EPA-450/2-77-035
December 1977
(OAQPS No. 1.2-085)

GUIDELINE SERIES

# CONTROL OF VOLATILE ORGANIC EMISSIONS FROM BULK GASOLINE PLANTS

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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Emissions 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.

| Abbreviations | Conversion Factor |
|---|---|
| l - liters | liters X .26 = gallons<br>gallon X 3.79 = liters |
| kg - kilograms | kilograms X 2.203 = pounds<br>pounds X .454 = kilograms |
| m tons - metric tons | metric tons X 1.1 = tons<br>tons X .907 = metric tons |
| m - meters<br>cm - centimeters | meters X 3.28 = feet<br>centimeters X .394 = inches |
| $kg/10^3 l$ - kilograms/thousand liters | $kg/10^3 l$ X 8.33 = $lb/10^3 gal$<br>$lb/10^3 gal$ X .12 = $kg/10^3 l$ |
| Pa - Pascals | $oz/in^2$ X 431 = Pascals |

Frequently used measurements in this document are:

| | |
|---|---|
| 76,000 l ∿ 20,000 gallons | 54 kg/day ∿ 120 lb/day |
| 19,000 l ∿ 5,000 gallons | 3 kg/day ∿ 6.6 lb/day |
| 15,000 l ∿ 4,000 gallons | 1.6 $kg/10^3 l$ ∿ 13 $lb/10^3$ gal |
| 15 cm ∿ 6 inches | 1.4 $kg/10^3 l$ ∿ 12 $lb/10^3$ gal |
| 6 $oz/in^2$ ∿ 2600 Pascals | 0.6 $kg/10^3 l$ ∿ 5 $lb/10^3$ gal |

## 1.0 INTRODUCTION AND SUMMARY

This document is related to the control of volatile organic compounds (VOC) from bulk plants with daily throughputs of 76,000 liters of gasoline or less. The techniques discussed herein are less complex and less costly than those which are applicable to bulk gasoline terminals. (See Control of Hydrocarbons from Tank Truck Gasoline Loading Terminals, EPA-450/2-77-026). VOC emitted during filling of account trucks and storage tanks are primarily $C_4$ and $C_5$ paraffins and olefins which are photochemically reactive (precursors to oxidants).

Methodology described in this document represents the presumptive norm or reasonably available control technology (RACT) that can be applied to existing bulk plants. RACT 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.

## 1.1 NEED TO REGULATE BULK PLANTS

Control techniques guidelines concerning RACT 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 bulk plants are a significant source of VOC.

Annual nationwide emissions from bulk plants are estimated to be 180,000 metric tons (70,000 metric tons from account trucks and 110,000 metric tons from storage tanks). This represents one percent of total VOC emissions from stationary sources.

## 1.2 SOURCES AND CONTROL OF VOLATILE ORGANIC COMPOUNDS FROM BULK PLANTS

At bulk plants vapors are displaced to the atmosphere from the filling of account trucks and storage tanks. Additional VOC emissions are traceable to "breathing" and "drainage" losses from storage tanks. Three levels of increasingly more effective VOC control are applicable to bulk plants. They are:

- Alternative I - Submerged filling of account trucks (either top-submerged or bottom fill).
- Alternative II - Alternative I plus vapor balance (displacement) system to control VOC displaced by gasoline delivery to the storage tank.
- Alternative III - Alternative II plus vapor balance system to control VOC displaced by filling account trucks.

Account truck emissions (splash fill) can be reduced by about 60 percent through the use of submerged fill techniques (Alternative I). Vapor balance systems provide an additional 90 percent reduction in emissions from truck and storage tank loading (Alternative III). Vapor balance is a simple technique wherein displaced vapors from account trucks are transferred to storage tanks and subsequently to the transport trucks that deliver gasoline to the bulk plant. Collected vapors are recovered or oxidized at the terminal where the transport trailer is filled.

Capital costs for a top-submerged balance system at a 76,000 liter per day bulk plant are $3,500. Top-submerged and bottom fill at the same size plant have capital costs of $730 and $12,110, respectively. Cost effectiveness is $40 credit for top-submerged fill balance systems, $130 credit for top-submerged fill only, and $20 credit for bottom fill (figures are in terms of dollars per 1000 kilograms of hydrocarbon removed).

## 1.3 REGULATORY APPROACH

Regulations should be written in terms of operating procedures and equipment specifications rather than emission limits. It is extremely difficult to quantify emissions from a bulk plant using conventional source testing procedures. Visual observation and the use of portable hydrocarbon detectors will be required to ensure that liquid and vapor leaks are minimized and that proper control equipment is in use.

In designing bulk plant regulations consideration should be given to their compatibility with Stage I service station regulations. For example, truck filling vapor control technology is most effective for plants which deliver to accounts covered by Stage I. Trucks which deliver to "non-exempt accounts"* return to the bulk plant with rich

*Under Transportation Control Plans and some State and local regulations, operators are required to equip certain gasoline storage tanks with vapor recovery systems. Existing tanks of less than 2000 gallon capacity and certain new tanks are typically exempted, e.g., Transportation Control Plans for the National Capital Interstate AQCR, December 6, 1973 (38 FR 33719). For tanks that are not exempted, the vapor-laden delivery vessel is to be refilled only at facilities equipped with a vapor recovery system or equivalent which recovers at least 90 percent by weight of displaced VOC.

vapor concentrations in the empty compartments. VOC losses on filling are potentially two or more times greater than from trucks servicing exempt accounts. Bulk plants serving non-exempt accounts tend to be larger than average while many of those delivering to exempt accounts are extremely small.

For some areas it may be reasonable to apply the most effective control alternative (III) to all bulk plants regardless of size and customers serviced. However, in many AQCR's, the less effective and less costly alternative (II) may be the appropriate strategy for small plants; their smaller throughputs and lesser truck filling emission rates tend to render balance systems less cost effective than at larger bulk plants. In addition, the economic impact of incremental control costs (Alternative III over II) is likely to be severe for many small independent bulk plants. Though it is not possible to characterize precisely the plant size cutoff for potentially severe economic effects, this is likely to occur in the range of 15,000 liters per day or less gasoline throughput. Therefore, where determining the level of control to require for small bulk plants, consideration should be given to potential economic impacts as well as retrofit difficulty and the status of accounts vis-a-vis Stage I regulations.

Cost information presented in Chapter 4 will assist States in making determinations of economic feasibility. Much of the information presented herein is based on recent experience in the Denver (Colorado) area. Capital costs in particular are markedly lower than had been projected by other sources. It is our opinion that the costs listed in Chapter 4 are representative of the type of equipment that will be installed in typical bulk plants across the nation.

# 2.0 SOURCE AND TYPES OF EMISSIONS

## 2.1 INDUSTRY DESCRIPTION

Bulk gasoline loading plants are typically secondary distribution facilities which receive gasoline from bulk terminals by trailer transports, store it in above-ground storage tanks, and subsequently dispense it via account trucks to local farms, businesses, and service stations. A typical bulk plant has a throughput of 15,000 liters of gasoline per day with storage capacity of about 189,000 liters of gasoline. EPA defines the bulk plant as having a throughput of less than 76,000 liters of gasoline per day averaged over the work days in one year.

The 1972 Census of Business indicates that there were 23,367 bulk plants in the U.S. having 7,948,500 liters of bulk capacity or less for all fuels.[1] Compared with the 1967 census, the 1972 data show an 11 percent decline in the number of bulk plants; economic factors appear to be the reason for this decline. The cost of bulk plant related labor and capital are eliminated if the bulk terminals can deliver directly to the account. There is a trend in the industry to deliver directly from bulk gasoline terminals to customers.

## 2.2 BULK PLANT FACILITIES AND EMISSIONS

This section discusses typical bulk plant facilities and emissions resulting from operation of these facilities. The facility sizes and typical emission factors used in this section are based on a survey of 385 bulk gasoline plants prepared for the EPA.[2,3] The areas surveyed include: San Diego, San Joaquin Valley (California), Denver, Baltimore/Washington, D.C. and Houston/Galveston areas.

