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EVAPORATIVE HC EMISSIONS FOR MOBILE3

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1.0 INTRODUCTION

It has been recognized that in estimating the mobile source emissions, a sizeable portion of the hydrocarbon (HC) emissions comes from the evaporation of fuel from both carburetor and fuel tank of a parked vehicle. The evaporation of fuel from a vehicle at the end of a trip is called the hot soak loss. The primary source of emissions during hot soak is the carburetor system. A small amount of the hot soak emissions may also occur due to fuel tank heating. Evaporation of fuel from a vehicle due to changes in ambient temperature resulting in an expansion of air-fuel mixture in a partially filled fuel tank is called the diurnal breathing loss. The primary source of emissions in this phase is the gasoline tank. As the fuel temperature rises, evaporation of fuel increases.

All current automobiles since 1971 use a carbon-filled canister (or canisters) to collect hot soak or diurnal fuel vapors. These vapors are then pulled into the engine during engine operation to purge the canister. The hot soak or diurnal emissions can escape if the canister is saturated or if there are other problems in the evaporative emission control system. Evaporative emissions are generally associated only with gasoline-powered vehicles and trucks. For diesel-powered vehicles and trucks, the evaporative emissions are relatively insignificant due to a very low volatility of the diesel fuel.

Since 1971, EPA's Emission Factor (EF) programs have been collecting evaporative emission data from in-use light-duty vehicles and trucks. Indolene has been the primary fuel used for evaporative tests[1] because Indolene is the specified certification fuel, and the quality of Indolene is generally more consistent than other fuels. This consistency in fuel quality was desired to reduce the variability in exhaust and evaporative emission data. Data from light-duty vehicles (LDGVs) were analyzed and the calculated Indolene evaporative emission rates were used in MOBILE2.

Evaporative emissions are estimated for both the hot soak and diurnal phases of testing. The sum of these two emissions is the value to be compared with the standards. The evaporative emission standards for all vehicle types are summarized in Table 1.

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1 At some test sites both Indolene and commercial fuels were used on certain vehicles.

Table 1

Evaporative Emission Standards

Veh. Type	Test Procedure*	Standard** (grams)	Low Altitude Non-California	California	High Altitude Non-California
LDGV	None	None	Pre-1971	Pre-1970	-
	Canister	6.0	1971	1970-71	-
	Canister	2.0	1972-77	1972-77	1977
	SHED	6.0	1978-80	1978-79	-
	SHED	2.6	-	-	1982-83
	SHED	2.0	1981+	1980+	1984+
LDGT1	None	None	pre-1971	Pre-1970	-
	Canister	6.0	1971	1970-71	-
	Canister	2.0	1972-77	1972-77	1977
	SHED	6.0	1978-80	1978-79	-
	SHED	2.6	-	-	1982+
	SHED	2.0	1981+	1980+	-
LDGT2	Same as HDGV	None	Pre-1979	Pre-1977	-
	SHED	6.0	1979-80	1978-79	-
	SHED	2.6	-	-	1982+
	SHED	2.0	1981+	1980+	-
HDGV	None	None	Pre-1985	Pre-1973	-
	Canister	2.0	-	1973-77	-
	SHED	6.0	-	1978-79	-
	SHED	3.0/4.0	1985+***	-	-
	SHED	2.0	-	1980+	-

* The two test procedures are: canister (or carbon) trap method and Sealed Housing for Evaporative Determinations (SHED) method.

** The sum of hot soak and diurnal emissions.

*** The 1985+ evaporative standards are split by the gross vehicle weight, with 3.0 grams/test for vehicles less than 14,000 lb. GVW, and 4.0 grams/test for vehicles greater than or equal to 14,000 lb. GVW.

The purpose of this report is to analyze the evaporative emission data collected from EF programs and to provide evaporative emission rates for MOBILE3. Some of the basic assumptions used in MOBILE2 are carried over to MOBILE3. For clarity, assumptions used in MOBILE2 are briefly presented in Section 2. Section 3 is a detailed discussion of the LDGV EF data. Section 4 provides evaporative emission rates for both the light-duty and heavy-duty trucks.

2.0 MOBILE2 ASSUMPTIONS

The LDGV evaporative emission data from EF programs prior to 1981 were used to establish evaporative emission rates for MOBILE2. Only tests on Indolene fuel were used. In calculating emissions, MOBILE2 used the following assumptions:

a. The available LDGV test data from low altitude California and Federal 49-state sites (EF71 through EF80 programs) were combined where their evaporative emission standards were the same to establish one set of evaporative emission rates to represent both low altitude non-California (Federal) and California regions.

b. Since there were very few data on 1981 vehicles available when MOBILE2 was being developed, the evaporative emission levels for 1981 and later model years were based upon 1980 in-use data factored for changes in 1980 and 1981 certification data.

c. The high altitude evaporative emission rates were the rates from low altitude multiplied by an altitude correction factor.[2] This altitude factor was derived from a mathematical model which calculated low and high altitude (5200 ft.) evaporative emissions from uncontrolled test vehicles. The basic premise of the model is that evaporative emissions are inversely related to the atmospheric pressure. The derived ratio of high to low altitude uncontrolled emissions was 1.30. MOBILE2 used this ratio for all model year groups except one, the one exception being the 1977 model year in which the high altitude evaporative emission standard was the same as the low altitude standard.

d. Since the evaporative emission standards were the same for LDGVs and LDGT1s[3], the MOBILE2 LDGT1 evaporative emission rates were the same as the LDGVs.

e. The LDGT2[4] evaporative emission rates for pre-1979 model years were the same as those for HDGVs. For 1979 and later years, the LDGT2 evaporative emission standards were equivalent to LDGT1s, therefore, the MOBILE2 emission rates were the same.

