a US perspective on hydrocarbon controls at service stations

A paper by Lee M. Thomas, Chairman and CEO of Law Environmental and former Administrator of the US Environmental Protection Agency, presented at the international workshop on refuelling emissions held in Berlin on 2nd November 1989.

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ABSTRACT

This paper was presented by Lee M. Thomas, Chairman and CEO of Law Environmental and former Administrator of the US Environmental Protection Agency (EPA), at the international workshop on refuelling emissions, held in Berlin on 2nd November 1989.

The US government has had 20 years experience with legislation for control of VOC emissions from the gasoline distribution system and gasoline fuelled vehicles. The decision made by some US states in the early 1970s to require Stage I gasoline vapour controls at marketing terminals and service stations, and on-board vehicle evaporative emission controls using small carbon canisters, have proved highly effective. But extending controls at a later date to address vehicle running losses and refuelling emissions has the potential for duplication of effort or application of less effective controls. Only in recent years has the EPA discovered the significance of managing car evaporative emissions, including running losses, and refuelling losses together. The on-board strategy, using enlarged carbon canisters, is the most efficient and cost-effective pollution control option and is safe.

The European Community is at a crossroads where evaluating the US experience is helpful in finalizing the approach so that advantage can be taken of the on-board system for the cause of environmental protection.

FOREWORD

The author, Mr Lee M. Thomas, the Chairman and CEO of Law Environmental and former Administrator of the US Environmental Protection Agency during President Reagan's Administration, presented this paper at the International Workshop in Berlin on control of gasoline emissions from vehicle refuelling at service stations, organized by the Federal Environmental Ministry of the Federal Republic of Germany..

At the workshop were representatives from the European Commission, the Austrian, Dutch, German, Swedish and Swiss government environmental ministries/agencies and California Air Resources Board, and the German automobile, emission control manufacturing and European oil industries including CONCAWE. The objective of the workshop was to gather together the results of the German research into the on-board system (enlarged carbon canisters installed on cars), and various practical experiences of Stage II at service stations (special fuel dispensers to recover car fuel tank vapour for return to service station underground tanks).

The consideration of this recently available information is vital to the making of a rational choice for Europe between these two options for control of refuelling emissions from gasoline engined vehicles. This falls within the overall context of closing the gasoline system to counteract atmospheric pollution by volatile organic compounds (VOCs) from automotive sources. The technical data and cost assessments continue to show that evaporative emissions, including running losses, and refuelling emissions are best controlled by the on-board system.

A U.S. PERSPECTIVE ON HYDROCARBON CONTROLS AT SERVICE STATIONS

If America is to be labeled with one cause in the late 1980s, it would have to be environmentalism. The closing years of this decade have been characterized by an immense rise in the public's knowledge and concern with water quality, hazardous waste disposal and other environmental issues. Analogous sentiments are arising across the globe, small and large showings of concern that reflect mankind's growing intolerance for environmental neglect and abuse. This has led to a careful examination of control methods for all sources of emissions. Today we are discussing control of one of those sources, vehicle refueling emissions. The U.S. Environmental Protection Agency (EPA) has spent nearly twenty years studying this subject, its challenges and its remedies. This effort has generated scientific studies on every aspect of the problem, including: health effects, vapor recovery device design and effectiveness costs and benefits, and system safety. U.S. industry has similarly devoted large resources to the study of refueling emissions and vapor recovery devices. This long endeavor has led me to believe that the onboard canister is the preferred option for refueling vapor recovery.

Of special importance to Germany at this juncture, EPA also believes that an enlarged onboard canister can effectively contain evaporative emissions and running losses as well as refueling emissions. Since 1970 the U.S. has conducted a research and regulatory program that has until recently addressed each of these three emissions separately. Were the U.S. to do it over again, I am confident that the enlarged onboard canister, with its greater effectiveness and safety, would be the main thrust of the effort. Germany now has the opportunity to take a leadership role in objectively evaluating the U.S. experience with refueling emission control. It can carefully plan an onboard program which will bypass the less effective intermediate steps of emissions control.

