GASOLINE TRAILER FLEET[20]

(Million 1978 Dollars*)

Capital Cost (Retrofit Market)	15.2
Capital Cost (New Market)	19.1
Financing** (3 years)	3.9
Operating Expense (12 years)***	41.3
TOTAL CONVERSION COST	79.5

* Future cash streams discounted to present value. Discount rate = 10%.

** 100% debt financing for 3 years @ 9%.

*** Estimated trailer lifetime of 12.3 years.

6.2 BULK PLANTS

6.2.1 Bulk Plant Industry Characterization

6.2.1.1 Introduction

Bulk plants are secondary storage facilities which operate as satellite distribution centers receiving petroleum products from primary terminals. Most bulk plants receive product from primary terminals via truck transport. These vehicles deliver 30-34 M^3 (8,000-9,000 gallons) of product and are usually owned by terminal operators or by common carriers. Some bulk plants receive product by rail and a few are supplied by small tanker, barge or pipeline. Bulk plants supplied by rail are most common in the Rocky Mountains and along the West Coast. Delivery by barge is most common on the East and West Coasts and along the Mississippi River.

6.2.1.2 Operations and Market Environment

Because bulk plants service agricultural, commercial and residential accounts as well as retail gasoline outlets, most facilities store a variety of products, e.g., kerosene, gasoline, diesel and distillate. In the Northeast, however, bulk plants tend to specialize in either gasoline or distillate sales.

Bulk plants distribute petroleum products to accounts requiring small and infrequent deliveries; however, bulk plant operators may also supply a number of high volume accounts. Products are delivered by truck transport to high volume customers directly from primary terminals, thus bypassing storage at the bulk plant. Smaller tank wagons, 8-16 M^3 (2,000-4,000 gallons), are used if customers do not have sufficient storage to permit transport deliveries or if roads are impossible to transport traffic.

Approximately two-thirds of all petroleum products sold by bulk plant operators are delivered by tank wagons which are usually owned by the bulk plant operator.

Bulk plants are also subject to the same "stand alone" economics under which bulk terminals now operate. A substantial number of plants have already closed because of their marginal profitability. More closures are expected in the future; however, some rural and semi-rural bulk plants are more secure than urban facilities because they are partially shielded from competitive market forces by transportation economics.

6.2.1.3 Bulk Plant Population

There are presently 18,640 bulk plants of which 17,850, or 96 percent, store gasoline (Table 6-21). The total number of bulk plants has declined 20 percent from the 23,370 facilities reported in 1972. Because bulk plants have been subject to the same "stand alone" economics as terminals, shrinking margins and increasing operating costs have forced the less efficient facilities to close. Furthermore, the withdrawal of the major oil companies from bulk plant operations has removed the financial subsidy required by many marginal facilities. Almost half of all bulk plants and half of the gasoline bulk plants are located in PADD II where distribution logistics and a large concentration of rural accounts warrant secondary storage.

Total storage of bulk plants was estimated to be 6.8 million M^3 (1.8 billion gallons) in 1978. Storage capacity has been declining due to the number of facilities going out of business. Gasoline storage is estimated to be 4.0 million M^3 (1.1 billion gallons), or 60 percent of the total storage. Gasoline storage has also been declining because of the number of bulk plant closures and because an increasing portion of national

TABLE 6.21

BULK PLANT POPULATION [21]

PADD	ALL BULK PLANTS: Number of Bulk Plants	% Total	Total Storage Capacity 000 M^3	(000 Gal)	% Total	BULK PLANTS STORING GASOLINE: Number of Bulk Plants	% Total	Total Storage Capacity 000 M^3	(000 Gal)	% Total
I	3,510	19%	1,641	(433,290)	24%	3,190	18%	947	(250,270)	24%
II	8,850	47%	2,691	(710,670)	40%	8,540	48%	1,521	(401,830)	38%
III	3,320	18%	958	(253,380)	14%	3,320	19%	709	(187,190)	18%
IV	990	5%	323	(85,490)	5%	990	5%	221	(58,490)	5%
V	1,970	11%	1,144	(302,270)	17%	1,810	10%	623	(164,600)	15%
Total	18,640	100%	6,757	(1,785,100)	100%	17,850	100%	4,021	(1,062,380)	100%

Source: Bureau of Census, 1972 Census of Wholesale Trade; National Oil Jobbers Council; National Petroleum News, Factbook, (1972-1978); Industry contacts; ADL estimates.

gasoline throughput is bypassing storage at the bulk plant and is being delivered directly to end-users. Over 60 percent of the gasoline storage capacity at bulk plants is located in PADD's I and II.

6.2.1.4 Size Distribution

The average storage capacity of bulk plants is approximately 300 M^3 (80,000 gallons). Almost 80 percent of all bulk plants and all gasoline bulk plants have total storage between 151 and 568 M^3 (40,000 and 150,000 gallons); approximately 13 percent have storage capacities less than 151 M^3 (40,000 gallons); and 8 percent have capacities greater than 568 M^3 (150,000 gallons) (Table 6-22).

Almost 60 percent of all bulk plant have a total product throughput between 11 and 30 M^3/day (3,000 and 8,000 gallon/day) (Table 6-23). Almost 25 percent have a throughput less than 11 M^3/day (3,000 gallon/day) and 18 percent have a throughput greater than 30 M^3/day (8,000 gallon/day). Similarly, 63 percent of all gasoline bulk plants have a daily gasoline throughput between 11 and 30 M^3/day (3,000 and 8,000 gallon/day); 29 percent have a gasoline throughput less than 11 M^3/day (3,000 gallon/day); and 8 percent have a throughput greater than 30 M^3/day (8,000 gallon/day).

6.2.1.5 Ownership

Jobbers own the greatest number of bulk plants. Jobbers own 74 percent of all bulk plants and 76 percent of the gasoline bulk plants (Table 6-24). The majors' share is 22 percent and 20 percent, respectively, while independent wholesale/marketers own approximately 4 percent of each group. The jobbers' share of the market has been increasing steadily in recent years as the majors have been pulling out of secondary storage operations as part of an overall marketing strategy.

TABLE 6-22

BULK PLANT STORAGE DISTRIBUTION[22]

TOTAL STORAGE CAPACITY M^3 (000 Gal)	ALL BULK PLANTS NUMBER OF BULK PLANTS	ALL BULK PLANTS % TOTAL	BULK PLANTS STORING GASOLINE NUMBER OF BULK PLANTS	BULK PLANTS STORING GASOLINE % TOTAL
$<$ 150(40)	2,380	13%	2,380	13%
150(40) - 568(150)	14,800	79%	14,100	79%
568(150) - 1,136(300)	1,180	6%	1,100	6%
$>$ 1,136(300)	280	2%	260	2%
Total	18,640	100%	17,850	100%

Source: Bureau of Census, 1972 Census of Wholesale Trade; National Oil Jobbers Council; National Petroleum News, Factbook (1972-1978); Industry contacts; ADL estimates.

TABLE 6-23

BULK PLANT THROUGHPUT DISTRIBUTION[23]

ALL BULK PLANTS			BULK PLANTS STORING GASOLINE		
AVERAGE PRODUCT THROUGHPUT M^3/Day (000 Gal/Day)	NUMBER OF PLANTS	% TOTAL	AVERAGE GASOLINE THROUGHPUT M^3/Day (000 Gal/Day)	NUMBER OF PLANTS	% TOTAL
< 11(3)	4,400	24%	< 11(3)	5,210	29%
11(3) - 30(8)	10,760	58%	11(3) - 30(8)	11,210	63%
30(8) - 65(17)	2,650	14%	30(8) - 65(17)	1,170	7%
> 65(17)	830	4%	> 65(17)	260	1%
Total	18,640	100%	Total	17,850	100%

Source: Bureau of Census, 1972 Census of Wholesale Trade; National Oil Jobbers Council; National Petroleum News, Factbook, (1972-1978); Industry contacts; ADL estimates.

TABLE 6-24

BULK PLANT OWNERSHIP[24]

OWNERSHIP SEGMENT	ALL BULK PLANTS: NUMBER OF BULK PLANTS	ALL BULK PLANTS: % TOTAL	BULK PLANTS STORING GASOLINE: NUMBER OF BULK PLANTS	BULK PLANTS STORING GASOLINE: % TOTAL
Majors	4,110	22%	3,610	20%
Independent Marketers/Wholesalers	770	4%	770	4%
Jobbers	13,760	74%	13,470	76%
Total	18,640	100%	17,850	100%

Source: National Oil Jobbers Council; National Petroleum News, Factbook, (1972-1978); Industry contacts; ADL estimates.

Jobbers tend to own a greater portion of the small gasoline bulk plants and a smaller portion of the large bulk plants than either the majors or the independent wholesale/marketers. Jobbers, who own 76 percent of all gasoline bulk plants, own 82 percent of the smallest bulk plants, i.e. less than 150 M^3 (40,000 gallons) of storage capacity, and only 36 percent of the largest facilities, i.e. storage greater than 1,136 M^3 (300,000 gallons) (Table 6-25). The majors, who own 20 percent of the gasoline bulk plants, own 75 percent of the largest bulk plants and only 18 percent of the smallest facilities.

6.2.1.6 Employment

Total employment at bulk plants decreased from 105,525 in 1972 to 75,010 in 1978, a decline of 24 percent (Table 6-26). Employment at gasoline bulk plants was estimated to be 72,130 in 1978 or 96 percent of the total bulk plant employment. PADD's I and II account for almost 75 percent of the total bulk plant employment and employment at gasoline facilities.

6.2.1.7 Future Trends

Because gasoline demand is not expected to increase substantially from its present level and because more gasoline throughput will bypass storage at bulk plants, no new gasoline storage at bulk plants is expected to be built. Furthermore, no new bulk plants are expected.

Additional bulk plant closures are anticipated due to increasing market competition and the ongoing rationalization of petroleum marketing facilities. Increasing operating costs will continue to favor the larger, more efficient operators. Because of these factors, an estimated 3,480 gasoline bulk plants will close over the next 5 years.[27] All of the closures are expected to be in bulk plants having less than 30 M^3/day (8,000 gallons/day) of gasoline throughput.

TABLE 6-25

GASOLINE BULK PLANT DISTRIBUTION BY SIZE AND OWNERSHIP [25]

TOTAL STORAGE CAPACITY M^3 (000 Gal)	MAJORS	INDEPENDENT/ MARKETERS WHOLESALERS	JOBBERS	% TOTAL	TOTAL NUMBER OF BULK PLANTS STORING GASOLINE
<150(40)	2.0	0.4	11.0	13.4	2,380
150(40)-568(150)	16.2	3.5	59.3	79.0	14,100
568(150)-1,136(300)	1.2	0.3	4.7	6.2	1,110
>1,136(300)	0.8	0.1	0.5	1.4	260
% Total	20.2	4.3	75.5	100.0	
Total Number of Bulk Plants Storing Gasoline	3,610	770	13,470		17,850

Source: Bureau of Census, 1972 Census of Wholesale Trade; National Oil Jobbers Council; National Petroleum News, Factbook (1972-1978); Industry contacts; ADL estimates.

TABLE 6-26 26

BULK PLANT EMPLOYMENT

PADD	ALL BULK PLANTS EMPLOYMENT	ALL BULK PLANTS % TOTAL	BULK PLANTS STORING GASOLINE EMPLOYMENT	BULK PLANTS STORING GASOLINE % TOTAL
I	24,210	32%	22,850	32%
II	31,220	42%	30,180	42%
III	9,780	13%	9,780	13%
IV	3,520	5%	3,520	5%
V	6,280	8%	5,800	8%
Total	75,010	100%	72,130	100%

Source: Bureau of Census, 1972 Census of Wholesale Trade; National Oil Jobbers Council; National Petroleum News, Factbook (1972-1978); Industry contacts; ADL estimates.

Major oil companies will continue to withdraw from bulk plant operations in rural and semi-rural areas. An estimated 1,540 bulk plants will be offered for sale by the majors over the next 5 years.[28] Most of these bulk plants will be bought by jobbers who will consolidate these facilities with their existing operations. Some attrition, however, will take place in the total number of facilities.

6.2.2 COST ANALYSIS FOR BULK PLANTS

6.2.2.1 Introduction

Estimates of the costs for the control of benzene emissions from the transfer and storage of gasoline at bulk plants are presented for each of the control options described in Chapter 3: Option 1 is vapor balancing of incoming transport trucks and either top-submerged or bottom-loading of delivery trucks (tank wagons); Option 3 is vapor balancing of both incoming transport trucks and delivery trucks with either bottom or top-submerged loading; Option 4 is vapor processing, either by refrigeration or incineration, in addition to the vapor balancing specified for Option 3. Both installed capital and total annualized costs, in January 1978 dollars, are presented for each of the three options. The control options apply to gasoline bulk plants, which are less than 76,000 liters per day of throughput.

The estimates were developed from a combination of costs incurred by owners of bulk plants and prices quoted from suppliers of control equipment. The considerable variation in vapor balance equipment costs which results from the wide variety of equipment already installed and/or differences in availability is addressed by the presentation of alternative costs for three systems. The first vapor balance system is the one described by National Oil Jobbers Council members McCormack and Shuster on February 28, 1978.[11] This system includes all the features such as check valves, flame arrestors, and high-quality supports and piping, which would be necessary to meet the strictest local fire and safety regulations.

The second vapor balance system is the one commonly known as the "Wiggins system" for bottom loading. For top-loading, the system commonly known as the "Houston-Galveston" system is presented as the top-loading alternative to the Wiggins system and as a part of this second vapor balance system.[30] The cost estimates for the Wiggins system have been corroborated by recent estimates by the National Oil Jobbers Council.[31]

The third type of vapor balance systems is the one reported by the Colorado Air Pollution Control Division in October, 1976.[32] This system is an adaptation of the Wiggins system, for bottom-loading, and various combinations of less expensive piping and supports for top-loading. Detailed lists of the existing and installed equipment used are not available, because the permit applications show total costs, but these combinations of equipment have been judged adequate by the Colorado Department of Health.

Two other large variations exist in the estimates. Variation in the labor rate, age, existing equipment, and physical configuration of bulk plants, have not been addressed in the estimates. Therefore, where a specific facility has conditions which vary substantially from the assumed parameters of the model plants, considerable variation in cost should be expected.

Estimates relate to application of the control options to existing bulk plants and do not include application to new facilities. The bulk plant portion of the gasoline marketing industry has a negative growth rate, as mentioned in Section 2.3, and industry members do not foresee building new bulk plants.[33] Knowledgeable estimates from the industry indicate that, for the few new bulk plants which might be built, the only significant difference in the cost of control equipment would be a reduction of the installation costs by at least 75 percent for a new facility compared with installation costs for an existing bulk plant.[34]

Monitoring costs are not included for any of the three control options. For Option 4, monitoring of the vapor processing portion of the control equipment can be accomplished by use of a gas chromatograph. Since the application of continuous monitoring is a separate decision from selection of one of the control options, the costs of such monitoring are not included in the capital and annualized costs estimated for the control options. The control options do not require monitoring.

State Implementation Plan (SIP) emission levels are the uncontrolled levels shown in Table 4-2, because there are virtually no SIP requirements for control during loading and unloading of storage tanks, as mentioned in Section 5.1. The cost estimates in this chapter represent the cost of increasing control from the uncontrolled (SIP) level to the options described. All of these costs, therefore, are attributable to the proposed control options, and none of the costs is attributable to SIP requirements.

Cost-effectiveness comparisons among the three control options are presented for each control option. Although the installed capital control costs are not significantly related to throughput, the recovery credit varies directly with throughput. Some conclusions on the cost-effectiveness of options for various volumes of operation are presented.

Two model plants are used to illustrate the range of cost estimates. The 15,000 liters per day (4,000 gallons per day) model consists of three above-ground storage tanks, one loading rack with three arms, and two account delivery trucks (tank wagons) each with four compartments. The 76,000 liters per day (20,000 gallons per day) model consists of the same equipment as the smaller model, with two additional account trucks. The parameters which serve as the basis for the cost estimates are summarized in Table 6-22.

6.2.2.2 Capital and Annualized Cost Estimates

Shown in Tables 6-23 and 6-24 are cost estimates for the three control options, based on the assumption that the model bulk plant uses the most complete and expensive vapor balance equipment, including check valves, pre-set meters, and high quality support materials and piping. Shown in Tables 6-25 and 6-26 are cost estimates for the three control options, based on the assumption that the bulk plant uses less expensive vapor balance equipment; i.e., the Wiggins system or the Houston-Galveston system. Shown in Tables 6-27 and 6-28 are cost estimates for the three control options based on use of the third least expensive type of vapor balance equipment as described in reference 10. Applications of these less expensive systems are dependent on acceptances by local fire and safety officials. General descriptions of the items included in the estimates are presented in the following paragraphs.

Capital costs include hardware, transportation, installation and sales tax. Annualized costs include (1) operating costs, such as labor, utilities,

Table 6-27. PARAMETERS USED FOR COST ESTIMATES

	Small Model	Large Model
1. Throughput, (gallons per day)	15,000 (4,000 gallons/day)	76,000 (20,000 gallons/day)
2. Loading Racks	1	1
3. Loading Arms per Rack	3	3
4. Storage Tanks (above-ground)	3	3
5. Account Trucks (Tank Wagons)	2	4
6. Account Trucks Converted to Bottom Loading	1	2
7. Compartments per account truck	4	4
8. Density of gasoline (lb/gal)		
9. Emissions of HC prevented (mg/liter)		
Option 1	800	800
Option 3	1260	1260
Option 4	3429	3429
10. Working Days per Year	286	286
11. Working hours per day	8	8
12. Peak Loading Rate (liters per min.)	490 (130 gallons/min)	490 (130 gallons/min)
13. Liquid to Vapor Ratio	7.5	7.5
14. Operating Labor Cost ($/hour)	10.0	10.0
15. Propane for Oxidizer (gallons/hour)	0.72	0.72
16. Price of propane ($/gallon)	0.40	0.40
17. Price of electricity ($/KWH)	0.05	0.05
18. Capital Recovery Factors (interest)		
a. Vapor Balance Equipment at 20-year life, 10% interest	0.118	0.118
b. Refrigeration or oxidation equipment at 10-year life, 10% interest	0.163	0.163
c. Taxes, insurance, administration on capital (all equipment)	0.04	0.04

Table 6-28. OPTIONS 1 AND 3 CAPITAL AND ANNUALIZED COST ESTIMATES
(In thousands of January 1978 dollars)

	Option 1				Option 3			
	Bottom or Top-Submerged Loading with Incoming Vapor Balance				Bottom or Top-Submerged Loading With Incoming and Outgoing Vapor Balance			
	Bottom Loading		Top-Submerged		Bottom Loading		Top-Submerged	
	15,000 lpd	76,000 lpd	15,000 lpd	76,000 lpd	15,000 lpd	76,000 lpd	15,000 lpd	76,000 lpd
1. Truck (Tank Wagon) Conversion, including Labor	6.27	12.54	N/A	N/A	7.02	14.05	2.38	4.76
2. Rack Conversion, including labor	35.45	35.45	3.54	3.54	35.45	35.45	18.30	18.30
3. Installation, excluding labor	5.31	5.82	0.71	0.71	5.52	6.22	2.35	2.67
4. TOTAL INSTALLED CAPITAL	47.03	53.81	4.25	4.25	47.99	55.72	23.03	25.73
5. Operating Labor	NONE		NONE		NONE		NONE	
6. Utilities	NONE		NONE		NONE		NONE	
7. Maintenance Labor and Materials	1.41	1.61	0.13	0.13	1.43	1.67	0.69	0.77
8. Capital Charges	7.41	8.48	0.67	0.67	7.56	8.76	3.63	4.05
9. TOTAL ANNUALIZED COST	8.82	10.09	0.80	0.80	8.99	10.43	4.32	4.82
10. Less Recovery Credit	0.51	2.59	0.51	2.59	0.81	4.08	0.81	4.08
11. NET ANNUALIZED COST	8.31	7.50	0.29	(1.79)	8.18	6.35	3.51	0.74

Table 6-29 OPTION 4 (Vapor Processing) CAPITAL AND ANNUALIZED COST ESTIMATES
(in thousands of January, 1978 Dollars)

SINGLE SYSTEMS

	Refrigeration				Oxidation			
	Bottom Loading		Top Submerged		Bottom Loading		Top Submerged	
	15,000 lpd	76,000 lpd	15,000 lpd	76,000 lpd	15,000 lpd	76,000 lpd	15,000 lpd	76,000 lpd
Recovery Equipment	42.47	49.50	20.68	23.06	42.47	49.50	20.68	23.06
Processing Equipment	43.22	43.22	43.22	43.22	15.50	15.50	15.50	15.50
Recovery Installation	5.52	6.22	2.35	2.67	5.52	6.22	2.38	2.67
Processing INstallation	25.93	25.93	25.93	25.93	9.76	9.76	9.76	9.76
TOTAL INSTALLED CAPITAL	117.14	124.87	92.18	94.88	73.25	80.98	48.32	50.99
Recovery Operating Labor	NONE	NONE	NONE	NONE	NONE	NONE	NONE	NONE
Processing Operating Labor	1.43	1.43	1.43	1.43	1.43	1.43	1.43	1.43
Recovery Utilities	NONE	NONE	NONE	NONE	NONE	NONE	NONE	NONE
Processing Utilities	2.17	2.17	2.17	2.17	0.16	0.16	0.16	0.16
Recovery Maintenance	1.43	1.67	0.69	0.77	1.43	1.67	0.69	0.77
Processing Maintenance	2.59	2.59	2.59	2.59	0.62	0.62	0.62	0.62
Recovery Capital Charges	7.56	8.76	3.63	4.05	7.56	8.76	3.63	4.05
Processing Capital Charges	14.02	14.02	14.02	14.02	5.12	5.12	5.12	5.12
TOTAL ANNUALIZED COST	29.20	30.64	24.53	25.03	16.32	17.76	11.65	12.15
Less: Processing Recovery Credit	2.19	11.11	2.19	11.11	NONE	NONE	NONE	NONE
NET ANNUALIZED COST	27.01	19.53	22.34	13.92	16.32	17.76	11.65	12.15