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2 Michael W. Leiferman, "Effect of Altitude on noncontrolled Evaporative Emissions from Gasoline Fueled Vehicles," January 1979, an EPA technical report from Standards Development and Support Branch.

3 Light-duty trucks with 0-6000 lbs. GVW.

4 Light-duty trucks with 6001-8500 lbs. GVW.

f. The HDGV evaporative emission rates for the pre-1968 low altitude non-California region were derived from nine in-use heavy-duty vehicles.[5] In MOBILE2, the same rates were applied for years 1968-83 since there was no evaporative emission standard for HDGVs. MOBILE2 assumed a proposed standard of 3.0 grams/test for 1984 and later HDGVs[6], and the evaporative emission rates for 3.0 gram HDGVs were derived by observing the changes in in-use LDGV evaporative emission rates between 6.0 gram vehicles and 2.0 gram vehicles, and assuming a portion of those changes would also occur in heavy duty trucks if the standard were 3.0 grams/test.

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5 See discussions on Section 4.3.

6 Subsequent to the publication of MOBILE2, the HDGV evaporative emission standards have been set as 3.0 or 4.0 grams depending on the gross vehicle weight. See footnote under Table 1, section 1.0.

3.0 LDGV DATA ANALYSIS FOR MOBILE3

More evaporative emission test data have become available since MOBILE2, mostly from FY82 and later EF Programs. In November 1983, the EF programs started to collect evaporative emission data based upon both Indolene and commercial fuels. Also available are Indolene fuel evaporative emission data from the California Air Resources Board (CARB)[7]. Only LDGV data from as-received testing are included in this analysis.

The analysis on LDGV data is divided into two parts: 1) the evaporative emission rates based on Indolene fuel, and 2) the commercial fuel emission levels. Since more vehicles have been tested on Indolene fuel than commercial fuel, the Indolene rates are used to draw conclusions on issues such as deterioration and fuel injection versus carburetion. However, the MOBILE3 evaporative emission rates are based on commercial fuel data.

3.1 Indolene Rates

As almost all the Indolene test data collected since MOBILE2 are on vehicles designed to meet the 2.0 gram SHED standard, this section is concentrating mainly on results of these vehicles. Attachment 1 is a summary of the sample size in the complete Indolene fuel evaporative data base stratified by model year and region.

3.1.1 Low Altitude

For 2.0 grams/test SHED standard, available Indolene fuel test data representing the Federal region are the EF data collected in Ann Arbor. The California data, on the other hand, include results from 1980 and 1981 California vehicles collected by EPA and data obtained from CARB surveillance programs.

Discussions on low altitude evaporative emissions are divided into three specific areas: tampering, California data vs. Federal data, and differences in fuel injected and carbureted vehicles.

3.1.1.1 Tampering

One of the major revisions in MOBILE3 computer model is that the effect of visible tampering on mobile source emissions is to be considered

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7 "Test Report of the High Mileage (Three-Way) Catalyst Vehicle Surveillance Program, Series 2 (HMCVSP2)," California Air Resources Board, March, 1983.

separately from the untampered emission factors. For this reason, vehicles that are suspected of being tampered are to be analyzed separately[8].

Tampering is defined as the disablement of any component of the emission control system, whether it was done deliberately, inadvertently, or through neglect. The components of the evaporative emission control system include the charcoal canister (or canisters), purge valves, vent lines, vacuum lines, and gas cap. Therefore, the disablements of the evaporative emission control system include disconnected, misrouted, or cut lines (bowl, tank vent or vacuum) or hoses (purge control), missing canisters, missing gas caps, and the removal of the entire evaporative emission control system.

Under these criteria, one California vehicle and five Federal vehicles were classified as tampered vehicles. Attachment 2 is a list of tampered vehicles, their evaporative emission test results, and their tampering characteristics. Mechanic comments on vehicle conditions indicated that the California vehicle and three of the Federal vehicles had disconnected vacuum lines. For the two remaining Federal vehicles, one had misrouted vacuum lines plus missing gas cap, and one had canister missing.

Tampering of evaporative emission control system has a significant effect on evaporative emissions, this is illustrated in Attachment 2. For example, vehicle No. 4095 was found with canister missing, the Indolene fuel evaporative emission total was about ten times the emission standard (2.0 grams/test). Several vehicles listed in Attachment 2 had disconnected vacuum lines, the Indolene fuel emission totals for these vehicles were from three to five times the emission standard.

To derive the untampered evaporative emissions for MOBILE3, all tampered vehicles were excluded from the sample. Thus, subsequent analyses and conclusions are all based upon the data base with no tampered vehicles.