### 2.2.1 Bulk Plant Facilities

Facilities include: (1) tanks for gasoline storage; (2) loading racks; and (3) incoming and outgoing tank trucks. All three are emission points within the plant.

#### 2.2.1.1 Gasoline Storage

Above-ground storage facilities account for approximately 65 percent of the plants surveyed and underground for 30 percent; 5 percent use both types.

Above-ground tanks are usually cylindrical with domed ends (vertical or horizontal axis). Because storage tanks found at bulk plants are relatively small, the use of floating roof tanks is not common. Typical capacities of bulk plant storage tanks range from 50,000 to 75,000 liters. The number of gasoline tanks per plant varies between one and eight with an average of three, resulting in a storage capacity of 50,000 to 600,000 liters. Similar tanks are also used to store other petroleum products, including diesel fuel, kerosene, lubricants, and fuel oils. Underground storage tanks tend to be more prevalent in large cities; most are of 38,000 liter capacity. Three underground gasoline tanks are an average number per plant.

2.2.1.2 Loading Racks -

A typical loading rack includes shut-off valves, meters, relief valves, electrical grounding, lighting, by-pass plumbing, and loading arms. Loading may be by bottom fill, top splash, submerged fill pipe through hatches or by dry connections on the tops of trucks. Top-filling is used in 90 percent of the surveyed plants; 75 percent are using top-submerged filling rather than top-splash filling. Bottom filling is used in only 10 percent of the surveyed plants although an industry trend toward bottom-filling was noted. A typical plant has one rack with an average gasoline pumping rate of 490 liters per minute.

2.2.1.3 Tank Trucks -

Truck-trailer transports supply bulk plants with gasoline while account (bobtail) trucks deliver gasoline to bulk plant customers. Truck-trailer transports have four to six compartments and deliver approximately 34,000 liters of one grade gasoline to the bulk plant. Most commonly, truck-trailer transports are owned by oil companies or commercial carriers; such vehicles are not devoted solely to bulk plant service. Bulk plants typically average two account trucks each. Account trucks average four compartments and a total capacity of 7,200 liters. Account trucks are almost always owned by the plant operators, even when the plant is owned by a refiner.

2.2.2 Emission Sources

Vapors can escape from fixed roof storage tanks and tank trucks even when there is no transfer activity. Temperature induced pressure differentials can expel vapor-laden air or induce fresh air into the tank. The vapor escaping under these conditions is referred to as a "breathing loss." Liquid transfer forces air-hydrocarbon vapors out during filling (filling losses) of the tank and ingests air during draining (draining losses). The draining and filling losses combined are called "working losses." Miscellaneous or fugitive loss sources can also occur from pressure-vacuum valves, shut-off valves, truck hatches, piping, and pumping seals.

2.2.2.1 Breathing Losses -

Factors affecting breathing or standing losses for fixed roof tanks and tank trucks include ullage and volatility of the gasoline stored, type and condition of tanks and appendages, and meteorological conditions. If there are no leaks or direct openings, then temperature fluctuations are the major cause of breathing losses. As the temperature of the liquid rises, the vapor pressure increases and evaporation takes place. When overall pressure in the gas space increases and exceeds the vent pressure set point (usually $2.6 \times 10^3$ Pascals), a mixture of air and hydrocarbons is discharged into the atmosphere. As the temperature decreases, gases partially condense and contract, and fresh air is drawn into the vapor space. This permits additional hydrocarbons to vaporize resulting in a positive pressure. Since hydrocarbons are emitted, but generally not drawn back into the tanks, a continued loss of hydrocarbons results from the daily changes in ambient temperature.

2.2.2.2 Working Losses -

Working losses, generated during liquid transfer, can be divided into filling and draining losses. A filling loss occurs when the liquid transferred into the receiving vessel displaces an equal volume of air saturated or nearly saturated with hydrocarbons, venting to the atmosphere. A draining loss occurs when the transferred liquid is replaced by an equal volume of air. Subsequently hydrocarbons vaporize and saturate the air causing a 20 to 40 percent increase in volume; excess air saturated with hydrocarbons is vented.

The quantity of hydrocarbon emission is a function of the volume displaced and the fraction of hydrocarbon contained in the displaced gases. For gasoline of a given Reid vapor pressure, the quantity of hydrocarbon increases with temperature. However, the relative temperatures of the tank and delivered gasoline may cause a positive or negative vapor growth which is more pronounced under splash than submerged filling.

The two basic types of gasoline loading into truck tanks are presented in Figure 2-1.[4] In the splash filling method, the fill pipe dispensing the gasoline is only partially lowered into the truck tank. Significant turbulence and vapor-liquid contact occurs during splash filling resulting in high levels of vapor generation and loss. If the turbulence is high enough, liquid droplets will be entrained in the vented

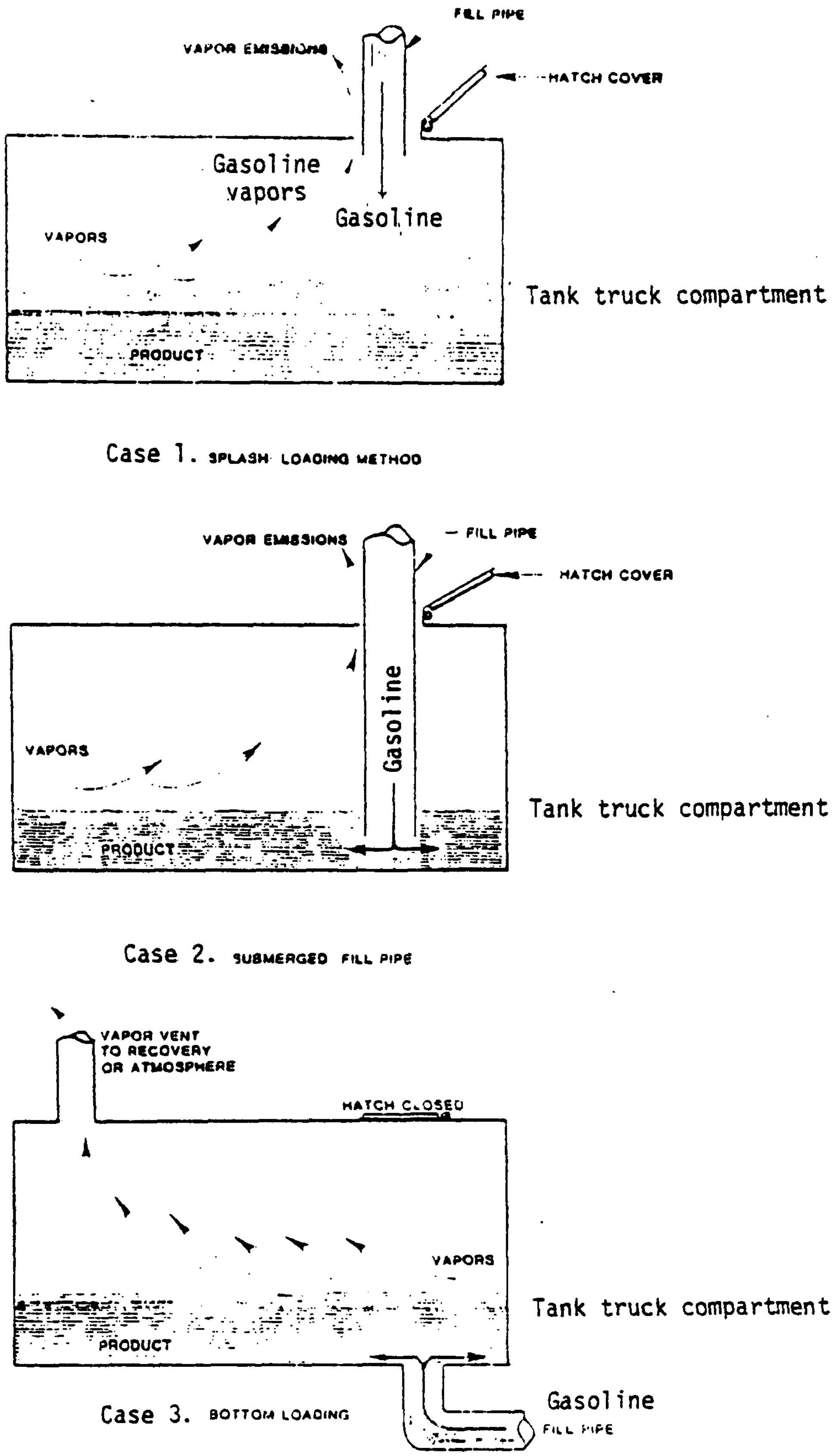



Figure 2-1. Gasoline Tank Truck Loading Methods

vapors. A second method is submerged filling either with a submerged fill pipe or bottom filling. In the top submerged fill pipe method, the fill pipe descends to within 15 centimeters of the bottom of the truck tank. In the bottom filling method, the fixed fill pipe enters the truck tank from the bottom. Submerged filling significantly reduces liquid turbulence and vapor-liquid contact, resulting in much lower hydrocarbon losses than encountered during splash filling.