DUAL SYSTEMS

	Refrigeration Plus Oxidation				Oxidation Plus Oxidation			
	Bottom Loading		Top Submerged		Bottom Loading		Top Submerged	
	15,000 lpd	76,000 lpd	15,000 lpd	76,000 lpd	15,000 lpd	76,000 lpd	15,000 lpd	76,000 lpd
Recovery Equipment	42.47	49.50	20.68	22.06	42.47	49.50	20.68	23.06
Processing Equipment	58.70	58.70	58.70	58.70	31.00	31.00	31.00	31.00
Recovery Installation	5.52	5.52	2.35	2.67	5.52	5.52	2.35	2.67
Processing Installation	35.69	35.69	35.69	35.69	19.52	19.52	19.52	19.52
TOTAL INSTALLED CAPITAL	142.38	149.41	117.42	120.12	98.51	105.54	73.55	76.25
Recovery Operating Labor	NONE	NONE	NONE	NONE	NONE	NONE	NONE	NONE
Processing Operating Labor	1.42	1.43	1.43	1.43	1.43	1.43	1.43	1.43
Recovery Utilities	NONE	NONE	NONE	NONE	NONE	NONE	NONE	NONE
Processing Utilities	2.17	2.17	2.17	2.17	0.16	0.16	0.16	0.16
Recovery Maintenance	1.43	1.67	0.69	0.77	1.43	1.67	0.69	0.77
Processing Maintenance	2.90	2.90	2.90	2.90	0.93	0.93	0.93	0.93
Recovery Capital Charge	7.56	8.76	3.63	4.05	7.56	8.76	3.63	4.05
Processing Capital Charges	19.54	19.54	19.54	19.54	10.24	10.24	10.24	10.24
TOTAL ANNUALIZED COST	35.03	36.47	30.36	30.86	21.75	23.19	17.08	17.58
Less: Processing Recovery Credit	2.19	11.11	2.19	11.11	NONE	NONE	NONE	NONE
NET ANNUALIZED COST	32.84	25.36	28.17	19.75	21.75	23.19	17.08	17.58

Table 6-30. OPTIONS 1 AND 3 (VAPOR BALANCE WITH LESS EXPENSIVE EQUIPMENT) COST ESTIMATES[5] (in thousands of January 1978 dollars)

	Option 1: Bottom or Top-Submerged Loading with Incoming Vapor Balance				Option 3: Bottom or Top-Submerged Loading With Incoming and Outgoing Vapor Balance			
	Bottom Loading		Top-Submerged		Bottom Loading		Top-Submerged	
	15,000 lpd	76,000 lpd	15,000 lpd	76,000 lpd	15,000 lpd	76,000 lpd	15,000 lpd	76,000 lpd
Truck (tank wagon) conversion, including labor	0.97	1.95	N/A	N/A	1.95	3.90	2.16	4.33
Rack conversion, including labor	7.47	7.47	3.54	3.54	7.47	7.47	6.71	6.71
Piping rack to storage, including labor	1.58	1.58	N/A	N/A	1.58	1.58	N/A	N/A
Installation, excluding labor	2.29	2.34	0.71	0.71	2.34	2.45	1.83	1.94
TOTAL INSTALLED CAPITAL	12.31	13.34	4.25	4.25	13.34	15.40	10.70	12.98
Operating Labor	NONE	NONE	NONE	NONE	NONE	NONE	NONE	NONE
Utilities	NONE	NONE	NONE	NONE	NONE	NONE	NONE	NONE
Maintenance Labor and Material	0.37	0.40	0.13	0.13	0.40	0.46	0.32	0.39
Capital charges	1.94	2.10	0.67	0.67	2.10	2.43	1.69	2.04
TOTAL ANNUALIZED COST	2.31	2.50	0.80	0.80	2.50	2.89	2.01	2.43
Less Recovery Credit	0.51	2.59	0.51	2.59	0.81	4.08	0.81	4.08
NET ANNUALIZED COST (credit)	1.70	(0.09)	0.29	(1.79)	1.69	(1.19)	1.20	(1.85)

Table 6-31. OPTION 4 (Vapor Processing with less expensive equipment) CAPITAL AND ANNUALIZED COST ESTIMATES (in thousands of January 1978 dollars)

	Refrigeration				Oxidation			
	Bottom Loading		Top Submerged		Bottom Loading		Top Submerged	
	15,000 lpd	76,000 lpd	15,000 lpd	76,000 lpd	15,000 lpd	76,000 lpd	15,000 lpd	76,000 lpd
Recovery Equipment	11.00	12.95	8.87	11.04	11.00	12.95	8.87	11.04
Processing Equipment	43.22	43.22	43.22	43.22	15.50	15.50	15.50	15.50
Recovery Installation	2.34	2.45	1.83	1.94	2.34	2.45	1.83	1.94
Processing Installation	25.93	25.93	25.93	25.93	9.76	9.76	9.76	9.76
TOTAL INSTALLED CAPITAL	82.49	84.55	79.85	82.13	38.60	40.66	35.96	38.24
Recovery Operating Labor	NONE	NONE	NONE	NONE	NONE	NONE	NONE	NONE
Processing Operating Labor	1.43	1.43	1.43	1.43	1.43	1.43	1.43	1.43
Recovery Utilities	NONE	NONE	NONE	NONE	NONE	NONE	NONE	NONE
Processing Utilities	2.17	2.17	2.17	2.17	0.16	0.16	0.16	0.16
Recovery Maintenance	0.40	0.46	0.32	0.39	0.40	0.46	0.32	0.39
Processing Maintenance	2.59	2.59	2.59	2.59	0.62	0.62	0.62	0.62
Recovery Capital Charges	2.10	2.43	1.69	2.04	2.10	2.43	1.69	2.04
Processing Capital Charges	14.02	14.02	14.02	14.02	5.12	5.12	5.12	5.12
TOTAL ANNUALIZED COST	22.71	23.10	22.22	22.64	9.83	10.22	9.34	9.76
Less: Processing Recovery Credit	2.19	11.11	2.19	11.11	NONE	NONE	NONE	NONE
NET ANNUALIZED COST	20.52	11.99	20.03	11.53	9.83	10.22	9.34	9.76

	Refrigeration Plus Oxidation				Oxidation Plus Oxidation			
	Bottom Loading		Top Submerged		Bottom Loading		Top Submerged	
	15,000 lpd	76,000 lpd	15,000 lpd	76,000 lpd	15,000 lpd	76,000 lpd	15,000 lpd	76,000 lpd
Recovery Equipment	4.00	12.95	8.87	11.04	11.00	12.95	8.87	11.04
Processing Equipment	58.70	58.70	58.70	58.70	31.00	31.00	31.00	31.00
Recovery Installation	2.34	2.45	1.83	1.94	2.34	2.45	1.83	1.94
Processing Installation	35.69	35.69	35.69	35.69	19.52	19.52	19.52	19.52
TOTAL INSTALLED CAPITAL	107.73	109.79	105.09	102.37	63.86	65.92	61.22	63.50
Recovery Operating Labor	NONE	NONE	NONE	NONE	NONE	NONE	NONE	NONE
Processing Operating Labor	1.42	1.43	1.43	1.43	1.43	1.43	1.43	1.43
Recovery Utilities	NONE	NONE	NONE	NONE	NONE	NONE	NONE	NONE
Processing Utilities	2.17	2.17	2.17	2.17	0.16	0.16	0.16	0.16
Recovery Maintenance	0.40	0.46	0.32	0.39	0.40	0.46	0.32	0.39
Processing Maintenance	2.90	2.90	2.90	2.90	0.93	0.93	0.93	0.93
Recovery Capital Charge	2.10	2.43	1.69	2.04	2.10	2.43	1.69	2.04
Processing Capital Charges	19.54	19.54	19.54	19.54	10.24	10.24	10.24	10.24
TOTAL ANNUALIZED COST	28.53	28.93	22.05	28.47	15.26	15.65	14.77	15.19
Less: Processing Recovery Credit	2.19	11.11	2.19	11.11	NONE	NONE	NONE	NONE
NET ANNUALIZED COST	26.34	17.82	25.86	17.36	15.26	15.65	14.77	15.19

Table 6-32. OPTIONS 1 AND 3 (VAPOR BALANCE WITH LEAST EXPENSIVE EQUIPMENT CAPITAL AND ANNUALIZED COST ESTIMATES (in thousands of January 1978 dollars)

	Option 1				Option 3			
	Bottom or Top-Submerged Loading with Incoming Vapor Balance				Bottom or Top-Submerged Loading With Incoming and Outgoing Vapor Balance			
	Bottom Loading		Top-Submerged		Bottom Loading		Top-Submerged	
	15,000 lpd	76,000 lpd	15,000 lpd	76,000 lpd	15,000 lpd	76,000 lpd	15,000 lpd	76,000 lpd
1. Truck (Tank Wagon) Conversion, including labor[b]	0.97	1.94	0.75	0.75	1.61	3.23	1.69	2.15
2. Rack Conversion, including labor[c]	1.08	1.08	0.75	0.75	1.08	1.08	1.69	2.15
3. Installation, excluding labor[d]	0.28	0.41	0.20	0.20	0.36	0.58	0.46	0.58
4. TOTAL INSTALLED CAPITAL	2.33	3.43	1.70	1.70	3.05	4.89	3.84	4.88
5. Operating Labor	NONE		NONE		NONE		NONE	
6. Utilities	NONE		NONE		NONE		NONE	
7. Maintenance Labor and Materials	0.07	0.10	0.05	0.05	0.09	0.15	0.12	0.15
8. Capital Charges[5]	0.37	0.54	0.27	0.27	0.48	0.77	0.60	0.77
9. TOTAL ANNUALIZED COST	0.44	0.64	0.32	0.32	0.57	0.92	0.72	0.92
10. Less Recovery Credit	0.51	2.59	0.51	2.59	0.81	4.08	0.81	4.08
11. NET ANNUALIZED COST	(0.07)	(1.95)	(0.19)	(2.27)	(0.24)	(3.16)	(0.09)	(3.16)

Table 6-33. OPTION 4 (VAPOR PROCESSING WITH THE LEAST EXPENSIVE VAPOR RECOVERY EQUIPMENT) CAPITAL AND ANNUALIZED COSTS
(in thousands of January 1978 dollars)

	Refrigeration				Oxidation			
	Bottom Loading		Top-Submerged		Bottom Loading		Top Submerged	
	15,000 lpd	76,000 lpd	15,000 lpd	76,000 lpd	15,000 lpd	76,000 lpd	15,000 lpd	76,000 lpd
Recovery Equipment	2.69	4.31	3.38	4.30	2.69	4.31	3.38	4.30
Processing Equipment	43.22	43.22	43.22	43.22	15.50	15.50	15.50	15.50
Recovery Installation	0.36	0.58	0.46	0.58	0.36	0.58	0.46	0.58
Processing Installation	25.93	25.93	25.93	25.93	9.76	9.76	9.76	9.76
TOTAL INSTALLED CAPITAL	72.20	74.04	72.99	74.03	28.31	30.15	29.10	30.14
Recovery Operating Labor	NONE	NONE	NONE	NONE	NONE	NONE	NONE	NONE
Processing Operating Labor	1.43	1.43	1.43	1.43	1.43	1.43	1.43	1.43
Recovery Utilities	NONE	NONE	NONE	NONE	NONE	NONE	NONE	NONE
Processing Utilities	2.17	2.17	2.17	2.17	0.16	0.16	0.16	0.16
Recovery Maintenance	0.09	0.15	0.12	0.15	0.09	0.15	0.12	0.15
Processing Maintenance	2.59	2.59	2.59	2.59	0.62	0.62	0.62	0.62
Recovery Capital Charges	0.48	0.77	0.60	0.77	0.48	0.77	0.60	0.77
Processing Capital Charges	14.02	14.02	14.02	14.02	5.12	5.12	5.12	5.12
TOTAL ANNUALIZED COST	20.78	21.13	20.93	21.13	7.90	8.25	8.05	8.25
Less: Processing Recovery Credit	2.19	11.11	2.19	11.11	NONE	NONE	NONE	NONE
NET ANNUALIZED COST	18.59	10.02	18.74	10.02	7.90	8.25	8.05	8.25

	Refrigeration Plus Oxidation				Oxidation Plus Oxidation			
	Bottom Loading		Top-Submerged		Bottom Loading		Top Submerged	
	15,000 lpd	76,000 lpd	15,000 lpd	76,000 lpd	15,000 lpd	76,000 lpd	15,000 lpd	76,000 lpd
Recovery Equipment	2.69	4.31	3.38	4.30	2.69	4.31	3.38	4.30
Processing Equipment	58.70	58.70	58.70	58.70	31.00	31.00	31.00	31.00
Recovery Installation	0.36	0.58	0.46	0.58	0.36	0.58	0.46	0.58
Processing Installation	35.69	35.69	35.69	35.69	19.52	19.52	19.52	19.52
TOTAL INSTALLED CAPITAL	97.68	99.28	98.23	99.27	53.57	55.41	54.36	55.40
Recovery Operating Labor	NONE	NONE	NONE	NONE	NONE	NONE	NONE	NONE
Processing Operating Labor	1.43	1.43	1.43	1.43	1.43	1.43	1.43	1.43
Recovery Utilities	NONE	NONE	NONE	NONE	NONE	NONE	NONE	NONE
Processing Utilities	2.17	2.17	2.17	2.17	0.16	0.16	0.16	0.16
Recovery Maintenance	0.09	0.15	0.12	0.15	0.09	0.15	0.12	0.15
Processing Maintenance	2.90	2.90	2.90	2.90	0.93	0.93	0.93	0.93
Recovery Capital Charge	0.48	0.77	0.60	0.77	0.48	0.77	0.60	0.77
Processing Capital Charges	19.54	19.54	19.54	19.54	10.24	10.24	10.24	10.24
TOTAL ANNUALIZED COST	26.61	26.96	26.76	26.96	13.33	13.68	13.36	13.58
Less: Processing Recovery Credit	2.19	11.11	2.19	11.11	NONE	NONE	NONE	NONE
NET ANNUALIZED COST	24.42	15.85	24.57	15.85	13.33	13.68	13.36	13.58

and maintenance (2) capital charges, such as interest, insurance and taxes, and (3) credit for recovery of gasoline as a salable product. Among the three control options there are some differences in the rates used to compute interest charges, recovery credits and indirect installation charges, as a result of differences in equipment. For example, the refrigeration equipment has an expected life and expected installation contingency factor different from those factors which apply to the vapor recovery equipment. Similarly, the refrigeration unit recovery credit factor, based on prevented emissions, differs from the factor used for the vapor recovery equipment. Operating costs for the vapor balance equipment in Options 1 and 3 are limited to maintenance costs, while the vapor processing equipment in Option 4 has labor, utilities and maintenance costs.

6.2.2.3 Comparisons of Costs

Capital and annualized costs for all three control options and for all three types of vapor balance equipment are presented in Table 6-29.

For Option 1, with most expensive equipment, installed capital costs range from $4,250 for top-submerged loading for the small model plant to $53,810 for bottom-loading, and annualized costs range from an $1,790 credit for top-submerged loading to $8,310 for bottom-loading. Using less expensive equipment, the top-loading installed capital costs are the same (same equipment) but the bottom-loading installed capital costs are $13,340 for use of the Wiggins system. Annualized costs for the less expensive equipment range from $1,790 credit for top-submerged loading to $1,700 for bottom-loading.

Table 6-34. COMPARISON OF CAPITAL AND ANNUALIZED COSTS (In thousands of January 1978 dollars)

Control Alternative	Most Expensive Equipment				Less Expensive Equipment				Least Expensive Equipment			
	Bottom Loading		Top-Submerged		Bottom Loading		Top-Submerged		Bottom Loading		Top-Submerged	
	15,000 lpd	76,000 lpd	15,000 lpd	76,000 lpd	15,000 lpd	76,000 lpd	15,000 lpd	76,000 lpd	15,000 lpd	76,000 lpd	15,000 lpd	76,000 lpd
Option 1												
Installed Capital	47.03	53.81	4.25	4.25	12.31	13.34	4.25	4.25	2.33	3.43	1.70	1.70
Net Annualized	8.31	7.50	0.29	(1.79)	1.70	(0.09)	0.29	(1.79)	(0.07)	(1.95)	(0.19)	(2.27)
Option 3												
Installed Capital	47.99	55.72	23.03	25.73	13.34	15.40	10.70	12.98	3.05	4.89	3.84	4.88
Net Annualized	8.18	6.35	3.51	0.74	1.69	(1.19)	1.20	(1.85)	(0.24)	(3.16)	(0.09)	(3.16)
Option 4												
Single Systems												
(1) Refrigeration												
Installed Capital	117.14	124.87	92.18	94.88	82.49	84.55	79.85	82.13	72.20	74.04	72.99	74.03
Net Annualized	27.01	19.53	22.34	13.92	20.52	11.99	20.03	11.53	18.59	10.02	18.74	10.02
(2) Oxidation												
Installed Capital	73.25	80.98	48.32	50.99	38.60	40.66	35.96	38.24	28.31	30.15	29.10	30.14
Net Annualized	16.32	17.76	11.65	12.15	9.83	10.22	9.34	9.76	7.90	8.25	8.05	8.25
Dual Systems												
(1) Refrigeration plus oxidation												
Installed Capital	142.38	149.41	117.42	120.12	107.73	109.79	105.09	102.37	97.68	99.28	98.23	99.27
Net Annualized	32.84	25.36	28.17	19.75	26.34	17.82	25.86	17.36	24.42	15.85	24.57	15.85
(2) Oxidation plus oxidation												
Installed Capital	98.51	105.54	73.55	76.25	63.86	65.92	61.22	63.50	53.57	55.41	54.36	55.40
Net Annualized	21.75	23.19	17.08	17.58	15.26	15.65	14.77	15.19	13.33	13.68	13.36	13.58

Because of this lack of experience in application of these control devices, installation costs include a 20 percent allowance for contingencies, compared with the 10 percent used for vapor recovery equipment.

Annualized costs range from $11,650 for the oxidation system with top-loading vapor recovery to $32,840 for the refrigeration system with bottom-loading vapor recovery. The refrigeration system and the refrigeration-plus-oxidation dual system show the effect of recovery credits, which cause the larger model plant to have lower net annualized costs. The oxidation system and the oxidation-plus-oxidation dual systems, which lack recovery credits, have higher annualized costs for the larger model plant.

Using the less expensive vapor recovery equipment installed capital costs for Option 4 range from $35,960 for single system oxidation using top-submerged vapor recovery to $109,730 for dual system refrigeration-plus-oxidation using bottom-loading. Annualized costs range from $9,340 for single-system oxidation to $26,340 for dual system refrigeration-plus-oxidation.

Using the least expensive vapor recovery equipment, installed capital costs for Option 1 range from $1,700 for the top-submerged loading to $3,430 for bottom-loading for the larger model plant. Annulaized costs range from the $2,270 credit for the larger plant with top loading to the $70 credit for the smaller plant with bottom-loading. For Option 3 installed capital costs range from $4,890 for the larger plant with bottom-loading to $3,050 for the smaller plant with bottom loading. Annualized costs range from the $3,160 credit for the larger plant with either bottom or top-submerged loading to the $90 credit for the smaller plant with top-loading.

Applying the least expensive vapor recovery equipment to the control systems required for Option 4 results in installed capital costs which range from $28,310 for the single oxidation system for the smaller plant using bottom loading to $99,280 for the refrigeration plus oxidation system for the larger plant using bottom loading. Annualized costs range from $7,900 for the single oxidation system for the smaller plant using bottom loading to $24,570 for the refrigeration plus oxidation system for the smaller plant using top-submerged loading.

The summary of capital and annualized costs for the three control alternatives shown in Table 6-29 presents several comparisons. For both all three categories of equipment, the highest installed capital and annualized costs result from using the dual system refrigeration-plus-oxidation. Also, for all three categories of equipment, the lowest installed capital and annualized costs result from using the single system oxidation with top-submerged loading.

6.2.2.4 Cost-Effectiveness

Comparisons of the control options cost-effectiveness ratios, in dollars per kilogram of hydrocarbon removed, are shown in Table 6-30 and graphically in Figures 6-3 through 6-8. The conversion of the

Table 6-35. COST-EFFECTIVENESS (in January 1978 dollars per kilogram of Benzene controlled)

Control Alternative	Most Expensive Equipment				Less Expensive Equipment				Least Expensive Equipment			
	Bottom Loading		Top-Submerged		Bottom Loading		Top-Submerged		Bottom Loading		Top-Submerged	
	15,000 lpd	76,000 lpd	15,000 lpd	76,000 lpd	15,000 lpd	76,000 lpd	15,000 lpd	76,000 lpd	15,000 lpd	76,000 lpd	15,000 lpd	76,000 lpd
Option 1	303	54	10	(13)	63	(1)	10	(13)	(3)	(14)	(8)	(16)
Option 3	189	29	81	4	39	(5)	28	(9)	(6)	(15)	(3)	(15)
Option 4												
(1) Single Systems												
Refrigeration	230	33	190	24	175	20	170	19	158	16	159	16
Oxidation	139	30	99	20	84	18	80	16	68	14	69	14
(2) Dual Systems												
Refrigeration plus oxidation	279	43	240	34	224	30	220	29	208	26	209	26
Oxidation plus oxidation	185	39	145	29	130	26	125	25	114	23	114	23

NOTE: (1) Values shown in parentheses are credits.
(2) Values are rounded to nearest dollar.