3.1.1.2 California Data versus Federal Data

The evaporative emission rates for MOBILE2 were derived from combining Federal data with the California data where the evaporative emission standards were the same. For example, the emission rates for vehicles built to meet the 2.0 gram SHED standard were developed from 1980 and later California vehicles and 1981 and later Federal vehicles. However, the current analysis has shown that these two samples appear to be

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8 "Anti-Tampering and Anti-Misfueling Programs to Reduce In-Use Emissions From Motor Vehicles", EPA-AA-TSS-83-10, pages 35-36.

nonhomogeneous. This nonhomogeneity is evident by examining the mean emissions from these two samples. Table 2 is a summary of the mean emission rates and mean mileages of the two samples.

Table 2

Comparisons of Indolene Evaporative Data
From the Two Low Altitude Regions
(SHED 2.0 Grams/Test Standard)

Region	N	MYR	Mean Mileage (Miles)	Mean Emissions (gms) Hot Soak	Diurnal	Total
Low Altitude Non-California	242	1981-83	37,749	1.97	2.85	4.82
Low Altitude	99	1980	16,889	1.64	0.88	2.52
California*	157	1981	9,109	0.84	1.10	1.94
	256	1980-81	12,118	1.15	1.01	2.16

* This includes 104 vehicles tested by CARB. The mean emissions of the CARB data are not significantly different from the mean emissions of data on California vehicles collected by EPA.

EPA investigated a number of areas to try to explain the emission differences between these two samples. Areas investigated include:

a. Evaporative test procedures (i.e., prep cycles)

b. Technology

c. Rates of observed malfunctions related to differences in age or mileage

d. Canister working capacities related to differences in age/mileage, or mean Reid Vapor Pressure (RVP) of summer and winter fuels.

The results of this investigation were summarized in an EPA memo.[9] The conclusions were that the emission differences of the two samples could be traced to items a and c and possibly item d. It is decided that the analysis of Indolene fuel evaporative emission rates should be based on the Ann Arbor data alone.

9 "Differences Between California and Ann Arbor Evaporative Data," from Tom Darlington to Charles L. Gray, August 24, 1984.

3.1.1.3 Differences in Fuel-Injected and Carbureted Vehicles

The type of fuel delivery system is considered to be one of the factors which may have an effect on the evaporative emissions, especially for the hot soak emissions. Vehicles with fuel injection (both ported and throttle body injection) do not have carburetor float bowls which are the major source of the hot soak emissions in carbureted vehicles.

Table 3 provides mean Indolene evaporative emissions and mean mileages for the fuel-injected and carbureted vehicles tested in Ann Arbor (sample distributions by model year are given in Attachment 3). The hot soak and diurnal emissions of the fuel-injected vehicles are lower than the emissions of carbureted vehicles. These differences are significant at the 95% level.

Table 3

Indolene Evaporative Emission Rates
by Fuel Delivery Systems

Sample	N	Mean Mileage	Mean Emissions (gms) Hot Soak	Diurnal
Carbureted	179	44,009	2.27	3.08
Fuel Injected	63	20,241	1.12	2.18

One reason for the difference in hot soak emissions between the fuel-injected and carbureted vehicles is the absence of float bowls on the fuel injection systems. However, the difference in hot soak emissions might be less if the two samples were at equivalent mileages. There is the potential for leaks around injectors in vehicles with ported injection, and the probability of leaks increases with the vehicle's mileage and age. This may be verified by future testing of high mileage fuel-injected vehicles.

There are a variety of reasons which could explain all or part of the differences in diurnal emissions of fuel-injected and carbureted vehicles. Possible reasons include:

a. Differences in mean fuel tank sizes (assuming that the canister sizes are the same)

b. Differences in observed rates of malfunctions related to age or mileage

c. Differences in unobserved malfunctions (such as deterioration in canister working capacity) related to age or mileage

d. Differences in purging technology, and

e. Differences in canister working capacity related to the lower hot soak emissions of fuel-injected vehicles.

Fuel Tank Sizes - One of the determinants of the amounts of vapor generated during a diurnal test is the vehicle's fuel tank volume or size. More vapor is generated from a large tank than a small one when both are filled to the same level. However, an examination of mean fuel tank sizes indicated that the fuel-injected and carbureted samples had the same mean fuel tank size of 14.5 gallons.

Malfunctions - The fuel-injected vehicles in the EF sample are mostly of late model year vehicles (1982 and 1983). The carbureted vehicles in the EF sample are high mileage 1981 model year vehicles. As a result, the fuel-injected vehicles have a much lower average odometer reading than carbureted vehicles.

Table 4 shows the different rates of malfunctions between the two samples and the mean emissions of malfunctioning and well-functioning vehicles.

Table 4

Indolene Evaporative Emission Rates

Sample	N	% of Sample	Mean Mileage	Mean Emissions (gms) Hot Soak	Diurnal
Vehicles with no malfunctions					
Carbureted	139	77.7	41,066	1.94	2.40
Fuel-Injected	58	92.0	20,351	1.01	1.45
Vehicles with malfunctions					
Carbureted	40	22.3	54,235	3.43	5.47
Fuel-Injected	5	8.0	18,964	2.40	10.65

The system malfunctions of the fuel-injected and carbureted vehicles are identified in Attachment 4. Note that 22% of the carbureted vehicles have some kind of system malfunction, while only 8% of the fuel-injected vehicles have malfunctions. The rate of malfunctions may be associated with vehicle's mileage and age, and it is possible that the fuel-injected vehicles may have similar numbers of malfunctions when they get to the age of the carbureted vehicles. However, the number of observable malfunctions between the two samples does not explain all of their emission differences, because the emission differences still remain when the malfunctioning vehicles are removed.

