EPA-450/2-77-026
October 1977
(OAQPS NO. 1.2-082)

GUIDELINE SERIES

CONTROL OF HYDROCARBONS FROM TANK TRUCK GASOLINE LOADING TERMINALS

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

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Emission Standards and Engineering Division
Chemical and Petroleum Branch

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OAQPS GUIDELINE SERIES

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ABBREVIATIONS AND CONVERSION FACTORS

EPA policy is to express all measurements in agency documents in metric units. Listed below are abbreviations and conversion factors for British equivalents of metric units for the use of engineers and scientists accustomed to using the British system.

Abbreviations

Mg - Megagrams

kg - kilograms

g - gram

mg - milligram

l - liters

cm - centimeters

Conversion Factors

liters X .264 = gallons

gallon X 3.785 = liters

mg/l X .008 = lb/1000 gallons

Joules X 3.6 X 10^6 = kwh

Joules X 9.48 X 10^{-4} = Btu

gram X 1 X 10^6 = 1 Megagram = 1 metric ton

pound = 454 grams

^oC = .5555 (^oF - 32)

1.0 INTRODUCTION

This document is related to the control of volatile organic compounds (VOC) from tank truck terminals with daily throughputs of greater than 76,000 liters of gasoline. The control techniques discussed are more complex and more costly than those which are applicable to smaller bulk plants. Control techniques applicable to bulk plants are being covered in a separate document. The VOC emitted during gasoline loading of tank trucks are primarily C_4 and C_5 paraffins and olefins which are photochemically reactive (precursors of oxidants).

1.1 NEED TO REGULATE TANK TRUCK TERMINALS

Many State or local regulations governing tank truck terminals require vapor control to reduce VOC emissions from tank trucks during gasoline loading operations. Estimated annual nationwide emissions from loading gasoline tank trucks at bulk terminals are 300,000 metric tons per year. This represents 1.8 percent of the 1975 estimate of total VOC from stationary sources.

Control techniques guidelines are being prepared for those industries that emit significant quantities of air pollutants in areas of the country where National Ambient Air Quality Standards (NAAQS) are not being attained. Gasoline tank truck terminals are a significant source of VOC and tend to be concentrated in areas where the oxidant NAAQS are likely to be exceeded.

1.2 SOURCES AND CONTROL OF VOLATILE ORGANIC COMPOUNDS FROM TANK TRUCK TERMINALS

Volatile organic compounds (VOC) are displaced to the atmosphere when tank trucks are filled with gasoline. There are an estimated 300 vapor control systems currently in operation at approximately 2000 tank truck terminals in the U.S. Many of those control systems were retrofitted to existing facilities.

It has been assumed in this document that as a minimum control measure (base case) all tank truck gasoline loading terminals are equipped for either top-submerged or bottom-fill (emission factor 600 mg/l). Top splash facilities are assumed to be equipped with a vapor control system.

If vapor control systems are used at tank truck delivery points (service stations, bulk plants, or commercial accounts), hydrocarbon vapor levels in tank trucks servicing these sources will approach saturation (emission factor 1400 mg/l). In these situations, vapor control systems will be more cost effective than in areas where tank truck delivery point vapor control systems have not been installed. Capital costs for a 950,000 liter per day tank truck terminal are estimated to range from $176,000 to $194,000 for a vapor recovery unit and $140,000 for an incineration unit. Average annualized costs are estimated at $20,600 for vapor recovery and $29,800 for vapor incineration. Recovered value is approximately $0.10 per liter.

1.3 REGULATORY APPROACH

The recommended tank truck gasoline loading terminal emission limit that represents the presumptive norm that can be achieved through the application of reasonably available control technology (RACT) is 80 milligrams of hydrocarbon per liter of gasoline loaded. Reasonably available control technology is defined as the lowest emission limit that a particular source is capable of meeting by the application of control technology that is reasonably available considering technological and economic feasibility. It may require technology that has been applied to similar, but not necessarily identical source categories. It is not intended that extensive research and development be conducted before a given control technology can be applied to the source. This does not, however, preclude requiring a short-term evaluation program to permit the application of a given technology to a particular source. This latter effort is an appropriate technology-forcing aspect of RACT. Monitoring terminal operational procedures and control system operating parameters by visual observation and by the use of portable hydrocarbon detectors will ensure that liquid and vapor leaks are minimized.

2.0 SOURCES AND TYPE OF EMISSIONS

The purpose of this chapter is to identify and describe tank truck gasoline loading processes currently in use and those processes likely to be installed in the future. When possible, emissions from each significant point source are quantified.

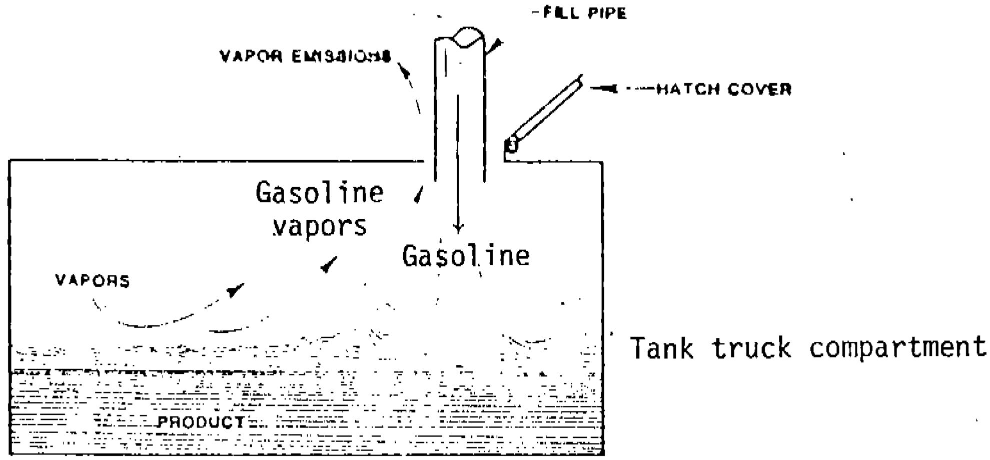
Hydrocarbon emissions from gasoline tank truck terminals may occur at storage tanks, tank trucks, points along the tank truck vapor gathering system, and from the hydrocarbon vapor control unit. Tank truck loading of gasoline may be by bottom fill, by top splash or by submerged fill pipe through hatches on the tops of the trucks. (See Figure 2-1)

Hydrocarbon vapors displaced from tank truck compartments are vented either directly to the atmosphere or to a gathering system and then to vapor control equipment. Air and residual hydrocarbons are vented directly to the atmosphere from the vapor control equipment.

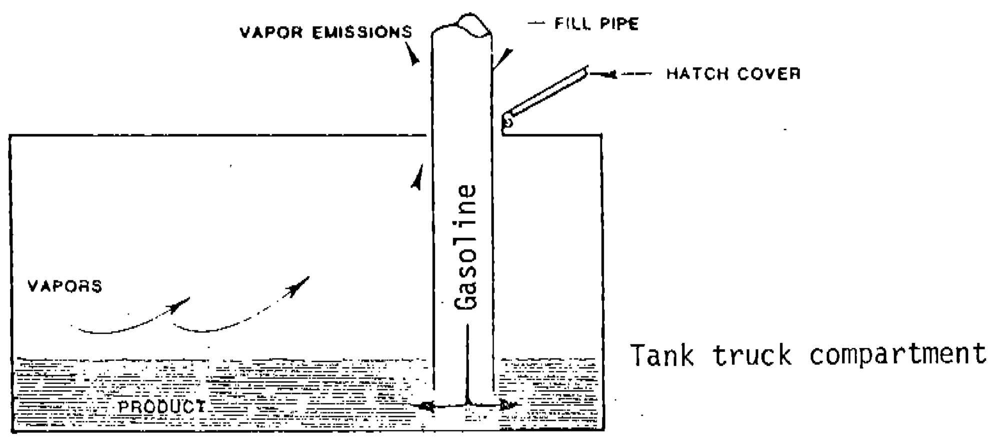
2.1 HYDROCARBON EMISSION POINTS AT TANK TRUCK GASOLINE LOADING FACILITIES.

Potential points of hydrocarbon emissions are leaking flow valves, relief valves, flanges, meters, pumps, etc.