2.2.2.3 Miscellaneous Losses -

Miscellaneous losses are highly variable from one bulk plant to another; these losses are usually the result of poor operating and maintenance procedures.

Some causes of miscellaneous losses are:

1) Cracks in seals and improper connections which cause partial venting of hydrocarbon vapors and liquid leakage.

2) High fill rates which cause higher vapor generation rates and pressures.

3) Improper setting of gasoline fill meters, residual gasoline in the tank truck compartment, and apparent shut-off valve failure which cause truck tank overfills.

4) Careless hooking up of liquid lines and top loading nozzles.

5) Truck cleaning.

6) Defective or maladjusted pressure-vacuum relief valves.

2.2.2.4 Emission Factors -

Emission factors used in this section are calculated from ideal gas laws or from formulas contained in "Compilation of Air Pollutant Emission Factors."[4] Affecting parameters for storage tank losses are from "Study of Gasoline Vapor Emission Controls of Small Bulk Plants."[5] Uncontrolled emissions from each source will be considered separately.

Tank Truck Losses

Uncontrolled filling losses are estimated to be 1.4 kg/$10^3$ liters of gasoline loaded by the splash fill method and 0.6 kg/$10^3$ liters of gasoline loaded by the submerged fill method.[6] For a typical gasoline plant with an average throughput of 15,000 liters of gasoline per day, the estimated uncontrolled filling losses with splash fill are 21 kg/day or 9 kg/day with submerged fill. Breathing losses in tank trucks are highly variable; besides temperature variations they are affected by settings of pressure-vacuum relief valves.

Storage Tank Losses

For 15,000 liter/day bulk gasoline plants, the uncontrolled breathing loss is estimated to be 3 kg/day per tank,[7] the draining loss .46 kg/1000 l and the filling loss 1.15 kg/1000 liters loaded. For a typical plant with three tanks, uncontrolled breathing and working losses are approximately 9 kg/day and 24 kg/day, respectively.

## 2.3 SUMMARY

A typical gasoline plant has a throughput of 15,000 ~~liters~~ of gasoline per day with bulk storage capacity of about 189,000 liters of gasoline. Estimated uncontrolled emissions from a 15,000 liter per day bulk gasoline plant are approximately 15,500 kg/yr or 54 kg/day. VOC emissions from each source are shown in Table 2-1. Losses from tank truck breathing, tank truck leakage or other miscellaneous sources are highly variable and are not included in the table.

Table 2-1. UNCONTROLLED VOC EMISSIONS FROM A SMALL BULK PLANT

| | Annual* | Working Day |
|---|---|---|
| Throughput | 4,290,000 liters | 15,000 liters |
| Storage Tank (above-ground fixed roof) (3 storage tanks) | | |
| Breathing losses (3 kg/day per tank) | 2,600 | 9 |
| Working losses (1.6 kg/$10^3$l) | 6,900 | 24 |
| Draining (.46 kg/$10^3$l) | | |
| Filling (1.15 kg/$10^3$l) | | |
| Tank Truck (splash filling) | | |
| Filling losses (1.4 kg/$10^3$l) | 6,000 | 21 |
| Total Uncontrolled Emissions | 15,500 | 54 |

* Using 286 working days per year.

## 2.4 REFERENCES

1. U.S. Department of Commerce, Bureau of Census, 1972 Census of Wholesale Trade, subject series, "Petroleum Bulk Stations and Terminals," #WL 72-5-2, U.S. Government Printing Office, Washington, D.C., page 2-155.

2. "Study of Gasoline Vapor Emissions Controls at Small Bulk Plants," Pacific Environmental Services, Inc., U.S. EPA Region VIII Report, EPA Contract No. 68-01-3156, Task Order No. 5, October, 1976.

3. "Effects of Stage I Vapor Recovery Regulations on Small Bulk Plants and on Air Quality in the Washington, D.C., Baltimore, Md., and Houston/Galveston, Texas Areas," U.S. EPA, DSSE, EPA Contract No. 68-01-3156, Task Order No. 28, March, 1977.

4. "Supplement No. 7 for Compilation of Air Pollutant Emission Factors," Second Edition, U.S. EPA, Office of Air Quality Planning and Standards, April, 1977.

5. Reference 2.

6. Reference 4.

7. Reference 2.

## 3.0 EMISSION CONTROL TECHNOLOGY

Control of breathing, working, and miscellaneous losses resulting from storage and handling of gasoline at bulk plants can be accomplished through submerged fill, balance systems, vapor processing systems, and control of truck loading leaks. Vapor processing systems have not been applied to bulk plants, but have been used to recover hydrocarbon vapors at bulk terminals during truck loading.

### 3.1 TYPES OF CONTROL TECHNIQUES

This document considers effectiveness and costs of three control techniques, i.e. submerged fill, balance or displacement systems, and leak prevention (control of tank truck loading leaks). Vapor recovery and oxidation systems, while technically feasible, have not been employed at bulk plants.

#### 3.1.1 Submerged Loading

One method of reducing vapors generated during the loading of tank trucks is by using submerged fill. By changing from top-splash to submerged fill, HC vapors generated by loading tank trucks can be reduced from 1.4 to 0.6 kg/$10^3$ liter transferred[1] (a 58 percent reduction). Submerged fill decreases turbulence, evaporation, and eliminates liquid entrainment.

#### 3.1.2 Balance System

The displacement, or vapor balance system operates by transferring vapors displaced from the receiving tank to the tank being unloaded. A vapor line between the truck and storage tanks essentially creates a closed system permitting the vapor spaces of the two tanks to balance with each other. Figure 3-1 shows a typical flow scheme of a vapor balance system.

Vapor balancing of incoming transport trucks displaces vapor from storage tanks to truck compartments; emissions are ultimately treated at the terminal with a secondary recovery/control system. EPA sponsored source tests at two bulk plants have shown that an efficiency greater than 90 percent is attainable with vapor balancing of transport trucks and storage tanks.[2]

Vapor balancing of storage tanks and account trucks also reduces account truck filling losses by 90 percent or greater efficiency.[2] Also, balance systems on account truck filling virtually eliminate drainage losses from storage tanks, since displaced air is saturated or nearly saturated with hydrocarbons. The efficiency attainable in loading account trucks is strongly affected by tightness of the truck compartments, i.e. condition of hatches and seals, and on care exercised in making connections.

### 3.1.3 Vapor Recovery and Oxidation Processing Systems

Vapor recovery and oxidation systems can be used to process vapors displaced from the storage tanks and the tank trucks during filling. These systems have been broadly applied to bulk terminal truck loading losses but have not been applied in bulk plants - probably due to costs. Combinations of compression, refrigeration and absorption systems can recover 90 to 93 percent of displaced VOC while incineration will destroy over 98 percent.

