

Mobile Source Evaporative Emissions

by

C. Don Paulsell

June 1974

Environmental Protection Agency
Office of Air and Waste Management Programs
Office of Mobile Source Air Pollution Control
Emission Control Technology Division
Regulations Development and Support Branch
Ann Arbor, Michigan

Executive Summary of Evaporative Emissions Document

The paragraphs below summarize the important points contained in each of the three parts of the attached document on mobile source evaporative emissions.

Position Paper: Evaporative emissions have been studied and measured since 1958. Federal regulations became effective in 1971 to reduce evaporative emissions.

The Federal canister test procedure which has been used with those regulations indicates that vehicles are emitting about 0.13 grams/mile from fuel evaporative processes. Tests have shown that this procedure does not adequately cover all potential sources and does not accurately measure the true magnitude of all evaporative emissions. An improved procedure (SAE J171) involves placing the vehicle inside an enclosure where all emissions can be measured on a mass basis by monitoring the concentration of hydrocarbons in a known volume. The SAE J171 test procedure indicates that 1972 model vehicles (controlled) are actually emitting about 1.87 grams/mile.

If evaporative regulations are not changed prior to implementation of the statutory exhaust emission hydrocarbon standard of 0.41 grams/mile, evaporative emissions will constitute the dominant hydrocarbon emission. The total hydrocarbon emissions would then exceed the established reductions necessary to meet the air quality standards for oxidant levels.

Adoption of the SAE J171 enclosure procedure will require that necessary changes be made in evaporative control systems to reduce evaporative emissions. However, to simply replace the canister test with the enclosure test would be very costly. Data indicate this implementation plan is unnecessary. By developing selection criteria for evaporative system families, the number of required tests could be reduced to less than 1000 per year, and the enclosure procedure could be implemented in a cost effective manner.

A program plan has been outlined to achieve the implementation of the enclosure procedure by December, 1975 (Start of 1977 MY testing).

Program Plan: A data base of 202 enclosure tests exists for a vehicle population covering 1957-72 model year vehicles. The program plan provides for supplementing that data with tests that specifically look for the cause of the emissions. A contract will be negotiated to assess evaporative sources and to develop the cost/effectiveness analysis for various evaporative control approaches.

Communications will be established with the automobile industry to maximize their lead time for hardware development and to solicit their comments and data on our approach to revised regulations.

This program will require the assignment of high priority in order to accomplish the critical deadlines scheduled in FY75. Costs, manpower, and tasks have been itemized and summarized.

Technical Appendix: The various specifications used in the enclosure procedure are discussed. Simulation of real world conditions related to time, temperature, fuel volumes, and types of fuel are documented.

The four phases of the evaporative process, (diurnal losses, running losses, hot soak losses, and refueling losses) have been discussed. The preferred measurement and recommended calculation procedures are covered.

A complete list of references on the subject of mobile source evaporative emissions has been compiled.

TABLE OF CONTENTS

A. <u>A Position Paper on Evaporative Emissions</u>	<u>Page</u>
I. Introduction	1
II. Background on Evaporative Emissions Regulations	1
III. Evaporative Emissions Test Procedures	9
A. Canister Test Procedure	
B. Enclosure Test Procedure	
IV. Implementation Alternatives	10
V. Problems of Implementation	14
VI. Conclusions	15
VII. Recommendations	16
VIII. Closure	16
IX. References	17-19
B. <u>A Program Plan for Evaporative Emissions Regulation Development</u>	
I. Title	1
II. Responsibility	1
III. Problem Assessment	1
IV. Purpose	1
V. Objectives	1
VI. Approach/Scope of Work	1
VII. Milestones/Accomplishments	1
VIII. Current Status	2
IX. Technical Support	2
X. Coordination and Manpower	2
XI. Program Description and Timetable	2
C. <u>A Technical Appendix on the Measurement of Evaporative Emissions</u>	
I. Introduction	1
II. Summary Statement and Background	1
III. Diurnal Emissions	2
IV. Running Losses	8
V. Hot Soak Emissions	9
VI. Measurements and Calculations	10
VII. Closure	11
VIII. Charts and Graphs	12-19
IX. References	20-22

A POSITION PAPER ON EVAPORATIVE EMISSIONS

I. Introduction: This document summarizes the background and the present state of knowledge regarding evaporative emissions from light duty motor vehicles. It discusses the effectiveness of our present evaporative emissions regulations and explores the revision of those regulations to facilitate more accurate measurement, assessment, and control of evaporative emissions.

The purpose of this document is: to present the facts that define the problem, to discuss the test techniques available as regulatory procedures, to weigh the pros and cons of actions which may effect a solution to the problem, and to outline the conclusions and recommendations that will lead to the revision of those regulations.

II. Background on Evaporative Emissions Regulations: Section 202(a) of the Clean Air Act requires the Administrator to prescribe regulations applicable to motor vehicle emissions which contribute to air pollution and endanger public health or welfare.