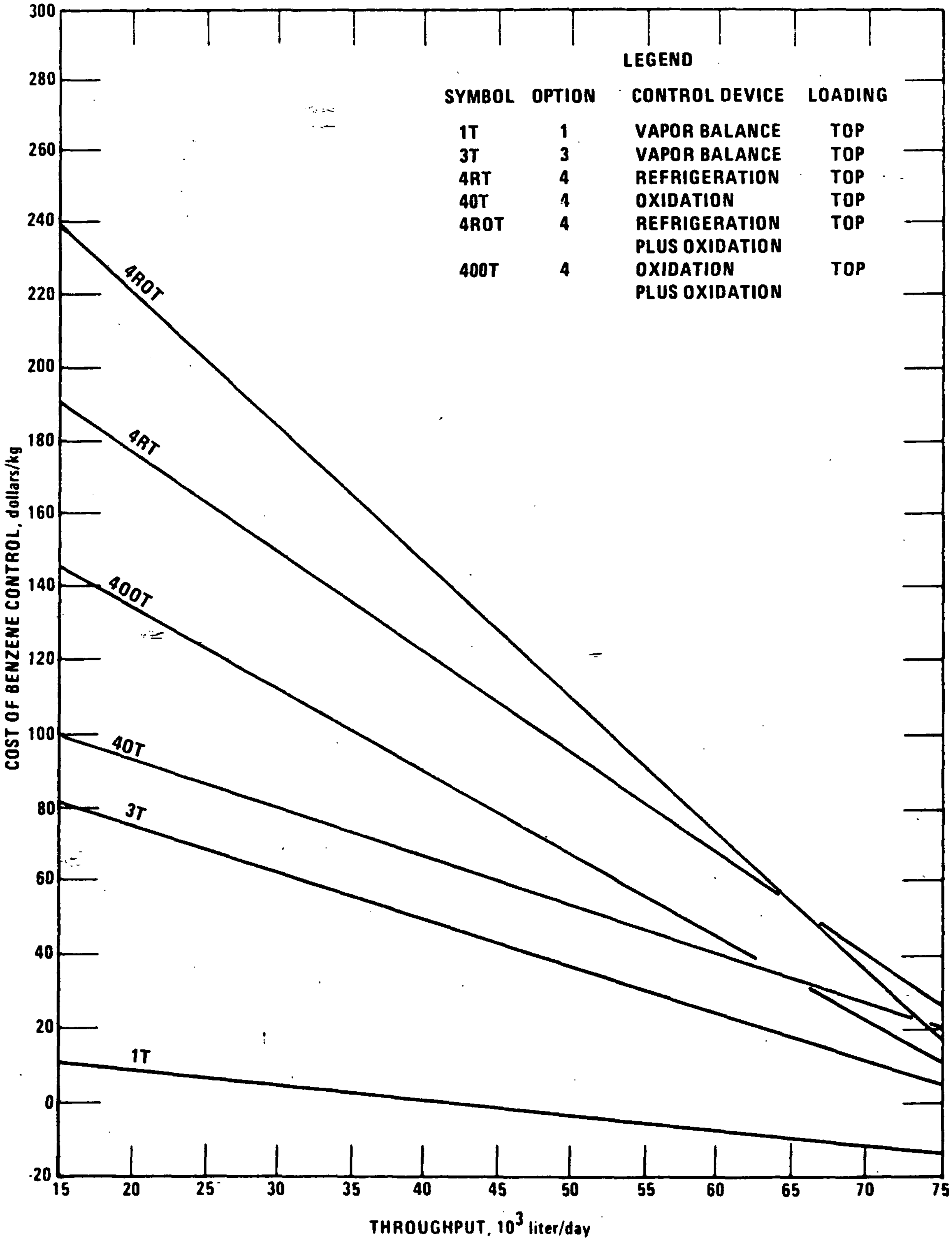

Figure 6-3. Cost-effectiveness for most expensive equipment (top-loading) in January, 1978 dollars.

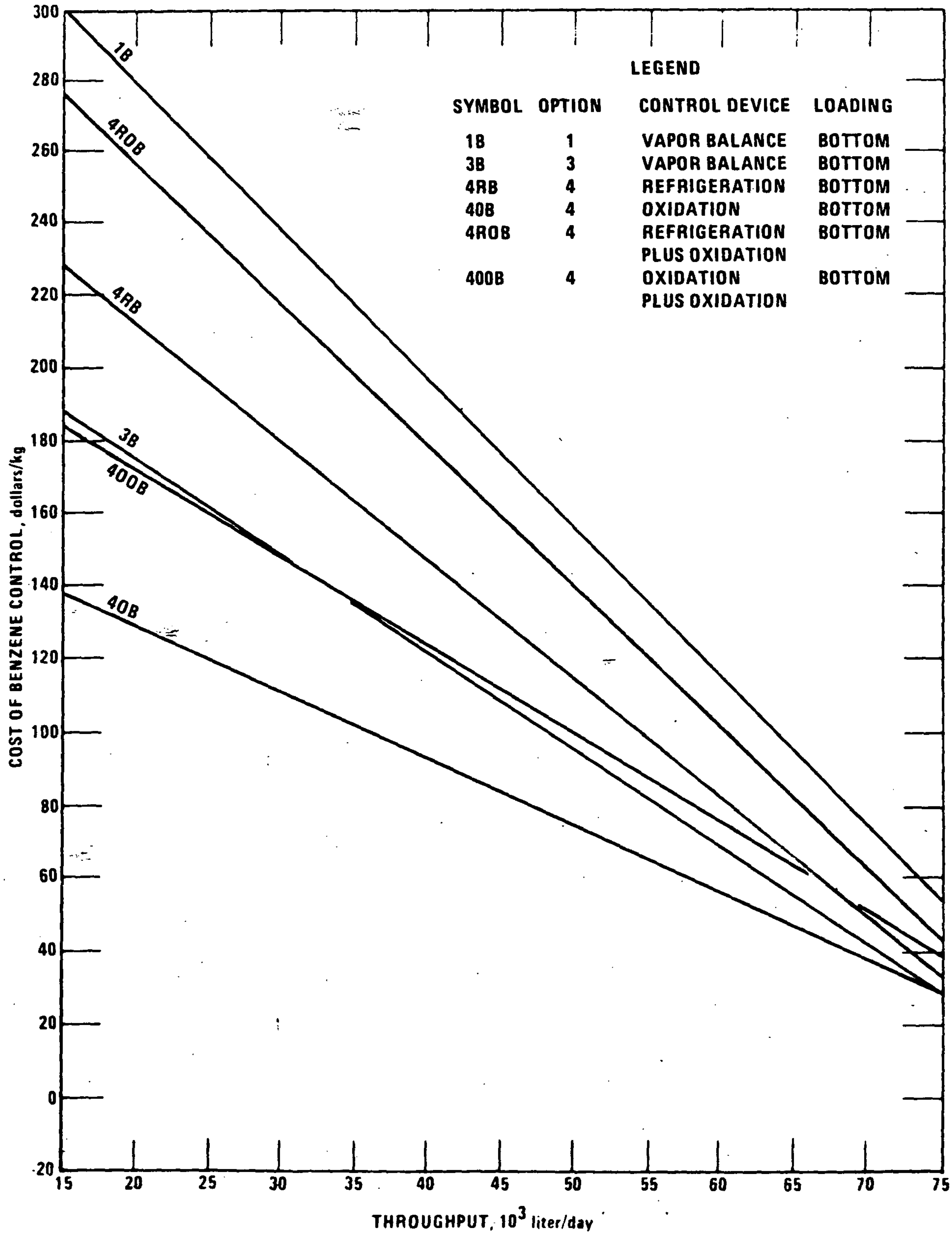

Figure 6-4. Cost-effectiveness for most expensive equipment (bottom-loading) in January, 1978 dollars.

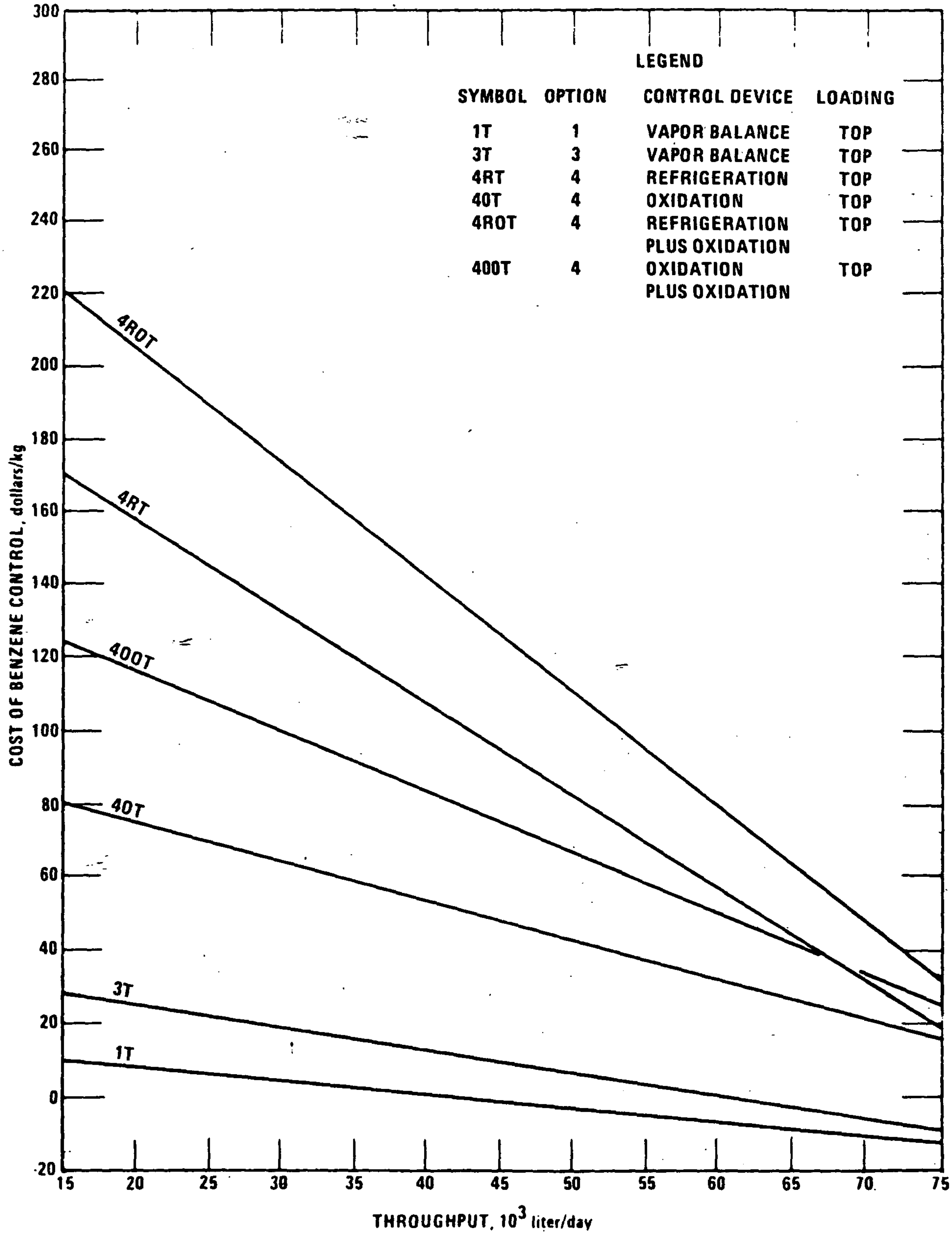

Figure 6-5. . Cost-effectiveness for less expensive equipment (top-loading) in January, 1978 dollars.

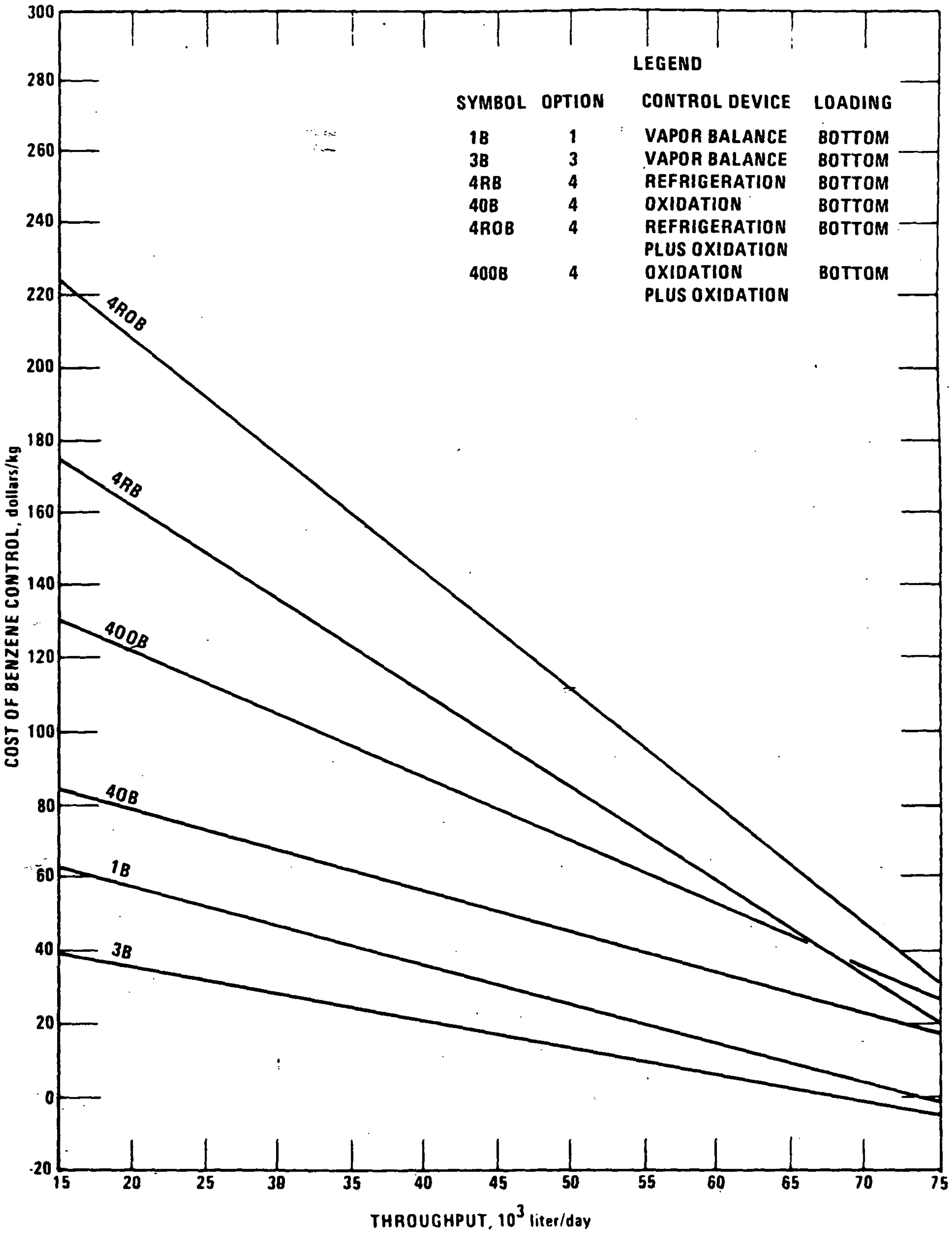

Figure 6-6. Cost-effectiveness for less expensive equipment (bottom-loading) in January, 1978 dollars.

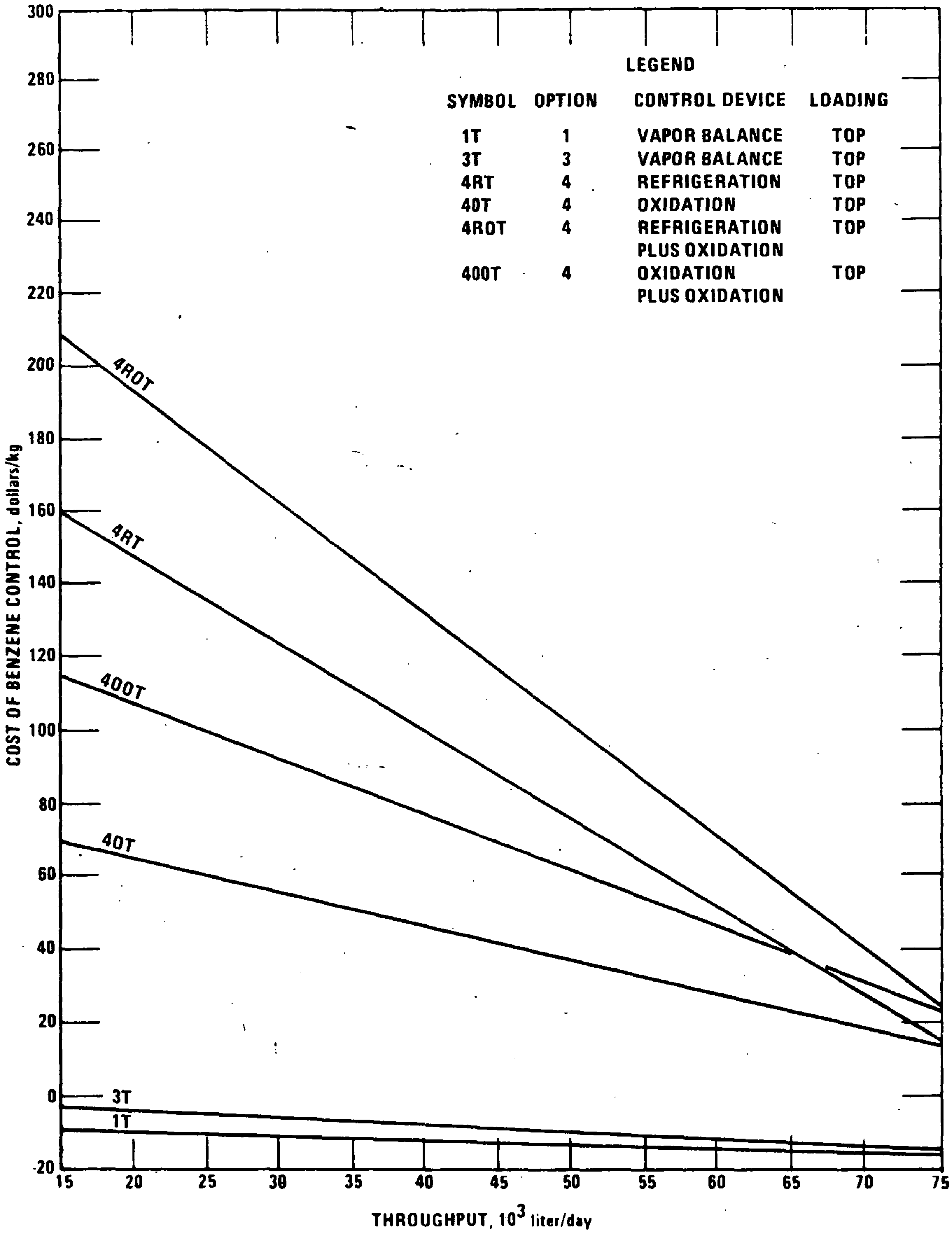

Figure 6-7. Cost-effectiveness for least expensive equipment (top-loading) in January, 1978 dollars.

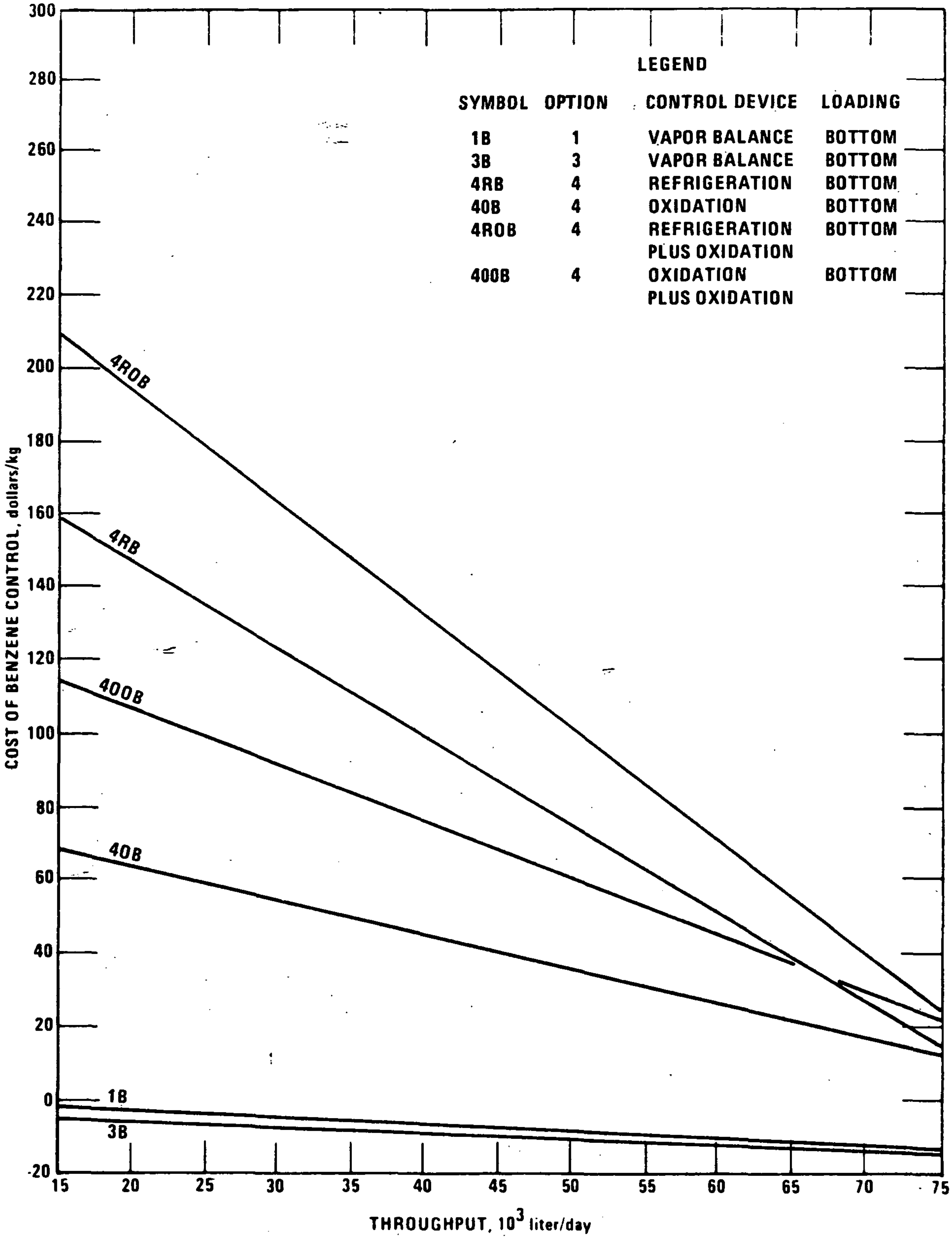

Figure 6-8 Cost-effectiveness for least expensive equipment (bottom-loading) in January, 1978 dollars.

second delivery truck to either bottom or top-submerged loading vapor balance (which is the only difference between the parameters of the small and the large model plants) would cause an abrupt step in the cost curves. Since the point at which this conversion would be made cannot be accurately estimated for an actual plant, a straight line is used to represent the change. Costs do not vary smoothly with throughput, but the recovery credit does vary directly with throughput. Thus, the cost-effectivenesses for each of the three control options, including single and dual systems, for all three categories of vapor balance equipment are presented in Figures 6-3 through 6-8 in such a way that comparisons among control options and control equipment can be made.