Unobserved Malfunctions - Examples of possible unobserved malfunctions are age cracks in hoses[10] and deterioration in canister's usable working capacity. Although canister's usable working capacity is known to stabilize at a certain level after declining somewhat from the "green" or new condition, it is possible for the canister working capacity to suffer a sharp drop from a stabilized level if the canister is subjected to a large quantity of vapor. This is more likely to occur on carbureted vehicles than the fuel-injected vehicles.

The method used to characterize the unobserved malfunctions is to perform regressions on the carbureted and fuel-injected samples that exclude vehicles with observed malfunctions. If the deterioration rates are the same and the zero mile levels are not significantly different, the conclusion would be that the fuel-injected vehicles should emit the same amount of emissions as the carbureted vehicles at similar mileages.

Least square regression analysis is used first to see the relation between the emissions and vehicles' mileages for the carbureted and fuel-injected vehicles. Results indicate that deterioration for the diurnal emissions of both types of vehicles was nonsignificant (the deterioration for hot soak emissions was also nonsignificant), as shown in Table 5. For fuel-injected GM vehicles, which made up the majority of the fuel-injected sample, regression analysis is performed again with result indicating that the deterioration is still nonsignificant. For the carbureted vehicles, a least square analysis of covariance is performed by using the manufacturers as strata to test if vehicles from various manufacturers have the same deterioration rate. Results, indicated in Table 5 also, show that carbureted vehicles from domestic manufacturers have the same and significant deterioration rate on diurnal emissions.

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10 Recently, vacuum testing of all hoses has been incorporated into the diagnostic work done on testing EF vehicles to detect age cracks or other leaks that are not readily visible.

Table 5

Regression Results* on Indolene Evaporative Emissions
From the Problem-Free Vehicles

Sample	N	Hot Soak		Diurnal	
		ZM	DR	ZM	DR
Carbureted-all	139	2.11	-0.04	2.27	0.03
GM	49	1.83	-0.01	1.16	0.31**
Ford	43	2.13	-0.01	2.50	0.31**
Other Domestic	20	2.21	-0.01	0.67	0.31**
Imports	27	3.10	-0.01	1.64	-0.09
Fuel-Injected-all	58	1.05	-0.02	1.57	-0.06
GM	47	1.02	0.03	1.14	0.09
Ford	8	-	-	-	-
Imports	3	-	-	-	-

* ZM=emissions in grams per test at zero miles, DR=deterioration rate in grams per test per 10K miles.

** Coefficient is significant at a level of 0.10.

Since most of the fuel-injected vehicles were from GM, it was decided to perform an analysis of covariance on the GM fuel injected versus carbureted vehicles to test the equality of the regression slopes and zero-mile levels. The results are shown in Table 6. This test showed that the deterioration rates, and their zero mile levels, were not statistically different for the GM fuel-injected and carbureted vehicles.

Table 6

Regression Results* on Indolene Evaporative Emissions
From the Problem-Free GM Vehicles

Sample	N	Hot Soak		Diurnal	
		ZM	DR	ZM	DR
Carbureted	49	1.30	0.14	1.17	0.30**
Fuel-Injected	47	1.02	0.03	0.74	0.30**

* ZM=zero mile in grams per test, DR=deterioration rate in grams per test per 10K miles.

** Coefficient is significant at a level of 0.10.

This latter data provides a preliminary indicator that the fuel-injected vehicles may have diurnal emissions similar to the carbureted vehicles when they are at equivalent mileages. However, there is not yet enough data to demonstrate this for the fleet.

Excess Canister Working Capacity of Fuel-Injected Vehicles - The evaporative test procedure leading up to the diurnal test consisted of the following sequence:

1. Drain and refuel test fuel to 40% level
2. Precondition (either a 10 minute road route or 10 to 10.5 minute dynamometer cycle)
3. Minimum 12 hour soak
4. Diurnal test

The preconditioning period produces a hot soak, which tends to add more vapor to the canister for a carbureted vehicle than is added to the canister of a fuel-injected vehicle.

If the canister sizes were similar, the fuel-injected vehicles would have more reserved capacity going into the diurnal test. This could also be a reason for the lower diurnal emissions of fuel-injected vehicles in these samples. However, the magnitude of this effect is difficult to quantify. Also, pressures from competitive pricing may lead manufacturers to downsize the canisters of fuel-injected vehicles if there is excess capacity.

Purging Technology - When the diurnal emission differences between fuel-injected and carbureted vehicles were first noted, the automobile manufacturers suggested that there might be differences in purging technology which would lead to the differences in diurnal emissions. EPA therefore investigated these potential differences, and found them to be mostly insignificant. Both fuel-injected and carbureted vehicles use engine vacuum (at the intake manifold or at the carburetor) to pull purge air through the canister and into the engine. Since many 1981 and later vehicles use closed-loop fuel control and have on-board computers, both fuel-injected and carbureted vehicles use various engine sensors (temperature, manifold vacuum, and/or engine rpm) to control purging.[11] Here there is one small difference - fuel-injected vehicles may use more precise sensors. The temperature sensor on fuel-injected vehicles must be a continuous temperature sensing device, so that the proper mixture is delivered to the engine. A continuous temperature sensing device is not necessary on most carbureted vehicles, because the mixture during cold start is controlled by the choke. The temperature sensing devices on carbureted vehicles are therefore on/off devices which sense when the engine passes a pre-set temperature point.