I would like to present a brief overview of my experience with refueling controls during my tenure as Administrator of the EPA. It is my hope that the knowledge and lessons learned there may be transferred to the decision-making process here in Germany.

THE U.S. PROBLEM AND CONCERNS IN THE 1980s

The passage of the Clean Air Act Amendments in 1970 was the U.S. government's first major effort at recognizing and addressing the air pollution problems generated by stationary and mobile sources. Amended many times, this legislation is the basic mandate from which the EPA issues air quality regulations and standards. Clean Air Act provisions regulate both ambient ozone levels and benzene emissions, the two main pollutants of concern in relation to refueling emissions.

Ozone Non-Attainment

The composition of refueling vapors depends on their sources (e.g. fuel tank displacement or spillage), the fuel type, and the volatility of the fuel. On average, however, emissions are at least ninety percent light-end hydrocarbons, also known as volatile organic compounds (VOCs). In the presence of sunlight, VOCs combine with other chemicals to produce ozone. The problems associated with ambient ozone exposure are well-documented, including pulmonary irritation and increased susceptibility to bacterial infection. Ozone adversely affects vegetation and causes damage to various types of elastic compounds. It is also believed to be a contributor to acid deposition.

In accordance with the Clean Air Act, the EPA promulgated and revised primary and secondary National Ambient Air Quality Standards (NAAQS) for ozone in the 1970s. These standards are intended to protect the public health and welfare with an adequate margin of safety. The initial timeline called for nationwide compliance with these standards by 1982. Despite the imposition of various hydrocarbon controls, EPA estimates that as many as one hundred urban zones and one hundred million people in the U.S. may live in areas that exceed the ozone standard.

While ambient ozone levels in Germany are much lower than the peaks experienced in the U.S., there is general agreement that VOC emissions should be controlled. Because of its efficiency and effectiveness in reducing VOC emissions from three sources, studies by CONCAWE, the oil companies' European organization for environmental and health protection, indicate that the adoption of a comprehensive onboard canister system will allow Germany to reduce its total automotive VOC emissions by more than thirty percent.

Gasoline/Benzene Health Effects

U.S. refueling vapors consist of less than one percent benzene, by weight. In 1977 benzene was listed by the EPA as a hazardous air pollutant, the result of studies which strongly suggest that exposure to the high levels of benzene reported in some industrial settings causes leukemia. The much lower levels of benzene exposure experienced in service stations would result in a significantly smaller risk. By addressing all vehicle evaporative emissions with a well-designed onboard system, benzene emissions will be controlled along with VOCs.

While refueling emissions account for a relatively small percentage of total VOC emissions, since they contain benzene, it is advisable to control them as an added precaution. As I will describe later, the EPA has proposed the onboard system as a sensible, effective method of controlling these emissions.

EFFORTS TO DATE

While today's discussion concerns the management of refueling emissions, much U.S. effort has been invested in the control and reduction of other automotive and stationary source emissions. Pragmatic decision-making has produced solutions which manage to improve air quality in a cost-effective manner. The success of these strategies, and the possible implications for similar German programs, merits a short overview.

Stationary Sources - Stage I Devices at Terminals and Service Stations

Stage I controls refer to a variety of techniques for avoiding VOC emissions at marketing terminals and when gasoline is delivered to service stations. They have been mandatory in the U.S. since the early 1970s and have proved to be highly effective. At marketing terminals, Stage I includes the use of floating roof tanks and vapor recovery at loading racks for tanker trucks. At service stations, Stage I systems capture the vapors which are displaced during the filling of the station's underground tank. As gasoline is pumped from the tanker truck to the underground tank, the vapor is channeled to the available volume in the tanker. The truck then transports the vapor back to the marketing terminal where it can either be recovered as gasoline or disposed of in an environmentally sound manner. My understanding is that the EC is considering a directive which would require Stage I controls at both service stations and marketing terminals. CONCAWE estimates that adoption of Stage I across the EC would reduce VOC emissions by two hundred thousand metric tons per year.