6.2.3 Bulk Plant Impacts

6.2.3.1 Introduction

The principal economic impacts of the three proposed vapor control options which would reduce the amount of benzene emitted into the atmosphere by bulk plants are:

- the number of potential bulk plant closures;*
- the employment displaced by these closures;*
- the total cost of installing vapor control at bulk plants.

Since all tank wagons (or account trucks) are owned by bulk plant operators, the cost of modifying the tank wagon fleet is included in the total cost of installing vapor control at bulk plants.

All of the control systems discussed in this section will be top-loading systems. It was assumed that bulk plant operators would choose a top-loading system in order to comply with the various control options because it is a less expensive modification than converting their operations to bottom-loading. Some bulk plant operators, however, may choose bottom-loading for reasons of greater efficiency and safety. But the operators that would choose a bottom-loading system are ones that are in a stronger financial position than the rest of the industry and their decision to bottom-load would not significantly affect the results of the closure analysis.

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* The monetary costs of these impacts have not been calculated.

6.2.3.2 Closure Methodology

The approach used to calculate bulk plant closures is the same as that which was used for bulk terminals in Section 6.1.3. Bulk plants may close because of vapor control economics for either of the following reasons:

- Bulk plant operators are unable to obtain the capital necessary to install vapor control equipment.
- Bulk plants would fail to achieve a sufficient or acceptible level of profitability if vapor control were installed.

However, in the closure analysis of bulk plants, three distinct cost scenarios were evaluated for each of the three proposed control options. These control costs were discussed in Section 6.2.3 and will be referred to here as NOJC (most expensive cost scenario), Houston-Galveston (less expensive) and Colorado APCD (least expensive). It is important to note that all of control systems represented by these cost scenarios were assumed to be equally efficient in controlling gasoline vapors for each one of the three control options.

Large and small bulk plant prototypes were developed to facilitate the bulk plant closure analysis. The gasoline throughput characteristic of these prototypes corresponds with the gasoline throughput capacities of the model vapor control systems described in Section 6.2.2. Because almost all bulk plants receive petroleum products by truck transport, no differentiation was made based upon mode of gasoline receipt.

For Option 3 compliance, refrigeration and incineration were the two control technologies chosen for analysis. These systems have the least capital requirement of the model control systems examined. Because the continuous and efficient control of hydrocarbon emissions must be assured, the above control systems will include an incineration stand-by unit, e.g. refrigeration/incineration and incineration/incineration. The incineration unit also had the least capital requirement of any of the stand-by systems examined.

6.2.3.3 Bulk Plant Closures

Depending upon the control option, cost scenario and control technology selected the number of bulk plant closures due to an inability to access adequate capital ranges from 0 to almost 9,000 (Table 6-36). All of these facilities are assumed to be operated by jobbers and independent marketers. No closures are expected under Option 1 compliance for any of the three cost scenarios. Under Option 3 an estimated 1,700 closures are expected for the NOJC cost scenario; no closures are likely for either of the other two cost scenarios. Bulk plant closures under Option 4 compliance are approximately the same for the various cost scenarios and control technologies, i.e. between 8,000 and 9,000 facilities or up to 48 percent of the 1978 bulk plant population.

The closures caused by capital constraints were then subtracted from the bulk plant population to avoid possible double counting. Not all of these closures, however, would have resulted from this factor exclusively. Some would also close because they were unable to achieve an an acceptable level of profitability.

The number of bulk plant closures due to insufficient profitability also depends upon the control option, cost scenario and control technology chosen. Up to 130 closures are expected under Option 1 for the NOJC and Houston-Galveston scenarios; no closures are likely for the Colorado APCD cost scenario (Table 6- 37). Option 3 compliance is expected to cause between 50 (Colorado APCD) and 530 (NOJC) closures while Option 4 compliance will cause roughly the same number of closures for each cost scenario.

TABLE 6-36

BULK PLANT CLOSURES DUE TO INACCESSIBILITY OF CAPITAL[35]

COST SCENARIO	OPTION 1	OPTION 3	OPTION 4	
	BALANCE INCOMING TRANSPORTS ONLY	BALANCE INCOMING & OUTGOING TRUCKS	REFRIGERATION/ INCINERATION	INCINERATION/ INCINERATION
NOJC Costs	0	1,690	8,990	8,880
Houston-Galveston Costs	0	0	8,960	8,820
Colorado APCD Costs	0	0	8,950	8,820

TABLE 6-37

BULK PLANT CLOSURES DUE TO INSUFFICIENT PROFITABILITY[36]

COST SCENARIO	OPTION 1 BALANCE INCOMING TRANSPORTS ONLY	OPTION 3 BALANCE INCOMING & OUTGOING TRUCKS	OPTION 4 REFRIGERATION/ INCINERATION	OPTION 4 INCINERATION/ INCINERATION
NOJC Costs	130	530	1,300	800
Houston-Galveston Costs	130	240	1,180	690
Colorado APCD Costs	0	50	1,100	610

Option 4 closures, however, will vary somewhat by control technology. Between 600 and 800 closures are expected due to the costs of and incineration/incineration system, which has the smaller capital requirement of the two technologies, while 1,100 to 1,300 bulk plant closures are expected due to the more expensive refrigeration/incineration costs. A summary of the bulk plant closures for each cost scenario appears in Table 6-38 .

Bulk plant closures will not significantly impact the national gasoline marketing network under Options 1 and 3 since most closures will be low throughput facilities. A large portion of these closures will occur in metropolitan areas where other bulk storage facilities, i.e. terminals and larger, more efficient bulk plants, will subsequently handle the product throughput of the closed facilities. Option 4, however, would impact a significant portion of the gasoline marketing network both in terms of number of facilities and the amount of product throughput. The product throughput of the closed facilities is assumed to continue to flow to end-users (at a higher price, however) but a major re-structuring of the bulk plant market would be likely.

Using the high and low closure estimates for Options 1 and 3 and the high and low closure estimates of the less expensive control, i.e. incineration/incineration, technology for Option 4, the number of bulk plant closures by ownership was calculated. Approximately 85 percent of the closures, or 110 bulk plants, which occur because of Option 1 compliance will be at jobber operated facilities (Table 6-39). The remaining 15 percent will be bulk plants owned by independent marketer/wholesalers; no closures are anticipated at any majors' facilities. Jobber closures under

TABLE 6-38

CLOSURE SUMMARY AT BULK PLANTS[37]

COST SCENARIO	OPTION 1 BALANCE INCOMING TRANSPORTS ONLY	OPTION 3 BALANCE INCOMING & OUTGOING TANKS	OPTION 4 REFRIGERATION/ INCINERATION	 INCINERATION/ INCINERATION
NOJC Costs	130	2,220	10,290	9,680
Houston-Galveston Costs	130	240	10.140	9,510
Colorado APCD Costs	0	50	10,050	9,430

TABLE 6-39

CLOSURE IMPACT AT BULK PLANTS BY OWNERSHIP[38]

COST SCENARIO*	OPTION 1		OPTION 3		OPTION 4	
	HIGH	LOW	HIGH	LOW	HIGH	LOW
Majors **	-	-	40	-	540	340
Independent Marketer/Wholesalers	20	-	80	10	180	130
Jobbers	110	-	2,100	40	8,960	8,960
TOTAL	130	0	2,220	50	9,680	9,430

* High impact = NOJC cost scenario
Low impact = Colorado APCD cost scenario

** Includes regional refineries

Option 3 range from 2100, or 95 percent of the total, in the high cost scenario to 40, or 80 percent of the total, in the low cost scenario. Most of the other closures will be at independents' facilities. Jobber closures in Option 4 are the same in the high and the low scenarios, representing 93 and 95 percent of the total closures in each respective case.

6.2.3.4 Employment Displaced by Closures

The number of workers employed at the bulk plants which are closed because of vapor control ranges from 0 to 43,000 (Table 6- 40). As many as 550 workers, less than 1 percent of the 72,000 workers at gasoline bulk plants, will be displaced by closures attributable to Option 1. Up to 9,400 workers, or 13 percent of bulk plant employment, are impacted by closures caused by Option 3 compliance while as many as 43,700 workers, or 61 percent of those employed at gasoline bulk plants, may be displaced by Option 4.

Because, on average, the labor force is not significantly different by ownership classification for facilities of the same size, the employment displaced by ownership will be proportional to the number of bulk plant closures. Since the overwhelming majority of bulk plant closures will be jobber operated, most of the employment impacts will also be jobber related. The jobber employment displaced by the proposed control options is between 0 and 490 under Option 1, between 170 and 8,930 under Option 3, and approximately 38,080 under Option 4 (using the less expensive incineration/incineration costs) (Table 6-41).

TABLE 6-40

EMPLOYMENT DISPLACED AT BULK PLANTS[39]

COST SCENARIO	OPTION 1 BALANCE INCOMING TRANSPORTS ONLY	OPTION 2 BALANCE INCOMING & OUTGOING TRUCKS	OPTION 4 REFRIGERATION/ INCINERATION	OPTION 4 INCINERATION/ INCINERATION
NOJC Costs	550	9,440	43,730	41,140
Houston-Galveston Costs	550	1,020	43,100	40,420
Colorado APCO Costs	0	210	42,710	40,080

TABLE 6-41

ESTIMATED EMPLOYMENT IMPACT AT BULK PLANTS BY OWNERSHIP[40]

COST SCENARIO*	OPTION 1 HIGH	OPTION 1 LOW	OPTION 3 HIGH	OPTION 3 LOW	OPTION 4 HIGH	OPTION 4 LOW
Majors**	-	-	170	-	2,300	1,450
Independent Marketer/Wholesalers	80	-	340	40	760	550
Jobbers	470	-	8,930	170	38,080	38,080
TOTAL	550	0	9,440	210	41,140	40,080

* High impact = NOJC cost scenario
Low impact = Colorado APCD cost scenario

** Includes regional refiners

6.2.3.5 Vapor Control Costs at Bulk Plants

The total cost of vapor control systems at bulk plants may cost up to $750 million or produce a savings of $23 million depending upon the control option, cost scenario and control technology chosen (Table 6- 42). These costs include capital, financing and operating costs less any recovery credits over the 10 year life of the vapor control equipment. The cost of Option 1 compliance ranges from $37 million down to a savings of $23 million. A cost savings is possible because the Colorado APCD cost scenario requires less than half the capital of the other scenarios, but it produces the same recovery credits as the more expensive scenarios. The cost of Option 3 compliances also varies from $376 million down to a savings of $6 million while Option 4 compliance costs between $465 and $750 million. The more expensive technology under Option 4 for each of the three cost scenarios is the refrigeration/incineration system. The individual capital, financing and operating costs, as well as any applicable recovery credits, are presented in Tables 6-43 through 6-45 for each cost scenario.

Jobbers will bear most of the cost of vapor control, not only because they would own most of the post-control bulk plants, but also because they would generally own most of the smaller facilities. The vapor recovery savings, via a recovery credit, is substantially less in small bulk plants than in the larger facilities. The jobbers' share of the vapor control costs will be $35.3 million, or 96 percent of the total, under the high cost scenario of Option 1 (Table 6-46). Similarly, jobbers will account for $14.2 million, or 63 percent, of the total savings produced by the low scenario. For Option 3, the jobbers' share of the cost could be as high as $301.9 million, or 80 percent of the total cost. Under the low cost scenario

TABLE 6-42

VAPOR CONTROL COSTS AT BULK PLANTS[41]

(Million 1978 Dollars)

COST SCENARIO	OPTION 1 BALANCE INCOMING TRANSPORTS ONLY	OPTION 3 BALANCE INCOMING & OUTGOING TRUCKS	OPTION 4 REFRIGERATION/ INCINERATION	OPTION 4 INCINERATION/ INCINERATION
NOJC COSTS				
Bulk Plants Installing Vapor Control	14,120	12,030	3,960	4,570
Total Vapor Control Cost	36.9	375.5	747.3	589.5
HOUSTON-GALVESTON COSTS				
Bulk Plants Installing Vapor Control	14,120	14,010	4,110	4,740
Total Vapor Control Cost	36.9	154.8	698.3	514.0
COLORADO APCD COSTS				
Bulk Plants Installing Vapor Control	14,250	14,200	4,190	4,820
Total Vapor Control Cost	(22.7)*	(6.5)*	656.0	465.2

* Negative cost

TABLE 6-43

VAPOR CONTROL COSTS AT BULK PLANTS BASED UPON NOJC COSTS [42]

(Million 1978 Dollars)

	OPTION 1	OPTION 3	OPTION 4	
	BALANCE INCOMING TRANSPORTS ONLY	BALANCE INCOMING & OUTGOING TRUCKS	REFRIGERATION/ INCINERATION	INCINERATION/ INCINERATION
Capital Investment	60.0	280.9	468.4	339.8
Financing (5 years)*	13.3	62.3	103.9	75.4
Operating Expense (10 years)*	26.0	120.7	290.7	174.3
Recovery Credit (10 years)*	(62.4)	(88.4)	(115.7)	--
Total Vapor Control Costs	36.9	375.5	747.3	589.5

* Future cash streams discounted to present value. Discount rate = 10%

TABLE 6-44

VAPOR CONTROL COSTS AT BULK PLANTS BASED UPON HOUSTON-GALVESTON COSTS[43]

(Million 1978 Dollars)

	OPTION 1	OPTION 2	OPTION 4	
	BALANCE INCOMING TRANSPORTS ONLY	BALANCE INCOMING & OUTGOING TRUCKS	REFRIGERATION/ INCINERATION	INCINERATION/ INCINERATION
Capital Investment	60.0	153.1	434.8	293.4
Financing (5 years)*	13.3	34.0	96.5	65.1
Operating Expense (10 Years)*	26.0	66.0	286.2	155.5
Recovery Credit (10 Years)*	(62.4)	(98.3)	(119.2)	--
Total Vapor Control Costs	36.9	154.8	698.3	514.0

* Future cash streams discounted to present value. Discount rate = 10%.

TABLE 6-45

VAPOR CONTROL COSTS AT BULK PLANTS BASED UPON COLORADO APCD COSTS[44]

(Million 1978 Dollars)

	OPTION 1	OPTION 3	OPTION 4	
	BALANCE INCOMING TRANSPORTS ONLY	BALANCE INCOMING & OUTGOING TRUCKS	REFRIGERATION/ INCINERATION	INCINERATION/ INCINERATION
Capital Investment	24.2	56.0	412.9	263.5
Financing (5 Years)*	5.4	12.4	91.6	58.5
Operating Expense (10 Years)*	10.5	24.3	272.2	143.2
Recovery Credit (10 Years)*	(62.8)	(99.2)	(120.7)	--
Total Vapor Control Costs	(22.7)	(6.5)	656.0	465.2

* Future cash streams discounted to present value. Discount rate = 10%

TABLE 6-46

TOTAL COSTS* OF VAPOR CONTROL AT GASOLINE BULK PLANTS BY OWNERSHIP[45]

(Million 1978 Dollars)

COST SCENARIO**	OPTION 1		OPTION 3		OPTION 4	
	HIGH	LOW	HIGH	LOW	HIGH	LOW
Majors***	1.1	(7.1)	58.0	(7.5)	192.8	163.2
Independent Marketer/Wholesalers	0.5	(1.4)	15.6	(1.1)	52.6	44.1
Jobbers	35.3	(14.2)	301.9	2.1	344.1	257.9
TOTAL	36.9	(22.7)	375.5	(6.5)	589.5	465.2

* Includes capital charge, financing cost and operating expense over life of control system expressed in constant 1978 dollars.

** High impact = NOJC cost scenario
Low impact = Colorado APCD cost scenario

*** Includes regional refineries.

for Option 3, however, the cost to jobbers will be $2.1 million while the majors and independents realize a $7.5 and $1.1 million savings, respectively. The total cost to jobbers under Option 4 is calculated to be $344.1 million, 58 percent of the total, in the high scenario and $257.9 million, 55 percent of the total, in the low scenario. Both of these cost figures assume that the less expensive control technology, i.e. incineration/incineration, will be installed in order to comply with the control option.

6.3 SERVICE STATIONS

6.3.1 Industry Characterization

6.3.1.1 Retail Service Stations

In 1977, there were approximately 178,400 retail service stations in the U.S. which dispensed nearly 84.5 billion gallons of gasoline.[46] Over 48,000 service stations have closed in the U.S. since the population peak of 226,000 in 1972. This attrition is expected to continue at least through the early 1980's to a leveling off point of anywhere from 125,000 to 150,000 outlets. The economies of scale of high volume stations and the shift to self-service operations are a prime factor in shrinking retail margins. Consequently, the closure of outlets due to market rationalization processes will be most severe for those outlets which have relatively low sales volume coupled with high unit expenses.

Retail service stations are supplied by various classes of suppliers. The largest suppliers are the major oil companies, which directly supply nearly 48 percent of the stations. These firms are the 17 largest oil companies which are fully integrated and market gasoline in 21 or more states. The next 21 largest oil companies are considered to be regional refiner/marketers which tend to be partially integrated, operate at least one refinery, and generally market gasoline in less than 21 states. These companies supply about nine percent of the retail outlets. Another group of suppliers is the independent marketer/wholesaler group, including gasoline-oriented super jobbers. These suppliers, which are multi-state retailers but lack their own refining capability, furnish gasoline to about 17 percent of the stations. The last direct supplier category is the small jobber which generally markets gasoline under major oil company brands through 6 to 12 service stations within a single state. There are approximately 9,000 small gasoline jobbers in the U.S. which supply almost 27 percent of the retail stations.[47]

A summary of the U.S. service station population by direct supplier as well as by type of operation in various throughput ranges is presented in Table 6-47.[48]

Service stations in the U.S. can broadly be classified into the following four operational groups:

- Direct outlets (supplier operated)
- Convenience stores
- Lessee dealers
- Open dealers (dealer owned/dealer operated)

The traditional retail marketing strategy of the major oil companies has been to operate stations through lessee dealers. These lessee outlets represent approximately two-thirds of the major oil company stations and about 47 percent of all the stations in the country. However, the proportion of these types of stations is expected to decline as the marketing strategy moves toward direct outlets, which are low expense, high volume operations. Currently, direct outlets represent 18 percent of the total U.S. outlets, with more than half of independent marketer/wholesaler and super jobber outlets being directly operated and about 26 percent of the regional refiner outlets being direct salary operation.[49]

Convenience store outlets have grown rapidly in the last few years and represent aggressive gasoline competitors. While such outlets currently account for only five percent of the retail station population, their proportion is expected to increase significantly.[50]

The second largest group of outlets is known as open dealers. In these operations, the onsite dealer actually owns or controls the investment in his station where he is physically employed. The dealer is not permanently tied to any particular brand, but "flies the flag" of the supplier from which he can extract the best deal. Open dealer sites, which tend to be older and more depreciated, represent about 30 percent of the total stations in the country but have less than the national average sales volume per outlet.[51]

Retail service stations dispense an average of about 40,000 gallons per month. In recent years, marketing economics have resulted in a trend toward stations with larger volumes, with small volume operations being marginal operations that have to rely on other parts of the retail trade, such as mechanical work and sales of accessories, in order to remain in business. The high volume stations tend to be mostly direct operations which are controlled and operated by the supplier and operate on relatively low margins. Low volume stations, those dispensing less than 25,000 gallons per month, are mostly lessee dealers and open dealers supplied by all classes of suppliers. These low volume stations, which comprise close to 50 percent of the total number of stations, are the segment of the retail industry that is most vulnerable to changes in marketing economics as well as external costs such as vapor recovery costs.