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11 Purging is avoided during cold start and idle because the additional HC causes enrichment of the fuel/air ratio, causing an increased risk of stalling.

Therefore, control of purging in fuel-injected vehicles may be somewhat more precise than in carbureted vehicles. However, the more precise control of purging may not necessarily lead to lower emissions. It is concluded that there may not be any differences in purging technology for the fuel-injected and carbureted vehicles that would lead to significant differences in diurnal emissions.

Conclusions on the Diurnal Emission Differences Between Fuel-Injected and Carbureted Vehicles - The differences in diurnal emissions between fuel-injected and carbureted vehicles have been attributed to differences in observed malfunctions, possibly unobserved malfunctions (both of these two are probably related to age/mileage differences between the two samples), and possibly also the current excess capacity of canisters used on fuel-injected vehicles due to smaller hot soak loading. This excess capacity may not be a permanent difference. The first two differences would suggest that fuel-injected vehicles will have diurnal emissions similar to the carbureted vehicles when they are at equivalent mileages. Therefore, it is concluded that the diurnal emission rates from carbureted vehicles are the most representative for all vehicles (fuel-injected and carbureted) at this time.

Conclusions on the Hot Soak Emission Differences Between Fuel-Injected and Carbureted Vehicles - The differences in hot soak emissions between carbureted and fuel-injected vehicles may be attributed to their differences in a fuel delivery system (with and without the carburetor float bowls). Therefore, it is concluded that the hot soak emissions should be derived from separate hot soak rates for the two types of fuel delivery systems and weighted according to their respective market shares.

3.1.1.4 Summary of Low Altitude Indolene Rates

A summary of low altitude Indolene fuel evaporative emission rates is given in Table 7. The MOBILE2 emission rates, which were based upon Indolene fuel data, are also listed for comparison purposes. Note that the MOBILE2 hot soak and diurnal emission rates for 1981 and later years were updated. Rates for pre-1978 years remain unchanged.

The MOBILE2 low altitude 1978-80 rates, 1.56 grams for hot soak and 2.65 grams for diurnal, seem unrealistically low, in comparison with the new 1981+ rates. There have been no significant design changes[12] made to the evaporative emission control hardware since 1978 model year

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12 There are no significant hardware differences between the 1978-80 and 1981 and later model year group low altitude vehicles. The only exception is the 1980 California vehicles that had extra charcoal in their canisters because of the new SHED 2.0 grams/test standard that came into effect in 1980. That extra charcoal, however, has been taken out for 1981 and later California vehicles.

vehicles. MOBILE2 derived 1978-80 evaporative emission rates based upon mostly low mileage non-California vehicles (with mean mileage at 14,100 miles, from Table 8, Section 3.1.2) and a few California vehicles. To use the MOBILE2 rates of 1.56 grams for hot soak and 2.65 grams for diurnal would imply that 1978-80 SHED 6.0 grams/test standard vehicles represented a better emission control than the 1981+ SHED 2.0 grams/test standard vehicles. It is more likely that the difference is due to sample differences. Since the sample of 1981+ vehicles is much larger and at more appropriate mileage, the 1978-80 emission rates were set equal to the 1981+ rates. No fuel-injection sales are assumed for 1978-80 vehicles. Therefore, the Indolene emission rates of 2.27 grams for hot soak and 3.08 grams for diurnal from the carbureted vehicles (from Table 3) are used also for 1978-80 model year vehicles.

The Indolene hot soak emission rates of 1.12 grams from the fuel-injected vehicles and 2.27 grams from the carbureted vehicles (from Table 3) are used to derive hot soak rates for 1981 and later model year vehicles. These two rates are weighted together by sales projections of fuel injected and carbureted vehicles to derive overall Indolene hot soak rates. The LDGV fuel injection sales projections are presented in Attachment 5. The Indolene emission rate of 3.08 grams for the diurnal loss from the carbureted vehicles (from Table 3) is used for the diurnal emission rate of all 1981 and later vehicles.

The Indolene evaporative emission rates, although not used directly in MOBILE3, are useful in fuel volatility studies. The conclusions from Indolene fuel emission analyses, such as deriving hot soak rates from fuel injected and carbureted vehicles, and using only the carbureted sample for diurnal emissions, are carried over into the analysis of commercial fuel rates used for MOBILE3.

Table 7

Low Altitude LDGV Indolene Evaporative Emissions (gms)

MYR Group	Equivalent MOBILE3 Indolene Rates		MOBILE2	
	Hot Soak	Diurnal	Hot Soak	Diurnal
Pre-1971	14.67	26.08	14.67	26.08
1971	10.91	16.28	10.91	16.28
1972-77	8.27	8.98	8.27	8.98
1978-80*	2.27	3.08	1.56	2.65
1981**	2.16	3.08	0.63	1.07
1982	2.06	3.08	0.63	1.07
1983	1.95	3.08	0.63	1.07
1984	1.81	3.08	0.63	1.07
1985-86	1.57	3.08	0.63	1.07
1987-89	1.36	3.08	0.63	1.07
1990+	1.25	3.08	0.63	1.07

* Emission rates for model year group 1978-80 are set equal to the emission rates from 1981 and later carbureted vehicles (2.27 grams for hot soak and 3.08 grams for diurnal). There are no fuel-injection sales (see Attachment 5).

