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The Effect of Fuel Volatility on Controlled and Uncontrolled Evaporative Emissions

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TABLE OF CONTENTS

1.0 BACKGROUND

EPA test data have shown that evaporative hot soak and diurnal emissions are sensitive to fuel volatility. Since July 1984, EPA has tested nearly 300 in-use vehicles in the Emission Factor (EF) program on three fuels of varying volatility. Based upon these data, equations for evaporative emissions versus fuel volatility were developed. Values from these equations were used in an EPA evaporative study which examined the benefits of volatility and other controls.(1) The purpose of this report is to summarize the results of the volatility testing, and to further document the values that were used in the aforementioned study.

Three types of evaporative emissions will be considered in this study: basic evaporative emission rates, tampering offsets, and refueling emissions. Basic evaporative emission rates are the emissions estimated from nontampered post-1970 model year (i.e., "controlled") vehicles. These vehicles are typically equipped with carbon-filled canister (or canisters) to help collect fuel vapors.

Tampering offsets are the emission increases due to evaporative system tampering. The offsets are defined as the difference between uncontrolled and controlled emissions. Uncontrolled emissions were estimated from precontrolled vehicles and vehicles with tampered evaporative systems. Examples of evaporative system tampering are missing canister and disconnected evaporative system hoses.

Refueling emissions occur when gasoline vapor in vehicle's fuel tank is displaced by liquid fuel during a refueling event. They also include spillage that occurs during refueling. Since EPA is considering promulgating onboard evaporative controls, refueling emissions are considered as mobile source evaporative emissions. Refueling emissions vary with fuel volatility, and the technique used to estimate refueling emissions at different volatilities will be briefly discussed.

This report primarily discusses data which were available immediately prior to the April 16, 1985 emission factor workshop, and were used in the EPA evaporative study released in November 1985.(1) More data have become available since, and these will be noted where necessary.

2.0 BASIC EVAPORATIVE EMISSIONS

In discussing the basic evaporative emissions, the rates for 1981 and later model year LDGVs with SHED 2.0 grams/test standard will be described first, since the majority of the fuel volatility related test data are from these vehicles. There are less data available for the pre-1981 LDGV and other vehicle types, therefore the emissions at different volatility levels of these vehicles are derived in part from the 2 gram vehicles. Shortly after the release of MOBILE3, test data on 1978-80 LDGVs (SHED 6.0 grams/test standard) at three different volatility levels became available from an American Petroleum Institute (API) test program and report.(2) Presentation of this model year group will be in section 2.2. Evaporative emission rates for pre-1978 LDGVs and other vehicle types are briefly presented in sections 2.3 and 2.4.

2.1 1981 and later LDGVs

The three fuels used in EPA's EF program are Indolene, a commercial fuel that is representative of the summer Reid Vapor Pressure (RVP) in Michigan cities, and a blend of these two fuels. Their average fuel RVPs are 9.0, 11.7 and 10.4 psi, respectively. All vehicles in this analysis were tested with the commercial (the highest RVP) fuel first, blended fuel second, and Indolene fuel last. This test sequence was based on the idea that vehicles had been operated on approximately 11.5 psi fuel prior to arriving at EPA; therefore, the most representative measurement of their in-use emissions would be obtained by testing on commercial fuel first. (For further discussion on test fuel order, please see reference 1.) The test procedure used was essentially the same as listed in the CFR, with two exceptions. One is that when vehicles were received from their owners the gas caps were partially opened to prevent saturation of the canister prior to testing. The other exception is that all vehicles were tested with their own gas caps, and externally mounted thermocouples were used to measure tank diurnal temperatures.

Measurements of test fuel RVP were performed each week from each of the four fuel dispensers (two dispensers are designated for Indolene fuel, one for commercial fuel, and one for the blend). All fuels were analyzed according to ASTM D323 procedure with two samples taken. An average of these two samples was used as the fuel RVP level for the week from each fuel dispenser. Monthly averages were then calculated for each fuel and assigned to all vehicles tested in that month. (The results from the two Indolene dispensers were averaged.) Table 1 presents a summary of the monthly averaged fuel RVP levels.

Out of the 166 vehicles tested up to the end of March 1985, two were found as tampered vehicles: one had a canister missing (vehicle No. 5033), and one had vacuum lines disconnected (vehicle No. 5124). To be consistent with the

MOBILE3 analysis (3), these two tampered vehicles were excluded from this sample. Table 2 is a summary of the sample distributions of this nontampered three-fuel evaporative emission data base stratified by model year and by manufacturer. (By December 5, 1985, the sample size of this data base had increased to 279 vehicles with the addition of 45 carbureted vehicles and 70 fuel-injected vehicles. One of these was a tampered vehicle -- No. 5117 -- which had a disconnected bowl vent line.)

Scatter plots of emissions versus fuel RVP are presented in Figures 1 through 4. Average emissions are listed in Table 3. Several things can be summarized from these scatter plots and averages:

a. Both hot soak and diurnal emission rates increase with the increasing fuel volatility. This is true for both the carbureted and fuel-injected vehicles.

b. Diurnal emissions on the average appear to be more sensitive to the fuel volatility than hot soak emissions.

c. The emissions are more dispersed at higher RVP fuels (especially diurnal). The distributions of emissions at each fuel RVP level are not exactly normal.

d. On the average, carbureted vehicles have higher hot soak and diurnal emissions than fuel-injected vehicles.

e. The diurnal emissions of ported fuel-injection (PFI) and throttle body injection (TBI) are very similar, while the hot soak emissions of the PFI vehicles are somewhat lower than the TBI vehicles.

Curve fitting methods were used to express the relationship between the evaporative emissions and fuel RVP. The analyses were done for carbureted and fuel-injected vehicles separately, because of their differences in average emissions. Ported and throttle body injected vehicles were combined because of their similarities in fuel control as opposed to carburetion (i.e., the absence of float bowls and bowl vent lines to the canisters). Since the distribution of emissions at each fuel RVP were not normal, the first model evaluated was a least squares regression through the natural log of emissions. Derived equations had good correlation coefficients, but they resulted poor predictions of emissions at higher RVP levels. For this reason, other curve fitting methods were explored, and derived equations were evaluated by both the correlation coefficients and the proximity by which they predicted the average emission levels at the three RVP means (8.96, 10.39, and 11.74).

With these criteria in mind, second degree polynomials were found to be best for both hot soak and diurnal emissions of the carbureted vehicles. For the diurnal emissions of the fuel-injected vehicles, two equations were used: a linear equation was fitted for low volatility fuels (RVP <10.4), and a second degree polynomial curve was used for higher volatility fuels (RVP equal to or greater than 10.4). This strategy of using two piece curves was viewed as a temporary solution to fit a relatively small sample. (On a later date, when 70 more fuel-injected vehicles were added to this sample, a single second degree polynomial equation was found to work for diurnal emissions of the fuel-injected vehicles.) A linear equation was used for the hot soak emissions of the fuel-injected vehicles. Regression coefficients are summarized in Table 4.

Table 5 is a list of the predicted evaporative emissions for RVP levels between 8.5 and 12.0, based upon the five equations. Emission averages at the three RVP means are indicated in parentheses for comparison. Since the coefficients were derived from RVP values 8.8 to 11.9 (see Table 1), predictions are valid only within these RVP ranges. Figure 5 is a pictorial view of the relationship between evaporative emissions and fuel volatility based upon these five equations. The averages for the three fuels are also presented.