Hydrocarbons emitted to the atmosphere from motor vehicles have been judged as a pollutant requiring regulation. Hydrocarbons are generated from three processes: gaseous products from combustion, engine crankcase blowby, and vapors from fuel evaporation. These emissions contribute to the formation of smog. References (4,19,20,23) at the end of this paper discuss this process and the interactions of the components. Basically, the conclusions have been that it is necessary to reduce both hydrocarbons and oxides of nitrogen to reduce the oxidant levels produced by the photochemical reactions; furthermore, a reduction in hydrocarbons has been shown more effective than an equal reduction in oxides of nitrogen. This fact underscores the importance of hydrocarbon regulation.

The preceding paragraph illustrates the importance of controlling all hydrocarbon emissions, but this document has been written to assess one source of hydrocarbons, evaporative emissions. Studies and measurements on evaporative losses have been documented since 1958. One of the first studies (1) which deals with carburetor losses was prompted by interest in idling performance, fuel economy, and air pollution.

Throughout the mid-sixties, many studies were conducted to quantify the magnitude, mechanism, and sources of fuel vapor emissions. At the time of this research vehicles were uncontrolled; fuel tanks had vented caps, carburetors had externally vented float bowls, and some engines had vented crankcases. Basically, the emissions have been differentiated into three categories: diurnal breathing losses, running losses, and hot soak losses. Diurnal breathing losses are caused by the daily temperature rise and resultant expulsion of vapors from the fuel tank vent. Running losses are similar to the diurnal losses, except that the temperature rise occurs during vehicle operation from engine waste heat flowing over the fuel tank and carburetor. Hot soak losses are caused

by boiling in the carburetor bowl after engine shutdown. A comprehensive discussion of the mechanisms and parameters related to these emissions has been written as a technical appendix to this paper.

Several test techniques for measuring these specific source locations were developed (16) and used to assess the amount, composition, and influencing factors on the fuel evaporative emissions. The technique most widely used was vapor condensation in a cold trap immersed in a slurry of dry ice, alcohol, and acetone to maintain a temperature of -80°F.

One AMA (Automobile Manufacturer's Association) program (15) extensively tested 5 vehicles and reported carburetor losses as high as 50 grams/test. Vehicle design was the largest single factor affecting carburetor losses. The program also reported tank emissions as high as 125 grams/day, with 69% of the losses occurring during vehicle operation (running loss). Fuel volatility and maximum temperature had the major impact on these tank emissions.

After the influence of fuel volatility and temperature had been assessed, a test procedure was developed that standardized the fuel and fuel temperature variations. Additional data were collected using this procedure and interim standards were proposed by the California Motor Vehicle Pollution Control Board in November, 1966. Their standards were based on an 80% reduction of baseline emissions from uncontrolled vehicles. The baseline emissions were consolidated from several references (25,26,21) and were set at average values of 30 grams per day from the diurnal and 10 grams per test from the hot soak. Hence, California standards were 6 grams and 2 grams for the respective diurnal and hot soak tests.

One system to control evaporative emissions had been in the development phase since 1960. It was the forerunner of the present control system and basically incorporated a canister of activated charcoal that was plumbed to the tank and carburetor vents and operated on a controlled adsorption-desorption principle. A report (8) on the effectiveness of this system concluded that vehicles controlled by this system achieved 90-100% reduction in emissions. This reduction has been shown dependent on the test procedure used to measure the emissions.

The California standards were never finalized as they had been proposed. Three months later, February 4, 1967, the Federal Government (HEW) issued a notice of proposed standards for evaporative emissions (27). The standard proposed, 2 grams per test, was a composite sample representing the total diurnal and hot soak emissions. The test procedure in this proposal involved running an exhaust emissions test on a dynamometer, fueling the vehicle with cold fuel, moving the vehicle into a sealable enclosure, and monitoring the hydrocarbon concentration within the enclosure to determine the mass of fuel vapors emitted. This proposal was technically correct and realistically practical because it

required no modification of the vehicle and measured the total diurnal and hot soak emissions from all sources. Unfortunately, the proposed concept had not been substantiated by quantitative data, was not supported by the automotive industry, and was consequently replaced by an alternate technique. This technique involved trapping the vapors from specific sources by attaching charcoal canisters; this was basically the proposal California had made. A test procedure employing the vapor trapping technique was finalized and published as a federal regulation on June 4, 1968. The evaporative emission standard of 6 grams per test was applicable to 1971 model year vehicles sold nationwide; the MVPCB of California adopted the procedure and standard to apply to 1970 model year vehicles sold in California.

The 1971 HEW certification results showed that 107 of 131 (82%) vehicles tested emitted less than 1.0 gram. Consequently, the standard was lowered to 2 grams per test for 1972 vehicles and evaporative emissions regulations have not changed since.

This brief summary on the regulation of evaporative emissions has hopefully provided the reader with the necessary background to place the remainder of this paper in the proper perspective.

The enclosure procedure that had been proposed in 1967 by HEW was technically correct and had many merits, as mentioned before. A few days after that proposal was made, one company of the automotive industry built an enclosure and conducted extensive tests to study the potential problem areas and to assess the value of the proposal. Two published reports (5, 6) on these evaluations concluded that the technique was accurate, simple, and repeatable, and represented "a superior technique and versatile tool" for evaporative emissions measurements. Subsequent tests by HEW engineers and various other organizations substantiated those initial results and lead to refinements which were published by the Society of Automotive Engineers (12) in a formal recommended test procedure. This procedure, SAE J171a, has the same specifications as the presently used canister procedure except that the enclosure-FID setup replaced the gravimetric determination as the measurement method.