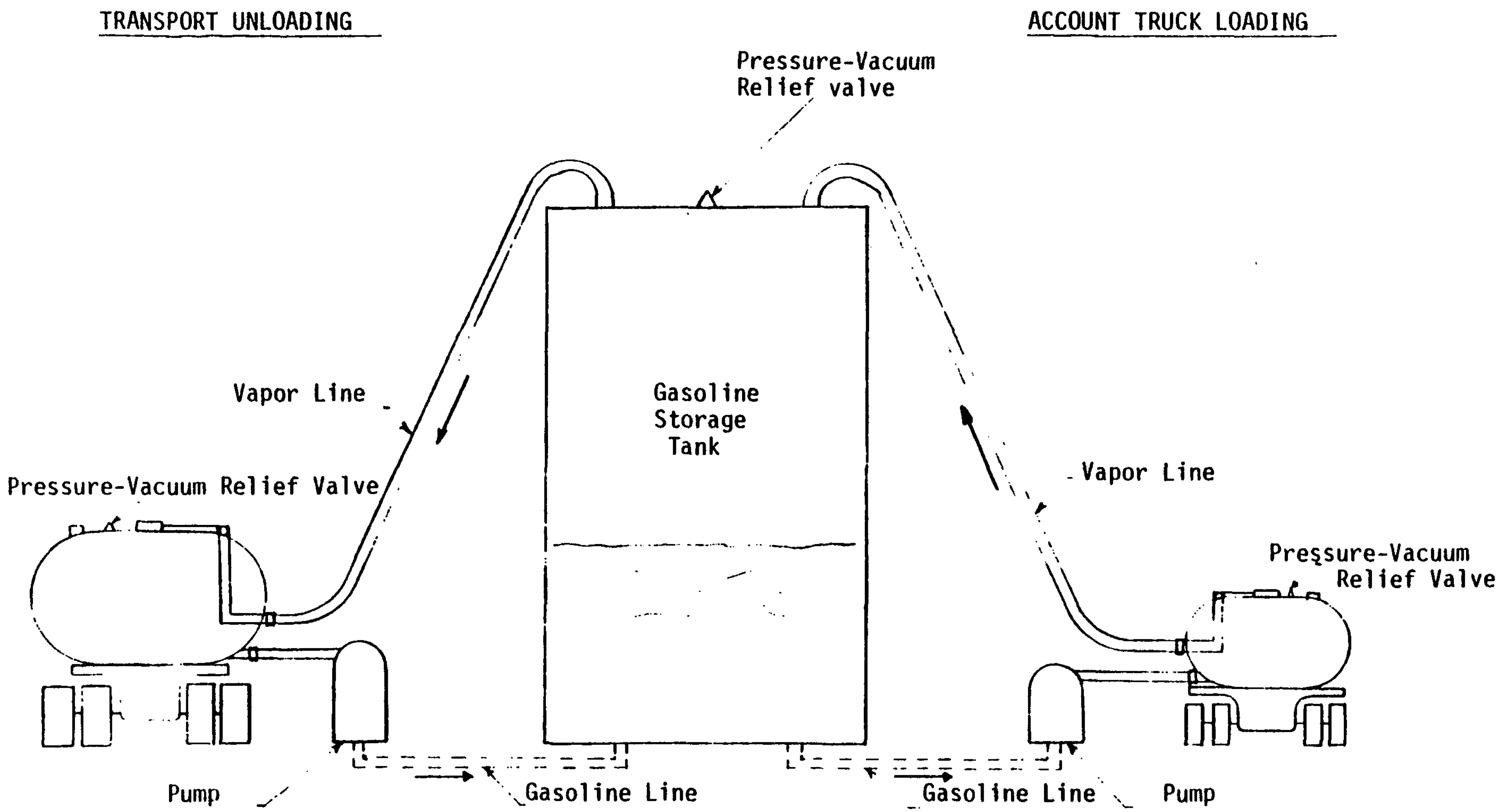



Figure 3-1. VAPOR BALANCE SYSTEM
(bottom fill)

### 3.1.4 Leak Prevention

Proper maintenance, operation, and good housekeeping is required to assure effective collection of vapors at bulk plants. EPA source tests have shown that from 30 to 70 percent of vapors generated, during tank truck loadings at vapor recovery bulk terminals, were vented to the atmosphere.[4] Tank truck leakage was also observed during EPA sponsored emission tests at two bulk plants employing vapor balance to control hydrocarbon emissions.

## 3.2 CONTROL ALTERNATIVES

The control alternative considered are:

- I Submerged filling.
- II Submerged filling account trucks with vapor balancing of transport trucks and storage tanks.
- III Submerged filling account trucks with vapor balancing of storage tanks, account and transport trucks.

Figure 3-2 shows these control alternatives along with estimated reductions from an uncontrolled 15,000 liter per day plant. In Alternatives II and III a leak-free system is assumed such that the only VOC emissions considered are breathing, drainage and displacement losses. Losses are itemized in Table 3-1. Submerged fill is seen to provide a 22 percent VOC reduction from the base case; Alternative II and III yield 54 and 77 percent respectively. For the total balance system (Alternative III), the daily reduction in emissions is 41.5 kg. Only 24.5 kg of the total is realized as a product recovery credit by the bulk plant operator; the other 12 kg is recovered at the terminal.

## 3.3 SUMMARY

1. By changing from top-splash to submerged filling, hydrocarbon vapors from account truck loading can be reduced by 58 percent.

2. A vapor balance system can control vapor emissions during unloading and loading of tank trucks with an efficiency greater than 90 percent.

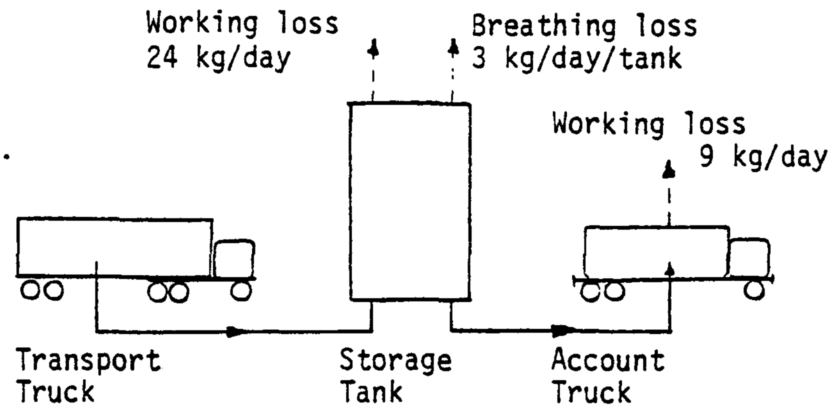
3. Vapor processing technology has been broadly applied to bulk terminal truck loading emissions and is capable of handling the smaller emission rates from bulk plants. Such systems would be expected to reduce VOC emissions by 90 percent or more if applied to storage tanks and account trucks.

4. Proper maintenance, operation, and good housekeeping is required to prevent leaks and assure effective collection of VOC emissions when balance systems are installed. To maintain high efficiencies tank trucks, storage tanks and all piping must be vapor tight.

