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The Control of Hydrocarbon Emissions from Gasoline Marketing Operations

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NOTE TO EDITORS

The purpose of this report is to review methods currently available for controlling hydrocarbon emissions generated during gasoline marketing operations. For this purpose, gasoline will be defined as a petroleum distillate with a Reid Vapor Pressure of 4 pounds or greater.[1] The need for controlling this source of emissions was initiated by Federal regulations promulgated in November of 1973. It was mandated that oxidant concentrations, in specific areas of the country, be reduced. This was to be achieved by limiting the amounts of oxidant-forming hydrocarbons from both stationary and mobile sources. The gasoline marketing network accounts for approximately 28% of total hydrocarbons being emitted from the petroleum industry and as such was a prime target for control. Hydrocarbon emissions from gasoline marketing result in about 1.4 million tons per year.[2] This paper discusses the methods of control which have been instituted within recent years for meeting the requirements of the regulations.

NETWORK OPERATION

The gasoline marketing industry contributes hydrocarbon compounds to the atmosphere through the mechanism of evaporation during the many handling processes involved in transferring gasoline from the terminal to the vehicle. If left uncontrolled, the industry would become a greater relative contributor to hydrocarbon emissions because other emission sources are being brought into control, because gasoline sales are increasing and because of increased reactivity of non-leaded gasoline vapors.

Terminal operations are the central point of the gasoline marketing network. Here the product is received by rail, truck, barge and pipeline and transported to the service station by tank trucks. Emissions are generated during the bulk terminal loading operation, during delivery to the service station and during vehicular refueling operations. Regulations have been promulgated for controlling emissions from the terminal and service station sources; regulations have been proposed for the vehicular refueling operation.

During the year 1973 106.5 billion gallons of gasoline were consumed in the United States.An average annual increase in consumption of about 5% is expected for the foreseeable future. The distribution was made through more than 25,000 bulk stations and terminals to over a quarter million service stations. Virtually, all gasoline product was transported by tank truck to the retail outlet. Because of the nature of this operation, the gasoline product can be subject to two or three transfers before being consumed. This factor makes the control of this source category increasingly important.

In most terminal operations, tank trucks ranging in size from 500 to 8500 gallons are loaded by a variety of techniques. The method used for loading has the greatest influence on the amount of emissions generated at the loading rack. Product can be transferred by splash loading techniques, where the stock is discharged into the upper part of the truck compartment through a short spout which never dips below the surface. The fall increases evaporation and can result in the loss of liquid droplets and subsequent entrainment of vapors. Subsurface or submerged loading operations result in rapid evaporation loss until the end of the loading spout is covered to give a calm surface. Most loading of this type requires that, ideally, the spout be within a few inches of the bottom of the compartment. However, because of the size and shapes of the various transport trucks, this ideal situation can be realized in only a certain percentage of the delivery vessels. Loading losses can be kept to a minimum by the use of bottom loading techniques where the transfer piping is connected directly to the tank bottom.[4]

To insure the maximum degree of control, regulations required that all displaced vapors and air be vented to a vapor collection or disposal system. This is accomplished by connecting a vapor recovery arm to the delivery vessel during loading. The vapor arm is a permanent fixture at the rack and allows the vapor to be directed to the control unit for processing. Recently, there have been many advances in the technology of controlling emissions at the terminal. To date, there are seven different types of systems available for this purpose. Vapor recovery or disposal units are connected to the loading rack and process gasoline vapors into liquid product, combust the vapors, or use the vapors as a source of fuel gas.

TERMINAL CONTROL SYSTEMS

Each type of system will be briefly described below:

(a) The operation of the compression-refrigeration-absorption system is based on absorbing vapors with cool gasoline. The vapors are first saturated to insure that they are above the upper explosive limit (UEL), compressed and then cooled before introduction into the absorber. Here, the vapors are bubbled through cold gasoline (at -10°F) and absorbed. Air is vented at the top of the absorber and gasoline product,drawn from the bottom of the absorber,is returned to storage. As in most recovery systems, the efficiency of the unit is dependent on the inlet hydrocarbon concentration. If necessary, booster compressors can be installed to increase recovery efficiency.