2.2 1978-80 LDGVs

Additional data have been made available since the release of MOBILE3. This set of data came from a fuel volatility study conducted at Automotive Testing Laboratories, Inc., East Liberty, Ohio (ATL), through an API contract.(2) A total of 40 vehicles covering model years 1978 through 1983 were tested with three volatility level fuels (9.0, 10.5, and 11.7) under randomized fuel sequences. (See reference 1 as to why using a randomized fuel sequence could confound some of the results.) Out of the sixteen 1978-80 vehicles, there was one tampered vehicle: a 1980 Fairmont which had the evaporative system totally disabled. Another vehicle, (1980 Sunbird) was retested with its gas cap replaced. It was not certain whether the high diurnal emissions from as-received tests on the Sunbird were caused by a missing gas cap or a leaking gas cap. For this reason, this vehicle was also excluded from the sample. Table 6 presents the two excluded vehicles and the average evaporative emissions of the nontampered vehicles.

The sample size of these API data is considered insufficient in developing emission rates through a curve fitting approach. To express the relationship between emissions and fuel volatility, the 1981+ carbureted curves were fitted through the 1978-80 averages at 9.0 and 11.7 RVP fuels with the following equation:

$$E_{78-80,RVPx} = E_{78-80,9.0} + \Delta E_{78-80,(11.7-9.0)} *(\Delta E_{81,(x-9.0)}/\Delta E_{81,(11.7-9.0)}) \qquad (1)$$

where

$E_{78-80,RVPx}$ = Emission level in grams at RVP = x for 1978-80 vehicles

$E_{78-80,\ 9.0}$ = Emission level in grams at 9.0 RVP for 1978-80 vehicles

$\Delta E_{78-80,(11.7-9.0)}$ = Emission difference from 11.7 to 9.0 for 1978-80 vehicles

$\Delta E_{81,(x-9.0)}$ = Emission difference from RVP=x to 9.0 for 1981+ carbureted vehicles

$\Delta E_{81,(11.7-9.0)}$ = Emission difference from 11.7 to 9.0 for 1981+ carbureted vehicles.

With this equation and emission rates from Tables 5 and 6, the 1978-80 hot soak and diurnal emissions at various volatility levels can be easily calculated. For example, at 10.5 psi the predicted emissions are 2.91 grams for hot soak and 8.89 grams for diurnal. The average emissions of the actual data from 1978-80 vehicles (from Table 6) at 10.5 psi were 2.25 grams for hot soak and 10.11 grams for diurnal. The estimated emissions for 1978-80 LDGVs are plotted in Figures 6 and 7.

2.3 Pre-1978 LDGVs

Evaporative emission data at 11.5 psi fuel for pre-1978 LDGVs were very limited.(3) To estimate their emission levels at various volatilities, the same technique described in Section 2.2 was used. The pre-1978 emission averages at 9.0 and 11.5 RVP fuels were obtained from the MOBILE3 evaporative report (3) and are presented in Table 7.

For pre-1971 LDGVs (with no evaporative emission standard), changes in emissions from any RVP fuel to Indolene fuel are calculated through a linear interpolation between the two measured RVP levels. The equation used is similar to that of the previous section (equation 1), except that the emission differences from 2 gram carbureted vehicles are replaced by the volatility changes.

$$E_{Pre-71,RVPx} = E_{Pre-71,\ 9.0} + \Delta E_{pre-71,(11.5-9.0)}*((x-9.0)/2.5) \quad (2)$$

where

$E_{Pre-71,9.0}$= Emission level in grams at 9.0 RVP for pre-1971 vehicles

$\Delta E_{Pre-71,(11.5-9.0)}$ = Emission difference from 11.5 to 9.0 for pre-1971 vehicles

x = Fuel RVP.

For model year 1971 and 1972-77 LDGVs, emissions are estimated by equation 1 with emission rates from Tables 7 and 5. Evaporative emissions at various volatility levels for pre-1978 model year vehicles are also plotted in Figures 6 and 7.

2.4 Other Vehicle Types and High Altitude Rates

The evaporative emissions of light duty gasoline truck class one (LDGT1s) and 1979 and later light duty gasoline truck class two (LDGT2s) at various volatilities are the same as LDGVs. For pre-1979 LDGT2s and pre-1985 heavy duty gasoline vehicles (HDGVs), it is assumed that evaporative emissions vary linearly with fuel RVPs between 9.0 and 11.5 psi. For 1985 and later HDGVs, emissions at different volatilities are obtained from fitting the 1981 and later carbureted curves through 9.0 and 11.5 psi emission rates. These 9.0 and 11.5 RVP rates for pre-1979 LDGT2s and HDGVs are listed in the MOBILE3 evaporative report. (3)

The high altitude emission rates are derived from low altitude emissions in a manner consistent with the methods described in the MOBILE3 evaporative report.(3) This report used several altitude factors to adjust the emissions at low altitude to high altitude emissions.

3.0 TAMPERING OFFSETS

3.1 Discussion

The MOBILE3 program estimates the fraction of vehicles that are tampered and nontampered, their corresponding emission levels, and combines them to obtain the overall fleet emissions. Consequently, to properly account for fleet emissions at different volatility levels, there is a need to estimate how the emissions of tampered vehicles change with fuel volatility.

Emissions from tampered vehicles are estimated in MOBILE3 by tampering offsets, which are the increases in emissions that vehicles experience from their baseline state when they are tampered. For evaporative emissions, the baseline state is represented by the in-use emissions at different volatilities that were presented in the previous sections of this report. To estimate the tampering offsets at different volatilities, it is necessary to know the "uncontrolled" emissions of the different vehicle types and model years over a range of volatilities. The tampering offsets can then be estimated by the difference in "uncontrolled" and "controlled" emissions at different volatilities.

Tampered items affecting evaporative emissions that were included in MOBILE3 were disconnected evaporative system hoses and missing canisters.(3) The incidence rates for these items were taken from EPA's 1982 Tampering Survey.(4) Since the time MOBILE3 was issued, fuel cap removal and misrouted evaporative hoses have also been found to be more prevalent in the Tampering Surveys than in EPA's emission factors testing. Therefore, both hot soak and diurnal emissions must be estimated for all four tampered conditions.

The uncontrolled evaporative emission rates used to quantify the tampering effects are based on SHED testing of vehicles with removed canisters and/or fuel caps. It is currently assumed that misrouted or disconnected hoses eventually cause the same effect as a missing canister or fuel cap, since they can cause the canister to become saturated and incapable of holding additional fuel vapor. This might not be precisely correct, because the fuel tank pressure is probably somewhat higher with a saturated canister than a removed one, which could result in lower emissions.

It is also assumed that fuel cap removal has no effect on the hot soak emissions of carbureted vehicles, since the primary source of hot soak emissions in carbureted vehicles is the float bowl. However, for fuel-injected vehicles the primary source of hot soak emissions is thought to be fuel in the tank which is heated by a recirculating fuel system and exhaust system. Therefore, fuel cap removal is assumed to result in uncontrolled hot soak emissions in fuel injected vehicles. A number of other assumptions were made in deriving the emission rates, most of which are described in a separate EPA report. (See reference 1, page 2-59.) The remainder of this section will describe the data used to obtain uncontrolled emissions at two fuel volatilities (9.0 and 11.5 psi), and how the emissions are estimated at intermediate volatilities.