Auto Exhaust

I believe that most of you are familiar with the history of automotive exhaust controls in the U.S., so I will limit my comments to some of the more recent developments. One of the most impressive is the improvement in the quality and sophistication of catalytic emission control systems. According to published EPA data, ten percent of the cars certified in 1988 emitted 0.1 grams per mile or less of hydrocarbons, and fifty percent emitted 0.21 grams per mile or less. These low rates have been achieved by imported German automobiles, which have had to meet all of the exhaust standards. Clean Air Act Amendments that are currently being debated in Congress call for a 1994-1996 phase in of a 0.25 grams per mile hydrocarbon standard. The ability to meet this stringent standard, however, can be easily compromised by an improperly maintained system. Well designed inspection/maintenance programs can be one of the more cost-effective ways of controlling exhaust emissions. As many of you know, such programs are being implemented in certain U.S. locations, and the issues of inspection and maintenance are currently receiving a large amount of attention in Congress' Clean Air Act debates.

Auto Evaporative Emissions

In place in the U.S. since 1970, evaporative emissions controls have efficiently curtailed VOC releases resulting from 'diurnal' and 'hot soak' volatilization processes. Diurnal losses occur while a vehicle is stationary with the engine off, and are due to the expansion and emission of vapor from the fuel tank as a result of the normal temperature changes which occur over a twenty-four hour period. Hot soak losses occur when a warm engine is stopped, allowing the engine heat to dissipate into the fuel system causing evaporation of fuel from the tank.

Currently in the U.S. both diurnal and hot soak vapors are collected in a small charcoal canister. When the engine is restarted, intake air is used to purge the hydrocarbons off the charcoal and into the engine, where they are consumed. These systems are cheap, safe and very effective, representing a control level of approximately ninety-five percent. The small canister currently in operation in the U.S. is under consideration by the European Parliament in Brussels.

However, the control of these emissions is only part of the solution. A simple increase in the volume of this canister, combined with other minor design modifications, would enable the system to also capture refueling emissions and running losses, a total control of potentially one million metric tons of emissions per year here in Europe.

Emergence of Running Losses

Running losses are emissions of VOCs released during vehicle operation from points other than the tailpipe or crankcase. Running losses result mostly from evaporation of fuel from the fuel tank. When a vehicle is running, its fuel tank temperature tends to rise above the ambient air temperature. This is caused by hot air from the engine compartment moving down under the vehicle, from the proximity of the hot exhaust, from hot pavement, and from heat generated in the rear axle bearings and gears. Additionally, on fuel injected cars gasoline is constantly circulated from the fuel tank to the engine compartment and back, transfering significant amounts of heat back to the tank. Although running losses are currently unregulated in the U.S., a proposed EPA regulation would require the installation on new vehicles of enlarged carbon canisters capable of recovering evaporative emissions and running losses. As I have said previously, I believe these larger canisters can be modified to recover refueling emissions as well, and this entire system could be successfully moved into the European market.

The U.S. has made noteable gains since the early 1970s in its ability to isolate and eliminate automotive pollutants. It has been an iterative process, however, and not without a certain amount of duplicative effort. I believe that Germany and the European Community can capitalize on the groundwork that has already been laid by realizing that multiple benefits can be derived from a single, integrated system. A history of this groundwork, where the U.S. was many years ago and where we are today, may help you to understand the advantages in such an approach.

THE U.S. EPA's PROPOSED RULEMAKING

Recognizing that emissions from vehicle refueling remained a problem. Congress amended the Clean Air Act in 1977 to require a study of the effectiveness of onboard controls for vehicle refueling vapor recovery.

The EPA in its effort to satisfy this Congressional mandate, has invested an enormous amount of resources in a careful analysis of the system and its effects. EPA scientists and engineers at the Mobile Sources Laboratory in Ann Arbor, Michigan, tested prototype onboard devices for efficiency and safety. Case studies of Stage II implementation in California and Washington, D.C. were scrutinized for sampling error and accuracy. The effectiveness of operating pollution control devices was reassessed and evaluated. After careful review of this information, EPA determined that onboard control for light duty vehicles was technically feasible. Due to the financial difficulties faced by the U.S. automotive industry in the early 1980s, however, EPA decided that onboard controls would not be required.