During the last three years of certification testing, the official results shown in Table A were obtained from the canister evaporative emissions test.

Table A

1971-1974 Certification Results

<u>MY</u>	<u>No. Tests</u>	<u>% Tests < 0.1gm</u>	<u>% Tests < 1.0gm</u>	<u>Grams/Test</u>		<u>Std.</u>
				<u>Max. Value</u>	<u>Avg. Value</u>	
71	131	32%	82%	3.65	.545	6
72	370	45	91	1.90	.307	2
73	351	56	94	1.90	.251	2
74	399	45	98	1.90	.258	2

Note: 60% of tests < .1 gm were actually 0.0 gms.

The emissions shown in Table A seem to indicate that the evaporative control systems are very effective. However, for this analysis, all the data gathered should be considered. The data collected during the 1974 model year program was readily accessible.

Actually, there were a total of 1141 evaporative emissions tests performed in that program. Durability vehicles accounted for the 399 published results but the emission data vehicles tested totaled 742. There were 20 failures in the emission data population. These failures occurred on 12 vehicles. Most failures were caused by test procedure errors; the vehicles passed subsequent retests. Three of the vehicles required hardware changes to pass. There were no failures on any durability vehicles and the deterioration factors for evaporative emissions were less than .2 (additive D.F.) for 93% of the vehicle families.

Another observation can be made concerning the tests listed as 0.0 emissions. Roughly 60% of those values less than 0.1 grams were actually 0.0. Investigation disclosed that values listed as 0.0 were almost always negative canister weight changes. This aspect of the canister procedure is the most indicative evidence of the canister technique's questionable validity.

As a followup to the certification process, the mobile source program conducts surveillance testing to assess the net effect of the regulatory process. Vehicles are procured from private owners and emissions tests are performed to quantify the emission levels generated from production vehicles that have been maintained by the consumer.

The surveillance program in 1972 measured evaporative emissions from both controlled and uncontrolled vehicles. The questionable results which had been obtained from the canister procedure prompted the surveillance personnel to consider using the enclosure technique which was more simply applied to both controlled and uncontrolled vehicles. The enclosure technique accounts for emissions from areas that are difficult to "trap", i.e. gaskets and throttle shafts, whereas the canister procedure requires many connections and lengthy preparation for uncontrolled vehicles. Consequently, in order to provide a simple and common basis for comparison of data, the surveillance program adopted the enclosure procedure, SAE J171. The measurements made in Los Angeles encompassed a distribution of 136 California vehicles from model years 1957 to 1971. In addition, twenty-two (22) 1971 model vehicles were tested in Denver to assess the effect of high altitude. The next year, the surveillance program concentrated on 1972 model vehicles only, testing twenty-two (22) each at Los Angeles and Denver. The results of all these tests are summarized in Table B.

Table B

Surveillance Results - Enclosure Procedure

<u>Model Year</u>	<u>No. Tests</u>	<u>L.A. Data (gms)</u>		<u>Denver Data (gms)</u>		<u>Weighted Values**</u>
		<u>Diurnal</u>	<u>Hot Soak</u>	<u>Diurnal</u>	<u>Hot Soak</u>	<u>gms/mile</u>
'57-'69	102	26.08	14.67	-	-	2.72
'70	13	17.75	10.70	-	-	1.95
'71	21	14.87	10.89	-	-	1.88
'71	22	-	-	47.2*	34.8*	6.02*
'72	22	12.40	11.80	-	-	1.87
'72	22	-	-	17.4	14.2	2.40

Note: *Winter grade fuel (11.7 RVP) used on all tests, L.A. Data up to 1971 used all types of fuel (7.8 - 12.0 RVP).

**Emission = Diurnal + 4.7(Hot Soak)/35 miles/day.

Before the comparison of Table A and Table B is made, a few qualifying remarks are necessary. The first contrast one observes in Table B is the disparity between the 1971 and 1972 Denver values. This large difference has been explained by the fact that the 1971 vehicles were tested using commercial winter grade fuel of high volatility (Reid Vapor Pressure (RVP) = 11.7 psi), and the 1972 vehicles used the standard test fuel of summer grade volatility, (RVP = 8.8 psi). Several reports (1,2,3,7,9,11) have quantified that the emissions from fuel having an RVP of 11.7 will be double to triple those from fuel with an RVP of 8.8. This correction factor will

tend to bring the Denver results for the two model years (both controlled vehicles) into closer agreement. The same situation occurred during the tests in Los Angeles, but the effect on the overall average is less pronounced because a wide variety of vehicles was tested at random times with both types of fuel. However, the standard test fuel was used during the Los Angeles tests on 1972 model vehicles and a valid comparison to the Denver data can be made. The consistent difference in this comparison can be attributed to the effect on the evaporative process of the lower barometric pressure at Denver (24.5"Hg) as compared to that at L.A. (30.2"Hg).

A comparison of the values for the diurnal and hot soak emissions from controlled and uncontrolled vehicles does not indicate a significant improvement. Diurnal emission control shows the highest reduction (54%), but the hot soak control techniques produced a much smaller reduction (27%). It is reiterated here that the volatility correction factor will lower the uncontrolled vehicle emissions, a change which demonstrates even lower reductions than those indicated.