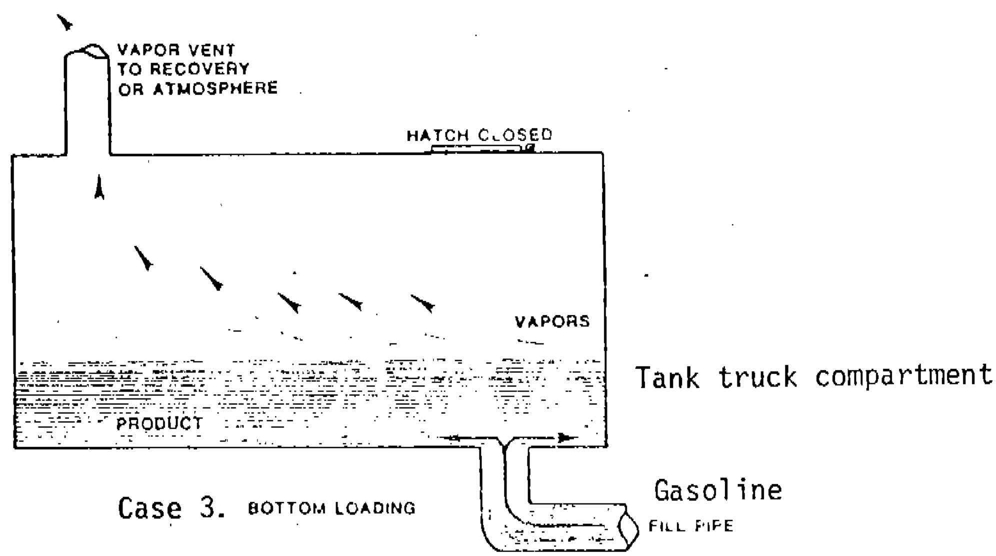
The overall effectiveness of vapor control systems is dependent on the concentration of hydrocarbon vapors in the tank trucks, the degree of VOC capture at the truck and the efficiency of the control equipment. Several factors may influence capture and recovery efficiency of VOC at terminals. They are discussed below.



Case 1. SPLASH LOADING METHOD



Case 2. SUBMERGED FILL PIPE



Case 3. BOTTOM LOADING

Figure 2-1. Gasoline Tank Truck Loading Methods

2.1.1 Leaks at Tank Trucks

Urethane or other gasoline-resistant, rubber-like materials are used for sealing hatches and pipe connections on tank trucks. Cracks in seals and improper connections can cause leaks even when vapor recovery equipment is in operation. Recent source tests conducted by EPA at terminals have shown appreciable leakage. In five cases, from 30 to 70 percent of the vapor escaped capture at the truck. These losses are attributed to leaks in seals and pressure-vacuum valves, as well as other factors cited below:

Tank Truck Overfills - Tank trucks are bottom loaded by dispensing a metered amount of gasoline into each compartment. In some instances, apparently due to improper setting of the meter, residual gasoline in the tank truck compartment, and apparent overflow shut-off valve failure, overfills have occurred. If vapor recovery systems are in use, overfilling can result in the partial filling of vapor lines and the blockage of flow to the vapor recovery system. Hydrocarbon vapors in these instances may vent through tank truck pressure relief valves or through poorly mating connections or other leaks in the vapor lines.

2.1.2 Back Pressure in Vapor Recovery Facilities

High fill rates combined with an undersized vapor collection/recovery system can cause back pressure and losses through poorly maintained seals and pressure-vacuum relief valves on the trucks.

2.1.3 Vapor Holder Tanks

Compression-refrigeration-absorption (CRA) units and some incinceration devices as well as other types of control systems use vapor holders to compensate for surges in vapors from tank trucks and to increase the hydrocarbon concentration in the gases above the upper explosive limit. The vapor holder tanks are typically equipped with flexible membranes which add a potential source of leakage.

2.1.4 Knock-out Tanks

Many vapor recovery systems utilize knock-out tanks to recover condensed liquids in the vapor line or to capture liquids from the loading operations due to overfills or spills. These tanks normally include a pressure-vacuum vent that is susceptible to leakage.

2.2 UNCONTROLLED EMISSIONS

The emission factor for hydrocarbon emissions generated during submerged fill (top or bottom) gasoline loading operations is 600 mg/liter* transferred.[1] This figure represents 40-50 percent hydrocarbon saturation of the air in the tank trucks. In areas where service stations are controlled, hydrocarbon saturation approaches 100 percent (emission factor 1400 mg/l).

Application of the 600 mg/l emission factor to a 950,000 liter/day terminal results in an estimated emission of 600 kg/day.

The emissions discussed above do not include fugitive emissions (both gaseous leaks and liquid spillage) that could occur during loading operations.

2.3 GASOLINE VAPOR COMPOSITIONS

A composite analysis of 15 sample motor gasolines is shown in Table 2-1.

The principal compounds found in essentially all gasoline vapors are C_4 and C_5 paraffins and olefins. (See Table 2-2). The average molecular weight of vapors vented from the tank trucks during gasoline loading operations are in the range of 68.

*milligrams of HC emitted per liter of gasoline loaded.

Vapors vented from the vapor control equipment are typically of lower molecular weight since the heavier hydrocarbon molecules are recovered more readily.

Table 2-1. COMPOSITE ANALYSIS OF 15 SAMPLE MOTOR GASOLINES[2]

Component	% wt.
Saturates:	
Methane	...
Ethane	...
Isobutane	1
n-butane	7
Isopentane	10
n-pentane	4
2,3-dimethylbutane	2
2-methylpentane	3
3-methylpentane	2
n-hexane	2
Methylcyclopentane	1
2,4-dimethylpentane	2
Cyclohexane	1
2-methylhexane	5
2,2,4-trimethylpentane	6
n-heptane	1
Methylcyclohexane	1
2,4-dimethylhexane	1
2,3,4-trimethylpentane	2
2,3,3-trimethylpentane	1
2-methyl-3-ethylpentane	1
3,4-dimethylhexane	1
2,2,5-trimethylhexane	1
n-octane	1
Other saturates	6
Olefins and acetylenes:	
Ethylene	...
Propylene	...
Isobutylene/1-butene	...
2-butene	...
2-methyl-1-butene	1
2-pentene	1
2-methyl-2-butene	2
2-methyl-2-pentene	1
1,3-butadiene	...
2-methyl-1,3-butadiene	...
Acetylene	...
Methylacetylene	...
Other olefins	6
Aromatics:	
Benzene	1
Toluene	6
Ethylbenzene	1
m and p-xylene	5
o-xylene	2
n-propylbenzene	1

Table 2-1 (cont.)

1-methyl-4-ethylbenzene .	1
1,3,5-trimethylbenzene . .	1
1-methyl-2-ethylbenzene .	1
1,2,4-trimethylbenzene . .	3
1,2,3-trimethylbenzene . .	1
Other aromatics	4

Table 2-2. EXAMPLE: CHEMICAL COMPOSITION OF GASOLINE VAPORS[3]

	Vol %	Wt. %
Air	58.1	37.6
Propane	0.6	0.6
Iso-Butane	2.9	3.8
Butene	3.2	4.0
N-Butane	17.4	22.5
Iso-Pentane	7.7	12.4
Pentene	5.1	8.0
N-Pentane	2.0	3.1
Hexane	3.0	8.0
	100.0	100.0

2.4 REFERENCES

1. Supplement No. 7 for Compilation of Air Pollutant Emission Factors, Second Edition, EPA, April 1977.

2. A Study of Vapor Control Methods for Gasoline Marketing Operations: Vol. II - Appendix, EPA-450/3-75-046b, page 51.

3. Kinsey R. H., Air Pollution Engineering Manual, 2nd Ed, AP-40, EPA, May 1973, page 655.

3.0 APPLICABLE SYSTEMS OF EMISSION REDUCTION

The purpose of this chapter is to review control equipment and achievable emission levels applicable to tank truck gasoline loading terminals.

3.1 METHODS OF HYDROCARBON EMISSION REDUCTION

It is estimated that 300 vapor control systems have been installed at tank truck terminals and are in commercial operation. Stage I service station controls have provided impetus for such installations in air quality control regions with oxidant problems.

EPA test data indicate that with minimal gas leakage from trucks during loading, emissions to the atmosphere should not exceed 80 mg per liter of gasoline loaded when equipped with vapor collection and recovery or oxidation control systems. These data are summarized in the last column of Table 3-1.

3-2 VAPOR CONTROL SYSTEMS SOURCE TESTED BY EPA

Simplified schematics of the types of vapor control systems source tested by EPA are shown in Figures 3-1 and 3-2. A summary of major operating parameters for the systems are shown in Table 3-1.