The revitalization of the U.S. automotive industry in the mid 1980s reopened the file on onboard devices. Additional impetus for this move was the urgent need to reduce ambient ozone levels and the realization of the potential adverse health effects of inhaling gasoline vapors. New information was gathered and all of the studies were compiled and presented to me while I was EPA Administrator. After careful consideration of all the options, I signed a proposed rule in August of 1987 that would have required that all new cars sold in the U.S. contain onboard refueling vapor recovery devices.

Many of the decisions I made at EPA hinged upon the careful analysis of two very similar options. Oftentimes, the determination to follow one course over another rested upon small factors, details that did not clearly favour a particular course of action. This was not one of those decisions. The EPA studies indicate that the onboard canister can, through the use of a single integrated system, efficiently and safely capture refueling emissions.

My last few months at EPA were very busy, as scores of proposals were forwarded to my office in an attempt to beat the regulatory logjam that often besets a new Administration. I had hoped to make the comprehensive evaporative emissions control system one of the regulations I finalized before I left. The proposal was the logical result of the studies, a systematic look at Stage II and onboard options, which clearly indicated that onboard was the preferred route from both an environmental <u>and</u> economical viewpoint. The analysis of the comparison breaks down in to roughly three main divisions: effectiveness, cost, and safety. I would like to address each of these areas separately.

A COMPARISON OF ONBOARD AND STAGE II SYSTEMS

Effectiveness

As you are well aware, the onboard system is an enlargement of the evaporative emissions system in use in the U.S. for eighteen years. These devices are also used in Japan and Australia, and their introduction into the European market is currently under consideration. This introduction should not be burdensome to European car manufacturers, as for eighteen years most of them have been profitably producing and marketing cars in the U.S. that are equipped with these canisters. Onboard systems function during the refueling of the vehicle by sealing the vehicle fillneck, then rerouting the displaced vapor from the fuel tank to a storage canister. This canister is loaded with granules of activated carbon which absorb the hydrocarbon molecules in the vapor.

When the vehicle's engine is started, fresh air is drawn through the canister to purge the hydrocarbons from the activated carbon. The resulting mixture of air and hydrocarbon vapors is transferred to the fuel metering system and then burned in the engine. This burning provides the onboard system with a fuel recovery credit, because gasoline vapors that would normally be lost to the atmosphere are instead used to power the vehicle.

Control efficiencies for any system vary, but EPA and CONCAWE tests indicate that greater than 90% efficiencies are consistently achievable. The U.S. EPA has installed prototype onboard systems which have successfully accumulated more than fifty thousand miles of service at ninety-nine percent efficiency. CONCAWE studies reveal ninety-seven and ninety-nine percent control efficiencies in studies involving refitted models of a 1986 Honda Civic (with a 1.3 liter engine) and a 1985 Opel Ascona 1.8i (with a 1.8 liter engine), respectively.

Due to the similarity of the onboard and evaporative emissions systems, the U.S. EPA has determined that the in-use performance of onboard systems in capturing vapors displaced from a vehicle's fuel tank should be very much like that of evaporative emission control systems that have been properly designed. In particular, little or no deterioration in performance over the useful life of the vehicle would be expected for properly maintained systems. Estimated in-use efficiency is approximately ninety-three percent.

In a Stage II vapor recovery system, the vapor in the vehicle fuel tank that is displaced by liquid gasoline being dispensed is prevented from escaping to the atmosphere by a flexible rubber 'boot' which fits at the juncture of the fillneck and the dispensing nozzle. The boot is attached by a hose to the underground fuel tank, where a vapor-for-liquid exchange is made as gasoline vapor from the vehicle replaces liquid fuel drawn out. Essential to this system are standardized fill pipes. Shortened or severely curved fill pipes do not allow the boot to form a tight seal at the fillneck. Additionally, Stage II controls may only delay the venting of vapor to the atmosphere if Stage I devices are not in place at service stations. Captured Stage II vapors will simply be forced out the vapor vent of the underground tank during tank refueling. It is my understanding that Stage I devices will not be fully implemented in Germany for four years.