The very perplexing aspect of the diurnal data has been the magnitude of the emission from a supposedly closed system. Diurnal tests have been conducted on leak-tight controlled vehicles at the MSAPC laboratory using the enclosure technique. The results confirmed that a control system can limit diurnal emissions to less than 1 gram/test. One must conclude that a leak exists in the control system; speculation as to the sources would point to the canister, lines, tank fittings, or tank cap. Investigation of this latter speculation disclosed that 10-20% of the pressure leak tests performed during the 1974 certification program failed because of leaking caps. Generally, the manufacturers were allowed to replace the cap and the evaporative test proceeded. The surveillance program did not require a leak test because the purpose of the test was to measure "as received" emissions. However, testing experience indicates a cap leak would be the likely cause of these high diurnal emissions. The data indicate that hardware improvements are needed in this area.

The control of hot soak losses relies primarily on plumbing the carburetor bowl and air cleaner to the control canister. In most systems the internal carburetor vents continue to fill the air cleaner with vapors, and the diffusion-expulsion process follows the path of least resistance, the air cleaner inlet. In the canister test procedure, these vapors must make their way through small tubing before they can be adsorbed in the charcoal canister. The data indicate this is not happening.

A test was reported (5) that investigated this problem inside an enclosure. The author concluded that the air cleaner merely stores the vapors during a canister test when its inlet is plugged. However, subsequent removal of the plug produced a sudden increase in the enclosure hydrocarbon concentration. This is an example of how the modifications required by the canister procedure actually inhibit the emission of hydrocarbons.

The comparison of values from Table A and Table B indicates that the canister test procedure does not accurately assess evaporative emissions. There are several reasons to conclude that the enclosure procedure more accurately assesses the true magnitude.

During the surveillance program, replicate tests were performed on 14 of the 188 vehicles tested. After considering the variations caused by the fuel volatility problems cited earlier, the repeatability of the enclosure procedure is on the order of $\pm 10\%$ for all replicates. Similar repetitive testing using the canister procedure has produced standard deviations as high as 200% of the mean for a group of tests.

Another reason to accept the enclosure values is that the enclosure can be calibrated. Calibration tests are typically repeatable within $\pm 2\%$ for all tests. Enclosure background emissions (if any exist) can be measured and subtracted to yield net vehicle emissions. Finally, the enclosure measures all vehicle emissions without modification to the control system.

The discussion to this point has attempted to present the background and to illustrate the quantitative data available for evaluation. If the most valid block of data, the L.A. and Denver tests on 1972 vehicles, is representative of true emissions, the impact of evaporative emissions on air quality can be estimated. The weighting factors that have been used for exhaust emissions will be applied to evaporative emissions.

The model assumes that a vehicle experiences 4.7 starts per day and accumulates 35 miles in average daily operation. In the analysis of total evaporative emissions, the assumption of one diurnal and 4.7 hot soaks per day is made. When the average values from the 1972 vehicles are used in the model for total emissions, the final value is:

$$\text{gms/mile} = \frac{(\text{Diurnal gms/test} \times \text{test/day}) + (\text{Hot soak gms/test} \times \text{tests/day})}{\text{Miles/day}}$$

$$\begin{aligned} \text{Evap. gms/mile} &= \frac{(12.4 \times 1) + (11.3 \times 4.7)}{35} \\ &= \frac{65.5 \text{ gms/day}}{35} \end{aligned}$$

$$\begin{aligned} \text{Evaporative} & \\ \text{Emissions} &= 1.87 \text{ gms/mile} \end{aligned}$$

These 1972 vehicles, by similar analysis using the 2 gram standard test results, were certified at evaporative emission levels less than 0.13 gms/mile. To place this evaporative emission in perspective, the tailpipe emissions have also been considered.

The certification HC standard in California for 1972 vehicles was 3.2 grams/mile as opposed to the national standard of 3.4 grams/mile. The surveillance data that was measured on 35-1972 vehicles showed an average HC emission of 4.07 grams/mile.

One additional source of HC vapor should be discussed to complete this analysis of total emissions. Two reports (10,24) have been written on the fuel vapors emitted during fueling operations. For the purpose of this analysis, the rates of 5.0 gms/gal. and 13.4 miles/gal. will be used as the average values for fuel transfer emissions and fuel consumption. These values translate to approximately 0.4 grams/mile.

If the emission discussed represent the total mobile source contribution to HC pollution, the following table shows the relative contribution of each specific source for in-use 1972 vehicles.

Table C

Total HC Emissions From 1972 Vehicles

	<u>gms/mile</u>	
Exhaust	4.07	64.2%
Evaporative	1.87	29.5%
Refueling	<u>.40</u>	<u>6.3%</u>
Total HC	6.34	100.0%

This conservative analysis has shown that the minimum impact on HC emissions due to evaporative losses is presently about 30% from vehicles with evaporative control. The analysis can be developed one step further to show the impact of evaporative emissions relative to 1975 model year vehicles. Evaporative emissions or refueling losses are not expected to change for 1975 or 1976 vehicles because the evaporative and fueling control systems will be essentially the same as those used in 1972. Assuming the 1972 (in-use/cert. std.) factor ($4.07/3.2 = 1.27$) will be the same in 1975 and 1976, the in-use tailpipe emissions from 1975 and 1976 vehicles can be estimated and compared as shown in Table D.