Table 6-47. SUMMARY OF SERVICE STATION POPULATION[48]

THROUGHPUT (000 gal/mo)	% OF TOTAL OUTLETS <10	11-24	25-49	50-99	>100	% Total	Total
DIRECT SUPPLIER MAJOR							
Direct	0.4	0.1	0.9	1.4	0.8	3.6	6,320
"C" Store	-	0.4	-	-	-	0.4	800
Lessee	2.3	14.9	6.6	4.0	0.4	28.2	50,260
Open	-	9.0	5.7	0.9	-	15.6	27,890
SUBTOTAL	2.7%	24.4%	13.2%	6.3%	1.2%	47.8	85,270
REGIONAL REFINER							
Direct	-	0.1	0.5	1.1	0.6	2.3	4,010
"C" Store	-	0.1	-	-	-	0.1	200
Lessee	0.6	1.3	1.9	1.3	0.2	5.3	9,420
Open	-	0.4	0.6	0.1	-	1.1	2,030
SUBTOTAL	0.6%	1.9%	3.0%	2.5%	0.8%	8.8	15,660
INDEP. MARKETER/WHOLESALER "SUPER JOBBER"							
Direct	-	0.3	1.1	5.5	2.4	9.3	16,630
"C" Store	-	4.3	-	-	-	4.3	7,560
Lessee	0.2	0.6	0.8	0.6	0.3	2.5	4,510
Open	-	0.4	0.1	0.1	-	0.6	1,100
SUBTOTAL	0.2%	5.6%	2.0%	6.2%	2.7%	16.7	29,800
SMALL JOBBER							
Direct	-	0.5	1.0	1.1	0.2	2.8	5,110
"C" Store	-	0.6	-	-	-	0.6	1,040
Lessee	0.6	4.3	4.7	1.4	-	10.9	19,500
Open	0.4	3.4	7.3	1.2	-	12.3	22,010
SUBTOTAL	1.0%	8.8%	13.0%	3.7%	0.2%	26.7	47,660
% Total Outlets	4.5%	40.7%	31.2%	18.7%	4.9%	100%	
Total No. Outlets	8,100	72,650	55,740	33,270	8,630		178,390
% Total Annual Volume	1%	22%	30%	33%	14%	100%	
Total Annual Volume (MM gal/yr)	777.6	18,602.4	24,748.5	28,252.8	12,030.7		84,412.0

a) Direct: Company-controlled/company-operated
"C" STORES: Convenience stores
Lessee: Company-controlled/dealer-operated
Open: Dealer-controlled/dealer-operated

6.3.1.2 Private Gasoline Dispensing Facilities

In addition to the retail service stations, there are a significant number of facilities other than conventional retail stations which dispense gasoline. The number and geographical distribution of private dispensing facilities in the U.S. closely follows the pattern of service stations. Private facilities are maintained by governmental, commercial, and industrial consumers for their own fleet operations. Miscellaneous retail outlets not classified as service stations include marinas, parking garages, and rural businesses which sell gasoline as a convenience to their customers rather than as a major source of income. In 1977, there were an estimated 243,000 private locations in the country which dispensed over 25 billion gallons of gasoline.[52] However, only one percent of these facilities dispense more than 20,000 gallons per month since most have only one or two pumps. While these private facilities account for 58 percent of the total gasoline dispensing outlets in the country, they dispense only 23 percent of the total gasoline volume.

Table 6-48 indicates the breakdown of private dispensing facilities by end-use sector.[53] The largest group in terms of gasoline consumed is the trucking sector, which includes all non-government gasoline-powered vehicles used in wholesale/retail delivery operations, as well as miscellaneous services, construction, manufacturing, and extractive industries. This segment consumes approximately five percent of the total gasoline in the country and 21 percent of the total private gasoline volume.[54]

Table 6-48. DISTRIBUTION OF PRIVATE GASOLINE DISPENSING OUTLETS [53]

End-Use Sector	Number of "Private" Gasoline-Dispensing Outlets	Annual Gasoline Consumption (Million Gal)	% Total U.S. Private Gasoline Volume	% Total U.S. Gasoline Volume
Agriculture	32,600	3,801.3	15%	3%
Trucking and local service	21,900	5,241.6	21%	5%
Government	85,450		11%	2%
- Federal		227.6	0.9%	
- Military		174.1	0.6%	
- Other*		2,266.4	9.0%	
Taxis	5,380	882.1	3%	0.8%
School Busses	3,070	144.7	1%	0.1%
Miscellaneous**	94,530	12,497.2	49%	11%
Total Non-Service Station Segment	242,930	25,235.0	100%	23%
Retail Service Station Segment	178,390	84,412.0		77%
All Segments —	421,320	109,647.0		100%

*State and municipal governments.

**Auto rental, utilities, and other.

Another significant sector is agriculture related businesses. The estimate of nearly 33,000 outlets nationwide for the agricultural sector represents those outlets which have relatively large size tanks (greater than 1,000 gallon capacity) on the farm and an average of three to five trucks per farm. This would include all major farms and irrigation sites, nurseries, and landscaping firms. Approximately 2.7 million farms in the U.S. are not included in this estimate as they would typically have small, above-ground tanks (e.g., 275-500 gallons) and would have a higher proportion of diesel-fueled vehicles than of gasoline-powered equipment. In general, all agriculture outlets would have less than 10,000 gallons per month.[55]

Government agencies with central garages are typically regional locations for the postal service, Federal government agencies, and state and county agencies. The central facilities typically dispense more than 10,000 gallons per month. There are over 85,000 of these facilities but they dispense only two percent of the total nationwide volume of gasoline. Other miscellaneous facilities include utility companies, taxi fleets, rental car fleets, school buses, and corporate fleets. These sectors combine for over 94,000 outlets that dispense around 11 percent of the nationwide gasoline volume.

6.3.2 Cost Analysis

6.3.2.1 Capital Costs

Little data are available on capital and installation costs of a Stage I balance system alone since the system is normally installed in conjunction with Stage II systems and may share some of the piping. The earthwork and asphalt patching, if needed for Stage I, is also usually all done at once at the service station. Due to the limited cost data, costs in this section are presented as a range of costs which have been reported by a number of sources. Costs are based on limited information from vendors, oil companies, state and local agencies and other sources.

The capital cost of Stage I systems is dependent upon whether the station can use the coaxial fitting that combines the filling tube and the vapor return line into one piece of equipment. Some stations may have problems with small openings in the tanks preventing use of the coaxial fitting. In addition, the coaxial fitting prevents simultaneous filling of tanks, so large throughput stations may want to remedy this problem by manifolding the vapor return lines and not using the coaxial fitting. If the coaxial fitting can be used, the installed cost per tank is $150 to $250. No earthwork is needed since the fitting utilizes the existing tank opening.

If a station cannot or choses not to use the coaxial fitting, then earthwork and additional piping are needed. Separate vapor return lines have to be added to each tank and the lines manifolded into one return line at the surface. This cost is highly dependent upon the number and configuration of the underground tanks. Due to the fact that actual data usually contain overlap between Stage I and Stage II installation, the precise cost is not known. However, an estimated cost of additional piping, trenching backfilling, and paving is estimated to range from $1,000 to $1,500 per station. Thus, total capital cost for a manifolded Stage I system, including tank hardware, is expected to range from $1300 to $2000 per station.

These costs are consistent with other estimates of Stage I capital costs that have been made. One source indicates that experience in California has indicated that Stage I costs will range from $300 per tank to $2000 per station,[56] while another source reports that the cost submitted by two contractors for installing Stage I alone was $1,350.[57] Based on costs quoted by a Los Angeles contractor, another source reports a Stage I capital cost of $1955, based on separate new fill and vapor return risers and associated hardware.[58] An oil company reports that hardware costs for Stage I will be over $200 per tank, with an installation cost approaching $3000.[59] This cost appears high and probably contains much overlap with Stage II. The experience of another oil company at its installations indicates that the cost of Stage I hardware was $526 with contractor installation averaging $1411 for a total cost of $1937.[60] Finally, a consultant's report shows the installed cost of a coaxial system to be $150 per tank based on conversations with an equipment vendor.[61]

6.3.2.2 Operating and Maintenance Costs

There are no operating and maintenance costs associated with a Stage I system since there are no mechanical or moving parts involved with the system.

6.3.2.3 Annualized Costs of Control

Since there are no operating or maintenance costs involved with the Stage I systems, the annualized costs represent the annualized capital charges associated with the investment in the system. For purposes of this analysis, the costs are annualized over a 10-year period based on an interest rate of 10 percent.

Table 6-49 summarizes the capital costs and annualized costs for small, medium, and large service stations. Naturally, the costs per gallon of throughput are higher for the small station, but the costs are at most 0.10 cents per gallon for the most expensive manifolded Stage I balance system.

6.3.2.4 Cost-Effectiveness

Based on the costs presented in Table 6-49 and estimates of annual reductions in total benzene emissions in Table 2-1, the cost-effectiveness of Stage I controls at service stations is presented in Table 6-50. For the coaxial balance systems, the cost-effectiveness ranges from $2-4 per kilogram of benzene controlled at large stations to $9-14 per kilogram at small stations. For the manifolded systems, the cost-effectiveness ranges from $5-6 per kilogram at large stations to $24-28 per kilogram at small stations.

6.3.3 Service Station Impacts

6.3.3.1 Total Costs of Control

Based on the station costs summarized in Section 6.3.2 and the estimates of the service station population presented in Section 6.3.1, the

Table 6-49. SUMMARY OF COSTS FOR STAGE I BALANCE SYSTEMS

Monthly Throughput (liters)	Monthly Throughput (gallons)	No. of Tanks	Capital Cost	Coaxial System Annualized Cost*	¢/gal.	Capital Cost	Manifolded System Annualized Cost	¢/gal.
75,700	20,000	3	$450-750	$75-125	.03-.05	$1300-1500	$210-245	.10-.10
227,100	60,000	4	$600-1000	$100-165	.01-.02	$1400-1900	$230-310	.03-.04
454,200	120,000	5	$750-1250	$125-205	.01-.02	$1500-2000	$245-325	.02

*Based on 10-year life, 10% interest

Table 6-50. Cost-Effectiveness Estimates for Stage I Balance Systems

Monthly Throughput (liters)	Coaxial System ($/Kg Bz)	Manifolded System ($/Kg Bz)
75,700	9-14	24-28
227,100	4-6	9-12
454,000	2-4	5-6

total industry costs of installing Stage I equipment have been estimated. The costs are summarized in Table 6-51. The costs are dependent upon whether the industry uses a coaxial fitting for the system or whether the storage tanks are instead manifolded. It is likely that the portions of the industry will employ both techniques so that the actual costs will fall between the costs of installing either system industry-wide.

For the coaxial system, the total capital investment would range from $213.6 million to $356.0 million, with the costs almost evenly divided between retail outlets and non-retail facilities. While there are more non-retail facilities than retail outlets, retail stations' tend to have more underground storage tanks and thus higher investment costs. Taking into account the financing costs, the total cost of control, expressed as the discounted present value, would range from $257.4 million to $429.1 million.

The total costs for total installation of manifolded systems are two to three times greater than the costs for the coaxial system. The capital investment for the system would range from $563.7 million to $698.7 million. From 60 to 70 percent of the investment would be incurred by the non-retail sector. The total cost of control(discounted present value)of the manifolded system would range from $679.4 million to $842.1 million.

In the retail sector, the distribution of costs by ownership class closely parallels the distribuiton of service station ownership in the industry. Open dealers and major oil companies will each incur about 30 percent of the total costs, while small jobbers will incur about 15 percent of the costs. Other large independent marketers will account for the remainder of the costs.

Table 6-51. TOTAL SERVICE STATION INDUSTRY STAGE I COSTS
($ Millions)

	Coaxial System	Manifolded System
Retail Outlets		
Capital Investment	104.3-173.8	247.9-334-3
Financing (5 years)*	21.4- 35.7	50.9- 68.6
Operating Expense	0	0
TOTAL COST*	125.7-209.5	298.8-402.9
Non-retail Outlets		
Capital Investment	109.3-182.2	315.8-364.4
Financing (5 years)*	22.4- 37.4	64.8- 74.8
Operating Expense	0	0
TOTAL COST*	131.7-219.6	380.6-439.2
All Outlets		
Capital Investment	213.6-356.0	563.7-698.7
TOTAL COST*	257.4-429.1	679.4-842.1

*Future cash streams discounted to present value. Discount rate = 10%

6.3.3.2 Potential Service Station Closures

A Stage I only control program is not expected to have a significant impact upon incremental service station closures above those closed by "normal" market factors without vapor recovery. The magnitude of the capital investment is such that capital availability constraints for station owners do not appear likely. As a worst case, the costs could reduce the profitability of exceptionally marginal stations to the point that some could not justify making even the limited investment and thus would choose to close the station. One analysis estimates that at most 500 marginal stations could close as a result of Stage I over and above those expecting to close due to market rationalization. These closures would be concentrated in small leasse and open dealer stations. The potential closures represent 0.4 percent of the estimated 1981 service station population.[62]

It is also unlikely that Stage I costs would appreciably impact the non-retail sector. Most firms in this sector have a large enough financial base to be able to afford the equipment, which for these outlets will most likely be the less expensive coaxial system. For marginal operations that find investment in Stage I equipment to be unprofitable, the firms have the option of purchasing gasoline at commercial service stations. Furthermore, small agricultural outlets will not be affected by the control requirements since nearly all have tanks less than 2000 gallons in size.

6.3.3.3 Potential Employment Displaced by Service Station Closures

If 500 stations were closed due to Stage I requirements, from 1,000 to 1,500 service station workers would be displaced. This is based on an estimate of two to three employees, including the dealer, at small open dealer and leasse dealer stations.

6.4 REDUCTION OF BENZENE CONTENT IN GASOLINE

6.4.1 Petroleum Refining Industry Characterization

Crude petroleum is refined by 150 companies at 266 refineries located in 40 different states. Production of refined products in the U.S. totalled over 15 million barrels per day in 1976, or 93 percent of nameplate capacity. The industry employs 100,000 workers and is heavily concentrated in the West South Central region of Arkansas, Oklahoma, Texas, and Louisiana. These four states employ 44 percent of all industry workers and supply 43 percent of all refined products.

The petroleum refining industry is somewhat concentrated. The five leading producers own 36.5 percent of all industry capacity; the top ten, 58.5 percent. These leading producers are integrated, major oil companies that engage in exploration, production, refining, distribution, and marketing on the retail level. Other refiners are independent companies that are typically not integrated into more than one other segment of the industry. Prices vary little among companies, although there are occasional examples of price cutting when there is weak demand and an excess of supply.

6.4.2 National Costs of Benzene Removal

The costs presented in this section come from an analysis by Arthur D. Little, Inc.[63] The costs of benzene removal from reformates and FCC gasoline were developed on a 1977 Gulf Coast basis. The main variable affecting the costs of benzene removal from reformates and FCC gasoline was determined to be the total volume to fractionation, hydrogenation, and extraction. Although extraction costs are somewhat dependent on aromatics content, because of the greater dependence on total volume to extraction, the costs were assumed to be independent of aromatics content. The base case costs were scaled up on a regional basis by capacity in order to get the national cost impact of benzene removal in 1977 Gulf Coast dollars.

The national costs of benzene removal from reformates and FCC gasoline is shown in Table 6-52. The capital requirement in 1977 dollars for benzene removal from reformates is $2.0 billion, while the capital requirement for removal of benzene from FCC gasoline is $3.3 billion. The total investment required to remove benzene from both reformate and FCC gasoline is $5.3 billion. There would be some potential savings from economies of scale through combining the reformates and FCC gasoline streams prior to extraction.

The manufacturing costs to remove benzene from both reformates and FCC gasoline are over $2.0 billion per year.* About 42 percent of these costs are capital charges, 45 percent variable costs, and 13 percent for labor and maintenance. The main component of variable operating costs is energy

*The annualized cost differs from that presented in the Arthur D. Little report, which used a before tax capital recovery factor of 0.28. The capital charges have been changed to reflect an after tax capital recovery factor of 0.16 in order to be consistent with other costs presented in this document.

Table 6-52. National Cost of Benzene Removal From Reformate & FCC Gasoline

Investment Costs: $ Billion	Reformates	FCC Gasoline	Total
Process	1.009	1.746	2.755
Offsites	0.404	0.699	1.103
Total Plant	1.413	2.445	3.858
Other Capital	0.584	0.845	1.429
TOTAL CAPITAL	1.997	3.290	5.287
Manufacturing Costs: ($M/SD) (345 SD/Yr)			
Variable Costs	801	1,886	2,687
Labor & Maintenance	329	433	762
Fixed Costs(1)	944	1,554	2,498
Total Manufacturing ($M/SD)	2,074	3,873	5,947
Total Manufacturing ($MM/Yr)(2)	716	1,336	2,052
Total Manufacturing (¢/Gal)(3)	0.63	1.17	1.80
Energy Costs: (Fuel @ $12.00/FOEB)			
COE: MB/Yr	21,930	32,086	54,016
$MM/Yr	263	385	648

(1) Based on after tax capital recovery factors assuming 10% interest and 10 year life.

(2) Based on 345 SD/Yr.

(3) Based on 7,450 B/D gasoline

requirements for steam, fuel, and utilities. The total energy requirements are 54 million Crude Oil Equivalent (COE) barrels per year of $648 million per year. Energy requirements amount to 70 percent of variable costs or 26 percent of total operating costs.

The costs of removing benzene from gasoline were converted to costs per barrel of gasoline using the 1981 estimated gasoline production of 7.45 million barrels per day. The cost of removing benzene from reformates is 0.63 cents per gallon of U.S. gasoline, and the cost of removing benzene from FCC gasoline is 1.17 cents per gallon of U.S. gasoline. The cost of benzene removal from these two streams is 1.80 cents per gallon.

These costs are only for removal of benzene from reformates and FCC gasoline, and do not include the costs of removing benzene from other streams, or the costs associated with replacing lost octane, gasoline volume, and benzene disposal.

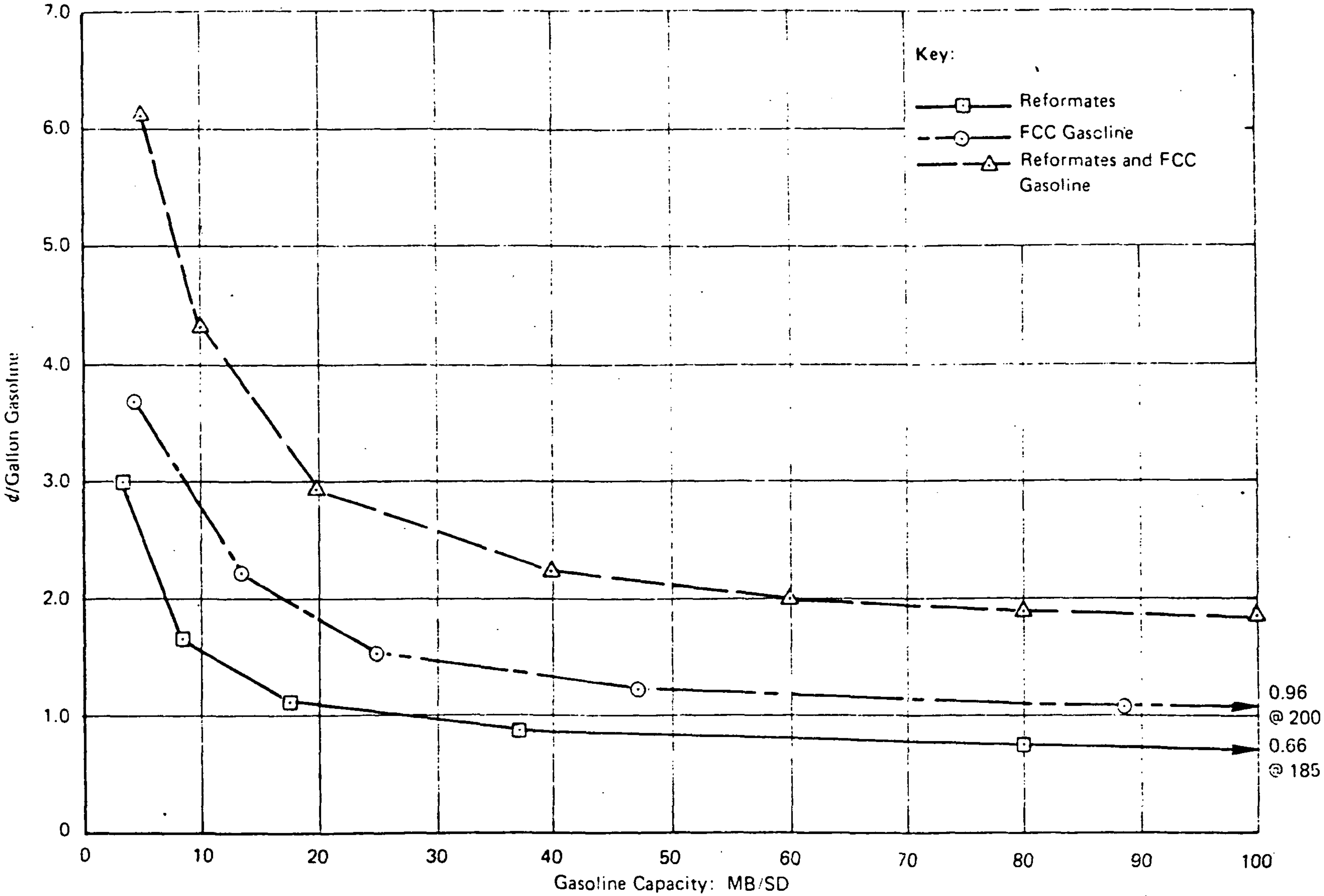
The national cost of benzene removal from FCC gasoline was based on producing hydrogen plant hydrogen at all locations with FCC unit capacity. Some locations may have sufficient reformer hydrogen available at fuel value. Since a detailed hydrogen balance at each location was beyond the scope of this study, the sensitivity to hydrogen cost was developed. If all locations were able to use refinery produced hydrogen at fuel value, the total cost of benzene removal would drop from 1.8 to 1.6 cents per gallon of U.S. gasoline. If the hydrogenation step were not required in the removal of benzene from gasoline, the total cost of benzene removal would drop from 1.8 to 1.2 cents per gallon of U.S. gasoline.

The most important variable affecting the economics of benzene removal is the unit capacity. The effect of capacity on benzene removal costs from reformates and FCC gasoline is shown in Figure 6-9. The increased costs with decreasing size results in a cost of benzene removal of up to 7 cents per gallon of gasoline produced for the small refiner, as compared with the U.S. average of 2.19 cents per gallon. In addition, the removal of benzene from gasoline would have a greater affect on the small refiner's ability to blend gasoline because of less operational flexibility and fewer blending stocks. It is likely that some small refiners may not be able to remain in business because of their significant cost differential and due to the high costs associated with meeting gasoline lead phasedown regulations.