** For 1981 and later years, the hot soak rates a sales weighted combination of 1.12 grams for the fuel-injected vehicles and 2.27 grams for the carbureted vehicles. Sales of fuel-injected vehicles can be obtained from Attachment 5. The diurnal emission of 3.08 grams for the carbureted vehicles is used for all Indolene diurnal rate.

3.1.2 High Altitude

There are no separate evaporative emission standards for the high altitude region except for model years 1977 and 1982 and later (see Table 1). For all model years, manufacturers have generally used the same evaporative emission control system on vehicles without differentiating whether the vehicles were to be sold at high or low altitude. MOBILE2 used the altitude factor of 1.30 for most of the model years to adjust the low altitude evaporative emission rates to high altitude (discussed previously in Section 2.0). The exception was 1977, in which high and low altitude rates were assumed to be the same because their emission standards were the same.

There were no high altitude evaporative emission data from in-use vehicles available for the pre-1972 years. An altitude correction factor of 1.30 was derived from emissions of uncontrolled test vehicles (see discussions on high altitude evaporative emission rates under Section 2.0). Since pre-1972 vehicles are basically uncontrolled vehicles (no evaporative emission standard for pre-1971 vehicles and 6.0 gram canister for 1971 vehicles), this altitude factor of 1.30 is probably appropriate for use. Therefore, the pre-1972 high altitude evaporative rates are derived from low altitude rates adjusted by the altitude factor of 1.30.

EPA's Emission Factor programs also collected evaporative emission data from in-use light-duty vehicles operated and tested in Denver. These data have shown that the altitude factor of 1.30 developed from emissions of uncontrolled vehicles may not be appropriate for the controlled vehicles. Table 8 is a comparison of high versus low altitude evaporative emissions. All vehicles with malfunctions have been included in the mean emission results, while the tampered vehicles have been excluded.

Note that for the 2.0 grams/test canister standard, the low altitude rates are represented by combining the non-California and California data, since there were practically no low altitude non-California data in this model year group. For the two SHED standards, only the low altitude non-California data are used for comparison. The 2.0 gram California vehicles have been excluded in estimating the 2.0 gram low altitude emission rates, for the reasons discussed in section 3.1.1.4.

Table 8

Comparison of Indolene Evaporative Data
for High vs. Low Altitudes

Standard Group	Altd.	MYR Group	N	Mean Mileage (miles)	Mean Emissions (gms) Hot Soak	Diurnal
Canister 2.0	High	1972-76	60	10,170	14.07	17.15
	Low&Calif	1972-77	96	17,500	8.27	8.98
	Ratio*				1.70	1.91
SHED 6.0	High	1978-80	169	13,100	4.26	6.77
	Low	1978-80	124	14,100	1.62	2.67
	Ratio				2.63	2.54
SHED 2.0	High	1981	64	6,800	1.36	2.81
	Low	1981+	242	37,821	1.97	2.85
	Ratio				0.69	0.99

* Ratio of high to low altitude mean emissions.

The ratios of high to low altitude Indolene fuel evaporative emissions for the SHED standard of 2.0 grams/test may not be valid because of the mileage difference between the high and low altitude data (6,800 versus 37,821 miles). For the other two standard groups, the mean mileages for the two regions are similar, and the ratios of high versus low altitude mean emissions are from 1.70 to 2.63, all considerably higher than the altitude factor of 1.30 used for MOBILE2.

One reason the high to low altitude emission ratios are higher for controlled vehicles may be that the canister has a capacity limit in holding the fuel vapor, whether at low or high altitude. For example, in an uncontrolled vehicle, 30 grams of fuel vapor may be produced by the fuel tank during a diurnal at low altitude. At high altitude because of a lower atmospheric pressure, the fuel tank may produce 39 grams of fuel vapor -- yielding a high to low altitude emission ratio of 1.30 (39 grams divided by 30 grams). However, if the canister can only hold 25 grams of fuel vapor before saturation in both low and high altitude regions, 5 grams of fuel vapor will be emitted at low altitude (30 grams minus 25 grams), while 14 grams will be emitted at high altitude (39 grams minus 25 grams). The resulting ratio of high to low altitude emissions is 2.8 (14 grams divided by 5 grams).

For the years of 1972-76, high altitude data from testing 60 in-use vehicles were available through EF programs. The average emission rates of 14.07 grams for hot soak and 17.15 grams for diurnal should be used as the Indolene rates to represent the emission rates at high altitude. Since the evaporative emission standard was the same for both low and high altitudes in 1977, MOBILE2 combined the high altitude data with the low altitude data to derive average emission levels and used them for both regions. No new data are available since MOBILE2, therefore the MOBILE2 1977 rates should remain unchanged in MOBILE3.