Table D

Predicted HC Emissions From 1975/76 Vehicles

HC Standard	<u>1975 (1.5 gms/mile)</u> <u>gms/mile</u>		<u>1976 (.41 gms/mile)</u> <u>gms/mile</u>	
Exhaust	1.91	45.7%	.52	18.5%
Evaporative	1.87	44.7%	1.87	67.0%
Refueling	<u>.40</u>	<u>9.5%</u>	<u>.40</u>	<u>14.4%</u>
Total HC	4.18	100.0%	2.79	100.0%

This analysis illustrates that evaporative emissions will represent the primary source of hydrocarbons from mobile sources if the present regulatory procedures and standards remain unchanged.

The cause of this problem is simply the inability of the evaporative emissions test procedure to measure the true total emissions from the test vehicle. The presence of this weakness has caused an erroneous assessment of the true magnitude of the emissions and has resulted in few improvements in control technology. The two effects are interdependent.

One may be tempted to jump at the obvious solution to this problem, which is to change the test procedure. While this is certainly an important aspect of the solution, it alone will not automatically result in the control of emissions.

III. Evaporative Emissions Test Procedures: The two principle techniques which have been used for measuring evaporative emissions, the canister and enclosure procedures, have been discussed in general terms previously in this paper. This section will discuss the advantages, limitations, costs, and problems associated with each procedure.

A. Canister Evaporative Test Procedure

Advantages:

1. Test equipment is simple and relatively low in cost.
2. Required test area is small and test setup is flexible.

Limitations:

1. Inability to measure all losses.
2. Poor repeatability of test data.
3. Use of tubing and connectors may actually inhibit real emissions.
4. Low percent of total emissions collected.
5. Time consuming and tedious procedure to perform.

Costs:

1. Lengthy preparation phase results in high manpower costs. (Preconditioning study indicates preparation could be shortened)

Problems:

1. High void test rate caused by numerous and complex steps.
2. Accurate calibration of test procedure is not possible.

B. Enclosure Evaporative Test Procedure

Advantages:

1. Accurate measurement of all emission sources.
2. Minimum vehicle modifications and preparation.
3. Good repeatability ($\pm 10\%$) on replicate tests.
4. Precise calibration and verification of equipment is possible.
5. Familiar instrumentation and calculation routines.

Limitations:

1. Area required to house an enclosure is large.

Costs:

1. Initial investment costs are very high (est. \$25K per enclosure)

Problems:

1. Vehicle background (tires, seals, paint, undercoat, etc.) emissions from new cars are high. Emissions decrease to low levels after 90 days of ageing.
2. Abnormal high ambient temperatures during hot soak tests must be avoided.

Other questions related to simulation of realistic environmental parameters have been addressed in a technical appendix to this report.

IV. Implementation Alternatives: Previous position papers and program plans on the subject of evaporative measurement by the enclosure procedure have taken the basic position that the enclosure technique replaces the canister in a test applied to each vehicle subject to certification. The cost benefit relationship, as well as the physical space requirements of such an implementation plan cannot be justified in light of the data available on evaporative emissions.

As discussed earlier, evaporative emissions occur from two primary sources, the fuel tank and the carburetor. The test procedure specifies the measurement of separate diurnal and hot soak losses. This differentiation is an important requirement because of the weighting factors which must be applied to translate test values to a grams per mile basis. Procedures that combine the diurnal and hot soak tests to reduce test time surrender a necessary part of the data.

A reduction of test time should be attainable without sacrifice of important data. An alternative method to reduce the manpower and test time required to obtain the necessary data is to reduce the number of vehicles required for testing. This proposal is more than an alternative; it is a technique that is justified by the character of the emissions and the data measured on many systems. For example, the factors that govern the diurnal emission are tank vapor volume, fuel volatility, and maximum fuel liquid temperature. These parameters have been regressed against diurnal emissions (11) which produced a correlation coefficient of 0.93. Similarly, carburetor hot soak losses are primarily dependent on fuel distillation characteristics (% @ 160°F), carburetor maximum fuel temperature, and carburetor bowl liquid volume. Hot soak emissions have been regressed against these three variables with a correlation coefficient of 0.89.

These characteristics can be applied to vehicle evaporative control system configurations to determine the appropriate vehicle selection criteria and sampling plan. This method of vehicle selection would predictably reduce the number of vehicles to be tested for evaporative emissions. It is then possible to assess the capability of all control system configurations without testing every vehicle and without expenditures for numerous enclosures and instruments. This implementation plan is justified by the data, and has a very low cost: benefit ratio.

In 1973, the Mobile Source Laboratory tested approximately 399 durability vehicles which represented 114 engine families and 35 manufacturers. In addition 742 emission data vehicles were tested. If sample selection criteria had been applied to fuel tank configurations and carburetor sizes, the number of evaporative emissions tests would have been reduced.