6.5 TOTAL COSTS OF GASOLINE MARKETING CONTROL OPTIONS

Table 6-53 presents a summary of the total costs for the four gasoline marketing control options. The table indicates the total capital investment costs, the annualized costs, and the total discounted costs that will be incurred by the gasoline marketing petroleum industries.

Option 1 is the least costly option since there is less control at bulk plants than with the other options. The difference between options 1 and 3 depends on the cost scenario assumption used for bulk plants. Assuming use of the "least expensive equipment," capital costs between the two options differ by only $32 million and annualized costs by $1.5 million. On the other hand, with the "most expensive equipment," the differences are $221 million in capital costs and $47 million in annualized costs. Option 4 is the most expensive vapor recovery option, with capital costs $60 million to $200 million greater than those of option 3.



Source: Arthur D. Little, Calculations.

Figure 6-9. Cost of Benzene Removal vs. Gasoline Production Using Refinery-Produced Hydrogen

Option 2 is by far the most expensive control option, with capital costs five to seven times greater than the other options and annualized costs 10 to 20 times greater. The cost per gallon for option 2 would be at least 1.8 cents, while the other options exhibit unit costs ranging from 0.10 to 0.17 cent per gallon. Likewise, option 2 is not as cost-effective as the other options, with a cost of $245 per kilogram of benzene removed while the other options have a cost of $13 to $21 per kilogram of benzene controlled.

The total costs do not give a complete indication of the differences in economic impact between the options. The impact on closures of bulk plants varies significantly between the options. As already discussed in section 6.2.3.3, option 1 would result in at most 130 bulk plants going out of business. The impact resulting from option 3 depends on the cost scenario assumed, with only 50 bulk plants projected to close with the "least expensive equipment" and up to 2,200 closures with the "most expensive equipment." For option 4, the closures could amount to 9,000 to 10,000 bulk plants, or close to 50 percent of the population. Thus, option 4 will have a much more significant impact, which is not entirely reflected in the total cost numbers for two reasons. First, the total costs for option 4 only reflect the costs incurred for vapor recovery by the bulk plants that remain in business. Secondly, the costs do not reflect the monetary costs of the closures of bulk plants since it is difficult to place a monetary value on the continued existence of a bulk plant.

Table 6-53. TOTAL COSTS AND COST-EFFECTIVENESS OF GASOLINE MARKETING CONTROL OPTIONS

	Option 1			Option 2			Option 3			Option 4		
	Capital Invest-ment ($MM)	Annualized Costs[5] ($MM/Yr)	Total Costs Discounted To Present ($MM)	Capital Invest-ment ($MM)	Annualized Costs ($MM/Yr)	Total Costs Discounted To Present ($MM)	Capital Invest-ment ($MM)	Annualized Costs ($MM/Yr)	Total Costs Discounted To Present ($MM)	Capital Invest-ment ($MM)	Annualized Costs ($MM/Yr)	Total Costs Discounted To Present ($MM)
Bulk Terminals	401.3	55.8	473.2	0	0	0	401.3	55.8	473.2	401.3	55.8	473.2
Bulk Plants[1]	24.2-60.0	(4.6)-3.9	(22.7)-36.9	0	0	0	56.0-280.9	(3.1)-51.0	(6.5)-375.5	263.5-339.8	66.3-83.8	465.2-589.5
Service Stations[2]	284.8	46.4	343.3	0	0	0	284.8	46.4	343.3	284.8	46.4	343.4
Tank Trucks	34.3	17.7	79.5	0	0	0	34.3	17.7	79.5	34.0	17.7	79.5
Refineries	0	0	0	5287.0	2052.0	13,106.0	0	0	0	0	0	0
TOTAL	744.6-780.4	115.3 123.8	873.3-932.9	5287.0	2052.0	13,106.0	776.4-1,001.3	116.8-170.9	889.5-1271.5	983.9-1060.2	186.2-203.7	1361.2-1485.5
¢/Gal[3]	--	0.10-0.11	--	--	1.8	--	--	0.10	--	--	0.16-0.17	--
$/Kg[4] of Benzene controlled[4]	--	18-19	--	--	245	--	--	13-19	--	--	19-21	--

[1]Range of bulk plant costs represent "least expensive equipment" and "most expensive equipment"

[2]Service station costs represent average of costs for coaxial system for all outlets

[3]Based on estimated 1981 volume of 115 billion gallons.

[4]Emission reduction estimates come from Table 4-2.

[5]Parentheses indicate net cost savings

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APPENDIX B

MATRIX OF ENVIRONMENTAL IMPACTS OF ALTERNATIVE CONTROL TECHNIQUE CONFIGURATIONS

Alternative	Impact on Benzene	Impact on HC	Other Air Impacts	Water Impact	Solid Waste Impact	Energy Impact	Air Quality Impact	Space Impact	Noise Impact
I	+2	+3	-1	-1	-1	+4	-	-1	-1
II	+2	0	-3	-3	0	-4	-	0	0
III	+3	+3	-1	-1	-1	+4	-	-1	-1
IV	+4	+4	-2	-2	-1	+4	-	-1	-1
Delayed Standard									
No Standard	0	0							

KEY
+ Beneficial Impact
- Adverse Impact

0 No impact
1 Negligible impact
2 Small impact
3 Moderate impact
4 Large impact

APPENDIX C

Much of the data used throughout this document was obtained from tests. This appendix briefly describes the test sites, the test methods, and the results of those tests.

C.1 BULK TERMINAL TESTS

This section of Appendix C summarizes and discusses bulk terminal source tests that were conducted by EPA during the period from November, 1973, to March, 1978. The purpose of the earlier tests (A-F) was to evaluate the effectiveness of bulk terminal gasoline loading vapor control systems in controlling total hydrocarbons. Later tests (G-K) evaluated the effectiveness of the control equipment in controlling total hydrocarbons and benzene.

The types of control systems tested included thermal oxidizer systems (TO); compression-refrigeration-absorption systems (CRA); refrigeration systems (RF); and an adsorption-absorption system (AA).

The various types of control systems tested were considered to be representative of best available control for hydrocarbons in the bulk terminal gasoline loading industry.

A brief discussion of each bulk terminal tested and conditions during the test periods follows.

C.1.1 Bulk Terminal Test A

Test No. A was conducted at a bulk terminal that had an average gasoline throughput of approximately 600,000 liters (160,000 gallons) per day. The terminal was source tested by EPA from December 10-12, 1974. The terminal has eight loading racks for various fuels. Gasoline is dispensed from three of the racks. Each of the gasoline loading racks are equipped for bottom loading of premium, regular, and unleaded gasoline. Also, on one of the gasoline racks, two grades of aviation fuel are dispensed and vapors are vented to the vapor control system.

Hydrocarbon vapors and air in the tank truck are displaced by the gasoline loaded. The vapor air mixture vents to vapor return hoses at each end of the racks. The vapor hoses are manifolded to a common header venting to a saturator. Saturated vapors pass to a vapor holder. At a preset volume the vapor holder automatically discharges to a 85,000 liters per minute (300 cfm) compression-refrigeration-absorption (CRA) system.

The purpose of the saturator is to ensure that the hydrocarbon vapors vented to the vapor holder are saturated with hydrocarbons and are above the upper explosive limit.

Testing was performed during 39 truck loadings to determine potential hydrocarbon emissions, actual hydrocarbon emissions and vapor recovery efficiency of the system. Only two loading racks were tested. The other rack was not used for loading purposes because insufficient test equipment was available. Hydrocarbon emissions from the vapor recovery unit were determined to be 31.2 milligrams per liter (0.118 grams per gallon) of gasoline loaded into the tank trucks.

The only difficulties in testing encountered in the loading of gasoline into the tank trucks were vapor leakage and spillage from the tank trucks. Vapor losses occurred at almost all hatches and pressure vents at the top of the trucks. Leakage of emissions from the trucks were estimated to be 115.2 milligrams per liter (0.554 grams per gallon). Liquid spillage occurred on occasion because of improper seating of the shut-off valve at the liquid connection to the tanker, and also from buckets used to catch a small amount of unleaded gasoline left in the tank truck compartments from its previous load. The loss due to leakage can be estimated; but, the loss due to liquid spillage cannot. This test was conducted only for total hydrocarbons.

Further details are presented in the emission test report.[1]

C.1.2 Bulk Terminal Test B

Test No. B was conducted at a relatively small bulk terminal since the facility has only one gasoline loading rack: however, the throughput of the bottom-loading rack is approximately 380,000 liters (100,000 gallons) per day. Three grades of gasoline (premium, regular, and unleaded) are dispensed at the loading facility.

Vapors displaced from the gasoline tank trucks are vented to a refrigeration-type vapor recovery system. During the test period by EPA, which ran from December 17-19, 1974, twenty-four trucks were loaded with gasoline to determine the potential hydrocarbon emissions, actual hydrocarbon emissions and the vapor recovery efficiency of the vapor recovery unit.

In the refrigeration-type system, hydrocarbon vapors and air from the tank trucks are directly processed and condensed in a double-pass finned tube condenser associated with the vapor recovery unit. There are no saturators or vapor holders utilized in the system. The efficiency of the condenser is directly related to the temperature of the condensing unit. In normal operation, a condenser of -73°C (-100°F) would be anticipated.

Moisture in the vent gases condense and collect as frost on the finned-tube vapor condenser. Defrosting of the condenser is conducted at periodic intervals; usually, once or twice a day. Defrosting is completed in 10 to 30 minutes depending on the amount of frost collected on the finned-tubes.

During the test period there were no difficulties encountered in the actual loading of the tankers; however, there was significant leakage from the hatches and pressure vents on top of the tankers. The majority of the fuel loaded during the test period was on independent carrier trucks. Only two company owned trucks were loaded.

Operational problems associated with the vapor processing unit were encountered however. A leak had developed in the high pressure portion of the refrigeration system resulting in refrigerant loss. This resulted in higher than design temperatures in the condenser. After repairs, testing was conducted at the time the temperature of the condenser was approximately -31°C (-60°F). As previously noted, the design operating temperature of the condenser is -73°C (-100°F).

Recovered gasoline is separated from the condensed water and pumped to storage. Condensed water vapor passes to a slop tank. Hydrocarbon emissions to the atmosphere from the recovery unit were determined to be 37.0 milligrams per liter (0.140 grams per gallon) of gasoline loaded into the tank trucks. Leakage from the trucks was estimated to be 100.9 milligrams per liter (0.382 grams per gallon). This test was conducted only for total hydrocarbons. Further details are presented in the test report.[2]

C.1.3 Bulk Terminal Test C

This test was conducted at a medium size bulk terminal. The facility consists of two loading racks. The bottom loading arms are situated on a concrete island so that the trucks load countercurrently to each other. Trained operators load the trucks. Throughput in the terminal is about 1,430,000 liters (378,000 gallons) of gasoline per day. (The plant operates from 6 a.m. to 3. p.m., Monday through Saturday.) Trucks servicing both Stage I and non-Stage I service stations are loaded at the terminal.

Trucks to be loaded carry gasoline vapor laden air. (The trucks have capacities of 30,300-36,000 liters (8,000-9,500 gallons) each. As gasoline is loaded, these vapors are displaced. A flexible hose is attached to the vapor vent on the trucks and the vapors are vented to a control device--in this case a refrigeration unit. The operation of this unit was described under C.1.2.

The facility and refrigeration unit were tested for three days (September 20-22, 1976). During all three days the refrigeration unit was operating below capacity due to refrigerant loss which resulted from a leaking pump seal. As a result the actual refrigeration temperature was -44 to -52^{o}C (-47 to -61^{o}F) rather than the -73^{o}C (-100^{o}F) design temperature. Hydrocarbon emissions from the vapor recovery unit were determined to be 33.6 milligrams per liter (0.127 grams per gallon) of gasoline loaded into the tank trucks. Emissions due to leakage were estimated to be 86.7 milligrams per liter (0.328 grams per gallon). This test was conducted only for total hydrocarbons. Further details are presented in the emission test report.[3]

C.1.4 Bulk Terminal Test D

This tank truck gasoline loading terminal consists of four loading racks loading 1,190,000 liters (315,000 gallons) of gasoline product per day and numerous product storage tanks. The facility is attended for about 10 hours per day, but drivers have pass keys which permit loading 24 hours per day, 7 days per week. Trucks servicing both Stage I and non-Stage I service stations are located at the terminal. Testing was conducted from September 23-25, 1976.

The vapor recovery system is a compression-refrigeration-absorption unit. The system handles emissions from the loading rack and from storage tank loading operations.

Gasoline vapors, collected from tank truck loading operations, are first sprayed with gasoline to ensure that they are saturated (above the explosive range). The vapors are then vented to a regular gasoline product storage tank equipped with a lifter roof. When the roof reaches a predetermined level the vapors are vented to the CRA unit where the vapors are sprayed with gasoline again (to saturate) and then compressed and cooled. The vapors are then vented to an absorber where they are absorbed in fresh gasoline and vented to atmosphere.

Throughout the test period, the unit operated with no apparent problems. In addition to truck and CRA outlets being monitored, the liquid levels in the storage tanks, the flow to the pipeline, and the liquid volumes into and out of the CRA were monitored.

One problem seen was that drivers frequently drained trucks of remaining gasoline into a sump before loading. This caused several liters of gasoline to evaporate to atmosphere during the course of the test period. This loss cannot be quantified. Hydrocarbon emissions from the vapor recovery unit were determined to be 43.3 milligrams per liter (0.164 grams per gallon) of gasoline loaded into the tank trucks. Leakage from the tank trucks was estimated to be 154.6 milligrams per liter (0.585 grams per gallon).

Trucks loading diesel fuel also hooked up to the vapor return line and vented emissions to the saturator of the CRA. The test was conducted only for total hydrocarbons. Further details are presented in the emission test report.[4]

C.1.5 Bulk Terminal Test E

Test No. E was conducted at a bulk terminal with a throughput of approximately 1,100,000 liters (291,000 gallons) per day. The terminal has two bottom-loading racks and one top-loading rack. Hydrocarbon vapors from the tank truck are vented through flexible connections to a common header venting to a vapor holder and to the thermal oxidizer.

An EPA contractor conducted extensive tests on a thermal oxidizer system at tank truck gasoline loading terminal E during the period November 18, 1973, to May 2, 1974. Hydrocarbon vapors from tank truck loading operations were vented to a vapor holder. The hydrocarbon vapors were enriched with propane to ensure they were above the upper explosive limit. The hydrocarbon vapors from the vaporsphere were then vented to the thermal oxidizer for incineration.

The oxidizer is a simple, reliable gas furnace which turns on and operates as needed; however, if it is necessary to shut down the oxidizer during tank truck loadings and if the vaporsphere fills beyond its capacity of 283 cubic meters (10,000 cubic feet) or about 8 truck loads, excess vapors would vent to the atmosphere.

Tests at the terminal during the test period indicated that the oxidizer disposes of 99+ percent of the hydrocarbon vapor collected, even in extremely cold weather when the air-gasoline vapor mixture is in the flammable range. Although the oxidizer disposed of 99 percent of the gasoline vapor it received, only about 70 percent of the air-vapor mixture displaced from the truck loading reached the oxidizer. Unusually high pressures 53.3 g/cm^2 (21 inches of water) produced in the truck during loading were responsible for the vapor loss through maladjusted hatch covers and faulty pressure-vacuum relief valves on the trucks. A problem also existed causing low vapor transfer and pressure build-up due to blockage of the vapor collection line by a column of gasoline. These problems were partly corrected and the overall disposal efficiency of the entire system now exceeds 90 percent. Hydrocarbon emissions to the atmosphere from the thermal oxidizer are estimated to be less than 1.32 milligrams per liter (0.1 grams per gallon) of gasoline loaded into the tank trucks. Leakage from the truck was not quantified, but is estimated to be 30 percent. Further details are presented in the test report.[5]

C.1.6 Bulk Terminal Test F

This tank truck gasoline loading terminal consists of three bottom loading racks. Throughput in the terminal is about 810,000 liters (220,000 gallons) per day. Trucks servicing both Stage I and non-Stage I service stations are loaded at the terminal. Testing was conducted from November 10-12, 1976.

Trucks to be loaded carry gasoline vapor laden air. The trucks have capacities of 30,300-36,000 liters (8,000-9,500 gallons) each. As gasoline is unloaded, these vapors are displaced. A flexible hose is attached to the vapor vent on the trucks and the vapors are vented to a control device--in this case a refrigeration unit. The operation of this unit has been described previously under C.1.2.

The facility and refrigeration unit were tested for three days. During all three days the refrigeration unit was operating at capacity. A valve on the coolant return line (from the coils) was not opening properly and thus return temperatures were higher than expected, but the problem was not significant. Icing at the decanter, caused by ambient air leaking into the separator occurred but did not cause any problems. Hydrocarbon emissions from the vapor recovery unit were determined to be 62.6 milligrams per liter (0.237 grams per gallon) Hydrocarbon leakage from the trucks was estimated to be 46.0 milligrams per liter (0.174 grams per gallon). The test was conducted only for total hydrocarbons. Further details are presented in the emission test report.[6]

C.1.7 Bulk Terminal Test G

This company operates a small tank truck gasoline loading terminal with a storage capacity of 3,600,000 liters (950,000 gallons) of gasoline and a daily throughput of 284,000 liters (75,000 gallons) of gasoline. Barges deliver the supply of gasoline to the terminal. There is no vapor recovery system for the barge unloading operations other than the vapors retained under floating roof storage tanks. Two truck racks employ five (5) bottom loading positions, with vapor recovery lines leading to a carbon adsorption type vapor recovery unit. The vapor recovery system was in good working order and appeared free from leaks.

Testing was performed May 25-27, 1977, during 33 tank truck loadings to determine actual hydrocarbon emissions, potential hydrocarbon emissions, and the vapor recovery efficiency of the system.

Hydrocarbons generated during bottom loading of tank trucks at the terminal are collected by a vapor line collection system and vented to a carbon adsorption and gasoline absorption vapor recovery system. Hydrocarbons broke through the carbon beds on the first two days of testing. Outlet concentrations from the unit were observed during these breakthroughs to be greater than 10 percent. The problems causing hydrocarbon bed breakthrough were found and corrected before the third (final) day of source testing. Hydrocarbon breakthroughs of the carbon beds were caused by incorrect settings in electrical timer switching of the dual bed system. In the system, one charcoal bed will remove gasoline vapors while the other bed is being vacuum regenerated. After a period of time, the beds will switch. The first day of testing, it was noted that the same bed was on line to absorb vapors whenever a truck started loading. This improper setting of the bed switching system caused an overload on one bed. The setting of the bed switching system was corrected before the second test day. However, some breakthrough was noted on the second day while the system was catching up. No hydrocarbon breakthrough was noted on the third day. The improper setting was due to the fact that the system was previously adjusted for processing a low volume lean stream and during the test had to be readjusted to operate on a high volume rich stream. Further details are presented in the emission test report.[7] Hydrocarbon and benzene emissions from the vapor recovery unit were determined to be 30 and .003 milligrams per liter of gasoline loaded into the tank trucks, respectively.

C.1.8 Bulk Terminal Test H

This tank truck gasoline loading terminal vapor control system was previously source tested by EPA on December 10-12, 1974 (see C.1.1). The vapor control unit, a CRA unit, was retested to determine the efficiency of the unit in removing benzene from tank truck gasoline inlet vapors.

Testing was conducted on December 16, 1977. Integrated bag samples were taken; 1) from the line between the vapor holder and the vapor control unit, and 2) from the outlet of the vapor control unit. In addition, liquid samples of regular, premium unleaded, AV gas-80 and AV gas-100 were obtained for benzene analysis.

The integrated bag samples were drawn during the period when the vapor recovery unit was in operation. During the test period the vapor holder vented to the vapor control system six times. A total of 24 tank trucks were loaded during this period and meter readings were taken at the loading rack for each gasoline product loaded. A turbine meter was utilized to measure the exhaust volume from the control unit.

During the test period the three loading racks as well as the vapor control system appeared to be in normal operation. The vapor holder would fill with vapors until the height of the diaphragm reached approximately 3.18 meters (10 feet). This height would actuate the vapor control unit and hydrocarbon vapors would vent to the system until the vapor holder diaphragm was drawn down to approximately 1.55 meters (5 feet). In some instances, trucks were loaded while the vapor recovery unit was in operation.

During the vapor recovery unit operation the absorber pressure was 3.52 kg/cm^2(50 psig) and the temperature was -16.6°C (2°F). This is normal operation for the unit. Liquid gasoline temperature at the loading rack varied from an estimated 1.1°C to 9.9°C (34°F to 50°F) during the testing period.

During the fourth cycle of the vapor holder, it was noted that the vapor recovery unit inlet sampling line had a small hole in it. Testing was stopped, the small hole was repaired, and testing was conducted during two additional vapor holder cycles. All bag samples collected were processed within a short time in the testing contractor's mobile van which was parked at the site.

Testing of this facility gave the efficiency of the vapor recovery unit in removing hydrocarbon and benzene from vapors vented from the vapor holder at the site. No relation can be made to tank truck emissions since a saturator is included in the system between the tank trucks and the vapor holder. Hydrocarbon and benzene emissions from the vapor recovery unit were determined to be 41.1 and .106 milligrams per liter of gasoline loaded into the tank trucks, respectively. Further details are presented in the test report.[8]

C.1.9 Bulk Terminal Test I

This tank truck gasoline loading terminal was selected for source testing because the loading facilities are vented directly to a thermal oxidizer. The other thermal oxidizer unit source tested by EPA was equipped with a vapor holder that allowed only vapors above the vapor explosive limit to be vented to the unit. (See Report No. EPA-650/2-75-042, June, 1975.)