3.2 Uncontrolled LDGV Emission Data

The uncontrolled evaporative emission rates for different vehicle types and model years at low altitude are shown in Tables 8 and 9. These rates are based in part on the vehicle test results presented in Table 10. The emission rates are shown at 9.0 and 11.5 psi for both disconnects and fuel cap removal.

The pre-1971 uncontrolled and controlled emission rates are identical. For 1971, the uncontroled emissions are assumed to be the same as pre-1971, with the exception that there is no hot soak effect of fuel cap removal. The diurnal rates for 1972-1977 are based on the averages of the two vehicles in this standard group shown in Table 10. These two vehicles experienced lower diurnal rates than the pre-1971 vehicles, which could be attributed to improvements in tank configuration and placement relative to the exhaust system, and tank downsizing. The average hot soak emission rates of these two vehicles, 17.97 grams, are higher than the pre-1971 vehicles. It is difficult to determine whether the hot soak emissions of all 1972-77 vehicles would be similarly higher than the pre-1971 vehicles. Rather than base the emissions of 1972-77 vehicles on the results of two vehicles, it was decided to use the pre-1971 hot soak emission rate of 14.67 grams for uncontrolled hot soak emissions of 1972-77 LDGVs.

The uncontrolled emissions for 1978-80 and 1981+ carbureted vehicles and unontrolled hot soak emissions for fuel-injected vehicles came from the vehicles in these two standard groups listed in Table 10. There was one 1982 fuel-injected vehicle tested with a missing gas cap; its results are also shown in Table 10. The diurnal emissions of this fuel-injected vehicle were similar enough to the carbureted vehicles that we decided to use the diurnal emissions of the 1981+ carbureted vehicles for both missing canisters and gas caps on fuel-injected vehicles. The hot soak emissions of this vehicle, however, were used as the hot soak emissions of all tampered fuel-injected vehicles. EPA is conducting additional testing of fuel-injected vehicles in tampered conditions to augment these data. Preliminary results indicate that this fuel-injected vehicle is very representative of the fleet.

At fuel volatilities between 9.0 and 11.5 psi, it is assumed that uncontrolled hot soak and diurnal emissions increase linearly with increasing RVP. Data on one vehicle

(No. 5033) with a missing canister tested in the emission factor program which supports linearity is shown in Figure 8.

Tampering offsets estimated as the difference in uncontrolled and controlled emissions at varying RVPs are shown for the different LDGV model year groups in Figures 9-12. Generaly, hot soak and diurnal tampering offsets increase with increasing RVP, since uncontrolled emissions are increasing faster (with RVP) than controlled emissions. At higher RVPs, however, uncontrolled and controlled emissions should increase (with RVP) at the same rate, leading to a constant tampering offset. This is what the diurnal emissions appear to be doing in Figures 10-12. The reduction of the tampering offset for diurnal emissions at higher RVPs of 1972-77 vehicles (Figure 9) is an artifact of the quadratic expression for controlled emissions fitted through the 1972-77 data, which has controlled emissions at higher RVPs (i.e., between 10.5 psi and 11.5 psi) increasing faster than uncontrolled emissions. This quadratic expression is probably not valid above 11.5 psi.

3.3 Other Vehicle Types and High Altitude Rates

The uncontrolled emission rates of LDGT1s and 1979 and later LDGT2s at varying RVPs are identical to the LDGVs. For pre-1979 LDGT2s and pre-1985 HDGVs, it is assumed that the uncontrolled evaporative emission rates vary linearly with RVP between 9.0 and 11.5 psi. The 9.0 and 11.5 psi emission rates for these vehicles are listed in the MOBILE3 evaporative report.(3) For 1985 and later HDGVs, the uncontrolled evaporative emission rates for 9.0 and 11.5 psi fuel were derived from the 1981 and later LDGV carbureted rates. The methodology is the same as the controlled evaporative emissions which is also described in the MOBILE3 evaporative report.(3)

For high altitude, it is assumed that the uncontrolled emission rates in most cases are equal to the low altitude uncontrolled rates multiplied by an altitude factor of 1.3.(3)

4.0 REFUELING EMISSIONS

The methodology for estimating refueling emissions in grams per mile from emissions in grams per gallon and fuel economies of the various classes of gasoline powered vehicles is discussed in a separate report.(5) The refueling emissions presented herein and used in the EPA evaporative study (1) are based on 6 grams/gallon at 11.5 psi (including spillage) and 4.8 grams/gallon at 9.0 psi. A linear relationship is assumed between the refueling emissions and fuel volatility to derive emissions at intermediate volatility levels. Refueling emissions in grams/mile for the four gasoline powered vehicle classes are shown in Table 11.

References

1. "Study of Gasoline Volatility and Hydrocarbon Emissions from Motor Vehicles", November 1985, Standards Development and Support Branch, Office of Air and Radiation, Environmental Protection Agency, EPA-AA-SDSB-85-5.

2. "A Study of Factors Influencing the Evaporative Emissions from In-Use Automobiles", API Publication 4406, April 1985.

3. "Evaporative HC Emissions for MOBILE3", August 1984, Test and Evaluation Branch, Office of Mobile Sources, Environmental Protection Agency, EPA-AA-TEB-EF-85-1.

4. "Motor Vehicle Tampering Survey - 1982", March 1982, Field Operations and Support Division, Office of Mobile Sources, Environmental Protection Agency, EPA-330/1-82-001.

5. "Refueling Emissions from Uncontroled Vehicles", July 1985, Standards Development and Support Branch, Office of Air and Radiation, Environmental Protection Agency, EPA-AA-SDSB-85-6.

Table 1

Summary of Average Fuel RVP
in EF Three-Fueled Data Base
March 29, 1985

Test Date (Month/Year)	No. of Vehicles	Average Fuel RVP (psi)		
		Indolene	Blend	Commercial
08-84	23	8.8	10.4	11.7
09-84	21	8.8	10.3	11.7
10-84	32	8.9	10.4	11.6
11-84	14	9.0	10.4	11.7
12-84	13	9.1	10.4	11.8
01-85	24	9.1	10.5	11.8
02-85	24	9.1	10.4	11.9
03-85	13	9.0	10.3	11.8
AVERAGE		8.96	10.39	11.74

Table 2

Summary of Three-Fueled Evaporative Data Base from EF Program: Nontampered Vehicles, March 29, 1985

Category	Sample size: All	Carbureted	Fuel-Injected*
Model Year			
1981	91	79	12 (10)
1982	19	4	15
1983	54	26	28 (18)
Manufacturer			
GM	47	32	15
Ford	28	26	2
Toyota	26	13	13 (13)
Nissan	22	14	8 (8)
Chrysler	17	17	0
AMC	10	0	10
Honda	3	3	0
Volkswagen of Germany	3	0	3 (3)
Fuji	2	2	0
Renault	2	0	2 (2)
Toyo Kogyo	1	1	0
Mitsubishi	1	1	0
Audi	1	0	1 (1)
Volkswagen of America	1	0	1 (1)
TOTAL	164	109	55 (28)

* Numbers of ported fuel injected vehicles are indicated in parentheses.