For example, if a manufacturer uses the same fuel tank system with several different carburetors, it is not necessary to perform a diurnal tank test for each carburetor hot soak test. The emission value could be assigned to each evaporative configuration on the basis of fuel tank and carburetor combinations.

It has been estimated that a testing scheme based on selection criteria would result in approximately 50 fuel tank families and 150 carburetor families. If each selected system is tested three times, i.e. 5000, 25,000 and 50,000 miles, the test load would be reduced from an estimated 4500 tests to 600 for upcoming model years.

The discussion above is contrary to the established certification process. However, evaporative emissions are generated from physical mechanisms that are hardware oriented rather than chemical reactions as in the case of exhaust emissions. Furthermore, control systems are prone to deteriorate with time rather than with the mileage accumulated in the accelerated durability testing. For these reasons, it does not appear to be necessary to test each durability vehicle at 5 mileage points.

In general, the evaporative emissions test should be separated from the exhaust emissions test to allow more flexibility in the testing sequence. However, when a hot soak test is required on a vehicle, the hot soak test should obviously follow a phase of hot vehicle operation. The diurnal test could be conducted as an independent test. Tests (22) have been conducted that showed that the inclusion or exclusion of the diurnal test prior to the exhaust emissions test has no detectable effect on the exhaust emissions. Similarly, vehicle operating temperatures are generally at stable conditions during hot operation, and the hot soak temperature profile tends to achieve the same maximum temperature regardless of the previous operation. Hot soak testing obviously does not influence the exhaust test phase.

The evaporative emission that has not been specifically measured heretofore is the "running loss" emission. At present, the assumption is made that the only possible source for a running loss would be at the tank cap or recognized vents. In most cases, no canister measurement is made at the tank cap because the caps are considered leak tight and void of emissions. The fallacy of this assumption is that running losses could occur from many unrecognized sources.

A scheme has been developed at the MSAPC laboratory to measure the total running losses by essentially operating the dynamometer and vehicle inside an enclosure. A flow through the enclosure is maintained and sampled during the exhaust emissions test. In practice, this has been achieved by sampling the inlet and outlet of the test cell air handling system. Exhaust emissions were measured by the normal CVS while the air handler acted as a running loss CVS. This concept is a CVS within a CVS which measures and differentiates all vehicle hydrocarbon emissions. A description of this concept and some data collected using it have been presented in the technical appendix.

This method of measuring running losses has been discussed here as a potential part of the implementation plan because it is compatible with the enclosure principle, CVS concept, and vehicle sample selection plan. This total concept could be implemented by constructing one enclosure that incorporated all the phases of a total emissions test. One such enclosure would have the capability of handling about 2 total emissions tests/day or about 40 vehicles per month; this capacity will not accommodate the number of tests that might be required under the sample selection criteria.

However, if running losses are not measured this way, one enclosure could handle 120 diurnal and hot soak tests per month if performed independently.

A fourth evaporative emission, refueling losses, can also be measured by the enclosure technique. Although this is presently unregulated, the effectiveness of a standard fueling connector which might be adopted to eliminate refueling losses could be assessed by this method. Again, the flexibility of the enclosure method has been illustrated.

Most of this discussion has been about an implementation plan that is based on vehicle sample selection criteria and testing with the enclosure - hydrocarbon analyzer combination. Several alternative plans have been previously proposed and are listed below with a brief discussion of their limitations and problems.

A. SAE Procedure applied to all vehicles.

- 1) Description: Replace the federal canister procedure with the enclosure technique and apply the test to every vehicle tested under the present vehicle selection plan.
- 2) Problems: The cost, space, and time involved to perform the test sequence on each vehicle are not justified by the data. It would be technically and politically unpopular to propose such a plan, and very costly to execute such a scheme.

B. SAE modified procedure applied to all vehicles.

- 1) Description: The diurnal and hot soak phases have been combined to shorten test time.
- 2) Problems: Separate emission data are lost and weighting factors cannot be properly applied. Diagnostic aspect is also sacrificed. Same problems of (a) apply here also.

Cost: benefit ratio is still high. Safety regulations may not permit the fueling operations required.

C. MSAPC/ECTD procedure.

- 1) Description: A procedure that employed radiant heat lamps instead of the electric blanket pads for the diurnal test, which was also combined with the hot soak.
- 2) Problems: The critical temperature profile, fuel tank liquid temperature, was not attained by this method. Vehicle color requirements (all black) were too restrictive. Enclosure ambient temperatures would be too high, separate emission data would be sacrificed, and energy consumption per test would be very high.

These alternatives were proposed to improve, simplify, and shorten the test. Unfortunately, each had an associated aspect that rendered the proposal less beneficial and more costly than the one recommended in this paper. That proposal has been summarized again for review.

D. MSAPC evaporative emission procedure.

- 1) Vehicle sample selection criteria are used to define evaporative diurnal and hot soak families and to reduce the number of vehicles and tests required for certification of evaporative control systems.
- 2) SAE J171 procedure used for testing.
- 3) Independent diurnal and hot soak tests are performed on selected vehicles; each vehicle may not get both tests.
- 4) Calculations are performed to yield weighted emission rates (g/mi) for each system defined.

V. Problems of Implementation: The proposal that has been made is not completely without problems. Lead time, control technology, vehicle sample selection criteria, and evaporative emission standards are all problems which must be addressed prior to a final implementation.