Table 3-1. Example: Vapor Control System Operating Parameters

Unit	Pressure cm. Hg.	Temperature °C	Absorbent Mole Ratio Liquid/Gas	Mass Efficiency
1. Refrigeration Compression (RF)	Ambient	-73	0	80-93
2. Refrigeration Absorption (CRA)	260 to 1090	-23 to -46	2 to 9	71-92
3. Thermal (TO) Oxidizer	Ambient -	760 Firebox Temp.	0	99+

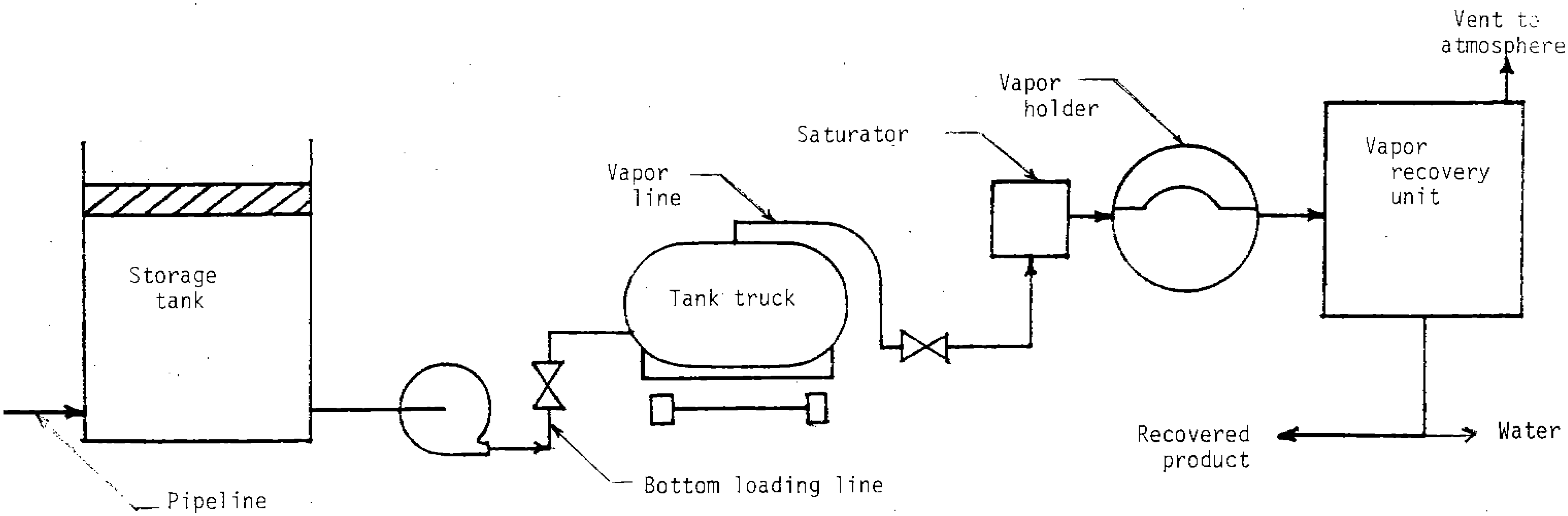


Figure 3-1. Tank Truck Terminal Gasoline Vapor Recovery

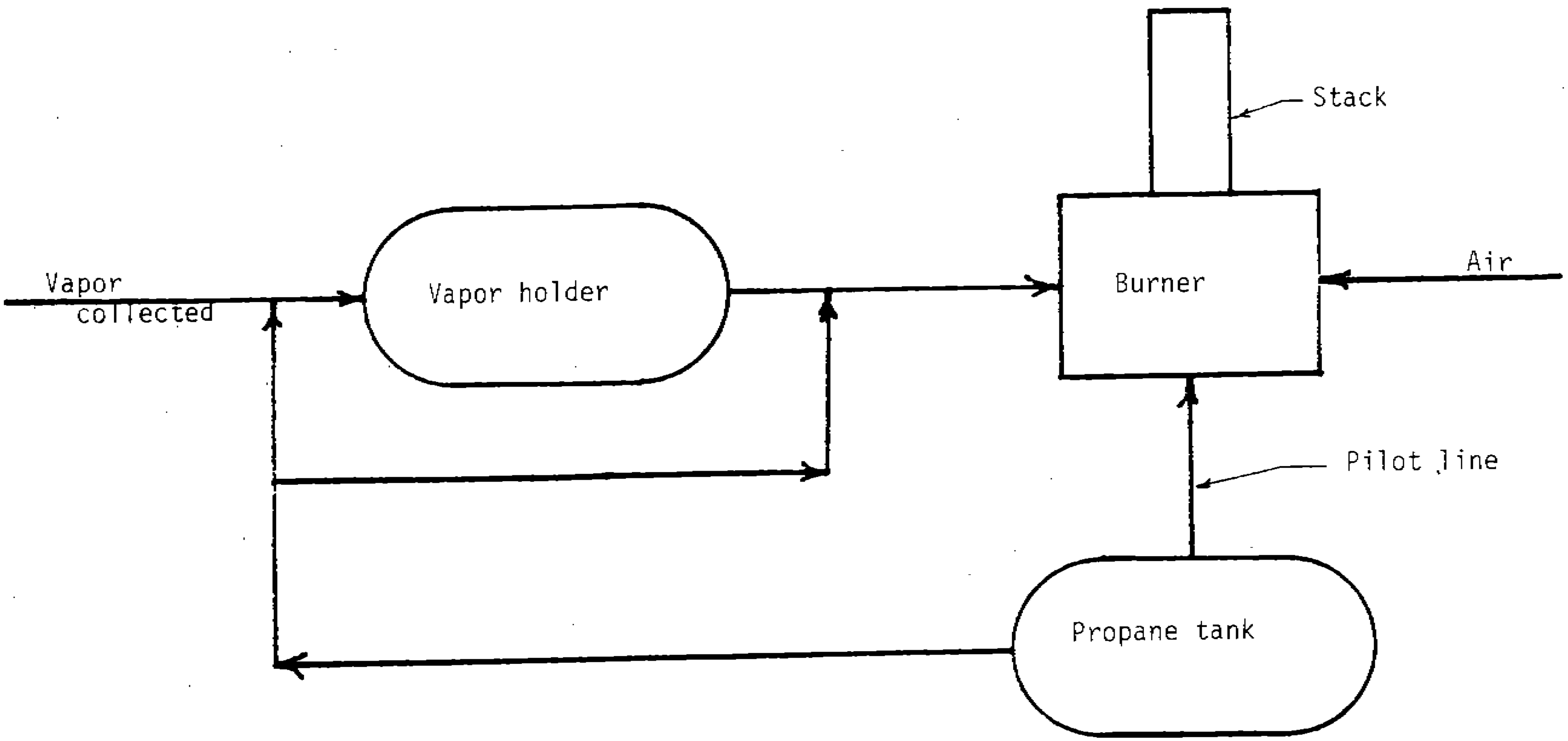


Figure 3-2. Thermal Oxidation System

3.2.1 Compression-Refrigeration-Absorption Systems

The compression-refrigeration-absorption vapor recovery system (CRA) is based on the absorption of gasoline vapors under pressure with chilled gasoline from storage. EPA tests on two CRA units at tank truck loading facilities indicated average outlet concentrations of 25,000 and 75,000 ppm and a maximum emission level of 43 milligrams per liter. See terminals A and D in Table 3-2 for detailed data.

3.2.2 Refrigeration Systems

One of the more recently developed vapor recovery systems is the straight refrigeration system (RF) based on the condensation of gasoline vapors by refrigeration at atmospheric pressure. It is estimated that 70 units of this type are in commercial operation. Vapors displaced from the terminal enter a horizontal fin-tube condenser where they are cooled to a temperature of about $-73^{o}C$ and condensed. Because vapors are treated as they are vented from the tank trucks, no vapor holder is required. Condensate is withdrawn from the condenser and the remaining air containing only a small amount of hydrocarbons is vented to the atmosphere. EPA conducted source tests on 3 units, outlet concentrations of hydrocarbons averaged 34,000 ppm (measured as propane). See terminals B, C and F in Table 3-2 for detailed data.

3.2.3. Oxidation Systems

The highest efficiency in hydrocarbon control (about 99 percent) can be obtained with incineration devices. Gasoline vapors from the terminal tested by EPA were displaced to a vapor holder as they were

Table 3-2 SUMMARY OF EPA TESTS AT TANK TRUCK TERMINALS[1-6]

Test Number	Date of test	Average throughput liters/day	No. of loading racks	No. of trucks loaded during testing period	Type of control system[a]	Type of fill	Hydrocarbon Concentration Vol. % as propane[b] inlet (tank truck)	Hydrocarbon Concentration Vol. % as propane[b] outlet (processing unit)	Processing unit avg. control effic.[g]	Processing unit avg. emission mg/l[e]	Avg. system loss due to leakage mg/l[e]	Avg. total system loss to atmosphere mg/l[e]	Calculated average system loss with no leakage (100 percent collection) mg/l[f]
A	12/10-12/74	605,600	3 (2 in use)	39	CRA	Bottom	2.5-23.2	4.3-4.8	70.9	31.2	115.2	146.4	64.7
B	12/16-19/74	378,500	1	24	RF	Bottom	10.8-30.5	1.4-4.83	84.4	37.0	100.9	137.9	52.8
C	9/20-22/76	1,430,700	1	45	RF	Bottom	8.93-74.96	3-5.41	93.1	33.6	86.7	120.2	40.9
D	9/23-25/76	1,192,300	4	43	CRA	Bottom	2.48-75.58	3.11-3.97	92.1	43.3	154.6	197.9	54.7
E	11/18/73 - 5/2/74	1,101,400	3	*c	TO	2 Bottom 1 Top	2.4-31.5[b]	1-45 ppm	99.9	Est. 1.32	Est.avg 30%[d]	Est.avg 30%	Est. <26.4
F	11/10-12/76	813,775	3	39	RF	Bottom	2.78-43.35	2.81-4.27	80.4	62.6	46.0	100.6	71.6

[a]CRA - Compression-Refrigeration-Absorption
RF - Refrigeration
TO - Thermal Oxidizer

[b]All concentrations are reported as propane except terminal "E" test which is reported as methane.