(b) Compression-refrigeration-condensation units recover vapor by first saturating the vapors above the UEL and then by compressing the vapors in a two cycle compressor equipped with an inter-cooler. Condensate is drawn from the inter-cooler prior to the second stage compressor. Compressed vapors are sent to a condenser where they are cooled and condensed. The vapors are then returned along with the condensate, from the inter-cooler, to storage.

(c) Lean-oil-absorption units operate by allowing the gasoline vapor to flow into a packed absorption column. The packing is continuously wetted by a stream of lean oil, which is gasoline stripped of its light ends. The clean air is usually passed through a demister to remove any entrained absorbent and the enriched gasoline is returned to storage. Lean or "sponge oil" absorbent is produced by heating gasoline from storage. All light ends from this heating are condensed and returned to storage. The quantity of lean oil is variable and is a direct function of the quantity of vapor flow to the absorber, the vapor temperature and the degree of vapor saturation.[5]

(d) Another method used for recovering gasoline vapor is the refrigeration system, based on condensing vapor at atmospheric pressure. This system employs a typical cascade refrigeration operation which produces temperatures in the evaporator-interchanger in the order of -100°F. A brine coolant is circulated through the finned tube sections of the vapor condenser and the gasoline vapor is passed over the sections of the condenser. Entrained moisture in the entering vapor condenses and collects as frost on the cold plate fins. Liquid hydrocarbon is collected at the bottom of the condenser. At periodic intervals, defrosting of the finned surfaces is accomplished by circulating warm brine from a separate storage reservoir. A two-stage refrigeration unit is used to cool the stored brine to about -120°F. Vapor holders are not required, since the unit operates on demand.[6]

(e) A recent development in reducing emissions of gasoline vapor has been the adsorption-absorption system. This process operates by adsorbing gasoline vapors on activated charcoal to near the saturation point of the charcoal and follows this with absorption of the recovered vapors with liquid gasoline. The design includes a duel charcoal bed system which allows one bed to operate while the other is being regenerated. Upon completion of regeneration, the bed operation is switched. Vapor holder tanks are not required since the vapor flow is directed straight to the charcoal bed.[7]

(f) One of the most direct vapor control systems is the flame oxidation method. Vapor emissions are controlled by combusting the vapor rather than recovering it. Gasoline vapor, displaced from the loading operation, is sent to a holder tank, which is used to reduce surging to the system and allow for an even air flow. Vapor is then drawn from the tank by a blower, compressed and fed to the oxidizer. A propane pilot light is used for oxidizer ignition and thus, a source of propane must be made available. The oxidizer operation is controlled by the gas volume in the vapor holder tank and starts at about 30% capacity and shuts down at about 10% capacity. Because of the nature of the operation, no recovered product tanks or lines are necessary. Capital and operating costs for these units are usually lower than that required for recovery units, but this can be offset by the economic loss of combusting the vapor rather than recovering it.[5,8]

(g) Another method of vapor disposal, by combustion, uses the heat generated by the operation as a source of space or process heat. Gasoline vapors are conducted to a saturator to obtain concentrations above the UEL. The enriched vapor is then sent to a vapor-holder tank, which is fitted with an internal diaphragm. When a preset level is approached, a negative pressure pump is activated and the vapors are sent to a standard burner. If the burner is oil-fired, a dual-burner system is needed to allow for proper combustion of the vapor feed. The capital expenditure necessary for this system includes ductwork, the vapor-holder tank and burner adjustment. However, this can be offset by savings in fuel oil consumption. High levels of burner efficiency must be maintained for compliance with Federal, State, or local regulations.