Another version of the Stage II apparatus is the vacuum assist system. This system uses a pump to draw air and refueling vapors through the vapor return hose to the underground tank. Since the volume of air and vapor returned to the underground tank is larger than the volume of fuel dispensed, some of the vapor will be emitted through the underground tank's vent line. Unless a control device is put on this vent line, the overall control efficiency of this type of system will be low. Compared with vapor balance Stage II systems, vacuum assist systems are more complicated, which means they are more expensive to install and maintain. Also, since the vacuum assist approach mixes air and hydrocarbon vapor, poor design or maintenance could create a safety hazard.

The efficiency of the Stage II apparatus is much more variable than that of the onboard system. Current EPA estimates indicate that although Stage II recovery has a theoretical limit which equals that of the onboard system, the actual in-use efficiency varies from sixty-two to eighty-six percent. This lower efficiency results from a number of factors, including the increased complexity of an inspection and enforcement system which, in the U.S., must be administrated through each of the fifty states. This could make the Stage II system an unpopular option at the local government level. The onboard system is more easily enforced through existing control programs that are managed at a federal agency. Other considerations are user inconvenience associated with Stage II devices. Many self-serve customers find Stage II devices awkward to operate. Maintaining the seal between the boot and the fillneck both during the filling process and after pumping has ceased can be difficult. Prematurely removing the nozzle from the fillneck may result in vapor release from the fuel tank, thus negating the recovery potential of the boot. Onboard controls are essentially 'invisible' to the automobile owner, generating none of the user variables associated with Stage II pumps.

Costs

An analysis indicates that the cost of the Stage II system exceeds that of the onboard canister. For the 1987 onboard proposal, the EPA estimated that the onboard vapor recovery system would add approximately fourteen dollars to the price of a vehicle. Fourteen dollars is approximately 0.1 to 0.2 percent of the average cost of a new vehicle in the U.S. This amount includes both the capital expenditures that must be made before production of emission control components can begin, and the cost of the hardware itself. Capital costs for the average car were computed at $1.36, while the control device and markup averaged approximately $17.50. The consumer receives an approximate $5 gasoline credit for recovered vapors that are burned in the engine. In a revised cost analysis, EPA indicated that there could actually be a cost saving to the consumer in the adoption of onboard requirements. This saving would result from combining evaporative emission and refueling control systems into a single onboard system that is simpler and more economical to build than current onboard evaporative emissions systems.

In the 1987 proposal, the estimated total capital cost of a Stage II vapor recovery system for the moderately sized U.S. service station was $12 200. (An American Petroleum Institute survey of Stage II installation in St. Louis, Missouri, indicates that the costs can escalate to over $55 000 for large stations).

When this is amortized over the expected lifetime of the equipment, and the annual operating expenses are included, the same service station will spend approximately $2600 per year for Stage II vapor recovery controls. I understand that Stage II installation costs could be significantly higher in Germany where most service station forecourts are covered in concrete rather than asphalt. These large capital investments could severely limit the operations of service stations that work on limited profit margins.

Another way to compare the cost of these alternatives is to measure the potential for pollutant recovery that each option offers against the expense of recovering that pollutant. European studies have indicated that large carbon canisters operating at ninety percent efficiency have the potential to recover just over one million metric tons of emissions per year. The cost-effectiveness of this recovery ranges from $335 per ton to $1340 per ton, depending upon which estimate is used for canister costs. Stage II control has the potential for recovering only one hundred and sixty thousand metric tons of emissions per year, and at the more expensive rate of approximately $5000 per ton. Onboard shows more than a six fold improvement in VOC control for a fraction of the cost. In short, the onboard system provides for more efficient recovery at a lower cost.