The lead time problem affects both MSAPC and industry laboratories. MSAPC has two enclosures that are operational, but a formal data collection and analysis program is required prior to conducting large numbers of tests. These problems can be resolved in the anticipated lead time. The industry has two lead time problems. Some automotive laboratories will require construction of enclosures, and all companies will require lead time to develop the appropriate evaporative emission control hardware. Communications should be established with the industry to inform them of our intentions so as to maximize their lead time. The proposed program plan, Part II of this document, estimates that 1977 MY vehicles could be tested by the enclosure procedure. These tests might begin as early as December, 1975.

As mentioned, the control technology represents the biggest problem to the industry. The evaporative emissions standards that would be set weigh heavily on the control technology changes that would be required. As the program plan outlines, the potential for control by various techniques and devices will be determined. The cost of extensive changes will be weighed against their impact on overall air quality. This is an area where additional information and data are needed. The program plan provides for obtaining this information by a control technology assessment contract.

The final problem associated with adopting a new procedure is to determine the appropriate standard of compliance. The data indicate that the average evaporative emissions as measured by the enclosure are much higher than the 2 gram/test (.13 g/mi) standard presently in effect. The existing data base from enclosure tests can be combined with data

generated during the control technology assessment, development, and demonstration programs to provide a concise determination of the appropriate standard and timetable for compliance.

The control systems now in use appear to have an emission rate somewhere between 1.5-2.0 g/mi as calculated from the weighted enclosure emission values and average daily mileage. Had the evaporative standards been established using the enclosure procedure and weighted calculations, the 1975 standard would have been 0.27 g/mi. Assuming the diurnal emission can be reduced to zero, the allowable one hour hot soak emission translates to a value of 2.0 grams per test. There have been some hot soak enclosure results obtained at the 2.0 gram per test level, but the overall vehicle population average of 11.0 grams per test illustrates the amount of reduction still required. It is unlikely that this reduction can be achieved in one year, although the fact that the problem is a single component, hardware oriented phenomenon makes its solution much simpler than the multi-component, chemical reactions associated with vehicle exhaust emissions. The design work being done to meet impact/fuel spillage safety regulations may improve evaporative emissions.

Other questions related to simulation of realistic environmental parameters have been addressed in a technical appendix to this report.

VI. Conclusions:

- A. The canister test procedure is so limited in its accuracy and integrity that its continued use has little value towards continued improvement in air quality.
- B. The enclosure test procedure as specified in SAE J171 will accurately and repeatedly measure true total evaporative emissions. The parameters of the procedure represent a realistic simulation of the critical environmental conditions. Its use will correctly assess the performance of control techniques and their impact on air quality.
- C. Data indicate that evaporative emissions control can be assessed on a vehicle sample selected by use of characteristic criteria. This is an evaporative family approach which is similar to the engine family scheme used for exhaust emissions. This type of regulatory program would be highly cost effective.
- D. Evaporative emissions will become the dominant hydrocarbon emission by 1976 under present control techniques and will result in reductions that are lower than those needed to meet ambient air quality requirements. Actions to regulate evaporative emissions are required by the Clean Air Act.

- E. The problems of changing the procedure and standard can be solved. Some automotive companies will require a larger effort to implement the change and to develop the control techniques.
- F. A program plan can be executed to provide a regulatory program and evaporative emissions standard by September, 1975. A milestone chart has been included at the end of this paper to show the tasks required.

VII. Recommendations:

- A. The use of the canister procedure should be minimized as soon as possible for the following reasons:
 - 1) High costs are incurred that produce no benefits.
 - 2) Evaporative control technology has not changed; therefore, evaporative emission values should remain the same. From the data shown in Table A, the probability of a vehicle failing the evaporative standard is very low.
 - 3) Tests (22) have shown that the vehicle preparation and diurnal test have no detectable effect on exhaust emissions and could therefore be deleted or separated.
 - 4) Test time could be reduced to facilitate highway fuel economy measurements and enclosure testing for evaporative emissions.
- B. The enclosure procedure should be adopted as the official test procedure for measuring evaporative emissions. Communications with the automobile industry should be established as soon as possible to express the intended changes in evaporative regulation, to maximize lead time, and to solicit their comments on our program.
- C. The program plan to achieve the development and implementation of an appropriate standard should be approved and given high priority. The revised regulation could possibly be implemented by December, 1975 if high priorities are assigned.

VIII. Closure: This document has attempted to reveal the problems associated with mobile source evaporative emissions. These environmental, technical, and political problems pose a challenge to the OMSAPC which requires action. In the consideration of alternative actions, "no action" is not a responsible alternative.

IX. References for Evaporative Losses

SAE Vehicle Emissions - Part I Vol. 6, 1955-1962

1. Wentworth, J. T., "Carburetor Evaporation Losses", SAE Transactions 1955.

SAE Vehicle Emissions - Part II Vol. 12, 1963-1966

2. Muller, H. L., Kay, R. E., and Wagner, T. O., "Determining the Amount and Composition of Evaporative Losses from Automotive Fuel Systems". SAE Transactions, Vol. 75, 1967.
3. Ebersole, G. D., and McReynolds, L. A., "An Evaluation of Automobile Total Hydrocarbon Emissions", SAE Transactions, Vol. 75, 1967.
4. Caplan, J. D., "Smog Chemistry Points and the Way to Rational Vehicle Emissions Controls". SAE Transactions, Vol. 74, 1966.