[c]Many tank trucks loaded with gasoline over 4 month period.

[d]N/K - not known - reportedly about 70 percent of air hydrocarbon mixture displaced from trucks reached the thermal oxidizer.

[e]See Appendix B.

[f]This column was calculated using source test data indicating the potential mass recovery factor and the processor efficiency (see Appendix B)

[g]The inlet hydrocarbon concentration greatly affects the calculated efficiency of the processing unit. Low inlet hydrocarbon concentrations result in lower process unit efficiencies. In normal operation the process unit outlet hydrocarbon concentrations vary within narrow limits regardless of inlet hydrocarbon concentrations. If inlet hydrocarbon concentrations were near saturation, higher control efficiencies would be anticipated.

generated. When the vapor holder reached its capacity, the gasoline vapors were released to the oxidizer after mixing with a properly metered air stream and combusted. The thermal oxidizer is not a true afterburner, rather it operates in the manner of an enclosed flare.

Twelve to fifteen thermal oxidizer have reportedly been installed by terminal operators. Later models of this type of control equipment do not require vapor holders; vapors from the tank trucks during loading operations are vented directly to the thermal oxidizer. Hydrocarbon emissions to the atmosphere (assuming 100 percent collection of vapors) are less than 80 milligrams per liter. See Terminal E in Table 3-2 for detailed data.

3.3 LEAK PREVENTION FROM TANK TRUCKS

Essentially all hydrocarbon vapors from the tank truck must be vented to the control system for optimum operation. Therefore the integrity of the vapor control systems at gasoline tank truck gasoline loading terminals will depend heavily on maintaining essentially leakless tank trucks.

To ensure that such leakless tank trucks are used, proper operating procedures and periodic maintenance of hatches, P-V valves and liquid and gaseous connections will be required. Also, periodic qualitative testing can be done by the use of an explosimeter.

3.4 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.

4.0 COST ANALYSIS

4.1 INTRODUCTION

4.1.1 Purpose

The purpose of this chapter is to present estimated costs for control of hydrocarbon emissions resulting from the loading of gasoline into tank trucks at bulk terminals.

4.1.2 Scope

Control cost estimates are developed for top-submerged and bottom loading rack configurations. The control alternatives considered include vapor collection systems venting either to a vapor recovery unit (refrigeration or CRA) or a vapor incinerator. Detailed costs are presented for 950,000 liters/day and 1,900,000 liters/day model terminals. Cost effectiveness ratios (annualized cost per kilogram of hydrocarbon controlled) are developed from the model terminal analyses for terminals ranging from 76,000 liters/day to 2,000,000 liters/day gasoline loaded.

4.1.3 Use of Model Terminals

Cost estimates developed for this analysis rely upon the use of model terminals. Terminal loading rack configurations, operating factors and control system capacities will influence vapor control costs for actual facilities.[1] While actual costs for specific terminal sizes may vary, model terminal cost estimates are useful in comparing control alternatives. How these estimates compare to actual costs incurred by terminals is addressed in Section 4.2.4.

4.1.4 Bases for Capital and Annualized Cost Estimates

Capital cost estimates are intended to represent the total investment required to purchase and install a particular control system. Costs obtained from equipment vendors and from terminal installations are the bases for the model terminal estimates. Retrofit installations are assumed. New installation costs are expected to be only slightly lower. No attempt was made to include production losses during installation and start-up. All capital cost estimates presented reflect second quarter 1977 dollars.

Annualized control cost estimates include operating labor, maintenance, utilities, credits for gasoline recovery and capital related changes. Credits for gasoline recovery in vapor recovery units have been calculated based upon an emission factor of 600 mg/liter for top-submerged or bottom loading, an achievable emission level of 80 mg/liter with vapor control and a recovered gasoline value of $.10/liter (F.O.B. terminal before tax). Assumed cost factors for model terminal cost estimates are summarized in Table 4-1. All annualized cost estimates are for a one-year period commencing with the second quarter of 1977.

4.2 VAPOR CONTROL AT LOADING RACKS

4.2.1 Model Terminal Parameters

Technical parameters used for the model existing 950,000 liters/day and 1,900,000 liters/day terminals are based upon those obtained through EPA source testing and questionnaires. Estimates of maximum instantaneous vapor generation rates were used in sizing both vapor recovery and thermal oxidation systems. For a given terminal size these rates are based upon the number of loading arms and their respective pumping capacities. It has been assumed that

4-1. COST FACTORS USED IN DEVELOPING ANNUALIZED COST ESTIMATES FOR MODEL TERMINALS

Utilities:	
- Electricity	$\$.01/10^6$ joules
- Propane (oxidizer pilot only)	$\$3.30/10^9$ joules
Maintenance (percent of capital cost)[a]:	
- Refrigeration vapor recovery	3 percent
- CRA vapor recovery	3 percent
- Oxidizer	2 percent
Capital charges (percent of capital cost):	
- Refrigeration, CRA or oxidizer system	13 percent[b]
plus	
- Taxes, insurance and administrative overhead	4 percent
Gasoline value (recovered) FOB terminal[c] before tax:	$.10/liter

[a]Based upon reported costs for actual installations

[b]Calculated using capital recovery factor formula assuming 15 year equipment life and 10 percent interest rate.

[c]Oil Daily - May 1977.

pumps are rated at 1900 liters/minute. Although it appears to be common practice to oversize vapor control units to accomodate projected growth, no attempt has been made to include such a factor into model terminal costs.

Emission reductions and gasoline recoveries (where applicable) were calculated using the following emission factors:

Top-submerged or bottom loading . . . . . 600 mg/liter loaded

Vapor recovery or incineration . . . . . 80 mg/liter loaded

As mentioned in Section 2.2, the 600 mg/l emission factor cited above for loading assumes about 50 percent saturation of vapors in the tanker prior to loading. Should trucks be vapor balanced prior to terminal loading, Section 2.2 estimates uncontrolled vapor emissions at 1400 mg/liter loaded. Under these conditions, gasoline recovery credits and vapor emission reductions presented for model terminals would be increased proportionately. Conversely, recovery credits and emission reductions can be reduced if vapor capture is not maintained. Factors affecting capture have been discussed in Section 2.1.

4.2.2 Control Costs (Model Terminals)

Estimates of control costs for vapor recovery or incineration at two model terminal sizes are presented in Table 4-2. As evidenced by these estimates, for a given terminal size, thermal oxidation systems are generally less expensive to purchase, install, and operate than vapor recovery units (VRU). However, gasoline recoveries associated with VRU's help to recoup these expenses to the extent that net annualized costs, i.e., direct operating plus capital charges less recovered gasoline credits, are generally lower for VRU's than oxidizers. As depicted later in the discussion of cost-effectiveness for these systems, as gasoline recoveries diminish at lower gasoline throughputs the net annualized costs for VRU's and oxidizers approach parity.

Table 4-2. CONTROL COST ESTIMATES FOR MODEL EXISTING TERMINALS[2,3,4,5,6]

950,000 liters/day Terminal[a]
(Two rack positions and three products per rack)

Rack Design	Top-Submerged or Bottom Fill		
Control System	Refrigeration	CRA	Oxidizer
Installed Capital Cost ($000)	176	194	140
Direct Operating Cost ($000/yr):			
Utilities	6.0	3.9	3.2
Maintenance	5.3	5.8	2.8
Capital Charges ($000/yr)	30.0	33.0	23.8
Gasoline (credit) ($000/yr)	(21.4)	(21.4)	0
Net Annualized Cost (credit) ($000/yr)	19.9	21.3	29.8
Controlled Emissions (Mg/yr)[b]	150	150	150
Emission Reduction (%)	87	87	87
Cost (credit) per Mg of HC controlled ($/Mg)	133	142	199

1,900,000 liters/day Terminal[a]
(Three rack positions and three products per rack)

Rack Design	Top-Submerged or Bottom Fill		
Control System	Refrigeration	CRA	Oxidizer
Installed Capital Cost ($000)	264	310	202
Direct Operating Cost ($000/yr):			
Utilities	12.0	7.8	6.4
Maintenance	7.9	9.3	4.0
Capital Charges ($000/yr)	44.9	52.7	34.3
Gasoline (credit) ($000/yr)	(42.8)	(42.8)	0
Net Annualized Cost (credit) ($000/yr)	22.0	27.0	44.7
Controlled Emissions (Mg/yr)[b]	300	300	300
Emission Reduction (%)	87	87	87
Cost (credit) per Mg of HC controlled ($/Mg)	73	90	149

[a] Average gasoline loaded daily - truck modification costs not included.
[b] 1 Mg = 1000 Kg = 2205 pounds

Some terminals decide to convert top loading racks to bottom loading in conjunction with vapor recovery or incineration system installations. They will incur capital costs of about $80,000 per rack if extensive modifications are required.[4] These conversions enhance safety and operational characteristics of the loading racks but are not considered to be necessary for vapor control at terminals.