Table 3

Summary of Average Evaporative Emissions of Nontampered 2.0 Gram Vehicles, March 29, 1985

Engine Type	N	Average Miles	Fuel RVP	Average Emissions (g/test) Hot Soak	Diurnal	Total
Carbureted	109	55,050	9.0	2.33	2.36	4.69
			10.4	2.93	4.92	7.85
			11.7	4.05	10.14	14.19
Fuel-Injected	55	45,922	9.0	0.93	1.21	2.14
			10.4	1.38	2.23	3.61
			11.7	1.92	6.48	8.40
PFI*	28	44,204	9.0	0.63	1.19	1.82
			10.4	0.80	2.05	2.85
			11.7	1.10	6.42	7.52
TBI**	27	47,704	9.0	1.25	1.23	2.48
			10.4	1.97	2.42	4.39
			11.7	2.77	6.54	9.31

*Ported Fuel-Injection

**Throttle Body Injection

Table 4

Regression Coefficients
For 1981+ Light-Duty Vehicles
March 29, 1985

Engine Type	Emissions	Coefficients*		
		Constant	A	B
Carbureted	Hot Soak	14.1630	-2.82200	0.16733
	Diurnal	42.1720	-9.98890	0.61782
Fuel-Injected	Hot Soak	-2.4817	0.37520	0.0
	Diurnal**	-4.9468	0.68815	0.0
		84.5950	-17.87500	0.95632

* Emissions = Constant + A*RVP + B*RVP*RVP.

** Use linear form (with B coefficient = 0.0) if RVP <10.4, and quadratic form if RVP $\geq$ 10.4.

Table 5

Predicted Evaporative Emissions*
On 1981+ Nontampered Vehicles
March 29, 1985

Fuel	------Hot Soak--------		---------Diurnal------	
RVP	FINJ	CARB	FINJ	CARB
8.5	0.71	2.27	0.90	1.90
8.6	0.75	2.27	0.97	1.96
8.7	0.78	2.28	1.04	2.03
8.8	0.82	2.29	1.11	2.11
8.9	0.86	2.30	1.18	2.21
9.0	0.90(0.93)	2.32(2.33)	1.25(1.21)	2.32(2.36)
9.1	0.93	2.34	1.32	2.43
9.2	0.97	2.36	1.38	2.57
9.3	1.01	2.39	1.45	2.71
9.4	1.05	2.42	1.52	2.87
9.5	1.08	2.46	1.59	3.04
9.6	1.12	2.49	1.66	3.22
9.7	1.16	2.53	1.73	3.41
9.8	1.20	2.58	1.80	3.62
9.9	1.23	2.63	1.87	3.83
10.0	1.27	2.68	1.93	4.06
10.1	1.31	2.73	2.00	4.31
10.2	1.35	2.79	2.07	4.56
10.3	1.38	2.85	2.14	4.83
10.4	1.42(1.38)	2.91(2.93)	2.21(2.23)	5.11(4.92)
10.5	1.46	2.98	2.34	5.40
10.6	1.50	3.05	2.57	5.71
10.7	1.53	3.13	2.82	6.02
10.8	1.57	3.20	3.09	6.35
10.9	1.61	3.28	3.38	6.70
11.0	1.65	3.37	3.68	7.05
11.1	1.68	3.46	4.01	7.42
11.2	1.72	3.55	4.36	7.80
11.3	1.76	3.64	4.72	8.19
11.4	1.80	3.74	5.10	8.59
11.5	1.83	3.84	5.51	9.01
11.6	1.87	3.94	5.93	9.43
11.7	1.91(1.92)	4.05(4.05)	6.37(6.48)	9.88(10.14)
11.8	1.95	4.16	6.83	10.33
11.9	1.98	4.28	7.31	10.79
12.0	2.02	4.39	7.80	11.27

* Emission averages are indicated in parentheses for comparison.

Table 6

Summary of Average Evaporative Emissions of 6.0 gram Vehicles[1]

Category	Fuel RVP	Average Emissions(g/test) Hot Soak	Diurnal	Total
1980 Fairmont[2]	9.0	17.55	17.39	34.94
	10.5	19.54	19.55	39.10
	11.7	25.83	24.84	50.67
1980 Sunbird[3]	9.0	2.74	15.31	18.05
	10.5	3.56	20.37	23.93
	11.7	7.45	25.51	32.96
Nontampered Vehicles[4]	9.0	2.44	5.16	7.60
	10.5	2.25	10.11	12.36
	11.7	3.35	15.92	19.27

1. "A Study of Factors Influencing the Evaporative Emissions from In-Use Automobiles," API Publication 4406, April 1985.

2. A high mileage (81,979 miles) vehicle with its evaporative system totally disabled.

3. As-received results from a high mileage (80,125 miles) vehicle which was later retested with its gas cap replaced.

4. Based on the remaining 14 nontampered vehicles, with average mileage of 44,467.

Table 7

Emission Rates for 11.5 and 9.0 RVP Fuels
for Pre-1978 LDGVs*

	------Hot Soak------		------Diurnal------	
MYR Group	9.0 Fuel	11.5 Fuel	9.0 Fuel	11.5 Fuel
Pre-1971	14.67	22.45	26.08	47.99
1971	10.91	16.15	16.28	38.58
1972-77	8.27	12.32	8.98	23.53

* "Evaporative HC Emissions for MOBILE3", August 1984, Test and Evaluation Branch, Office of Mobile Sources, Environmental Protection Agency, EPA-AA-TEB-EF-85-01.

Table 8

Uncontrolled Evaporative Emissions (grams/test)
LDGVs and LDGT1s

	Disconnects				Fuel Cap Removed			
	9.0 Fuel		11.5 Fuel		9.0 Fuel		11.5 Fuel	
MY GROUP	HS	DI	HS	DI	HS	DI	HS	DI
Pre-1971	14.67	26.08	22.45	47.99	14.67	26.08	22.45	47.99
1971	14.67	26.08	22.45	47.99	10.91	26.08	16.15	47.99
1972-77	14.67	20.90	22.45	35.45	8.27	20.90	12.32	35.45
1978-80	13.29	16.32	18.50	25.71	2.32	16.32	3.79	25.11
1981+ Carb	10.36	14.95	17.47	25.71	2.32	14.95	3.79	25.71
1981+ Finj	4.93	14.95	11.59	25.71	4.93	14.95	11.59	25.71

Table 9

Uncontrolled Evaporative Emissions (grams/test)
LDGT2s and HDGVs

MY GROUP	Disconnects				Fuel Cap Removed			
	9.0 Fuel		11.5 Fuel		9.0 Fuel		11.5 Fuel	
	HS	DI	HS	DI	HS	DI	HS	DI
LDGT2								
Pre-1979	18.08	42.33	27.66	77.89	18.08	42.33	27.66	77.89
1979+	Same as LDGVs, LDGT1s							
HDGV								
Pre-1985	18.08	42.33	27.66	77.89	18.08	42.33	27.66	77.89
1985+	14.67	26.08	23.31	39.87	3.69	26.08	6.03	39.87

Table 10

Evaporative Emissions (grams/test) of Vehicles
Used to Develop Uncontrolled Emissions

MYR Group	MYR	Make	---9.0 Fuel--- HS	Diurnal	--11.5 Fuel-- HS	Diurnal	Ref
1972-77	1974	Buick	15.95	22.46	27.32	36.59	1
	1975	Chevrolet	19.95	19.33	34.86	34.31	1
	Average		17.97	20.90	31.09	35.45	
1978-80	1979	Ford Pinto	9.73	10.25	12.18	15.16	1
	1979	Cutlass	12.60	21.33	17.48	35.53	1
	1980	Fairmont	17.55	17.39	25.83	24.84	2
	Average		13.29	16.32	18.50	25.11	
1981+ Carb	1983	Olds	7.41	19.12	13.79	32.98	1
	1983	Reliant	11.22	10.97	20.66	18.52	1
	1981	Cutlass	7.34	18.81	-----	-----	3
	1981	Malibu	12.73	19.51	-----	-----	3
	1982	Ford EXP	7.00	14.81	10.87	24.16	5
	1981	Fairmont	10.89	10.73	20.52	23.11	4
	1981	Mustang	15.95	10.70	20.74	15.31	4
	Average		10.36	14.95	17.47	25.71	
1981+ Finj	1982	Pont 6000	4.93	16.69	11.59	25.01	4

1. "Effect of Evaporative Canister Removal and Reid Vapor Pressure on Hydrocarbon Evaporative Emission", William M. Pidgeon, September 1984, EPA-AA-TEB-84-04. These tests utilized a shortened (10-minute) preconditioning period.