COST DATA

Table I depicts actual installed costs for a variety of systems presently in operation in New Jersey. Column I represents the cost of the unit and Column II shows an installed cost which includes all associated terminal work such as loading rack retrofit piping, electrical work, etc. Column III gives gasoline throughput at the rack to describe the units' work load. This data has been presented to illustrate the range of costs that may be encountered when installing a vapor recovery unit. Expenditures for each type of unit will fluctuate with the work load but not necessarily in arithmetic proportion. Most terminal units have been oversized to compensate for expected growth in gasoline consumption. Where cost data were available for more than one installation of a particular type unit, a range of costs and throughputs are supplied. It is difficult to generalize and use these figures for cost estimation at other terminals since different parameters will be encountered at each facility. For example, it may be desirable to retrofit an existing rack instead of demolishing it and rebuilding a new one. Piping costs will be dependent on diameter and lengths of pipe required. Labor costs will differ with geographical areas. The desired quality of the completed terminal will affect overall costs; resurfacing costs and quality of equipment must also be considered.

Table II presents an analysis of the actual associated costs for retrofitting a two-rack top loading operation to bottom loading. When considering annualized cost for the various types of units, utility and maintenance costs must be included in the estimates. Depending on the type and size of the unit, these costs can range from 2-5% of capital cost. Annualized costs for oxidation systems are dependent on the pilot light propane requirements.

Operating costs can be offset by the recovery of saleable product. For example, a 500,000 gallon/day terminal can recover about 600 gallons of gasoline product per day if all the displaced vapor is sent to the recovery unit and if the unit is operating at 90% efficiency. This also assumes bottom or submerged loading into trucks used exclusively for gasoline delivery to service stations equipped with vapor recovery. The recovered product consists of light ends, and is mixed in storage, usually with regular grades of gasoline. Thus, this product can be worth several hundred dollars per day, based on current resale value of gasoline. A typical calculation is shown in Figure I.

The reliability of vapor recovery systems must also be considered. For example, in New Jersey there are 26 terminals equipped with vapor recovery systems. As of March, 1977 there have been 257 total operating months, with a reported downtime of 10 months or 4%. Thus, reliability of operation is 96%. Most units are automated and require very little maintenance except for daily checks on operating parameters which are usually displayed on a control board for easy access. In the event of a system or component failure, the manufacturer will supply the required technical assistance. Units are commercially available for terminals with daily throughputs as low as 70,000 gallons and as high as one million gallons.

SERVICE STATION CONTROLS

Recovery of vapor generated during bulk delivery at the service station can be accomplished by a closed loop balance system which simply returns the displaced vapors to the delivery vessel. The liquid gasoline acts as a driving force sending the vapors back to the tank truck. Some important factors in designing an efficient balance system are the type of loading technique, vapor and liquid line fitting, vent pipe restrictions and vapor-tight delivery vessels. Design criteria calls for loading to be done with the use of a submerged fill pipe to keep splash effects at a minimum. Systems will also include dry-break or cam-lock fittings on the product and vapor return lines, to insure a tight fit and eliminate leaks. A restriction on the underground tank "breathing" vent line is necessary to establish a path of least resistance thus assuring a high percentage return to the tank truck.

Also, the tightness of the delivery vessel is extremely important. The trucks should be kept vapor-tight so that a maximum amount of recycled vapor can be returned to the terminal for processing through the recovery or disposal unit. Systems currently available on the market, include a two-point system (separate vapor and product line) and one-point or co-axial system where the liquid line is surrounded by an outer annular space for vapor return to the truck.