Figure 3-2. TYPICAL BULK GASOLINE PLANT CONFIGURATIONS

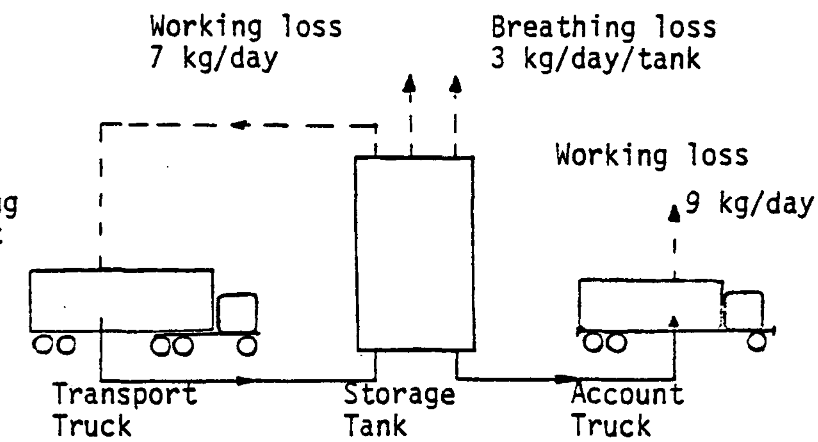
Throughput - 15,000 liters/day -- 3 storage tanks
Base Case Emissions - 54 kg/day (top splash fill, no control)

Alternative I - Submerged filling.
Total Emissions 42 kg/day
Reductions from Base 12 kg/day



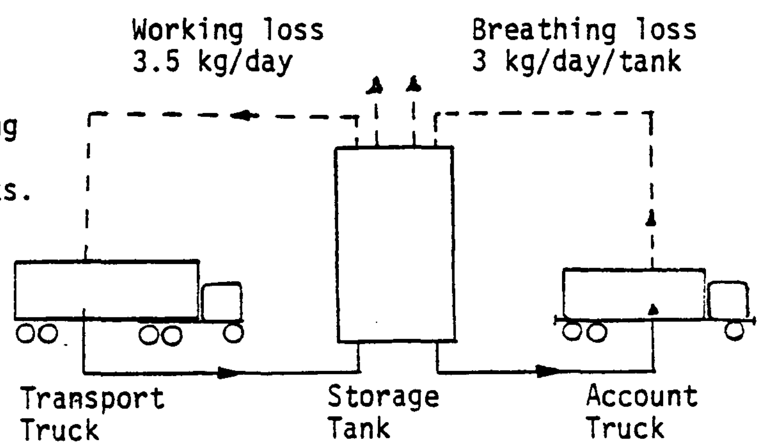

Alternative II - Submerged filling with vapor balancing of transport trucks and storage tanks.

| | |
|---|---|
| Total Emissions | 25 kg/day |
| Reduction from Base | 29 kg/day |
| Reduction from Alt. I | 17 kg/day |




Alternative III - Submerged filling with vapor balancing of storage tanks, account and transport trucks.

| | |
|---|---|
| Total Emissions | 12.5 kg/day |
| Reduction from Base | 41.5 kg/day |
| Reduction from Alt. I | 30 kg/day |
| Reduction from Alt. II | 13 kg/day |




——— Liquid
- - - - Vapor

Table 3-1. AIR POLLUTION IMPACT OF CONTROL ALTERNATIVES ON TYPICAL PLANT
(15,000 liters per day throughput operating 286 days/year)

| Control Alternatives * | Storage Tank Losses: Breathing[1] | Storage Tank Losses: Drainage[2] | | Storage Tank Losses: Filling[3] | | Storage Tank Losses: Total | Account Truck Losses: Loading | | Total Bulk Plant Losses | | Reduction from Uncontrolled Plant | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | kg/day | kg/day | kg/1000 l | kg/day | kg/1000 l | kg/day | kg/day | kg/1000 l | kg/day | m ton | kg/day | m ton/year |
| 1. Base Case - Uncontrolled (splash loading) | 9 | 7 | 0.46 | 17 | 1.15 | 33 | 21 | 1.4 | 54 | 15.4 | -- | -- |
| 2. Alternative I - Bottom or top submerged loading of account truck. | 9 | 7 | 0.46 | 17 | 1.15 | 33 | 9 | 0.6 | 42 | 12.0 | 12 | 3.4 |
| 3. Alternative II - Bottom or top submerged loading with vapor balance of transport trucks and storage tanks. | 9 | 7 | 0.46 | 0 | 0 | 16 | 9 | 0.6 | 25 | 7.1 | 29 | 8.3 |
| 4. Alternative III - Bottom or top submerged loading with vapor balance of storage tanks, transport and account trucks. | 9 | 3.5 | 0.23 | 0 | 0 | 12.5 | 0 | 0 | 12.5 | 3.6 | 41.5 | 11.9 |

* Assume no leaks

1 Three fixed roof above-ground storage tanks (3.2 x 8 meters)
2 Assuming 20 percent HC concentration in account trucks
3 Assuming ideal gas laws

## 3.4 REFERENCES

1. "Supplement No. 7 For Compilation of Air Pollutant Emissions Factors," Second Edition, U.S. EPA, Library Services, MD-35, Research Triangle Park, N.C. 27711, April 1977.

2. "Compliance Analysis of Small Bulk Plants," U.S. EPA, Enforcement Division, Region VIII, Contract No. 68-01-3156, Task Order No. 17, October, 1976.

3. Reference 2.

4. "Control of Hydrocarbons From Tank Truck Gasoline Loading Terminals," Guideline series, EPA-450/2-77-026, U.S. EPA, Office of Air Quality Planning and Standards, October, 1977.

5. Reference 2.

# 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 from the transfer and storage of gasoline at gasoline bulk plants.

### 4.1.2 Scope

Control costs have been developed for the three control alternatives described in Chapter 3, namely, I - conversion to submerged filling of account trucks, II - conversion to submerged filling of account trucks with vapor balance of transport trucks and storage tanks, and III - conversion to submerged filling of account trucks with vapor balance of account trucks, transport trucks and storage tanks. Costs associated with prevention of accidental emissions such as spillage are not included. Costs for applying controls to existing plants are included, but costs for new plants are not included.

### 4.1.3 Use of Model Plants

Two model plants are used. The 15,000 liter per day throughput model represents the smaller bulk plants and consists of three storage tanks, one loading rack with three arms, and two account trucks, each with four compartments. The 76,000 liter per day model represents the larger bulk plants and consists of the same equipment as the smaller model, with two additional account trucks.

The process for which costs are estimated includes two emission points: emissions during transfer from transport trucks to storage tanks and emissions during transfer from storage tanks to delivery (account) trucks. Although any actual plant will have costs which differ from the model plants, the model is an average which reflects the extreme variability of actual costs. As such, the model plant is a more accurate estimate than any single actual plant cost.

### 4.1.4 Bases for Capital and Annualized Cost Estimates

Capital costs include hardware, freight, installation, and sales tax. For conversion to the top-submerged fill technique, the estimate is based on costs of extender piping, swing joints, connecting materials and fittings, freight and tax, and installation labor for a plant with one three-armed loading rack, as shown in Table 4-1. For conversion to the bottom fill technique, the estimate is based on a major overhaul of existing pumps, product flow lines, and the concrete pad (which together comprise what is commonly called the loading rack) at an average cost of $1700;[1] in addition to the conversion of two trucks, each at a cost of $2600.[2] For vapor balance systems, the estimate is based on actual purchase data from permit applications of 45 bulk plants in Colorado during 1976 and 1977. This data was part of a larger inventory of about 250 bulk plants in the Denver (Colorado) and San Joaquin Valley (California) areas.[3] Data from the Colorado plants are considered a more accurate representation of cost than the larger sample, which was conducted primarily by telephone and short personal interviews with bulk plant owners, and which consisted of estimates of potential purchases rather than actual records of purchase prices.

Annualized costs consist of (1) operating costs, i.e., labor, utilities, and maintenance, (2) capital charges, i.e., interest, taxes, insurance, and

Table 4-1. PARAMETERS OF MODEL PLANTS

| | | Small Model | Large Model |
|---|---|---|---|
| 1. | Throughput | 15,000 liters/day | 76,000 liters/day |
| 2. | Loading Racks | 1 | 1 |
| 3. | Storage Tanks | 3 | 3 |
| 4. | Account Trucks | 2 | 4 |
| 5. | Compartments per Account Truck | 4 | 4 |
| 6. | Value of Gasoline | $0.10 per liter | $0.10 per liter |
| 7. | Density of Gasoline | 0.739 kg/liter | 0.739 kg/liter |
| 8. | Emissions | | |
| | a. Uncontrolled | 54 kg/day | 274 kg/day |
| | b. Control Alternative I | 42 kg/day | 213 kg/day |
| | c. Control Alternative II | 25 kg/day | 127 kg/day |
| | d. Control Alternative III | 12.5 kg/day | 63 kg/day |
| 9. | Working Days per Year | 286 | 286 |
| 10. | Maintenance (% of capital cost)[a] | 3 | 3 |
| 11. | Capital Charges (% of capital cost)[b] | 17.17 | 17.17 |

[a] Pacific Environmental Services, Inc., Evaluation of Top Loading Vapor Balance Systems for Small Bulk Plants, Contract No. 68-01-4140, Task Order No. 9, June, 1977, p. V-3.