Safety

A system that is effective and inexpensive is useless if it is not safe. The issue of safety has been raised in the U.S. during the course of refueling control debates. It is still the subject of discussion between the various government agencies that need to authorize the final guidelines implementing the accepted system. Let me define both my own and EPA's position on safety by reading the following passage from EPA's most recent safety study. "EPA feels onboard controls can and will be implemented with the same or a better safety level as current (evaporative emissions) systems. Further, because of the potential design improvements and service stations benefits, EPA believes onboard control systems will have the potential for an overall beneficial impact on safety." My confidence in this system is firmly rooted in the fact that evaporative emissions controls and refueling emissions controls are very similar in design, and that evaporative emissions systems have operated for eighteen years with outstanding success and safety. Government statistics support this position:

- Over 200 000 000 U.S. vehicles have been fitted with evaporative emissions canisters, yet no serious injuries or deaths have ever been reported as resulting from the failure of these devices during either operational or crash scenarios.

- The U.S. Center for Auto Safety reviewed over 20 000 fuel system related owner complaints maintained by the National Highway Traffic Safety Administration. This study indicated that 1501 of these complaints involved fires, and that only 6 of the 1501 were even tangentially related to the evaporative system. This is only 0.4 percent of the reports involving fire.

- After studying eighteen years of recall records, the Center for Auto Safety concluded that "evaporative emission controls have not resulted in any significant incidence of vehicle fires or recalls".

Detractors of the onboard system suggest that the addition of a new component will increase the complexity of the fuel system. Complexity, they argue, can lead to an incease in potential points of failure. EPA has found that levels of complexity vary considerably from one vehicle model to another, and that in fact many features proposed for onboard systems that have been characterized by manufacturers as an increased safety risk were found to already exist in use on numerous fuel/evaporative system designs. Complexity is not a valid yardstick for safety.

As an offshoot of its investigation of the complexity issue, the Agency developed a simplified onboard system at its Mobile Sources Lab. The three design tenets for the system were straightforward: 1) the system should add as few features as possible to the fuel distribution design without compromising efficiency; 2) the components used in the system should be based on current production hardware; and 3) the system should be safe. The resulting prototype canister consistently met the proposed EPA refueling standard and federal rollover safety standards while managing to operate as an efficient evaporative emissions control unit. Onboard devices are not complex labyrinths of valves and hoses. They are simple extensions or modifications of present evaporative systems.

PRESENT U.S. ACTION

There are a number of ongoing U.S. federal activities that reflect broad support for the onboard approach. The EPA is continuing research on its in-house version of the onboard system. The Clean Air Act will be amended sometime in 1990, and bills have been introduced in both Houses of Congress that explicitly call for onboard controls. They allow three years for leadtime, and they would require 95 percent recovery efficiency.

This is clearly a show of Congressional confidence in the effectiveness of the system. The U.S. government is committed to improving national air quality, and onboard refueling vapor recovery will certainly play an important role in the fulfillment of that committment.

THE OPPORTUNITIES IN WEST GERMANY AND EUROPE

The European Community is at an important crossroads in vehicle pollution control. The Stage II system offers short-term, somewhat effective control of refueling emissions, but does not address the related issues of evaporative emissions or running losses. The cost of its implementation is borne by service station owners, a burden that may be intolerable for many marginally profitable service stations.

The adoption of onboard controls reflects a far-sighted approach that not only substantially reduces refueling emissions, but also opens opportunities for integrated pollution control. In taking this route, Germany can swiftly and effectively establish a regulatory scheme that has taken twenty years to evolve in the U.S. Evaporative emissions, refueling emissions and running losses can all be addressed and managed. Historically, U.S. efforts have tackled these problems individually in a process that has generated redundant effort. Only in recent years has EPA discovered the significance of managing these pollutants together. It has been proven that large onboard canisters can contain and control evaporative emissions and refueling emissions. It is also believed that these devices can significantly reduce running losses. During my last few months at EPA I supported a proposal for onboard controls that would have managed all of these emissions. The onboard strategy is effective, and safe. Its adoption would reaffirm the advantages of cooperation and ingenuity in the fight for environmental protection. It is my hope that Germany and the European Community take this direction in finalizing their approach.