The terminal is equipped with three gasoline loading rack positions (No. 9, 7, and 5). Regular, premium, and unleaded gasolines are loaded at each of these racks. At the No.9 loading rack, the tank truck vapor vent line was connected to a turbine meter to quantitatively measure the volume of vapors vented from the tank truck to the vapor control system. Integrated bag samples of vent gases from the trucks were taken at this point and tank trucks loaded were monitored for leaks. A liquid sample for each type of gasoline loaded was also obtained for analysis.

During the test period the terminal appeared to be in normal operation and the thermal oxidizer appeared to be operating properly. It was stated that the daily throughput of gasoline approximated 757,000 to 1,135,500 liters (200,000 -300,000 gallons) of gasoline. To ensure that a sufficient number of tank trucks were monitored, most of the trucks were loaded at the No. 9 rack.

The gallons loaded for each rack, temperature of product and the date are continuously recorded in the terminal office. Six trucks were monitored the first day, fifteen the second, and ten on the third day.

The test appeared to have been conducted in a satisfactory manner. The possibility exists that due to low temperature conditions, the vapors vented to the thermal oxidizer unit in some instances may have been below the lower explosive limit and could have passed through the thermal oxidizer without being incinerated. Hydrocarbon and benzene emissions to the atmosphere from the thermal oxidizer were determined to be 34.2 and .330 milligrams per liter of gasoline loaded into the tank trucks, respectively. Further details are presented in the emission test report.[9]

C.1.10 Bulk Terminal Test J

This tank truck gasoline loading terminal vapor control system was previously source tested by EPA on November 10-12, 1976 (see C.1.6). The vapor control unit was retested to determine the efficiency of the unit in removing benzene from tank truck gasoline loading inlet vapors.

Testing was conducted on March 7, 1978. Integrated bag samples were taken; (1) from the vapor line from the tank trucks, and (2) from the outlet of the vapor control unit. In addition, liquid samples of the gasoline from the vapor recovery unit were determined to be 53.4 and 0.052 milligrams of gasoline loaded into the tank trucks, respectively. The operation of the terminal is discussed in C.1.6. Further details are presented in the emission test report.[10]

C.1.11 Bulk Terminal Test K

This tank truck gasoline loading terminal vapor control system was source tested by EPA on May 1-5, 1978.[11] The terminal has a gasoline throughput that approximates 1,000,000 liters per day.

The vapor control system at this plant is similar to that described in Test No. H. The unit was tested to determine the efficiency of the unit in removing benzene from tank truck gasoline loading vapors.

The total hydrocarbon concentration, at both the inlet and outlet of the vapor recovery unit, was continuously monitored, the vapor volumes were determined at these two sampling points and bag samples were collected at each sampling point for analysis of benzene using gas chromatography. Measurement of the liquid volume percent of benzene in the different grades of gasoline was also performed during this test.

Test results reported are based on preliminary data and indicate that the benzene concentration in the control system vent averages 18.5 ppm. Inlet concentrations average 920 ppm. The benzene removal efficiency averages 98.5 percent. It would appear that this type of compression-refrigeration-absorption (CRA) unit will effectively remove benzene from gasoline vapors generated during tank truck loading operations.

C-1. SUMMARY OF BULK TERMINAL GASOLINE LOADING VAPOR CONTROL DEVICES SOURCE TESTED BY EPA

	A	B	C	D	E	F	G	H	I	J	K
TYPE OF VAPOR CONTROL SYSTEM (VRS)*	CRA	RF	RF	CRA	** TO	RF	AA	CRA	*** TO	RF	CRA
1. VRS Inlet-HC, mg/l	107.3	236.7	486.9	554.0	-	318.9	684	447	368	203	998
2. VRS Outlet HC, mg/l	31.2	37.0	33.6	43.3	-	62.6	30	41.1	34.2	53.4	53.6
3. VRS Inlet, BZ, mg/l	-	-	-	-	-	-	2.51	2.45	1.68	0.992	4.51
4. VRS Outlet BZ, mg/l	-	-	-	-	-	-	0.003	0.106	0.33	0.052	0.07
5. VRS HC Effic. (%)	70.9	84.4	93.1	92.1	99+	80.4	95.9	91.0	91.0	73.0	93
6. VRS BZ Effic. (%)	-	-	-	-	-	-	99+	96.0	81.0	95.0	98.5
7. VRS Outlet HC Conc. (Vol %)					.0001 to .0045		0.21	4.16		4.0	2.6
8. VRS Outlet BZ Conc. (Vol %)	-	-	-	-			0.0004	0.006		0.001	.002
9. Benzene Content of Liquid Gasoline											
REGULAR								1.81	1.64	1.00	0.64
PREMIUM								1.28	1.87	0.68	0.59
UNLEADED								2.49	1.92	1.04	0.39
AV-80								0.36	-	-	-
AV-100								1.06	-	-	-

* CRA - Compression-Refrigeration-Absorption
RF - Refrigeration
TO - Thermal Oxidizer
AA - Adsorption-Absorption

** See EPA Test Report, EPA-650/2-75-042, June, 1975. Thermal Oxidizer with Vapor Holder

*** Thermal Oxidizer without Vapor Holder

C.2 BULK PLANT TESTS

Pacific Environmental Services (PES), under EPA contract, conducted hydrocarbon efficiency testing[12] of vapor recovery systems installed at bulk plants. Two installations were studied; one (Plant A) employed a vapor balance system modified by refrigeration to maintain a reduced temperature in the storage tanks, and the other (Plant B) employed a vapor balance system without secondary vapor recovery.

Efficiency testing was done by measuring amounts of liquid gasoline transferred and of gasoline vapor retrieved during transfer of gasoline into and out of the storage tanks. Efficiency was defined as the ratio of vapor retrieved to a theoretical estimate of the amount which would be lost during transfer if emissions were uncontrolled.

C.2.1 Plant A - Description and Operation

The vapor recovery system installed at Plant A employs a refrigeration unit to reduce pressure in the storage tanks and thereby to minimize venting. In this system, vapors are drawn from the storage tanks by a blower, pass over cooling coils in the refrigeration unit and exhaust back to the storage tanks through an insulated return line. The system makes no effort to condense vapors but is designed strictly to maintain a constant temperature in the storage tanks (in this case $16^{\circ}C$) and thereby maintain a pressure below the venting level. The system is actuated when the storage tank pressure reaches 748 N/m^2 (3 in. H_2O) and continues to operate until the pressure falls below

374 N/m^2 (1.5 in. H_2O) or until 20 minutes have elapsed. If after 20 minutes the pressure has not decreased to 374 N/m^2 the system is actuated again and runs for another 20 minutes. This cycle continues until the pressure falls below the set level of 374 N/m^2.

Plant A incorporates a 7.6 cm vapor return line manifolded to all tanks handling gasoline which includes the insulated line that runs from the refrigeration unit back to the storage tanks. Separate vapor return connections are used for the delivery of gasoline to the bulk plant and the loading racks for dispensing gasoline. At each location the vapor return connection was sealed with a spring activated valve. A series of safety vents similar to those described for Plant B are in the storage tank system. The bulk plant also has four gasoline service station type pumps connected into the vapor recovery system. The same blower which is used for the storage tank refrigeration system is also used to supply vacuum assist at the nozzle of these pumps and is activated when the dispensing pump is started.

C.2.2 Testing of Plant A

The testing of Plant A was treated as a vapor balance system. The refrigeration system at this facility does not condense vapors but is designed strictly to maintain a constant temperature (16°C) in the storage tanks and thereby maintain a pressure below the vent level, thus decreasing both breathing and working losses. This design made a direct evaluation of the refrigeration system impossible since it was difficult to relate its operation as being independent of the vapor balance system.

Seven transport deliveries were tested at Plant A and an average volumetric efficiency of 97.0 was obtained, based on five deliveries. The average loss in volume (theoretical minus standard) was estimated as one cubic meter. For the account truck tests, the average efficiency would be a rather misleading number since various factors have to be considered, such as the type of account truck, system pressure and ambient temperature. Each account truck has its own characteristics (i.e., hatch leakage, capacity, etc.) and these all vary from one truck to another. Average volumetric efficiencies for the trucks ranged from 58 to 94 percent. An average concentration of 30 percent by volume as propane (20 percent by volume as hydrocarbons) was found in the vapor return line during delivery of gasoline by transport truck. Twenty-five percent by volume as propane (17 percent by volume as hydrocarbons) was found during loadings of the account trucks.

C.2.3 Plant B - Description and Operation

The vapor recovery system installed at Plant B employs a vapor balance system which operates on the principle of a simple exchange of vapors between the truck tank and the storage tanks. The liquid gasoline is pumped from the incoming tank truck into the storage tanks and displaces an equivalent volume of vapor-laden air which is routed back to the truck tank through the vapor line. When loading delivery tank trucks with gasoline, the vapor-laden air in the delivery tank trucks is displaced back into the storage tanks through the vapor return lines.

The vapor balance system incorporates a 5 cm vapor return line which is manifolded to each of the five storage tanks handling gasoline. A spring actuated poppet valve is at the loading rack outlet of the vapor return line to eliminate hydrocarbon losses when the plant is idle.

Plant B is also designed to utilize one vapor return hook-up for both transport deliveries and dispensing product into delivery trucks. This is accomplished through a series of valves enabling the loading rack pumps to be used for pumping in either direction. The system also incorporates a series of pressure relief vents installed in the storage tank system. A, pressure vacuum (PV) vent is located in the vapor line with a 2586 N/m^2 (10 in. of water) pressure setting and a 2.5 N/m^2 (0.9 in. of water) vacuum setting to allow the release of vapors or the entrance of air into the system during severe pressure changes in the loading or unloading operations. If the system pressure continues to increase and the PV vent cannot allow the escape of vapors quickly enough, each storage tank has an emergency vent to open at 5309 N/m^2 (17 in. of water) of pressure. If under extreme conditions these vents could not relieve the system pressure, a series of carbon shear pins and hatch covers will open between 13,790 N/m^2 and 20,680 N/m^2 (55 and 83 inches of water) pressure. These final two steps in pressure relief are installed primarily as safety features if the PV vent cannot handle the pressure load.

C.2.4 Testing of Plant B

The testing at Plant B was less complex, mainly because Plant B had a much smaller throughput (13,000 liters/day for Plant B as compared to 50,000 liters/day for Plant A). Five tank truck deliveries and eleven delivery truck loadings were tested. The average volumetric efficiencies for truck deliveries were found to be 95 percent. Consistent readings were obtained indicating that leaks were minimal. An average concentration of 45 percent by volume propane (29 percent by volume as hydrocarbons) was found in the vapor return line.

The efficiencies for the account trucks ranged from 79 to 97 percent. This wide range of efficiencies was due to the leaks present in the account trucks and bulk storage tanks. An average concentration of 38 percent by volume as propane (26 percent by volume as hydrocarbons) was found in the vapor return lines.

C.2.5 Conclusions

As a result of tests performed on vapor recovery installations at two gasoline bulk plants, the following conclusions are reached:

1. Vapor balance systems, with or without associated refrigeration for cooling storage tanks, can control vapor emissions during delivery of gasoline by tank trucks with efficiency greater than 90 percent. In all of ten such transfers observed in this study, the volume efficiency observed ranged from 90 to 100 percent.

2. Vapor balance systems, with or without associated refrigeration, can control vapor emissions during loading of delivery trucks with overall volumtetric efficiency greater than 90 percent. In twelve of thirty such transfers observed in this study, the volumetric efficiency observed ranged from 90 to 100 percent.

3. The tests performed yielded no evidence that the secondary system employed at one bulk plant provided better emission control than the unassisted system employed at the other plant. Minimum observed volumetric efficiencies in loading of delivery trucks were 43 percent with the refrigeration system as compared with 79 percent for the unassisted vapor balance system.

4. The efficiency attainable in loading account trucks appears to depend markedly on the condition of hatches and seals, and on the degree of care exercised in making connections. At Plant A, four delivery trucks

were used; during loading, the two newer trucks had consistently lower emissions than the oldest truck, but none of the four consistently showed control volume efficiency as high as 90 percent.

5. Venting of a storage tank occurred once at each of the plants during the period of testing. The venting of the tank at Plant A, with the refrigeration system, released only a negligible amount of vapor, unmeasurable with the study equipment. The venting from the tank at Plant B, however, continued for about an hour and released an estimated 7 cubic meters (250 cubic feet) of gas containing about 25 percent hydrocarbons. (This would be roughly equivalent to about 7 liters of liquid gasoline, or about two gallons.)

6. The average molecular weight of hydrocarbon vapors recovered, as indicated by gas chromatographic analysis, was about 64 (intermediate between butane and pentane).

7. Reid Vapor Pressure measurements of the liquid gasoline transferred indicated that gases emitted during liquid transfer at Plant A were typically not saturated with gasoline vapor, whereas those emitted during transfer at Plant B were near saturation. This difference is possibly attributable to the effect of the refrigeration unit at Plant A.

C.3 SERVICE STATION TESTS

In June of 1974, EPA tested five service stations during bulk deliveries.[13] Two of these stations were equipped with balance systems for both refueling of automobiles and bulk drops. Three of the stations had balance systems for bulk drops with excess vapors being treated in secondary processors on the underground storage tank vents. The secondary processors were part of systems used to control vapors from automobile refueling. All systems were installed to comply with local hydrocarbon air pollution control regulations.

As previously discussed in this document, balance system control efficiency is equivalent for hydrocarbons and benzene emissions. Thus, the performance of these five systems for hydrocarbon reduction demonstrates the performance of the systems for benzene reduction. (The effect of the secondary processors on benzene emissions was not established. However, since the processors handled only excess vapors from the system, it is expected that the three systems performed as well, if not better, than the two straight balance systems. Further, while the two straight balance systems were used in conjunction with balance systems on refueling, the system efficiency is not expected to be any different than balance systems unassociated with refueling controls.)

C.3.1 Service Station A

Station A was tested during a bulk drop of 33,000 liters (8250 gallons) on June 12, 1974. The station employed a balance system on both vehicle refueling operations and bulk deliveries. The station pumped about 115,000 liters (30,000 gallons) of gasoline per month based on the average gasoline pumped for three grades of gasoline during the test period.

Underground storage tank vents were manifolded by underground piping to a common connection to which the delivery truck attached a single vapor return hose. The hose had been attached to the truck vapor connector. With such manifolded underground piping, it is possible to load more than one storage tank at a time.

The truck unloaded four compartments of gasoline simultaneously into two tanks holding regular and premium gasoline. The drop took 40 minutes from arrival at station to completion of the drop. The actual unloading took 20 minutes (1220-1240). Based on a comparison of the volume of air/vapor vented to the volume of air/vapor displaced, the system achieved 97.6 volume percent efficiency. The mass rate was 8 mg HC/liter of gasoline dropped. The benzene rate would approximate 0.07 mg/liter. Table C-2 summarizes these data.

C.3.2 Service Station B

Station B also employed a balance system for vehicle and bulk drop sources. The system was tested on June 18, 1974, and the data indicated that throughput approximated 77,000 liters (20,000 gallons) per month. The underground storage tank vapor lines were not manifolded, so only a single drop could be made at a time. The test took place during the loading of 18,000 liters (4665 gallons) of gasoline around 1030. The volume efficiency was 96.2 percent and hydrocarbon mass rate was 10 mg/liter of gasoline dropped. Benzene mass rate would approximate 0.08 mg/liter.

C.3.3 Service Station C

Station C was tested during a bulk drop on June 21, 1974. The station was equipped with a balance system and secondary processor (in this case an incinerator). Station throughput was estimated as 135,000 liters (35,000 gallons) per month. Underground storage tank vent lines were manifolded and the 30,000 liter (7800 gallon) delivery took about 35 minutes to complete for the two tanks which were loaded. Volume efficiency was shown to be over 99 percent and the hydrocarbon mass emission rate was 0.5 mg HC/liter of gasoline dropped. This would convert to approximately 0.004 mg BZ/liter. Efficiency is high and mass rate is low because excess vapors were incinerated in the system (installed to control vehicle refueling losses).

C.3.4 Service Station D

Station D employed a balance system with a refrigeration secondary processor. The station, which was tested on June 7, 1974, had an estimated throughput of 289,000 liters (75,000 gallons) per month.

Venting of the storage tanks was manifolded and thus the truck driver unloaded two compartments at a time. The total delivery totalled 33,000 liters (8600 gallons) and took 20 minutes. The total time from arrival at the station to completion of load was about 45 minutes. Volume percent efficiency was over 99 percent. Hydrocarbon emissions were about 0.9 mg/liter. This converts to about 0.007 mg BZ/liter of gasoline.

C.3.5 Service Station E

Station E was tested on June 25, 1974. The station employed a balance system with a refrigeration/adsorption secondary processor. Station throughput approximated 115,000 liters (30,000 gallons) per month.

Storage tank vents were manifolded so that two compartments were unloaded simultaneously. (Four compartments totalling 34,000 liters were unloaded during the test period which lasted about 10 minutes--1015 to 1025.)

The processor vent did not exhaust during the load, indicating that the system approached 100 percent efficiency. However, the test report notes that a leak in an underground pipe was located and may have vented during the test. Thus hydrocarbon and benzene emission rates are uncertain in this test.

C.4 DETERMINATION OF BENZENE TO HYDROCARBON RATIO FOR GASOLINE VAPOR

Many attempts were made by EPA to theoretically predict benzene/gasoline vapor-liquid equilibrium. None of these efforts conclusively collaborated the test data on hand, presumably because of the number of complicating influential parameters. Thus we have decided to rely entirely upon the actual test data to supply the necessary information. Test data were available from three sources; Colonial Pipeline, Gulf Oil (Runion), and Shell Oil Company, as discussed below.

Field sampling and analyses were conducted at the Colonial Pipeline Company tank farm in Greensboro, North Carolina, in September, 1977.[14] These tests were performed to determine the extent of saturation in the vapors under floating roof tank seals, and to help establish the relationship between benzene liquid and vapor concentrations for gasoline.

In the Colonial Pipeline test, three samples were drawn from the vapor space on each of nine gasoline tanks. Two liquid samples were taken from each tank. Of the nine tanks tested, one contained unleaded premium gasoline, three contained leaded premium gasoline, two held unleaded regular gasoline, and the remaining three tanks stored leaded regular gasoline.

TABLE C-2. SERVICE STATION BULK DROP RATE

STATION	Estimated Monthly Throughput (liters)	Drop (Liters)	Volume Efficiency	Mass HC Emissions (gm)	Mass HC (mg/liter)	Estimated BZ (mg/liter)
A	115,000 (30,000 gal)	32,000 liters (8250 gal)	97.6	260	8	0.07
B	77,000 (20,000 gal)	18,000 (4665 gal)	96.2	183	10	0.08
C	135,000 (35,000 gal)	30,000 (7800 gal)	99+	14.5	0.5	0.004
D	289,000 (75,000 gal)	33,000 (8685 gal)	99+	28.5	0.9	0.007
E	115,000 (30,000 gal)	34,000 (8800 gal)	—	—	—	—

The results of these analyses are presented in Table C-3, along with previous data obtained by Gulf Oil Corporation and Shell Oil Company. The benzene vapor concentrations (ppm and gm benzene/gm hydrocarbon) were calculated directly from gas chromatography analyses and averaged for each tank in the Colonial Pipeline test.

The paper by Runion (Gulf Oil)[15] presented benzene vapor concentrations as air-free vapor volume percent benzene. Thus, the ppm quoted in Table C-3 for the Runion work is converted to benzene in gasoline/air vapor by assuming 46 percent hydrocarbon in the vapor. (Forty-six percent hydrocarbon in the vapor is the average of all the Colonial Pipeline tests.) The gm benzene/gm hydrocarbon for the Runion tests were estimated by:

$$\frac{(\text{Vapor volume \% benzene})\ (\text{MWB})}{[1 - (\text{Vapor volume \% benzene})]\ (\text{MWV})} = \frac{\text{gm benzene}}{\text{gm hydrocarbon}}$$

Where the average molecular weight of the vapor(MWV) was also averaged from the Colonial Pipeline test data.

Similarly, assumptions were made in estimating the gm benzene/gm hydrocarbon from Shell Oil Company work.[16] Because the Shell work only gave an average vapor benzene concentration, it was necessary to assume that the average liquid gasoline in the 86 Shell tests was about one liquid volume percent.

Data from Colonial Pipeline, Gulf, and Shell were then plotted as gram benzene/gram hydrocarbon versus gasoline liquid volume percent benzene to yield Figure 2-2. A least squares analysis of the data provided the best linear fit. At the current national average of 1.3 liquid volume percent benzene, the least square analysis predicts 0.0078 (rounded to 0.008) grams benzene/gram hydrocarbon, which is used throughout this document.

TABLE C-3. COLONIAL PIPELINE

TANK NO.	GASOLINE	LIQUID VOLUME PERCENT BENZENE	LIQUID VAPOR TEMPERATURE(^{o}F)	VAPOR ANALYSIS PPM BENZENE	gm BENZENE / gm HYDROCARBON
810	UNLEADED PREMIUM	1.23	82	3600	0.007
818	UNLEADED REGULAR	1.33	87	3900	0.009
819	LEADED PREMIUM	1.41	84	3900	0.011
821	UNLEADED REGULAR	1.19	81	3000	0.007
822	LEADED PREMIUM	1.02	84	4100	0.009
824	LEADED PREMIUM	0.819	83	2600	0.006
837	LEADED REGULAR	1.48	86	4200	0.010
840	LEADED REGULAR	1.07	83	3000	[illegible]
844	LEADED REGULAR	1.23	82	2900	0.008

C-3. COLONIAL PIPELINE (Cont'd)

SOURCE	LIQUID VOLUME PERCENT BENZENE	TEMPERATURE	VAPOR ANALYSIS PPM	VAPOR ANALYSIS gm/BENZENE / gm HYDROCARBON
RUNION				
Low Octane Regular	0.85	78	4600	0.006
Leaded Regular	1.22	78	4400	0.005
Unleaded Regular	1.10	78	3700	0.005
SHELL				
(Average of 86 samples)	1.0	-	7000	0.009
EPA Hackensack Test	-	-	-	0.009

Additional testing by EPA at a bulk loading terminal in Hackensack, New Jersey,[17] confirmed that the average weight fraction of benzene in the vapors displaced during gasoline loading was about 0.009.