[b] Capital recovery factor for 15-year equipment life and 10 percent interest is 13.17 percent of capital, to which is added 4 percent for taxes, insurance, and administration.

administration, and (3) gasoline credit for recovery of gasoline as a salable product. Operating costs are negligible for conversions to top-submerged or bottom fill techniques, and are limited to maintenance costs for vapor balance equipment, which is estimated to be 3% of the installed capital cost. Capital costs are computed using a capital recovery factor based on a 10% interest rate during a fifteen-year equipment life, plus a 4% charge to cover taxes, insurance, and administration. Gasoline credit is a reduction to annualized costs by the amount of gasoline retained for sale by not being emitted as vapor. The credit is calculated by multiplying the controlled emissions by $.10 per liter, as shown in Table 4-2.

## 4.2 CONTROL OF EMISSIONS FROM UNLOADING AND LOADING AT GASOLINE BULK PLANTS

### 4.2.1 Model Plant Parameters

Table 4-1 shows the physical parameters of the two model plants. It is assumed that the larger plant uses two additional account trucks for its increased throughput, even though the increased throughput might possibly be handled by increased frequency of trips with the same number of account trucks. In computing emission reductions for the large model plant, the emission reductions for the small model plant were multiplied by the size ratio of 76,000 liters per day divided by 15,000 liters per day.

4.2.2 Control Costs

Shown in Table 4-2 are cost estimates for the three control alternatives and for the two model plants. The table begins with estimates of installed capital costs, identifies annualized operating costs, and concludes with a cost-effectiveness ratio which relates the net annualized cost to the annual emission reduction for each control alternative. As mentioned in Section 4.1.4, the estimates for vapor balance systems are averages from actual purchase costs. Estimates for bottom loading conversion originated as part of the larger inventory discussed in Section 4.1.4.

The net annualized cost is the sum of the operating costs and capital charges, less gasoline credit. For the smaller model plant, the net annualized cost ranges from a $330 credit with conversion to top-submerged fill technique under Control Alternative I to a $1,150 cost for bottom loading under Control Alternative III. For the larger model plant, net annual cost ranges from a $2,340 credit with conversion to top-submerged fill technique under Control Alternative III to a $10 cost with bottom-loading Control Alternative II. As Table 4-2 shows, top-submerged loading is less costly than bottom-loading for both models and for all control alternatives. This results from the relatively large average cost of converting to bottom loading of $2600 per account truck and $1700 per loading rack.

Capital costs for conversion to top-submerged fill technique are the same for the smaller and the larger model bulk plants. Differences in total cost among the three control alternatives arise from cost components other than conversion to the top-submerged fill technique. The first difference is in vapor recovery equipment required

Table 4-2. COST ESTIMATES FOR CONTROL OF HYDROCARBON EMISSIONS FROM THE TRANSFER AND STORAGE OF GASOLINE AT GASOLINE BULK PLANTS (IN THOUSANDS OF 1976 DOLLARS)

| | CONTROL ALTERNATIVE I Conversion to Bottom or Top-Submerged Loading of Account Truck | | | | CONTROL ALTERNATIVE II Conversion to Bottom or Top-Submerged Loading of Account Truck, with Vapor Balance of Transport Trucks & Storage Tanks | | | | CONTROL ALTERNATIVE III Conversion to Bottom or Top-Submerged Loading of Account Trucks with Vapor Balance of Both Account Trucks & Transport Trucks and Storage Tanks | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Bottom Loading (l/day) | | Top-Submerged Loading (l/day) | | Bottom Loading (l/day) | | Top-Submerged Loading (l/day) | | Bottom Loading (l/day) | | Top-Submerged Loading (l/day) | |
| | 15,000 | 76,000 | 15,000 | 76,000 | 15,000 | 76,000 | 15,000 | 76,000 | 15,000 | 76,000 | 15,000 | 76,000 |
| Conversion Cost | 6.91 | 12.11 | 0.73 | 0.73 | 6.91 | 12.11 | 0.73 | 0.73 | 6.91 | 12.11 | 0.73 | 0.73 |
| Vapor Balance Cost | -- | -- | -- | -- | 1.40 | 1.40 | 1.40 | 1.40 | 2.80 | 2.80 | 2.80 | 2.80 |
| Installed Capital[a] | 6.91 | 12.11 | 0.73[b] | 0.73[b] | 8.31 | 13.51 | 2.13 | 2.13 | 9.71 | 14.91 | 3.53 | 3.53 |
| Direct Operating Costs[c] | 0 | 0 | 0 | 0 | 0.04 | 0.04 | 0.04 | 0.04 | 0.08 | 0.08 | 0.08 | 0.08 |
| Capital Charges | 1.18 | 2.08 | 0.13 | 0.13 | 1.42 | 2.32 | 0.37 | 0.37 | 1.67 | 2.56 | 0.61 | 0.61 |
| Gasoline Credit[d] | (0.46) | (2.35) | (0.46) | (2.35) | (0.46) | (2.35) | (0.46) | (2.35) | (0.60) | (3.03) | (0.60) | (3.03) |
| Net Annual Cost/(credit) | 0.72 | (0.27) | (0.33) | (2.22) | 1.0 | 0.01 | (0.05) | (1.94) | 1.15 | (0.39) | .09 | (2.34) |
| Controlled Emissions[e] (in units of 1000 Kg) | 3.43 | 17.38 | 3.43 | 17.38 | 8.29 | 42.00 | 8.29 | 42.00 | 11.87 | 60.14 | 11.87 | 60.14 |
| Cost/(credit) per Kg (in units of $/Kg) | 0.21 | (0.02) | (0.10) | (0.13) | 0.12 | 0.00 | (0.01) | (0.05) | 0.10 | (0.01) | 0.01 | (0.04) |

[a]All installed capital costs, except for note b, below, are from the survey indicated in reference 1, supplemented by certain truck conversion costs from the analysis indicated in reference 2. The cost of each control alternative includes the cost of exactly those components which are stated in the title of the control alternative. For example, control alternatives II and III include the vapor balance equipment costs indicated plus the costs of bottom or top-submerged loading, as indicated in the titles.

[b]Catalogue E - 12/72, Revised 9/74, Emco Wheaton, Inc., Price List D, E-10/76. Based on the use of extender pipes and loading arms, cost estimates are: Piping cost (48" x 4") ($71.00) + Swing joint (4") ($128.50) = $199.50 + Tax and Freight (119.50 x .07) ($13.96)+ Labor (3 man-hrs x $10) ($30.00) = a total of $243.46. The typical plant has one rack with three arms: 3 x 243.46 = $730.38 per plant.

[c]Pacific Environmental Services, Inc., Final Report: Economic Analysis of Vapor Recovery Systems on Small Bulk Plants, September, 1976, p. 4-2, and Pacific Environmental Services, Inc., Evaluation of Top Loading Vapor Balance Systems for Small Bulk Plants, Contract No. 68-01-4140, Task Order No. 9, June 1977, p. V-3. Direct operating costs are estimated to be 3 percent of installed capital cost. For control alternatives II and III, the 3 percent is applied only to the vapor balance equipment cost, since the top-submerged and bottom-loading conversions are considered to have negligible maintenance and thus negligible operating costs.