2. "A Study of Factors Influencing the Evaporative Emissions from In-Use Automobiles", API Publication 4406, April 1985.

3. Results from EPA's testing of two 1981 vehicles, memo from Thomas Penninga to Charles L. Gray, May 10, 1983.

4. Results from EPA's Emission Factor Testing (vehicle Nos. 4095, 4097, and 4273). Vehicles have either canister or gas cap missing.

5. Vehicle No. 5033 from EPA's three-fueled data base. This vehicle has its canister missing.

Table 11

Emission Losses Due to Refueling
Low Altitude Region

MYR	LDGV 9.00	LDGV 11.50	LDGT1 9.00	LDGT1 11.50	LDGT2 9.00	LDGT2 11.50	HDGV 9.00	HDGV 11.50
1969	0.378	0.472	0.432	0.541	0.432	0.541	0.744	0.930
1970	0.378	0.472	0.432	0.541	0.432	0.541	0.744	0.930
1971	0.390	0.488	0.449	0.561	0.449	0.561	0.789	0.987
1972	0.387	0.484	0.444	0.556	0.444	0.556	0.842	1.053
1973	0.393	0.492	0.453	0.566	0.453	0.566	0.787	0.984
1974	0.393	0.492	0.453	0.566	0.453	0.566	0.738	0.923
1975	0.356	0.444	0.403	0.504	0.403	0.504	0.694	0.867
1976	0.322	0.403	0.390	0.488	0.390	0.488	0.705	0.881
1977	0.308	0.385	0.361	0.451	0.361	0.451	0.670	0.838
1978	0.282	0.353	0.369	0.462	0.369	0.462	0.620	0.775
1979	0.279	0.349	0.381	0.476	0.381	0.476	0.595	0.743
1980	0.241	0.302	0.304	0.380	0.304	0.380	0.549	0.686
1981	0.225	0.282	0.284	0.355	0.284	0.355	0.528	0.660
1982	0.217	0.271	0.279	0.349	0.279	0.349	0.508	0.635
1983	0.217	0.271	0.274	0.343	0.274	0.343	0.482	0.603
1984	0.212	0.265	0.274	0.343	0.274	0.343	0.480	0.599
1985	0.207	0.259	0.271	0.339	0.271	0.339	0.480	0.599
1986	0.203	0.253	0.268	0.335	0.268	0.335	0.479	0.598
1987	0.200	0.250	0.265	0.331	0.265	0.331	0.478	0.597
1988	0.198	0.247	0.262	0.328	0.262	0.328	0.474	0.592
1989	0.195	0.244	0.261	0.326	0.261	0.326	0.471	0.589
1990	0.192	0.240	0.258	0.323	0.258	0.323	0.468	0.585
1991	0.189	0.236	0.255	0.319	0.255	0.319	0.465	0.581
1992	0.185	0.232	0.254	0.317	0.254	0.317	0.461	0.576
1993	0.183	0.228	0.253	0.316	0.253	0.316	0.452	0.566
1994	0.180	0.226	0.253	0.316	0.253	0.316	0.448	0.560
1995	0.177	0.221	0.250	0.313	0.250	0.313	0.445	0.556
1996	0.174	0.217	0.246	0.308	0.246	0.308	0.441	0.551
1997	0.171	0.214	0.244	0.305	0.244	0.305	0.442	0.552
1998	0.169	0.211	0.239	0.299	0.239	0.299	0.439	0.548
1999	0.167	0.208	0.236	0.296	0.236	0.296	0.436	0.545
2000	0.165	0.206	0.233	0.291	0.233	0.291	0.433	0.542