For the 1978-80 and 1981 model years, the altitude factor used to adjust the low altitude rates to high altitude is 2.59, the average of hot soak and diurnal ratios (from Table 8) from the 1978-80 samples. The average 2.59 of the diurnal and hot soak ratios was used rather than the separate ratios for the sake of simplicity, since the two ratios were not significantly different.

The average emission rates from 1978-80 high altitude vehicles could be used directly for MOBILE3. However, this would result in an inconsistency of lower evaporative emissions for 1978-80 years, in comparison with the 1981 rates (4.26 grams for 1978-80 vs. 5.88 grams for 1981 on hot soak, and 6.77 grams for 1978-80 vs. 7.98 grams for 1981 on diurnal). This would imply that the 1978-80 vehicles represent a better level of control than the 1981 vehicles. To avoid this inconsistency, the altitude factor of 2.59 is used for both 1978-80 and 1981 years.

Since there are very limited data available from high altitude for 1982 and 1983, (only four 1982 vehicles were tested, and there was no 1983 vehicles tested) the high altitude rates are those from the low altitude multiplied by a ratio of the evaporative emission standards of 1.30 (SHED 2.6 grams/test standard for the high altitude vs. SHED 2.0 grams/test standard for the low altitude). Since both regions have the same SHED 2.0 gram standard for years 1984 and later, low altitude hot soak rates of 1.12 grams from the fuel-injected vehicles and 2.27 grams from the carbureted vehicles are used for high altitude Indolene hot soak rates. The low altitude diurnal rate of 3.08 grams from carbureted vehicles is used for the high altitude diurnal emission level for all 1984 and later year vehicles.

A summary of the high altitude Indolene evaporative emission rates is given in Table 9. MOBILE2 rates are also listed for comparison purposes. Note that for 1981 and later years, the Indolene hot soak rates are derived from the high altitude hot soak emissions of fuel injected and carbureted vehicles weighted by their sales projections. The high altitude fuel injection sales are assumed to be the same as the low altitude.

Table 9

High Altitude LDGV Indolene Evaporative Emissions (gms)

MYR Group	Indolene Rates Hot Soak	Indolene Rates Diurnal	MOBILE2 Hot Soak	MOBILE2 Diurnal
Pre-1971	19.07	33.90	19.07	33.90
1971	14.18	21.16	14.18	21.16
1972-76	14.07	17.15	10.75	11.67
1977	8.27	8.98	8.27	8.98
1978-80	5.88	7.98	2.03	3.45
1981	5.60	7.98	0.82	1.39
1982	2.68	4.00	0.82	1.39
1983	2.54	4.00	0.82	1.39
1984	1.81	3.08	0.82	1.39
1985-86	1.57	3.08	0.82	1.39
1987-89	1.36	3.08	0.82	1.39
1990+	1.25	3.08	0.82	1.39

Note 1: 1972-76 model year emission rates are the average emissions from 60 in-use vehicles tested at Denver available through EF programs.

Note 2: The 1978-80 Indolene emission rates are based on low altitude 1981+ emission rates from carbureted vehicles (there are no fuel-injection sales, see Attachment 5), adjusted by a factor of 2.59, i.e., hot soak of 5.88 grams is from 2.27 grams multiplied by 2.59, and diurnal of 7.98 grams is from 3.08 grams multiplied by 2.59.

Note 3: The Indolene hot soak rates for 1981 and later are derived from weighting the sales of fuel-injected and carbureted vehicles. The Indolene diurnal emissions are based on the average from the carbureted vehicles alone.

Note 4: For model years 1981 and 1982, an emission standard ratio of 1.30 is used to adjust the low altitude rates to be the high altitude rates.

Note 5: For 1984 and later model years, the high altitude rates are the same as the low altitude because their emission standards are the same.

3.2 Commercial Fuel Rates

Evaporative emissions are sensitive to the volatility of the test fuel. Using a higher volatility test fuel results in higher evaporative emissions. The Indolene fuel used for laboratory tests is of low volatility (approximately 9.0 RVP) in comparison with commercial fuel used by motor vehicles. It has also been noted that during recent years the spread between the volatilities of Indolene and commercial fuels has increased. Consequently, the MOBILE2 evaporative emission rates, which were based on tests with Indolene fuel, are unrealistically low at this time.

The EF programs since November of 1983 have been collecting evaporative emission data on both Indolene and commercial fuels at Ann Arbor. An unleaded summer grade gasoline with an average RVP of 11.5 has been selected as the representative commercial fuel used in this EF testing. All of the testing on this 11.5 RVP commercial fuel has been conducted in Ann Arbor.

The commercial fuel data collected under FY83 and later EF programs are from 2.0 gram SHED standard (1981 and later) vehicles. Evaporative emission rates derived from these commercial fuel data were used in MOBILE3 to represent 1981 and later model year vehicles. For pre-1981 years, MOBILE3 commercial fuel rates were estimated. Thus, the discussions on commercial fuel evaporative emission rates for low altitude vehicles are divided into two parts: 1981 and later model year vehicles and pre-1981 vehicles.

3.2.1 1981+ Vehicles

Among the 115 untampered vehicles that were tested on both Indolene and commercial fuels in the EF programs (indicated by parentheses in Attachment 3), 53 are from high mileage carbureted vehicles and 62 from relatively low mileage fuel-injected vehicles. A comparison of mean evaporative emissions from the two fuels is given in Table 10.