[d]Computed as follows: Emission reduction credited to bulk plant in Kg per day x 286 working days per year x 1.353 $\frac{1.}{\text{Kg}}$ x $.10 per liter. For the 15,000 liter/day plant: Control Alternative I: 12 x 286 x 1.353 x $.10 = $464.35; Control Alternative II: 12 x 286 x 1.353 x $.10 = $464.35; Control Alternative III: 15.5 x 286 x 1.353 x $.10 = $599.78. For the 76,000 liter/day plant: corresponding costs x $\frac{76}{15}$

[e]Computed as follows: Total Emission Reduction in Kg per day x 286 working days. For the 15,000 liter/day plant: Control Alternative I: 12 x 286 = 3432; Control Alternative II: 29 x 286 = 8294; Control Alternative III: 41.5 x 286 = 11,869. For the 76,000 liter/day plant: corresponding costs x $\frac{76}{15}$

for each control alternative. Secondly, for the larger model plant, two additional trucks have to be converted to bottom fill.

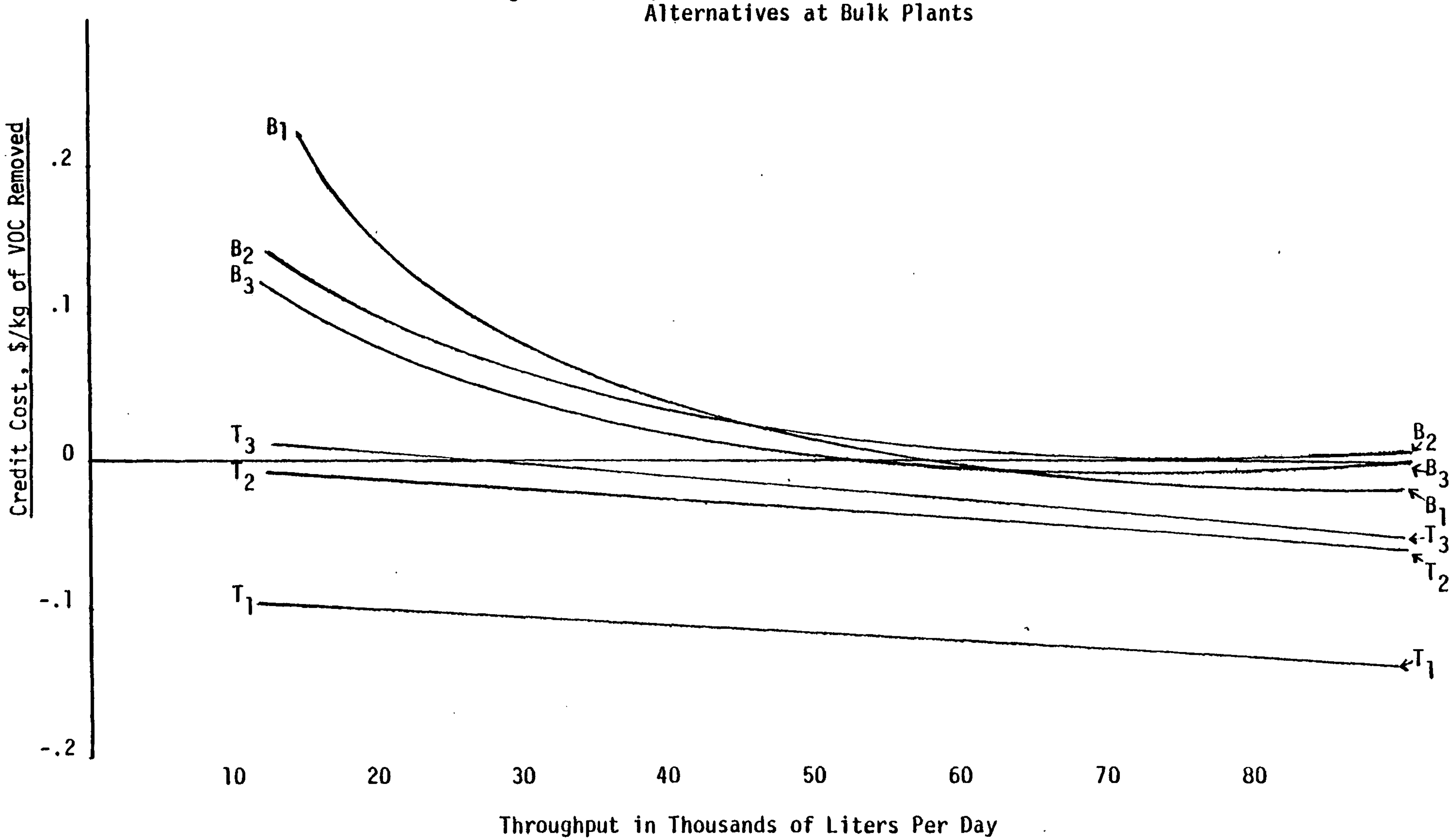
The installed capital cost estimates for vapor balance systems of $1400 for Control Alternative II and $2800 for Control Alternative III, shown in Table 4-2, are believed to be the most likely estimates for the model plants under consideration. It is possible, however, that actual control costs will vary from these estimates. Based upon information from the California Air Resources Board, it is estimated that installed capital costs for vapor balance for the model plants may vary from $1000 to $4200 for Control Alternative II and from $2000 to $8400 for Control Alternative III.[4]

4.2.3 Cost-Effectivenesses

Comparisons of the ratio of net annualized cost to controlled emissions are shown in Table 4-2 as cost/(credit) per kilogram of hydrocarbon emissions reduced. Since the ratio is cost divided by results, instead of vice-versa, low numbers are better than high numbers. Additionally, Figure 4-1 shows a graphical comparison of the cost-effectivenesses. For purposes of preparing the curves in Figure 4-1, an intermediate model plant with three delivery trucks and a throughput of 45,420 liters per day was used.

Several relationships are visible in Figure 4-1. First, the cost-effectiveness of each control alternative improves with increasing throughput. Secondly, the top-submerged option of each control alternative is more cost-effective than any control alternative using the bottom-fill option. Also, the top-submerged options remain in the same order of cost-effectiveness, regardless of throughput. Third, when the bottom-fill option is used,

Figure 4-1. Cost-Effectiveness of VOC Control Alternatives at Bulk Plants




Legend

B = Conversion to Bottom-fill
T = Conversion to Top-fill

1 = Control Alternative I
2 = Control Alternative II
3 = Control Alternative III

throughput is a determining factor: Below 45,000 liters per day Control Alternative I is the most cost-effective, but above this throughput Control Alternative II is the most cost-effective of the three alternatives. Similarly, above 62,000 liters per day Control Alternative III becomes more cost effective than Control Alternative I. Looking back from Figure 4-1 to Table 4-2 it is clear that while capital costs for bottom loading increase in going from Control Alternative I through Control Alternative II to Control Alternative III, the cost-effectiveness of the three alternatives improves, but the same progression through the control alternative using top-submerged loading results in worsening cost-effectiveness.

### 4.2.4 Source of Cost Information

The data shown in Table 4-3 is the basis for the cost estimates shown in Table 4-2. The data originated from permit applications recorded in the Colorado Air Pollution Control Division in October, 1976. In relating these data to the three control options, it was necessary to use averages. The estimate of $2600 for the conversion of a truck to bottom loading, as stated in Section 4.1.4, originated in an earlier study, indicated in reference 2. The purpose of Table 4-3 is to indicate the range of the values used as the basis for estimates.

Table 4-3. COLORADO BULK PLANT COSTS

A. Costs of Truck and Rack Conversions

| Throughput (litres/day) | No. of Plants | Inbound Recovery Only | For Delivery to Vapor Recovery Customers |
|---|---|---|---|
| 0 - 15,140 | 21 | Avg. $1,266<br>High $2,200<br>Low 300 | Avg. $2,800<br>High $4,000<br>Low $1,600 |
| 15,141 - 37,850 | 20 | Avg. $1,513<br>High $5,000<br>Low 250 | Avg. $3,490<br>High $5,000<br>Low $2,700 |
| 37,851 and higher | 4 | Avg. $1,000<br>High $1,000<br>Low $1,000 | Avg. $4,500<br>High $5,000<br>Low $4,000 |

B. Cost Breakdown

1. To convert tanks to return vapors during in-bound loading of bulk plant (all 45 plants affected):

   Average: $1,100 per plant ($300 per tank)

2. To add long loading arms to plants serving only exempt accounts:

   Average: $807 for telescoping sleeve assembly (Approximately 3 installed)

   Most installed long tubes on existing loading arms at $45 each. Approximately 75 installed. Most plants already had long tubes.