4.2.3 Cost-Effectiveness (Model Terminals)

Figure 4-1 graphically depicts the estimated cost-effectiveness of vapor recovery (average of refrigeration and CRA values) and incineration for top submerged or bottom loading of gasoline for the range of gasoline throughputs indicated. Although the same emission rate (post-control) has been assumed for vapor recovery and thermal oxidizer units, i.e., 80 mg/liter, EPA test data summarized in Table 3-2 indicates that much lower mass emission rates are achievable with incineration. Therefore, actual cost-effectiveness values for incineration may be lower than those presented in Table 4-2 and Figure 4-1. As depicted in Figure 4-1, vapor recovery units appear more cost effective than thermal oxidizers for most terminal sizes considered.

The apparent convergence of cost effectiveness curves for VRU's and oxidizers at gasoline throughputs of about 100,000 liters per day is noteworthy. It is emphasized that these curves reflect conservative estimates of cost-effectiveness. Using the 1400 mg/liter emission factor for tank trucks that have been vapor-balanced prior to loading (Section 2.2) would increase the spread between these two curves. For vapor recovery systems net annualized costs would decrease and emissions controlled would increase. The overall effect for larger terminal sizes would be a credit ($) for vapor recovery systems. Incineration cost effectiveness values would only be impacted by greater emission reductions.

Figure 4-1. Cost-Effectiveness [illegible] Hydrocarbon Control at Existing Gasoline Tank Truck Terminals

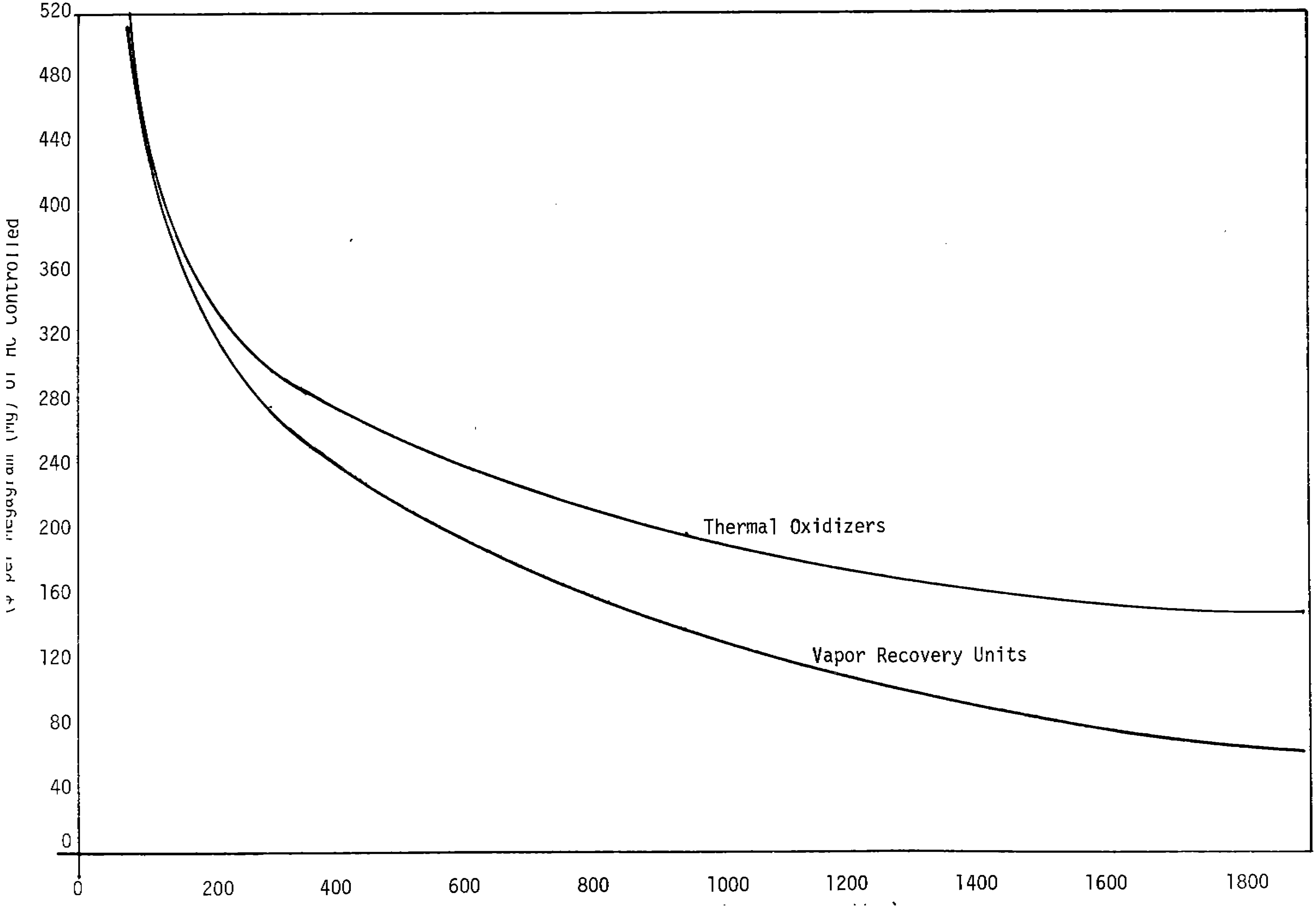


Table 4-3. ACTUAL CONTROL COSTS FOR BOTTOM FILL TERMINALS[4]
(Second quarter 1977 dollars)

Size:	1000 liters/day	492	598	1101	1230	1703	1930
	(1000 gal/day)	130	158	291	325	450	510
	Number of Racks	2	1	3	4	3	3
	Control Technique	RF	RF	OX	CRA	CRA	RF
	Installed Capital ($000)	126	126	153	192	282	265
	Direct Operating Costs ($000/yr)	10.5	6.5	9.8	5.4	16.1	15.2
	Capital Charges ($000/yr)	21.4	21.4	26.0	32.6	47.9	45.1
	Gasoline Recovery Credit ($000/yr)	(4.8)	(12.8)	0	(19.2)	(15.8)	(17.8)
	Net annualized Cost/(credit) ($000/yr)	27.1	15.1	35.8	18.8	48.2	42.5
	Controlled Emissions (Mg/yr)	47	100	297	133	122	104
	Cost/(credit) per Mg of HC controlled ($/Mg)	577	151	162	141	395	408

In no case would net annualized costs for incineration be a credit to the terminal. The difference between vapor recovery and incineration cost-effectiveness values would still be the smallest for terminals with low gasoline throughputs.

4.2.4 Actual Costs - Comparison to Model Estimates

Capital and operating costs for vapor control systems, gasoline recoveries and gasoline throughput information were obtained from actual terminal installations. Reported information is presented in Table 4-3. Since capital charges were not reported they were estimated based upon the factors and method included in Table 4-1.

A comparison of model and actual costs indicates reasonable correlation with respect to capital and annual direct operating costs. Gasoline recoveries are generally lower than EPA estimates for comparable model terminal sizes. Factors that should be considered when attempting to reconcile these discrepancies are addressed in Section 2.1 and will not be repeated here. Cost effectiveness ratios for vapor control at actual terminal installations agree with Figure 4-1 values for some terminals and exhibit extreme variances at other sizes. Discrepancies again are linked to lower gasoline recoveries for these actual terminals than those predicted using EPA factors.

Finally, it has been assumed throughout this chapter that, as a minimum, loading racks are designed for top-submerged or bottom loading. However, it is not unusual for actual terminal installations to splash load when incorporating a CRA vapor recovery unit. This insures saturation of vapors prior to the compression stage. Costs for the CRA unit on top splash fill terminals should be similar to those depicted in Table 4-2 for top-submerged or bottom-fill terminals provided the tank trucks have been vapor balanced prior to loading at the terminal.[5,7]

References

1. A Study of Vapor Control Methods for Gasoline Marketing: Volume I - Industry Survey and Control Techniques. Radian Corporation, Austin, Texas. EPA Contract No. 68-02-1319, April 1975.

2. Ibid, Volume II, Appendix.

3. Edwards Hydrocarbon Vapor Recovery Units for Terminals (Pricing and technical literature) May 1977.

4. Responses to EPA questionnaires sent to operators of gasoline bulk terminals employing vapor recovery or incineration and tested by EPA in 1976.

5. Comments received on May 15, 1977, draft document titled Control of Hydrocarbons from Tank Truck Gasoline Loading Terminals.

6. Personal communication from Triff Psyhojas, AER Corporation, Ramsey, N.J. to John Pratapas, OAQPS, U.S. Environmental Protection Agency, Research Triangle Park, North Carolina, February 1977.

7. Supplement No. 7 Compilation of Air Pollutant Emission Factors pp. 4.4-1 through 4.4-10. April 1977.

5.0 EFFECTS OF APPLYING THE TECHNOLOGY

The impacts on air pollution, water pollution, solid waste, and energy are discussed in this chapter.