SAE Vehicle Emissions - Part III, Vol. 14, 1967-1970

5. Martens, S. W., and Thurston, K. W., "Measurement of Total Vehicle Evaporative Emissions" SAE Transactions 680125, 1968, p. 191.
6. Martens, S. W., "Evaporative Emissions Measurements with the Shed - A Second Progress Report" SAE Transactions 690502, 1969, p. 202.
7. Wade, D. T., "Factors Influencing Vehicle Evaporative Emissions", SAE Transactions, 670126, 1967, p. 743.
8. Wade, Clarke, Gerrard, Skarstrom, Vardi, "An Adsorption-Regeneration Approach to the Problem of Evaporative Control", SAE Preprint, 670126, 1967, p. 756.
9. Koehl, W. J. Jr., "Mathematical Models for Prediction of Fuel Tank and Carburetor Evaporative Emissions", SAE Preprint, 690506, May, 1969.
10. Nelson, E. E., "HC Control for Los Angeles by Reducing Gasoline Volatility", SAE Transactions, 690087, 1969, p. 775.
11. Jackson, M. W., and Everett, R. L., "Effect of Fuel Composition on Amount and Reactivity of Evaporative Emissions", SAE Transactions, 690088, 1969, p. 802.
12. Society of Automotive Engineers, SAE J171a, "Measurement of Fuel Evaporative Emissions Using the Enclosure Technique", July, 1972.
13. Deeter, W. F., et. al. "An Approach for Controlling Vehicle Emissions", SAE Preprint 680400, (1968).

14. Deeter, W. F., and Jewell, R. G., "Factors Affecting Carburetor Vapor Losses".
15. Automobile Manufacturer's Association, AMA Engineering Notes 6/6, "Fuel Systems Evaporation Losses", September, 1961.
16. Coordinating Research Council, CRC Report No. 400, "1966 CRC Motor Vehicle Evaporation Loss Measurement Technique Evaluation", January, 1967.
17. U. S. Dept. of Commerce, NOAA, "Climatology of the United States No. 84, Daily Normals 1941-70", September, 1973.
18. National Academy of Sciences, "Semiannual Report to EPA by CMVE of NAS", January 1, 1972.
19. National Academy of Sciences, "A Critique of the 1975-76 Federal Automobile Emissions Standards for Hydrocarbons and Oxides of Nitrogen", Prepared for EPA, May 22, 1973.
20. Korth, M. W., Rose, A. H., and Stahman, R. C., "Effect of Hydrocarbon to Oxides of Nitrogen Ratios on Irradiated Auto Exhaust", APCA Annual Meeting, June, 1963, PHS Document.
21. Rose, A. H. Jr., "Summary Report of Vehicular Emissions and Their Control", PHS Report, Unpublished, 1966.
22. Kruse, R. E., "Evaluation of the Effect of Evaporative Emission Testing Upon Exhaust Emission Test Results", January, 1974. EPA Memo to M. W. Korth.
23. Patterson, D. J., and Henein, N. A., "Emissions from Combustion Engines and Their Control", (Ann Arbor: Science Publishers, Inc., 1972) Chapter 6, p. 181.
24. Society of Automotive Engineers, SAE J1045, "Instrumentation and Techniques for Vehicle Refueling Emissions Measurement", August, 1973.
25. Letter from D. A. Jensen to Technical Advisory Group on Evaporative Emissions, October 18, 1965.
26. Letter from M. L. Brubacker to the Evaporative Emissions Advisory Group, January 10, 1966.
27. Federal Register, Volume 32, Number 24, Part 85, "Control of Air Pollution from New Motor Vehicles and New Motor Vehicle Engines", February 4, 1967, p. 2448.

28. Federal Register, Volume 33, Number 108, Part II, "Standards for Exhaust Emissions, Fuel Evaporative Emissions and Smoke Emissions, Applicable to 1970 and Later Vehicles and Engines". June 4, 1968, p. 8304.
29. Federal Register, Volume 35, Number 136, July 15, 1970.
30. Federal Register, Volume 36, Number 70, "Certification Test Results for 1971 Model Year", April 10, 1971.
31. Federal Register, Volume 37, Number 114, "Certification Test Results for 1972 Model Year", June 13, 1972.
32. Federal Register, Volume 38, Number 84, "Certification Test Results for 1973 Model Year", May 2, 1973.
33. Federal Register, Volume 38, Number 212, "Certification Test Results for 1972 Model Year", November 5, 1973.
34. Miscellaneous reports on file in EPA Procedures Development File on Evaporative Emissions. MSAPC, Ann Arbor, Michigan, 1973
35. Coordinating Research Council, CRC-Scott Project No. 2602, CAPE-5-68, "Time-Temperature Histories of Specified Fuel Systems". Vol. 1, October, 1969.
36. Coordinating Research Council, CRC-SDC, CAPE-10, "Summary Report on Vehicle Driving Patterns", January 1971.