FIGURE 1

Hot Soak Emissions vs. Fuel RVP
Data from 1981+ Carbureted Vehicles

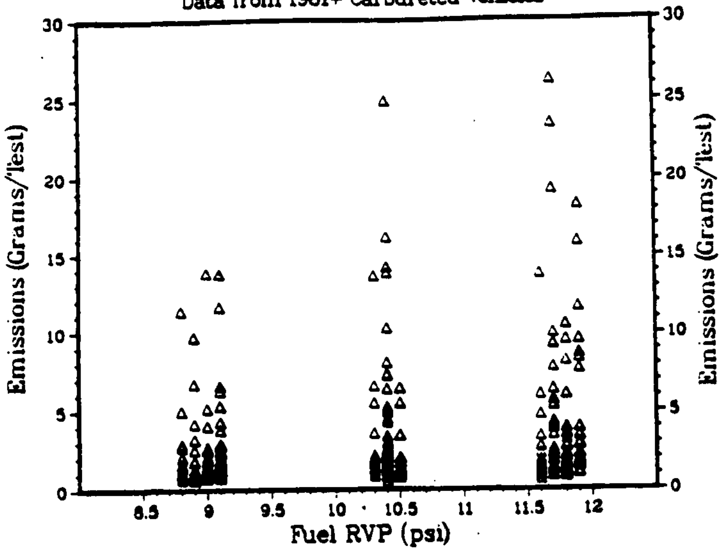

FIGURE 2

Hot Soak Emissions vs. Fuel RVP
Data from 1981+ Fuel-Injected Vehicles

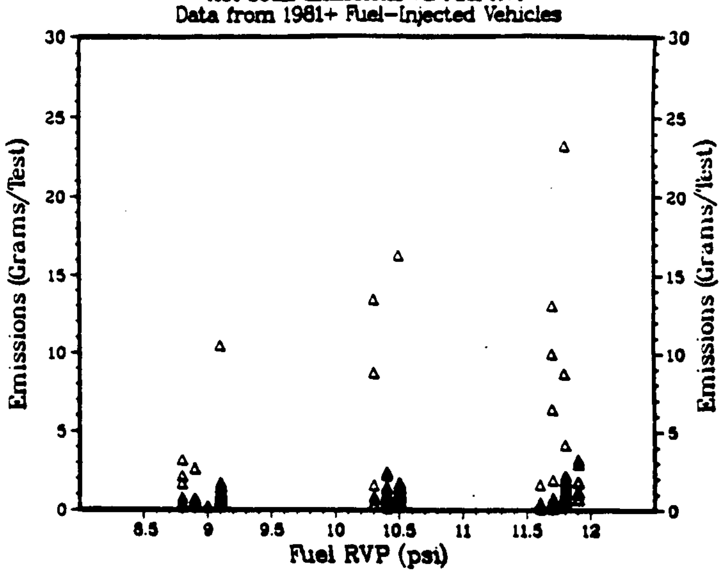

FIGURE 3

Diurnal Emissions vs. Fuel RVP
Data from 1981+ Carbureted Vehicles

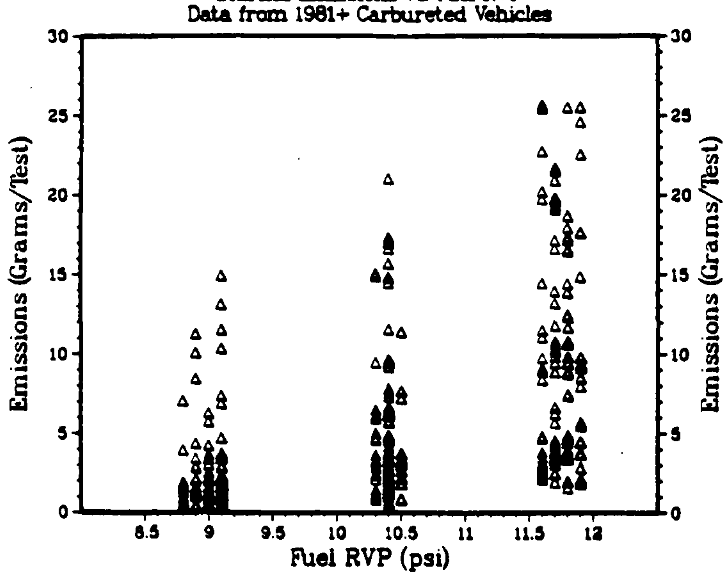

FIGURE 4

Diurnal Emissions vs. Fuel RVP