5.1 IMPACT OF CONTROL METHODS

The control methods described in Chapter 3.0 that minimize the emission of hydrocarbons to the atmosphere during tank truck loading of gasoline are bottom-fill, top-splash, or top-submerged fill with the tank trucks vented to a vapor recovery or oxidation system. Their impact on air pollution, water pollution, and solid waste and energy are as follows:

5.1.1 Air Pollution Impacts

The estimated uncontrolled hydrocarbon emissions in 1973 from tank truck gasoline loading terminals (base case) were 300,000 metric tons per year.[1] This represents approximately 1.8 percent of the estimated 1975 total stationary source hydrocarbon emissions of 18 million metric tons per year.[2]

Estimated emissions from equipment installed at terminals are as follows: (1) top-submerged or bottom-fill - 600 mg/liter of gasoline loaded; (2) top-submerged or bottom-fill with vapor recovery or incineration - 80 mg/liter of gasoline loaded or less. The average uncontrolled hydrocarbon loss for a 950,000 liter per day terminal is 600 kg/day.

Testing of a thermal oxidizer by EPA indicated hydrocarbon emissions of 1.32 mg/liter of gasoline loaded, nitrogen oxides less than 10 parts per million and carbon monoxide less than 35 parts per million.[3] Sulfur oxides were not determined during the test period but are considered to be essentially nil.

5.1.2. Water and Solid Waste Impact

There are no significant solid or liquid wastes associated with the control of loading of gasoline into tank trucks at tank truck terminals.

5.1.3. Energy Impact

The energy impact of vapor recovery systems at terminals is considered minimal. Energy is required to drive compressors, pumps, and other equipment; however, in many systems a valuable product is recovered that would otherwise be lost into the atmosphere.[4] In thermal oxidizer systems, additional energy may be required in the form of gaseous fuel[5] to convert the hydrocarbon vapor to carbon dioxide and water. An estimated 13,000 liters of propane per year were used in the oxidizer tested by EPA.

5.2 REFERENCES

1. "Control of Hydrocarbon Emissions from Petroleum Liquids," EPA-600/2-75-042, September 1975, pp. 3-5.

2. "Control of Volatile Organic Emissions from Existing Stationary Sources - Volume I: Control Methods for Surface Coating Operations," EPA-450/2-76-028, November 1976, pp. 1, 11-12.

3. "Demonstration of Reduced Hydrocarbon Emissions from Gasoline Loading Terminals," EPA-650/2-75-042, June 1975, p. 10.

4. "A Study of Vapor Control Methods for Gasoline Marketing Operations - Volume I: Industry Survey and Control Techniques." EPA-450/3-75-046a, April 1975, pp. 89-115.

5. Op. cit., Gasoline Loading Terminals, p. 2.

6.0 COMPLIANCE TEST METHOD AND MONITORING TECHNIQUES

6.1 COMPLIANCE TEST METHOD

The recommended compliance test method as detailed in Appendix A can be used to determine emissions from bulk terminal gasoline vapor control equipment under conditions of loading leak-free tank trucks and trailers, and leak-free operation of the vapor collection and processing systems. Direct measurements of volume and concentration of vapor processor emissions are made to calculate the total mass of vented hydrocarbons. This total mass emitted is divided by the total volume of liquid gasoline loaded during the test period to determine the mass emission factor.

To insure that the vapor collection and processor are operating under leak-free conditions, qualitative monitoring should be conducted using a combustible gas indicator to indicate any leakage from the tank truck or trailer cargo compartments and all equipment associated with the control system. Any incidence of direct hydrocarbon leakage would indicate that corrective actions are required prior to further compliance testing.

The test period specification is intended to allow inclusion of the typical daily variation in loading frequency in each repetition and three repetitions are specified in order to include the normal day-to-day variations in loading frequency.

For terminals employing intermittent vapor processing systems, each test repetition must include at least one fully automatic operating cycle of the vapor processing unit.

This procedure is applicable to determining hydrocarbon emission rates from systems serving tank truck or trailer loading only. For those facilities employing a single control system to process vapors generated from both tank truck and trailer loading and fixed roof storage tank filling, no storage tank filling may occur during the duration of test repetition.

Source testing may not be required after initial compliance testing or if preconstruction review indicates the equipment will achieve compliance. In such cases, the performance parameters of the vapor control system would be checked and compared with compliance tests of other installations using the same system design.

6.2 MONITORING TECHNIQUES

The vapor collection system and associated vapor control equipment must be designed so that under maximum instantaneous loading rates, the tank truck pressure relief valves will not vent.

An intermittent monitoring approach is recommended. In this type of program, a portable hydrocarbon analyzer would be used to determine the processing unit exhaust hydrocarbon concentration and a combustible gas indicator would be used to detect any incidence of leaks from the cargo tanks and vapor collection lines at specified intervals.

Such a procedure would require the establishment of a control equipment exhaust concentration level at which the compliance with a mass emission factor regulation is assured.

There are currently available instruments that have a dual range of 0-100 percent LEL and 0-100 percent by volume of hydrocarbons as propane. The cost of this type instrument is approximately $500. A disadvantage of this type instrument is that the accuracy of the measurements at 4 to 5 percent hydrocarbon level is about ± 20 percent. This may not provide the precision necessary to differentiate between complying and non-complying operation. It would, however, detect gross deviations from design operation. An additional disadvantage is that comparative calibrations would be necessary to relate the monitoring results to the reference test procedure concentration measurements.

Portable hydrocarbon analyzers based on FID or NDIR principles are also available at costs ranging from $1500-$4000. These instruments have the advantage of being the most precise measurement techniques available. Also, since these techniques are used for hydrocarbon measurements in the reference procedure, no comparative testing is necessary to establish relative accuracy of the monitoring technique.

For leak monitoring alone, many versions of combustible gas indicators with 0-100 percent LEL spans are available. The cost of this type of unit would range from $200 to $500 depending on the particular vendor and instrument features.

In addition to the use of instruments monitoring control equipment process variables (principally temperature and pressure) can give a good indication of performance. The primary variables of interest and the approximate values that would indicate acceptable performance are listed on page 3-1.

6.3 AFFECTED FACILITY

In developing terminal regulations, it is suggested that the affected facility be defined as the tank truck gasoline loading stations and appurtenant equipment necessary to load the tank truck compartments.

6.4 STANDARD FORMAT

It is recommended that the following provisions be written into the tank truck gasoline terminal loading regulations.

1. Gasoline is not to be discarded in sewers or stored in open containers or handled in any other manner that would result in evaporation.

2. The allowable mass emissions of hydrocarbons from control equipment are to be 80 milligrams per liter or less of gasoline loaded.

3. Pressure in the vapor collection lines should not exceed tank truck pressure relief valve settings.

Test procedures for determining allowable hydrocarbon emissions are detailed in Appendix A.

APPENDIX A

A.1 EMISSION TEST PROCEDURE FOR TANK TRUCK GASOLINE LOADING TERMINALS

Hydrocarbon mass emissions are determined directly using flow meters and hydrocarbon analysers. The volume of liquid gasoline dispensed is determined by calculation based on the metered quantity of gasoline at the loading rack. Test results are expressed in milligrams of hydrocarbons emitted per liter of gasoline transferred.

A.2 APPLICABILITY

This method is applicable to determining hydrocarbon emission rates at tank truck gasoline loading terminals employing vapor balance collection systems and either continuous or intermittent vapor processing devices. This method is applicable to motor tank truck and trailer loading only.

A.3 DEFINITIONS

3.1 Tank Truck Gasoline Terminal

A primary distribution point for delivering gasoline to bulk plants, service stations, and other distribution points, where the total gasoline throughput is greater than 76,000 liters/day.

3.2 Loading Rack

An aggregation or combination of gasoline loading equipment arranged so that all loading outlets in the combination can be connected to a tank truck or trailer parked in a specified loading space.

3.3 Vapor Balance Collection System

A vapor transport system which uses direct displacement by the liquid loaded to force vapors from the tank truck or trailer into the recovery system.

3.4 Continuous Vapor Processing Device

A hydrocarbon vapor control system that treats vapors from tank trucks or trailers on a demand basis without intermediate accumulation.

3.5 Intermittent Vapor Processing Device

A hydrocarbon vapor control system that employs an intermediate vapor holder to accumulate recovered vapors from tank trucks or trailers. The processing unit treats the accumulated vapors only during automatically controlled cycles.

A.4 SUMMARY OF THE METHOD

This method describes the test conditions and test procedures to be followed in determining the emissions from systems installed to control hydrocarbon vapors resulting from tank truck and trailer loading operations at bulk terminals. Under this procedure, direct measurements are made to calculate the hydrocarbon mass exhausted from the vapor processing equipment. All possible sources of leaks are qualitatively checked to insure that no unprocessed vapors are emitted to the atmosphere. The results are expressed in terms of mass hydrocarbons emitted per unit volume of gasoline transferred. Emissions are determined on a total hydrocarbon basis. If methane is present in the vapors returned from the tank trucks or trailers, provisions are included for conversion to a total non-methane hydrocarbon basis.