Recovery of vapors from vehicle refueling operations has generated much disagreement among the participating interests. It is uncertain whether balance-type systems can meet the requirements of the various codes. Efficient gasoline dispensing nozzle designs have been questionable. Vacuum-assisted systems, which create a negative pressure at the pump to capture the expelled vapors, are not desireable to the industry because of the high capital cost and questionable dependability. The vacuum-assist systems must be equipped with a secondary recovery or disposal unit to control the excess emissions generated by the evaporation of additional hydrocarbons in the additional ingested air. The main processing systems used in conjunction with vacuum assist are refrigeration, absorption, compression and oxidation. Some recent technology has sought to combine balance and vacuum-assist systems into a "hybrid" system which uses gasoline circulated through the dispensing nozzle as a source of vacuum. Hopefully, technology will soon be developed to satisfy both industrial and regulatory interests. Some typical cost data for retrofitting a service station for compliance with the bulk delivery and vehicular refueling regulations are given in Table III.[9,10]

SECONDARY BENEFITS

There are some ancillary benefits to be derived from controlling vapors generated during gasoline marketing operations. These will be considered below:

(1) Bottom loading techniques reduce the amount of vapor generated since there is less splashing of product. This is a direct saving of a valuable fuel. Tight fitting systems decrease the occurrence of spillage and thus, make the terminal area a safer place to work. Since bottom loading does not require the driver to load from the top of the truck, the incidence of falls will be eliminated. Bottom loading allows the operator to fill several compartments simultaneously and reduces overall fill time. The loading racks are equipped with automatic sensors to terminate loading and prevent compartment overfill.

(2) The gasoline fraction that is recycled results in a direct conservation of a valuable resource. It has been estimated that about 9 million gallons per year of gasoline fractions can be recycled in N.J., based on 1973 consumption. Resale of the recovered fraction will assist in recouping capital and operating expenses.

(3) By returning service station losses to the delivery trucks, a level above the UEL is constantly maintained in tight trucks, thus, eliminating any explosion hazard. Vapor concentration in retrofitted trucks is about 15-20% and does not approach the UEL of 7.6%. Criteria require that delivery vessels are to be inspected at least semi-annually by leak testing procedures to insure vapor tightness.

(4) Systems that use the captured vapor as a source of fuel result in a saving of valuable fuel oil and utilize an energy source that would have been wasted.

(5) The use of vapor recovery and disposal systems can reduce the emissions os suspected carcinogenic compounds of gasoline. Benzene and associated aromatic components constitute the largest percentage of suspected carcinogenic agents in the stock. The liquid phase content of benzene can range from 0.5% to 2.0% by liquid volume percent for regular and premium grades. For purposes of maintaining octane ratings, unleaded gasolines contain a higher benzene content, usually about 2.5% liquid volume percentage. With the increased use of unleaded fuels, (projected as a 10% increase per year) this problem will grow. More data must be compiled to adequately determine the magnitude of the problem.

(6) It is also possible that lead particles may be transported and emitted in the vapor phase. However, due to the lack of available data, this statement cannot be made with a high level of confidence. Further studies into this area are necessary.

CONCLUSIONS

Systems are currently available for meeting requirements of regulations controlling vapor emissions generated during the gasoline marketing operation. Technology has been developed to recover or dispose of 90% of vapors displaced during truck loading operations at the bulk terminal. Service station control systems can also effectively recover 90% of normal vapor loss during delivery operations. A cost-effective technology for vehicular refueling control is still in the development stage. The available control systems have been found to be reliable and will aid in the achievement and maintenance of the national ambient air quality standard for oxidants by reducing the emissions of precursor hydrocarbons.

Secondary benefits will also be realized by the implementation of these controls. Gasoline product will be recovered and recycled, the terminal and service station environment will be a safer and more pleasant area to work. Valuable fuel will be conserved and emissions of suspected carcinogenic agents will be reduced.

FUTURE CONSIDERATIONS

It is not yet known to what geographical extent these regulations will be applied. Presently, there are portions of seven states and Washington, D.C. where gasoline marketing controls have been required. Since technology is proven and available, this source of emissions can readily be controlled.

Vapor balance systems can be used at bulk loading stations which are secondary distribution facilities that receive gasoline from larger terminals by tank truck. Recovery and disposal systems can be sized for controlling emissions generated during marine loading operations. Losses from this source can be significant because of the large volumes handled. Marine controls should be considered for transporting the new sources of oil from the Alaska North Slope to the West Coast and for similar oil discoveries off the East Coast. Marine controls are being contemplated for the Houston-Galveston Area. In some cases, product is stored in underground tanks in waterfront terminal operations. Breathing and working losses, from these tanks, can also be controlled in conjunction with barge loading.