Data from 1981+ Fuel-Injected Vehicles

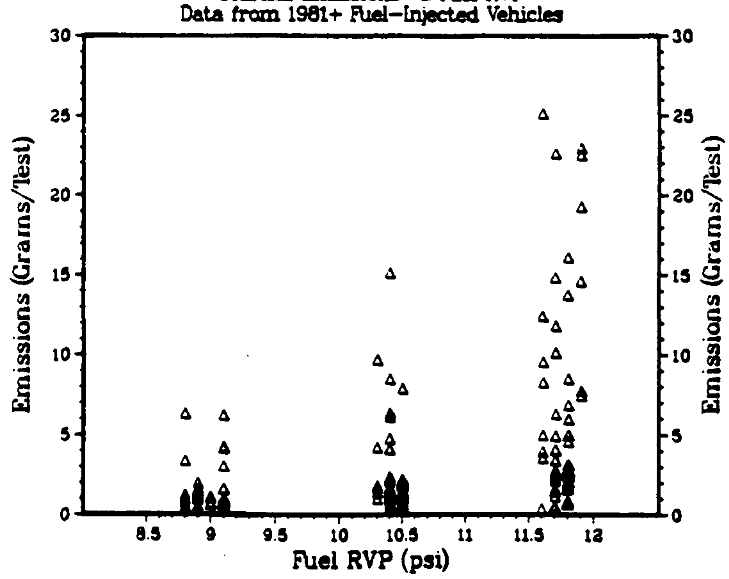

FIGURE 5

Evaporative Emissions vs. Fuel RVP
1981+ Model Year Vehicles

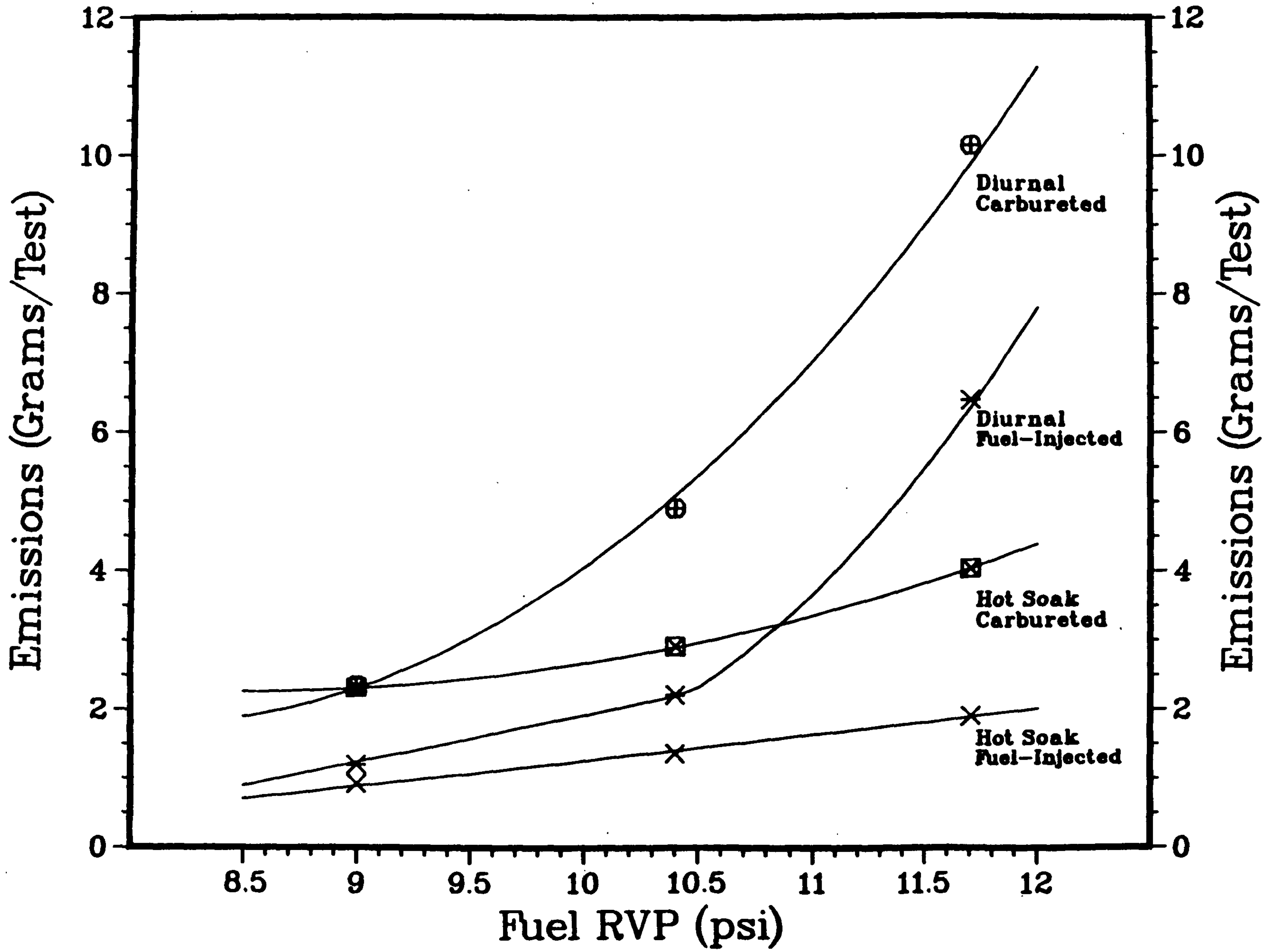

FIGURE 6

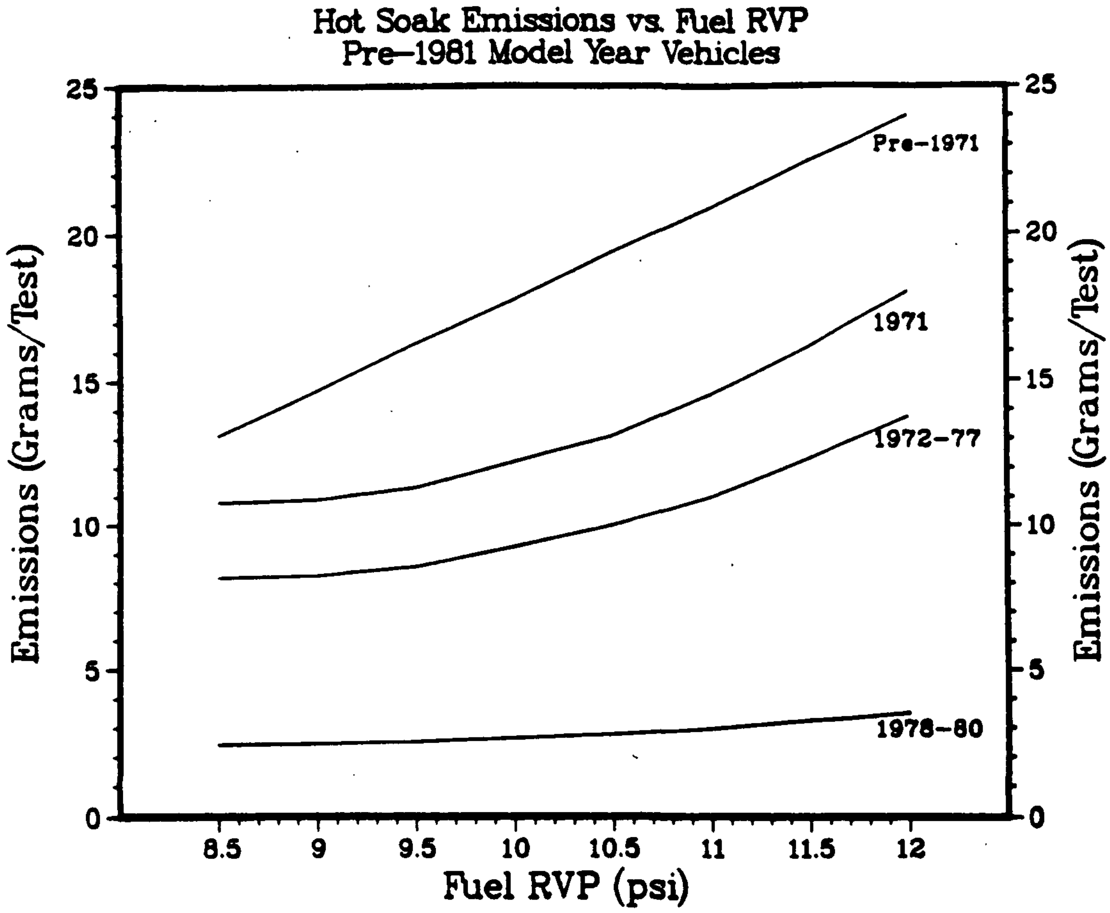

FIGURE 7

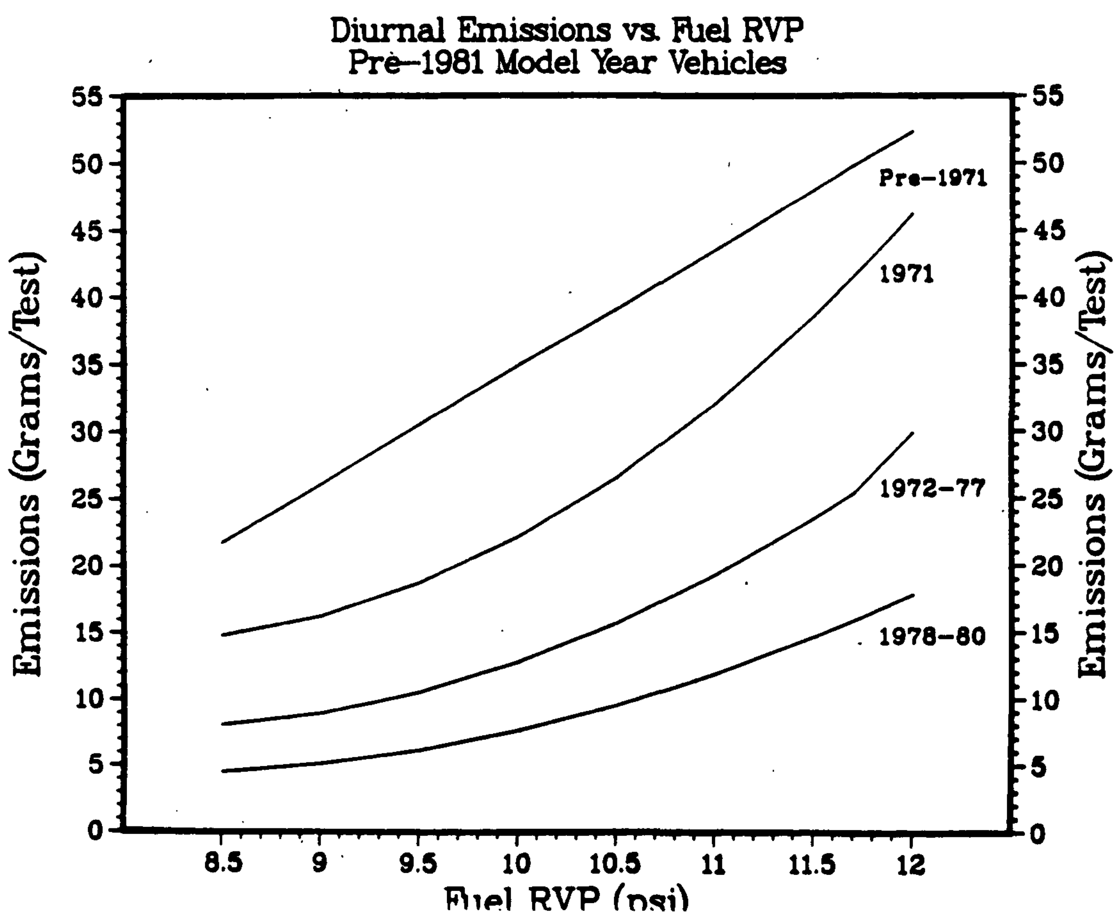

FIGURE 8

Evaporative Emissions vs. Fuel RVP
from Tampered Vehicle #5033

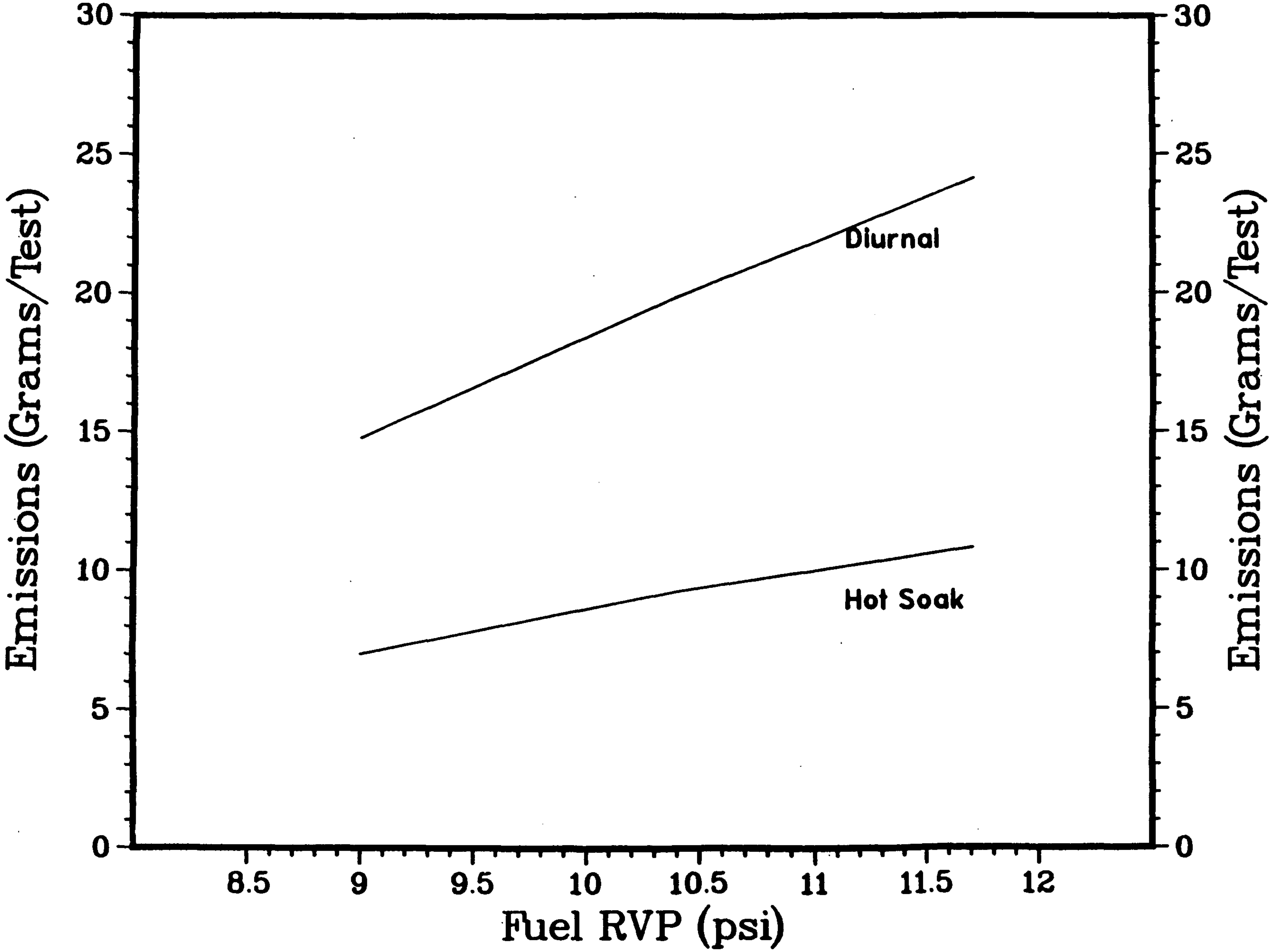