A.5 TEST SCOPE AND CONDITIONS APPLICABLE TO TEST

5.1 Test Period

The elapsed time during which the test is performed shall not be less than three 8-hour test repetitions.

5.2 Terminal Status During Test Period

The test procedure is designed to measure control system performance under conditions of normal operation. Normal operation will vary from terminal-to-terminal and from day-to-day. Therefore, no specific criteria can be set forth to define normal operation. The following guidelines are provided to assist in determining normal operation.

5.2.1 Closing of Loading Racks

During the test period, all loading racks shall be open for each product line which is controlled by the system under test. Simultaneous use of more than one loading rack shall occur to the extent that such use would normally occur.

5.2.2 Simultaneous use of more than one dispenser on each loading rack shall occur to the extent that such use would normally occur.

5.2.3 Dispensing rates shall be set at the maximum rate at which the equipment is designed to be operated. Automatic product dispensers are to be used according to normal operating practices.

5.3 Vapor Control System Status During Tests

Applicable operating parameters shall be monitored to demonstrate that the processing unit is operating at design levels. For intermittent vapor processing units employing a vapor holder, each test repetition shall include at least one fully automatic operation cycle of the vapor holder and processing device. Tank trucks shall be essentially leak free as determined by EPA Mobile Source Enforcement Division.

A.6 BASIC MEASUREMENTS AND EQUIPMENT REQUIRED

6.1 Basic measurements required for evaluation of emissions from gasoline bulk loading terminals are described below. The various sampling points are numbered in Figure 1.

Sample Point	Measurements Necessary
1. Gasoline dispensers	- Amount dispensed
2. Vapor Return Line	- Leak check all fittings
3. Processing unit exhaust	- Temperature of vapors exhausted
	- Press. of vapors exhausted
	- Volume of vapors exhausted
	- HC concentration of vapors
	- Gas chromatograph analysis of HC*
	- Leak check all fittings and vents

6.2 The equipment required for the basic measurements are listed below:

Sample Point	Equipment and Specifications
2	1 portable combustible gas detector, (0-100% LEL)
3	1 flexible thermocouple with recorder
	1 gas volume meter, appropriately sized for exhaust flow rate and range
	1 total hydrocarbon analyzer with recorder; (FID or NDIR type, equipped to read out 0-10% by volume hydrocarbons as propane for vapor recovery processing device; or, 0-10,000 ppmv HC as propane for incineration processing devices)
	1 portable combustible gas detector (0-100% LEL)
Miscellaneous	1 barometer
	1 GC/FID w/column to separate C_1 - C_7 alkanes**

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*Required if methane is present in recovered vapors

**Required if methane is present in recovered vapors or if incineration is the vapor processing technique.

A.7 TEST PROCEDURES

7.1 Preparation for testing includes:

7.1.1 Install an appropriately sized gas meter on the exhaust vent of the vapor processing device. A gas volume meter can be used at the exhaust of most vapor recovery processing devices. For those where size restrictions preclude the use of a volume meter; or when incineration is used for vapor processing, a gas flow rate meter (orifice, pitot tube annubar, etc.) is necessary. At the meter inlet, install a thermocouple with recorder. Install a tap at the volume meter outlet. Attach a sample line for a total hydrocarbon analyzer (0-10% as propane) to this tap. If the meter pressure is different than barometric pressure, install a second tap at the meter outlet and attach an appropriate manometer for pressure measurement. If methane analysis is required, install a third tap for connection to a constant volume sample pump/evacuated bag assembly.*

7.1.2 Calibrate and span all instruments as outlined in Section 9.

7.2 Measurements and data required for evaluating the system emissions include:

7.2.1 At the beginning and end of each test repetition, record the volume readings on each product dispenser on each loading rack served by the system under test.

7.2.2 At the beginning of each test repetition and each two hours thereafter, record the ambient temperature and the barometric pressure.

7.2.3 For intermittent processing units employing a vapor holder, the unit shall be manually started and allowed to process vapors in the holder until the lower automatic cut-off is reached. This cycle should be performed immediately prior to the beginning of the test repetition before reading in 7.2.1 are taken. No loading shall be in progress during this manual cycle.

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*Described in Method 3, Federal Register, V36, n247, December 23, 1971.

7.2.4 For each cycle of the processing unit during each test repetition, record the processor start and stop time, the initial and final gas meter readings, and the average vapor temperature, pressure and hydrocarbon concentration. If a flow rate meter is used, record flow meter readouts continuously during the cycle. If required, extract a sample continuously during each cycle for chromatographic analysis for specific hydrocarbons.

7.2.5 For each tank truck or trailer loading during the test period, check all fittings and seals on the tanker compartments with the combustible gas detector. Record the maximum combustible gas reading for any incidents of leakage of hydrocarbon vapors. Explore the entire periphery of the potential leak source with the sample hose inlet 1 cm away from the interface.

7.2.6 During each test period, monitor all possible sources of leaks in the vapor collection and processing system with the combustible gas indicator. Record the location and combustible gas reading for any incidents of leakage.

7.2.7 For intermittent systems, the processing unit shall be manually started and allowed to process vapors in the holder until the lower automatic shut-off is reached at the end of each test repetition. Record the data in 7.2.4 for this manual cycle. No loading shall be in progress during this manual cycle.

A.8 CALCULATIONS

8.1 Terminology

T_a = Ambient temperature (^oC)

P_b = Barometric pressure (mm Hg)

L_t = Total volume of liquid dispensed from all controlled racks during the test period (liters)

V_e = Volume of air-hydrocarbon mixture exhausted from the processing unit (M^3)

V_{es} = Normalized volume of air-hydrocarbon mixture exhausted, NM^3 @ 20^oC, 760 mmHg

C_e = Volume fraction of hydrocarbons in exhausted mixture (volume % as $C_3H_{10}/100$, corrected for methane content if required

T_e = Temperature at processing unit exhaust (^oC)

P_e = Pressure at processing unit exhaust (mm Hg abs)

$(M/L)_e$ = Mass of hydrocarbons exhausted from the processing unit per volume of liquid loaded, (mg/l)

8.2 Processing Unit Emissions

Calculate the following results for each period of processing unit operation:

8.2.1 Volume of air-hydrocarbon mixture exhausted from the processing unit:

$$V_e = V_{ef} - V_{ei}, \text{ or} \qquad (m^3)$$

V_e = totalized volume from flow rate and time records.

8.2.2 Normalized volume of exhausted mixture:

$$V_{es} = \frac{(0.3858\ ^oK/mmHg)\ VePe}{Tet\ 273.2} \qquad NM^3 \text{ @ } 20^oC, 760 \text{ mmHg}$$

8.2.3 Mass of hydrocarbons exhausted from the processing unit:

$$Me = (1.833 \times 10^6 \ \frac{mgC_3H_8}{NM^3C_3H_8}) \times V_{es}C_e \qquad (mg)$$

8.3 Average Processing Unit Emissions

8.3.1 Average mass of hydrocarbons emitted per volume of gasoline loaded:

$$(M/L)_e = \frac{\Sigma M_e}{L_t} \qquad (mg/liter)$$

A.9 CALIBRATIONS

9.1 Flow Meters

Use standard methods and equipment which have been approved by the

Administrator to calibrate the gas meters.

9.2 Temperature Recording Instruments

Calibrate prior to the test period and following the test period using an ice bath ($0^{o}C$) and a known reference temperature source of about $35^{o}C$. Baily during the test period, use an accurate reference to measure the ambient temperature and compare the ambient temperature reading of all other instruments to this value.

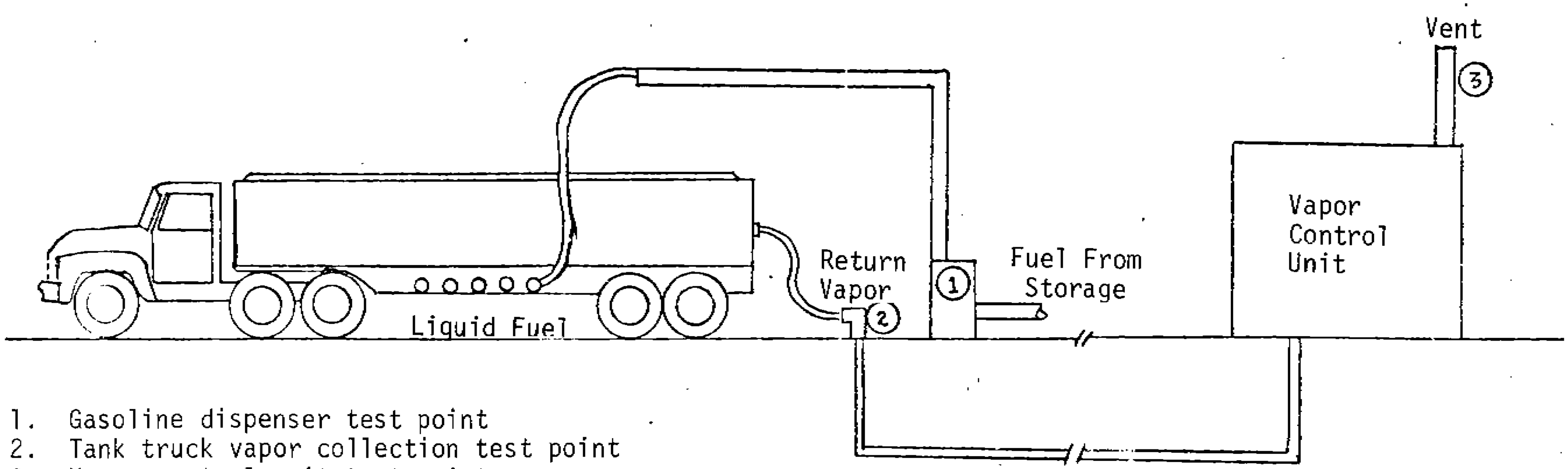
9.3 Total hydrocarbon analyzer

Follow the manufacturer's instructions concerning warm-up and adjustments. Prior to and immediately after the emission test, perform a comprehensive laboratory calibration on each analyzer used. Calibration gases should be propane in nitrogen prepared gravimetrically with mass quantities of approximately 100 percent propane. A calibration curve shall be provided using a minimum of five prepared standards in the range of concentrations expected during testing.