3. To modify loading racks to accommodate vapor recovery of out-bound loading to trucks delivering to controlled accounts:

   a. For bottom loading system for trucks that can also load at terminals (large nozzles):

      Average: $2,000 (3 plants affected)

   b. For bottom loading with a Wiggins System (small nozzle):

      Average: $1,000 (5 plants affected)

4. To modify delivery trucks filling at bulk plant and delivering to controlled accounts:

   a. Large nozzle system: $1,000 per compartment (usually four to five per vehicle)

   b. Wiggins System: $900 - $1,500 per vehicle.

## 4.3 REFERENCES

1. Joseph, David, (U.S. Environmental Protection Agency Regional Office VIII) and Mark Parsons (Air Pollution Control Division, Colorado Department of Health), Records of Permit Applications, Air Pollution Control Division, Colorado Department of Health, October 17, 1977.

2. Economic Analysis of Vapor Recovery Systems on Small Bulk Plants, U.S. EPA, DSSE, Contract No. 68-01-3156, Task Order No. 24, September, 1976, p. 4-3.

3. Study of Gasoline Vapor Emission Controls, Contract No. 68-01-3156, Task Order 15, U.S. Environmental Protection Agency, Region VIII, Pacific Environmental Services, Inc., December, 1976, p. 2-1.

4. Simeroth, Dean, California Air Resources Board, November 23, 1977.

# 5.0 EFFECTS OF APPLYING THE TECHNOLOGY

Air pollution impacts and other environmental consequences of applying control technology presented in Chapter 3 are discussed in this chapter.

## 5.1 IMPACT OF CONTROL TECHNIQUES ON HYDROCARBON EMISSIONS

To determine the actual emission reductions that would occur as a result of using each technique, it is necessary to estimate the reduction in air pollution the technique would effect beyond that which would otherwise be achieved by existing State or local regulations.

A number of States have developed regulations based on the recommendations of Appendix B of 40 CFR. For facilities with throughputs less than 20,000 gal/day (76,000 l/day), approximately 20 States required control of storage tanks (typically submerged fill) and only four States required control of loading facilities in 1975.

In 1973 and 1974, EPA promulgated regulations which affected gasoline bulk plants in 16 Air Quality Control Regions (AQCR's). Known as Stage I service station regulations, they required 90 percent control of VOC displaced during the filling of stationary storage tanks. They applied to all existing storage tanks of greater than 2000 gallon capacity. As an adjunct, they required that where vapor balance systems were employed (non-exempt accounts), the tank truck could be refilled only at facilities equipped to recover 90 percent or more of the displaced vapor. Most small bulk plants are believed to deliver only to exempt customers with tanks smaller than 2000 gallons; thus, these small bulk plants would not be required to install vapor control equipment if Stage I regulations were in force in that area. There are few data available which relate bulk plant throughput to size of customer tankage. Nonetheless, in the Denver (Colorado) area only 9 of 45 bulk plants were found to service "non-exempt accounts." The other 36 delivered gasoline only to accounts which were exempt from Stage I regulations because of tank size.

Table 3-1 lists emission factors and emissions for the uncontrolled plant and for the three control alternatives. For the typical bulk plant of 15,000 liters per day throughput, plant emissions can be reduced by 11.9 metric tons per year with a total (Alternative III) vapor balance system.

## 5.2 OTHER IMPACTS

EPA has examined secondary air impacts of applying control techniques to bulk plants and has also studied water pollution, solid waste, and energy impacts. There are no secondary air pollutants (as from power plants) since the applicable control technology does not consume energy. Neither are there significant adverse effects from either submerged fill, bottom loading, or vapor balance systems.

While the control systems handle flammable vapors, they do not present a safety hazard since vapor concentrations are greater than the upper explosive limit (too rich to burn). In many instances, they will be more safe to operate than existing uncontrolled bulk plants.

# 6.0 ENFORCEMENT ASPECTS

The purpose of this chapter is to define the affected facility to which the regulation will apply, to select the appropriate regulatory format, and to consider techniques that can be used to determine compliance with regulations.

## 6.1 AFFECTED FACILITY

A bulk plant is any facility loading gasoline into account trucks at 76,000 liters or less per day. This throughput distinguishes bulk plants from bulk terminals which are appreciably larger and employ different types of loading and storage facilities and different types of vapor control technology. The affected facility encompasses the unloading, loading, and storage facilities.

Account and transport trucks are included in the affected facility because: (1) the truck is the source of VOC vapors in a loading operation, (2) during loading the truck is physically connected to the facility, and (3) leaks from the truck can adversely affect the collection efficiency of the overall control system.

Storage tanks were included in the affected facility because: (1) they are significant sources in the plant, and (2) storage tanks must be vapor tight for the balance system to be effective.

## 6.2 STANDARD FORMAT

It would be impractical to apply a mass emission limit (kg/hr) or recovery efficiency (percent) for either Alternative I, II, or III.

Mass emissions will vary depending on the hydrocarbon concentration in the truck which may vary between 5 and 40 percent by volume depending on temperature, RVP, operating practices, and whether or not the vapors displaced from service station storage tanks (Stage I) were collected in the tank truck. Therefore, it is recommended that the standard format include equipment specifications and operating procedures as follows:

For top-submerged and bottom-fill (Alternatives I, II, and III)

1. The fill pipe is to extend to within 15 centimeters of the bottom of the account truck during top-submerged filling operations. The fill pipe is to extend to within 15 centimeters of the bottom of storage tanks during gasoline filling operations. Any bottom fill is acceptable if the inlet is flush with the tank bottom.

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

For balance system (Alternatives II and III)

1. Hatches of account trucks are not to be opened at any time during loading operations.

2. There are to be no leaks in the tank trucks' pressure vacuum relief valves and hatch covers, nor truck tanks or storage tanks or associated vapor return lines during loading or unloading operations.

3. Pressure relief valves on storage vessels and tank trucks are to be set to release at the highest possible pressure (in accordance with State or local fire codes, or the National Fire Prevention Association guidelines).

## 6.3 DETERMINING COMPLIANCE AND MONITORING

Determining compliance with Alternative I (bottom fill or top-submerged fill) will require only visual inspection to ensure minimal spillage of gasoline and proper installation of loading arm or bottom loading couples.

Compliance and monitoring procedures for Alternatives II and III (balance system) will be published at a later date. Compliance procedures under review include:

(1) Equipment specifications with qualitative leak checks using an explosimeter or combustible gas indicator calibrated on a 0-100 percent LEL (lower explosive limit, pentane) range.

(2) A rough quantitative test wherein the volume of air/hydrocarbon vented from the storage tank is measured and related to the volume of gasoline transferred.

(3) A quantitative full-scale test of the system employing flow meters and flame ionization detectors.

## TECHNICAL REPORT DATA
*(Please read Instructions on the reverse before completing)*

| | | |
|---|---|---|
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15. SUPPLEMENTARY NOTES

16. ABSTRACT

This report provides the necessary guidance for development of regulations to limit emissions of volatile organic compounds (VOC) from gasoline bulk plants. This guidance includes emission estimates, costs, environmental effects and enforcement; for the development of reasonable available control technology (RACT).

17. KEY WORDS AND DOCUMENT ANALYSIS

| a. DESCRIPTORS | b. IDENTIFIERS/OPEN ENDED TERMS | c. COSATI Field/Group |
|---|---|---|
| Air Pollution<br>Regulatory Guidance<br>Gasoline Loading<br>Vapor Balancing | Air Pollution Control<br>Stationary Sources<br>Organic Vapors | |

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