Table I

Capital Expenditure Vapor Recovery at the Terminal[A]

Type Unit	Column I Unit Cost ($10^3)	Column II Associated Installed Cost ($10^3)[B]	Column III Product Throughput
Compression-Refrigeration Absorption (range)	60-80	70-90	80,000- 325,000 gal/day
Compression-Refrigeration Condensation	250	125	385,000 gal/day
Lean-Oil-Absorption[C]	140	Not Available (N.A.)	500,000 gal/day
Refrigeration (range)	50-155	N.A. 500	70,000- 1,000,000 gal/day
Adsorption-Absorption	80	50	70,000 gal/day
Flame Oxidation	90	300	200,000 gal/day
Fuel Disposal System	---	350[D]	820,000 gal/day

[A]Data supplied is in 1974-76 dollars.

[B]Assume, two gasoline loading racks with a total of 12 loading arms.

[C]It is believed that this type of system has been removed from the market.

[D]Cost is $100,000 for saturator and vapor holder; $100,000 for piping (1300 ft.) and $150,000 for rack retrofit.

Table II

Associated Capital Expenditures

Item	Cost ($)
Rack Conversion[A]	80,000 (2 racks, 4 positions)
Combined Piping[B]	125,000
Labor	42,000
Meters[C]	25,000
Land Improvement[D]	33,000
Truck Retrofit (Bottom Load)	1500-2500 per compartment

[A] Includes reworking of rack from top splash to bottom load. (Cost of a top submerged arm $3500; cost of bottom load arm = $1100)

[B] Dependent on distance from loading rack to vapor recovery unit.

[C] Includes electrical meters and pre-set shut off switches.

[D] Includes unit foundation, area resurfacing, drainage system. Dependent on desired quality of completed retrofit terminal.

Note: The above represents actual on-site costs incurred by terminal operators throughputting 500,000 gallons/day.

Table III

Costs Service Station

A. Delivery Controls Only[A]

Two-Point System	$3100		
Co-Axial System	$2000		
Component Estimates	Excavation	42%	
	Labor	32%	
	Piping	20%	
	Valve Fittings	6%	

[A]Assume balance system for a station equipped with four underground tanks.

B. Delivery and Vehicular Refueling Controls[B]

Drybreak fittings	$ 320	
Excavation	$ 600	
Vapor pipes from dispenser	$1350	(assume 450 ft. total)
Installation of pipes	$1300	
Nozzles and hoses	$ 870	
Installation of nozzles	$ 240	
Trucks, compressor and misc. piping	- $ 300	
TOTAL	- $4,980	

Vacuum assist unit		$3000- $5800
Total cost	$8000	$10,800 (approximate)

[B]Costs include total service station retrofit for a station with a throughput of 30,000 gal. per month using six nozzles.

Example Calculation

Assume gasoline product throughput of 500,000 gallon/day with an RVP=10. Product temperature is 60°F and is loaded into trucks returning from service stations equipped for vapor recovery.

Uncontrolled Emission Factor for Gasoline 8 lb/1000 gallons transferred[2]

$$500{,}000\ \frac{\text{gallons}}{\text{day}} \times \frac{8\ \text{lb}}{1000\ \text{gallons}} \times 90\%\ \text{control}\quad 3600\ \text{lb/day}$$

Liquid density 6.2 lb/gallon

Thus,

$$3600\ \frac{\text{lb}}{\text{day}} \div 6.2\ \frac{\text{lb}}{\text{gallon}}\quad 581\ \text{gallons}$$

Net price; ex-tax of gasoline (1/76) - 35.2¢/gallon

Dollar value of recovered product is:

$$581\ \frac{\text{gallons}}{\text{day}} \times \frac{\$.352}{\text{gallon}}\quad \$204.51/\text{day}$$

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