For each repetition, zero with zero gas (3 ppm C) and span with 70% propane for instruments used in the vapor return lines and with 10% propane for instruments used at the control device exhaust.

The zero and span procedure shall be performed at least once prior to the first test measurement, once during the middle of the run, and once following the final test measurement for each run.

Conditions in calibration gas cylinders must be kept such that condensation of propane does not occur. A safety factor of 2 for pressure and temperature is recommended.



1. Gasoline dispenser test point
2. Tank truck vapor collection test point
3. Vapor control unit test point

Figure A-1. Tank Truck Gasoline Loading Vapor Control Schematic

Table A-1 GASOLINE BULK TRANSFER TERMINAL DATA SHEET No.

Terminal Name: ______________________ Date: ______________

Location: ______________________

Daily Ambient Data: (record every 2 hours)

	Time	T_a	P_b
Start:			
End:			

Schematic Diagram of Rack Layout

Dispenser Meter Readings

Time Pump No.	Initial	Final	Time Pump No.	Initial	Final

GASOLINE BULK TRANSFER TERMINAL CONTROL SYSTEM DATA SHEET No. 2

Terminal Name: ______________________ Date: ____________________

Location: ____________________________

Control Device Outlet

Gas meter readings   Initial __________   Final ______________

Time   Test Start ____________   Test End ________________

Record the following for each processing unit operating cycle or emission period.

Time		Volume Reading		Average		
Start	Stop	Initial	Final	Temperature	Pressure	HC Concentration % as ____

Appendix B

B.1 SUMMARY OF RESULTS FOR TANK TRUCK GASOLINE LOADING TERMINAL VAPOR RECOVERY SYSTEM TESTING

The following discussion summarizes the results of the five terminal tests conducted by EPA. These results are presented in Table B-1. The nomenclature used in the table is explained below.

1. $(\overline{V/L})_r$ - Average volumetric recovery factor; this is the actual volume of vapors that were returned from the tank trucks divided by the volume of liquid gasoline loaded.
2. $(\overline{M/L})_r$ - Average mass recovery factor; the mass of hydrocarbons that were returned from the tank trucks divided by the volume loaded.
3. $(\overline{V/L})_p$ - Average potential volumetric recovery factor; the volume of vapors returned divided by the volume of liquid loaded under conditions of no vapor leakage from the tank trucks.
4. $(\overline{M/L})_p$ - Average potential mass recovery factor; a calculated result that represents the mass of hydrocarbons that would have been returned from the tank truck if no leaks had occurred, divided by the volume of liquid loaded.

5. $\overline{(M/L)}_l$ - Average tank truck leakage; the mass of hydrocarbons leaked directly to the atmosphere during loading divided by the liquid volume loaded. This result is obtained by subtracting (2) from (4).

6. $\overline{(M/L)}_e$ - Processor emission factor; the mass of hydrocarbons exhausted from the processing unit divided by the total volume of gasoline loaded into tank trucks.

7. E_p - Processor efficiency; the hydrocarbon mass recovery efficiency for the vapors processed. Calculated using (6) and (2).

8. $\overline{(M/L)}_t$ - Total system emission factor; the sum of the processor emission factor(6) plus the leakage emission factor (5).

9. E_s - Total system efficiency; the hydrocarbon mass recovery efficiency for the total system. Includes the impact of incomplete vapor collection at the tank trucks and the processor efficiency. Calculated using the total system emission factor (8) and the potential mass recovery factor (4).

10. $\overline{(M/L)}_e^*$ - Leakless total system emission factor; an extrapolated estimate of the processor (system) emission factor if no leaks occurred at the tank trucks. Calculated using the potential mass recovery factor (4) and the processor efficiency (7).

In some cases, it was necessary to modify the calculation procedures in order to evaluate the systems. Comments about the results for the individual facilities are given below.

1. Facilities A, B, and E - All reported results are calculated directly from the test data. Sufficient information was available to allow the procedures specified in the emission test procedure to be followed.

2. Facility C - The calculated results for actual returned vapor factors and processor emissions are derived directly from the data. There were no loadings which met the leakless criteria, therefore, it was necessary to use those loadings with the lowest explosimeter readings during loading. In no case did the explosimeter readings exceed 100 percent LEL for those loadings selected to calculate a potential volumetric recovery factor. This estimated potential volumetric recovery factor was then used to calculate the potential mass recovery factor, the mass leakage rate, the total system emissions, the total system efficiency and the leakless system emission factor. The best estimate for the validity of these calculations can be made by comparing the calculated potential volumetric recovery factor to those obtained during testing at the other facilities. From this comparison, the estimate for this facility is not inconsistent with the other results.

A reliability factor of about 10 percent is probably a good estimate of the validity of the subsequent mass factors. The impact on the efficiency calculations will be less since ratios of mass factors are used.

3. Facility D - There were no leakless gasoline loadings at this facility during testing, therefore, the comments for Facility C are applicable.

In addition, it was necessary to assume that the filling of the storage tanks from the pipeline generated no excess vapors. (Excess vapors are defined as that volume of vapor displaced that is in excess of the volume of liquid transferred.) In other words, the lifter tank simply rose due to the liquid level change in the tanks. Thus, all vapors placed into the storage tanks came from tank trucks. In actual practice, some additional vapors may be generated during storage tank filling, but the above assumption allows a more direct calculation and more representative data comparison with the other facilities. In this model, the mass emission factor due to storage tank filling is assigned a value of zero. The volume of gasoline transferred to the storage tank is then irrelevant. All processor emissions are assigned to tank truck loading and the total volume of liquid loaded into trucks is used for emission factor calculations.

The only impact that this assumption would have would be in the estimation of the system total potential emissions and the controlled system emissions assuming no leaks. This is due to the methametical deletion of the contribution of storage tank-filling excess vapors. Since these excess vapors are not expected to be greater than 2 to 3 volume percent, the final impact on the calculated results is insignificant.

Table B-1. SUMMARY OF EPA TANK TRUCK GASOLINE LOADING TERMINAL VAPOR RECOVERY TESTS

	Terminals				
Average results	A	B	C	D	F
1. $(V/L)_r$, m^3/m^3	0.418	0.752	0.786	0.844	0.903
2. $(M/L)_r$, mg/liter	107.3	236.7	486.9	554.0	318.9
3. $(V/L)_p$, m^3/m^3	0.920	1.012	0.925	1.079	1.081
4. $(M/L)_p$, mg/liter	222.5	337.6	576.0	693.5	365.1
5. $(M/L)_l$, mg/liter	115.2	100.9	86.7	154.6	46.0
6. $(M/L)_e$, mg/liter	31.2	37.0	33.6	43.3	62.6
7. E_p, %	70.9	84.4	93.1	92.1	80.4
8. $(M/L)_t$, mg/liter	146.4	137.9	120.2	197.9	100.6
9. E_s %	34.2	59.2	79.5	71.5	70.3
10. $(M/L)_e$*, mg/liter	64.7	52.8	40.9	54.7	71.6

B.2 REFERENCE

Summary of Results for Bulk Terminal Testing, EPA internal memorandum from Winton Kelly, EMB, to William Polglase, CPB, dated April 16, 1977.

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(Please read Instructions on the reverse before completing)

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16. ABSTRACT

This report provides the necessary guidance for development of regulations to limit emissions of volatile organic sources (VOC) of hydrocarbons from tank truck gasoline loading operations. This guidance includes an emission limit which represents reasonable available control technology (RACT), an analytical technique for determining the emissions from control equipment, and cost analysis for evaluating cost effectiveness of tank truck gasoline loading terminal controls.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Air Pollution Tank Truck Gasoline Loading Operations Emission Limits Regulatory Guidance	Air Pollution Control Stationary Sources Organic Vapors	

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