FIGURE 9

Tampering Offsets vs. Fuel RVP
1972-77 Model Year Vehicles

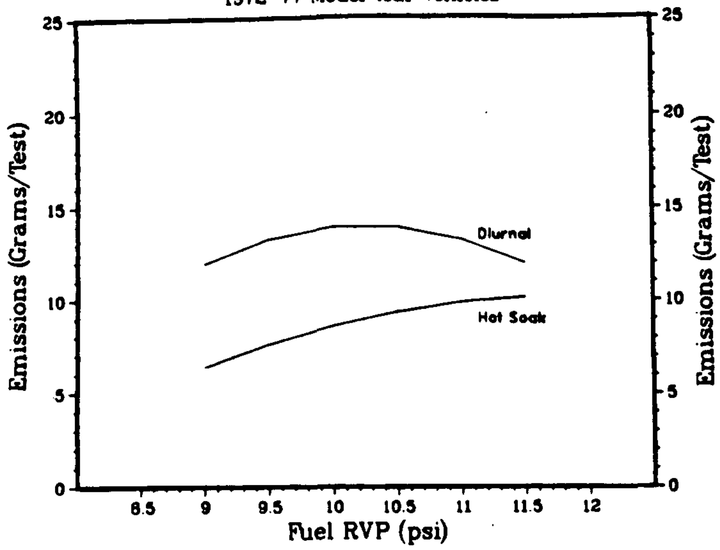

FIGURE 10

Tampering Offsets vs. Fuel RVP
1978-80 Model Year Vehicles

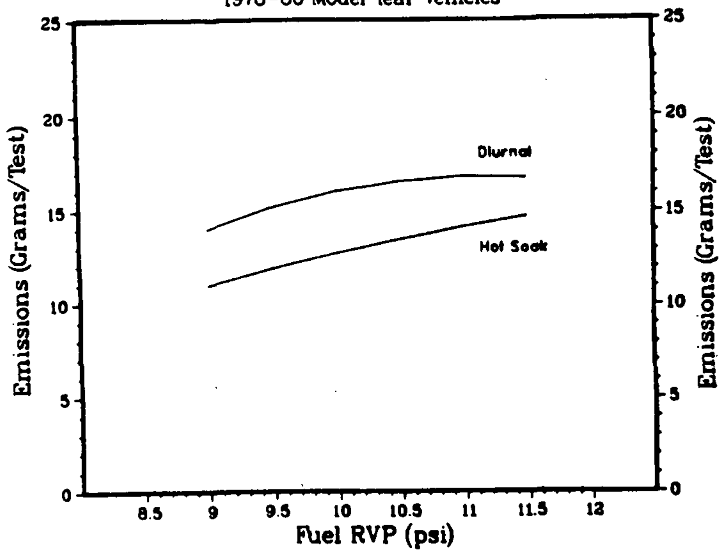

FIGURE 11

Tampering Offsets vs. Fuel RVP
1981+ Carburcted Vehicles

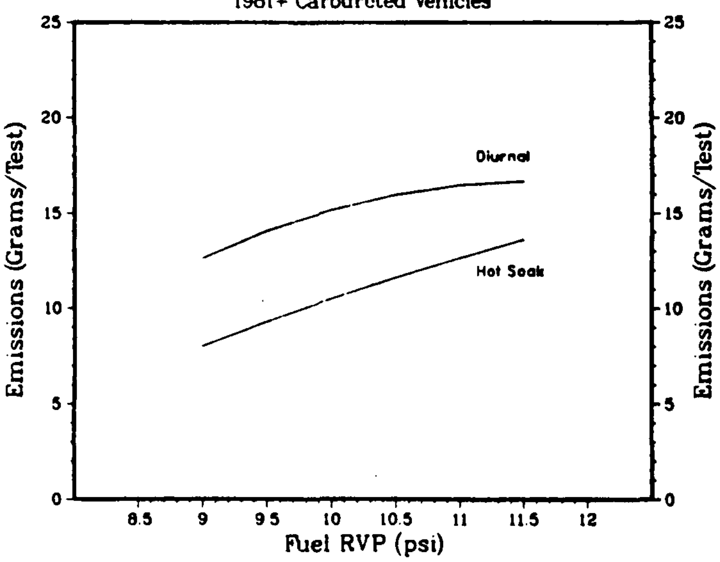

FIGURE 12

Tampering Offsets vs. Fuel RVP
1981+ Fuel-Injected Vehicles