C.5 REFERENCES

1. Test No. A, EMB Project No. 75-GAS-10, EPA Contract No. 68-02-1407, Task No. 7, September, 1975.

2. Test No. B, EMB Project No. 75-GAS-8, EPA Contract No. 68-02-1407, September, 1975.

3. Test No. C, EMB Project No. 76-GAS-16, EPA Contract No. 68-02-1407, September, 1976.

4. Test No. D, EMB Project No. 76-GAS-17, EPA Contract No. 68-02-1407, September, 1976.

5. Test No. E, EPA-650/2-75-042, June, 1975.

6. Test No. F, EMB Project No. 77-GAS-18, EPA Contract No. 68-02-1407, November, 1976.

7. Test No. G, EMB Project No. 77-GAS-19, EPA Contract No. 68-02-1400, October, 1977.

8. Test No. H, EMB Project No. 78-BEZ-4, EPA Contract No. 68-02-2813.

9. Test No. I, EMB Project No. 78-BEZ-5.

10. Test No. J, EMB Project No. 78-BEZ-3.

11. Test No. K, EMB Project No. 78-BEZ-11.

12. "Compliance Testing Analysis of Small Bulk Plants," Contract No. 68-01-3156, Task Order No.17, prepared by Pacific Environmental Services, Inc., for the U.S. EPA, Region VIII, Final Report, October, 1976.

13. Hasselmann, D.E., "Gasoline Transfer Vapor Recovery Systems - San Diego County, California," TRW Inc., Contract No. 68-02-0235, for EPA, November, 1974.

14. Analyses of Vapor Samples from Gasoline Storage Tanks (Colonial Pipeline Company, Greensboro, North Carolina), Scott Environmental Technology, EPA Set 1656 01 1177, November, 1977.

15. Runion, H.E., "Benzene in Gasoline," AIHA Journal, May, 1975.

16. McDermott, H.J., "Quest for a Gasoline TLV," AIHA Journal, February, 1978.

17. Reference 7, Op. Cit.

APPENDIX D

D.1 Emission Measurement Methods

D.1.1 General Background

For stack sampling purposes, benzene will, except in the case of systems handling pure benzene, exist in the presence of other organics. Accordingly, methods for benzene analysis consist of first separating the benzene from other organics, followed by measuring the quantity of benzene with a flame ionization detector. However, among various stack testing groups concerned with measuring benzene, non-uniformity in procedures could exist in the following areas: (1) sample collection, (2) introduction of sample to gas chromatograph, (3) chromatographic column and associated operating parameters, and (4) chromatograph calibration.

Two of the possible approaches for benzene sample collection are grab samples and integrated samples. Since emission contration may vary considerably during a relatively short period of time, the integrated sample approach offers a greater advantage over the grab sample approach because emission fluctuations due to process variations are automatically averaged. In addition, the integrated approach minimizes the number of samples that need to be analyzed. For integrated samples, both tubes containing activated charcoal and Tedlar bags have been used. However, charcoal sampling tubes were basically designed for sampling ambient concentration levels of organics. Since source effluent concentrations are expected to be higher (particularly since organics other than benzene could be present) there would be uncertainty involved with predicting sample breakthrough, or when sampling should be terminated. Bag samples would also offer the potential for the best precision, since no intermediate sample recovery step would be involved.

Based on the above considerations, collection of an integrated sample in Tedlar bags appears to be the best alternative. This conclusion is in agreement with an EPA funded report whose purpose was to propose a general measurement technique for gaseous organic emissions.[1] Another study of benzene stability, or deterioration in Tedlar bags was undertaken to confirm the soundness of this approach[2]. This study showed no significant deterioration of benzene over a period of 4 days. Consequently the integrated bag technique was deemed suitable; however, anyone preferring to use activated charcoal tubes has this option, provided that efficiency at least equal to the bag technique can be demonstrated, and procedures to protect the integrity of the sampling technique are followed.

A collected gas sample can be introduced to a gas chromatograph either through use of a gas-tight syringe or an automated sample loop. The latter approach was selected for the reference method since it has a lower potential for leakage and provides a more reproducible sample volume.

Several columns are mentioned in the literature which can be suitable for the separation of benzene from other gases;[3,4] most notable among them have been 1, 2, 3 - tris (2-cyanoethoxy) propane for the separation of aromatics from aliphatics; and Bentone 34 for separation of aromatics. A program was undertaken to establish whether various organics that were known to be associated with benzene in stack emissions interfered with the benzene peaks from the two columns. The study revealed the former column to be suitable for analysis of benzene in gasoline vapors, and the latter column to be suitable for analysis of benzene emissions from maleic anhydride plants.[5,6] It should be noted that selection of these two columns for inclusion in Method 111 does not mean that some other column(s) may not work equally well. In fact, the method has a conditional provision for use of other columns.

Calibration has been accomplished by two techniques, the most common being the use of cylinder standards. The second technique involves injecting known quantities of 99 Mol percent pure benzene into Tedlar bags as they are being filled with known volumes of nitrogen. The second technique has been found to produce equally acceptable results; both are included in Method 111.

D.1.2 Field Testing Experience

Based on the study of benzene stability in Tedlar bags, possible interferences by various process associated gases, and calibration methods, and as a result of a field study and tests conducted at sources of benzene emissions, a new draft of Method 111 was prepared for determining compliance with benzene standards or NESHAPS. This method is the same as the originally investigated method, except that the audit procedure has been refined, and an appendix has been added to aid in the verification of benzene peak resolution.

Four terminals have been tested during the development test program. Two of these terminals were originally tested to determine overall hydrocarbon emissions (including leaks at the trucks) without specific determination of benzene emissions. These two terminals were subsequently tested to specifically determine the control device's efficiency in controlling benzene. The other two terminals were tested to simultaneously determine total hydrocarbon emissions (including leaks at the truck) and benzene emissions. Each of the four terminals employed a different type of control device.

Of two terminals tested for benzene which had been previously tested for overall hydrocarbon emissions, one employed a compression-refrigeration, absorption system (CRA) and the other a refrigeration system. One of the terminals which was tested simultaneously for overall hydrocarbons and benzene employed a carbon adsorption system and the other employed a thermal oxidizer.

Emission test procedures used to collect the development test program data exceeded the procedures required for compliance testing of the proposed concentration standard. Data was collected to determine emissions in terms of pollutant concentration, (2) mass rate, (3) mass per mass of product dispensed, and (4) mass control efficiency. Additional data was collected to assess the impact of leaking trucks and unsaturated air-vapor mixtures in the trucks returning from uncontrolled service stations. These latter data were necessary because existing terminals typically have some trucks servicing stations without stage one control systems. However, it is anticipated that in the future all service stations will employ stage one controls.

The sampling procedure differed slightly from the proposed procedure. Instead of indirectly pulling the sample into a 100 liter Tedlar bag by means of a vacuum inside a rigid container housing the Tedlar bag, a sample stream was removed from the sample site by means of a stainless steel bellows sampling pump. A portion (5-10 percent) of this sample stream was collected in a smaller bag (10 liter) through a limiting orifice. The use of the smaller bags was verified in the laboratory by first filling a large bag with a known concentration of gasoline vapor and analyzing it and then filling the small bags from the large bag and analyzing the smaller bags.

The use of the sampling system was similarly verified by introducing a known concentration of vapor into the sampling system, analyzing the sample collected, and comparing with the known concentration.

Analyses of all the samples were performed using the following technique:

The Tedlar bag samples were analyzed for individual hydrocarbons and benzene using a Shimadzu - GC - Mini 1 gas chromatograph equipped with dual flame ionization detectors. A Chromatopac E1A Shimadzu Data Processor was used to measure peak areas. The column used was a Supelco 20 percent SP 2100/0.1 percent Carbowax 1500 on 100/120 mesh Supelcoport (D-4536) packed in 10 feet of 1/8 inch stainless steel tubing. This column was evaluated and shown to provide adequate results for this program[7,8]. The chromatograph was programmed from 40°C to 160°C initially at a rate of 4°C/minute for ten minutes; then the program rate was increased to 20°C/minute. Upon reaching 160°C, it was held isothermally until no more peaks eluted. The total analysis time was twenty minutes. The calibration gases were 1.02 percent propane in nitrogen and 152 ppm benzene in air.

Samples for injection into the chromatograph were extracted from the Tedlar bags through a rubber septum into a 100 cc gas sampling syringe. The inlet samples were diluted 50 percent with room air before injection into the chromatograph. The outlet samples were analyzed without dilution. Approximately 42 hydrocarbon species were identified and measured by chromatograhic separation.

Because two of the terminals had been previously tested for total hydrocarbons, the benzene test was conducted over a period of a single day at each of these two terminals. Daily variations in emissions had been adequately characterized in the earlier hydrocarbon testing. For the two terminals where total hydrocarbon and benzene emissions were simultaneously determined, the data were collected over a period of three days.

Testing of the thermal oxidizer also included analysis of the exhaust gas for carbon dioxide and carbon monoxide. Because of the inherent dilution effect of this type of control device, it was necessary to adjust the concentration for the dilution effect of the excess air and products of combustion.

Three additional terminals are to be tested to determine total hydrocarbon and benzene emissions. Two of these terminals employ a lean oil absorption control system and the third terminal uses a CRA unit. The results of these tests will be included at a later time.

Testing at three bulk plants is scheduled. During these tests, the recommended test procedure will be used. Also, a test program to collect leak test data on gasoline cargo compartments using the recommended test procedure is scheduled.

The results of these studies will be included at a later time.

D.2 Performance Test Methods

The generally recommended performance test method for benzene is Method 111. The method uses the Method 106 train for sampling, and a gas chromatograph/flame ionization detector equipped with a column selected for separation of benzene from the other organics present, for analysis.

If dilution air is present, Method 3 must also be used.

The recommended field test procedures for determining benzene emission concentrations at gasoline terminals incorporate Method 111 for benzene analysis. In addition, potential leak sources are surveyed with a combustible gas indicator to detect any incidence of direct leaks to the atmosphere.

The recommended field test procedure for bulk gasoline plants is Method 110. This procedure incorporates measurement of the volume of vapors vented during gasoline transfers. The vented volume is compared to the volume of liquid transferred to determine a recovery efficiency. In addition, all potential sources of direct leakage are monitored with a combustible gas detector. The recommended field test procedure for gasoline cargo compartments is Method 112. This is a pressure and vacuum tightness test. The criteria used to determine vapor tightness is the pressure change over a five-minute interval after the compartment has been initially pressurized or evacuated to a specified level.

Subpart A of 40 CFR 61 requires that facilities subject to Standards of Performance for New Stationary Sources be constructed so as to provide sampling ports adequate for the applicable test methods, and platforms, access, and utilities necessary to perform testing at those ports.

Assuming that the test location is near the analytical laboratory, and that sample collection and analytical equipment is on hand, the cost of field collection, laboratory analysis, and reporting of benzene emissions from a single stack is estimated to be $2500 to $3500 for a compliance test effort. This figure assumes a cost of $25/man-hour. While this amount would be reduced approximately 50 percent per stack if several stacks are tested, it does presume that all benzene samples would be collected and analyzed in triplicate.

If the plant has established in-house sampling capabilities and were to conduct their own tests and/or do their own analyses, the cost per man-hour could be less.

D.3 Continuous Monitoring

No emission monitoring instrumentation, data acquisition, and data processing equipment for measuring benzene from bulk terminal emission gases that are readily available (on an "as complete systems" basis) have been determined to date. However, EPA has only recently begun to explore the development of specifications for benzene monitoring, and it is felt that such specifications, which would employ a package of individually commercially available items, are feasible.

For a chromatographic system that reports benzene concentration, the installed cost of the chromatograph and its auxiliaries is $30,000.[a] This figure would increase by approximately $10,000 for the additional hardware necessary to report a benzene mass emissions rate in terms of benzene feedstock. Depending on the operating factor, the direct operating cost varies from about $1,200 to $1,400/year.

References

1. Feairheller, W. R.; Kemmer, A. M.; Warner, B. J.; and Douglas, D. Q. "Measurement of Gaseous Organic Compound Emissions by Gas Chromatography," EPA Contract No. 68-02-1404, Task 33 and 68-02-2818, Work Assignment 3. Jan., 1978.

2. Knoll, Joseph E.; Penny, Wade H.; Midgett, Rodney M.; Environmental Monitoring Series Publication in preparation.

[a] Includes: gas chromatograph with dual flame detector, automatic gas sampling valve, air sampler, post run calculator, and gas regulators.

Stability of Benzene Containing Gases in Tedlar Bags. QAB/EMSL U. S. Environmental Protection Agency.

3. Bulletins 743A, 740C, and D. "Separation of Hydrocarbons" 1974. Supelco, Inc. Bellefonte, Pennsylvania 16823.

4. Volume 10, No. 1 "Current Peaks," 1977. Carle Instruments, Inc., Fullerton, California 92631.

5. Communication from Joseph E. Knoll. Chromatographic Columns for Benzene Analysis. October 18, 1977.

6. Communication from Joseph E. Knoll. Gas Chromatographic Columns for Separating Benzene from Other Organics in Cumene and Maleic Anhydride Process Effluents. November 10, 1977.

7. Communication from Joseph E. Knoll. Gas Chromatographic Columns for Benzene Analysis - 20 percent SP 2100/0.1 percent Carbowax 1500 on 100/200 Mesh Supelcoport in 15" by 18" Stainless Steel. November 25, 1977.

8. Communication from Joseph E. Knoll. Analysis Methods for Determining Benzene in Liquid Gasoline. January 11, 1978.

APPENDIX E

STATE AND LOCAL HYDROCARBON REGULATIONS FOR GASOLINE MARKETING

STATE AND LOCAL REGULATION OF HYDROCARBONS

State	Terminal Loading Process	Bulk Plant Storage	Bulk Plant Loading Rack	Service Stations Underground Storage Tank Loading
Alabama	Submerged Fill	Submerged Fill	None	Submerged Fill
Alaska	None	None	None	None
Arkansas	None	None	None	None
Arizona	Submerged Fill	Submerged Fill	Submerged Fill	Submerged Fill
California *				
e.g. Bay Area	Vapor Recovery 90%	Balance & Submerged Fill	Balance & Submerged Fill	90% Collection
San Diego	Vapor Recovery	Submerged Fill/ Balance	Submerged Fill/Balance	90% Collection
South Coast	Vapor Recovery	Submerged Fill/ Balance	Submerged Fill/Balance	90% Collection
Colorado	Vapor Collection & Disposal = 90%	Submerged Fill & Collection = 1.15 lb/ 1000 gal	Vapor Collection & Disposal = 90%	Submerged Fill & Collection Equivalent to 1.15 lb/1000 gal
Connecticut	Vapor Collection & Disposal	Submerged Fill	<10,000 gal/day exempted	Submerged Fill
Washington, D.C.	Vapor Collection & Disposal = 90%	Submerged Fill & 90% Collection	Submerged Fill & 90% Collection	Submerged Fill & 90% Collection
Delaware	None	None	None	None
Florida	None	None	None	None

* Regulated by Regional Agencies

STATE AND LOCAL REGULATION OF HYDROCARBONS

State	Terminal Loading Process	Bulk Plant		Service Stations Underground Storage Tank Loading
		Storage	Loading Rack	
Georgia	None	None	None	None
Hawaii	None	Submerged Fill	None	Submerged Fill
Idaho	None	None	None	None
Illinois	Submerged Fill	Submerged Fill	None	Submerged Fill
Indiana	Submerged Fill	Submerged Fill	None	Submerged Fill
Iowa	None	None	None	None
Kansas	None	None	None	None
Kentucky	90% Control	Submerged Fill	None	Submerged Fill
Louisiana	Submerged Fill	Submerged Fill	None	Submerged Fill
Maine	None	None	None	None
Maryland	None	None	None	None
Massachusetts	None	None	None	None
Michigan	None	None	None	None
Minnesota	None	Submerged Fill	None	Submerged Fill
Mississippi	None	None	None	None
Missouri	None	None	None	None
Montana	None	None	None	None

STATE AND LOCAL REGULATION OF HYDROCARBONS

State	Terminal Loading Process	Bulk Plant Storage	Bulk Plant Loading Rack	Service Stations Underground Storage Tank Loading
Nebraska	None	None	None	None
Nevada	Submerged Fill	Submerged Fill	Submerged Fill	Submerged Fill
New Hampshire	None	None	None	None
New Jersey	Submerged Fill (Region Requires 90% control)	Submerged Fill	Submerged Fill	90% Collection
New Mexico	None	None	None	None
New York	None	None	None	None
North Carolina	Submerged Fill	None	None	None
North Dakota	Submerged Fill	Submerged Fill	None	Submerged Fill
Ohio	Vapor Collection & Recov.	Submerged Fill	None	Submerged Fill
Oklahoma	Bottom Loading	Submerged Fill	Submerged Fill	Submerged Fill
Oregon	None	None	None	None
Pennsylvania	Vapor Collection	Submerged Fill	None	Submerged Fill
Rhode Island	Submerged Fill	Submerged Fill	None	Submerged Fill
South Carolina	None	None	None	None
South Dakota	None	None	None	None
Tennessee	None	None	None	None

STATE AND LOCAL REGULATION OF HYDROCARBONS

State	Terminal Loading Process	Bulk Plant Storage	Bulk Plant Loading Rack	Service Stations Underground Storage Tank Loading
Texas	Vapor Recovery	Submerged Fill	None	Submerged Fill
Utah	None	None	None	None
Virginia	Vapor Control	None	None	None
Vermont	None	None	None	None
Washington	None	None	None	None
West Virginia	None	None	None	None
Wisconsin	None	None	None	None
Wyoming	None	Submerged Fill	None	Submerged Fill

APPENDIX F

DESCRIPTION OF OSHA BENZENE REGULATION

On Friday, February 19, 1978, the Occupational Safety and Health Administration promulgated a permanent standard for benzene exposure at workplaces. The standard, which was scheduled to become effective on March 13, 1978, provided for the measurement of employee exposure, engineering controls, work practices, personal protective clothing and equipment, signs and labels, employee training, medical surveillance, and recordkeeping.

In accordance with OSHA's regulatory approach to the control of employee exposure to carcinogens, the standard was set at the lowest feasible level, 1 ppm as an 8 hour time-weighted average and with a ceiling level of 5 ppm for any 15 minute period during an 8 hour day. Eye and skin contact with benzene are prohibited. The standard applies to occupational exposure to benzene in all workplaces in all industries where benzene is produced, reacted, released, packaged, transported, handled, or otherwise occupationally used, except for the agriculture industry. The standard does not apply to the sale, discharge, storage, transportation distribution, or use as a fuel of gasoline and other fuels, subsequent to discharge from bulk terminals. This means that bulk plant operators and service station attendants are not covered by the standard.

Each employer must determine airborne exposure levels from air samples that are representative of each employee's exposure to benzene over an 8 hour period. Initial monitoring must be conducted within 30 days of the effective date of the regulation and frequency of additional monitoring depends upon whether exposure is above or below the "action level" of 0.5 ppm, averaged over an 8 hour work day. If exposure levels are found to be below the action level, no further monitoring is required unless some change occurs which would lead the employer to believe that benzene levels may be increased. If exposure levels are above the action level, the employer must repeat monitoring at least quarterly. Employees must be notified of the exposure measurements and if exposure levels exceed permissible limits the employer must include in his report the corrective action being taken to reduce exposure levels.

The employer is required to use engineering and work practice controls to reduce exposure levels. If feasible engineering and work practice controls are not adequate to reduce exposure to permissible levels, then these controls must be used to reduce exposure to the lowest possible level. The employer is then required to supply respirators to reduce worker exposure to a permissible level. Where eye or dermal contact may occur, the employer is required to supply and assure that the employee wears impermeable clothing and equipment to protect the part of the body which may come in contact with benzene.

The employer must post signs in areas where the use of a respirator is necessary and affix caution labels to all containers of benzene. Labels and signs must contain the warning that benzene exposure presents a potential cancer hazard. The employer is also required to institute a training program to instruct employees on the contents of the standard, to medical surveillance program, the nature of operations which could result in exposures above permissible levels, and the proper use of personal protective equipment and clothing.

The medical surveillance program required by the standard includes the following elements for each employee: a medical history which includes past work exposure to benzene and other factors which could influence the effects of benzene on the worker; and laboratory tests, including a complete blood cell count with red cell count, white cell count with differential, platelet count, hematocrit, hemoglobin and red cell indices, serum bilirubin and reticulocyte count, and additional tests where, in the opinion of the examining physician, alterations in the components of the blood are related to benzene exposure. The employer is required to maintain a record of each employee's exposure to benzene and medical records for 40 years or the duration of employment plus 20 years, whichever is longer.

This standard has not yet gone into effect, however. Shortly after the standard was promulgated, OSHA was sued by DuPont Company and the American Petroleum Institute. In response to these petitions, the U.S. Court of Appeals for the Third and Fifth Circuits issued temporary stays on March 12, 1978.

Since the OSHA standard has been stayed, there are no regulations which require industry to use engineering controls to reduce benzene levels. Even if the standard had become effective on March 13, 1978, there is no guarantee that engineering controls will be installed in the near future since the standard does not specify a date by which controls must be implemented. Before engineering controls are installed, respirators must be used. Respirators offer protection only to the workers who wear them and other persons in the vicinity of the plant are not affected. Also, if the employer chooses to ventilate the work area, no beneficial environmental impact will result. For these reasons, EPA must develop and implement standards to protect the general public.