Table 10

Evaporative Emissions
Indolene vs. Commercial Fuels

		Hot Soak			Diurnal		
		Mean (gm/test)			Mean (gm/test)		
Sample	N	Indol.	Comm.	Ratio	Indol.	Comm.	Ratio
Carbureted	53	2.74	3.98	1.45	4.22	9.31	2.21
Fuel-Injected	62	1.12	1.55	1.38	2.21	3.13	1.42

Note that there exists a large difference in commercial fuel diurnal emissions between the carbureted and fuel-injected vehicles (9.31 grams vs. 3.13 grams from Table 10). The discussions on the reasons for the Indolene fuel diurnal emission differences between fuel-injected and carbureted vehicles (section 3.1.1.3) are applicable here also.

Based upon the above data and the conclusions obtained from the Indolene fuel data (Section 3.1.1.4), MOBILE3 has used the commercial fuel hot soak emissions of 1.55 and 3.98 grams (from Table 10) for fuel-injected and carbureted vehicles, respectively. These two rates are weighted together by sales projections of fuel injected and carbureted vehicles to derive overall MOBILE3 hot soak emission rates for 1981 and later years. The fuel injection sales projections are presented in Attachment 5. The commercial fuel diurnal emission rate of 9.31 grams from carbureted sample are used directly to represent MOBILE3 diurnal rates for all 1981 and later year vehicles.

3.2.2 Pre-1981 Vehicles

The Indolene emission rates for the SHED 2.0 gram vehicles are used also for the 6.0 gram SHED standard vehicles (model years 1978-80), as discussed in Section 3.1.1.4. To be consistent with the Indolene rates, the commercial fuel emission rates from the 2.0 gram SHED standard are also used for 6.0 gram SHED standard vehicles.

To establish LDGV commercial fuel levels for pre-1978 evaporative emission standards, the Test and Evaluation Branch of EPA initiated a testing program to test six vehicles on both Indolene and commercial fuels. The six vehicles represent the three pre-1978 evaporative emission standard eras as:

Standard	MYR	Vehicles
None	pre-1971	1963 Ford Galaxie 1970 Chrysler Newport
Canister 6.0	1971	1971 Ford Galaxie 1971 Ford LTD Wagon
Canister 2.0	1972-77	1974 Buick Century 1975 Chevrolet Nova

Each vehicle was tested at least twice with each fuel, with a total of 28 tests completed in early February of 1984. Five tests were not used in calculating the commercial to Indolene fuel emission ratios because of some technical problems detected after the data had been collected. Test results are summarized in Table 11.

Table 11

Evaporative Test Results
Indolene vs. Commercial Fuels

Evaporative Emissions	Standard	MYR	Mean(gm/test) MOBILE2	Indolene	Comm.	Ratio*
Hot Soak	None	pre-1971	14.67	16.03	24.59	1.53
	Canister 6.0	1971	10.91	16.40	24.24	1.48
	Canister 2.0	1972-77	8.27	10.38	29.45	2.84
Diurnal	None	pre-1971	26.08	12.09	22.26	1.84
	Canister 6.0	1971	16.28	5.18	12.26	2.37
	Canister 2.0	1972-77	8.98	4.04	13.72	3.40

* Ratio = Commercial fuel emissions divided by Indolene fuel emissions.

The Indolene emission rates obtained from the new tests are different from those used in MOBILE2. The MOBILE2 rates for Indolene fuel were obtained from in-use vehicles tested at Los Angeles, with a much larger sample size and are, therefore, used in MOBILE3. The MOBILE3 commercial fuel evaporative rates for pre-1978 cars are estimated from MOBILE2 Indolene rates, multiplied by commercial to Indolene emission ratios either from Table 11, or from Table 10.

The ratios of 1.53 for hot soak and 1.84 for diurnal (Table 11) developed from pre-1971 test vehicles are used to adjust the pre-1971 Indolene emissions to MOBILE3 commercial rates. The ratios of 1.48 for hot soak and 2.37 for diurnal developed from 1971 test vehicles are used to adjust the 1971 Indolene rates to MOBILE3 commercial fuel evaporative emissions. These ratios appear to be reasonable in comparison with the SHED 2.0 gram ratios (1.45 for hot soak and 2.21 for diurnal) from the carbureted sample in Table 10.

The ratios for the 2.0 gram canister standard vehicles from Table 11 appear too high (2.84 on hot soak and 3.40 on diurnal) when compared with all other ratios from precontrolled and controlled vehicles[13] (for example, 1.48 on hot soak and 2.37 on diurnal for the 6.0 gram canister

13 Tests on 1978 vehicles in St. Louis on both Indolene and commercial fuels yielded a hot soak ratio of 1.54 and a diurnal ratio of 2.12. These were not used, however, because of the uncertainty of the RVP of the commercial fuel used.

standard vehicles). The ratios of 1.49 for hot soak and 2.62 for diurnal emissions are used to adjust the Indolene levels to commercial rates for the 1972-77 vehicles. These ratios are derived from 32 in-use high mileage 1981 carbureted vehicles. They were used in the draft version of MOBILE3. They are used also in the final version of MOBILE3.

3.3 Summary of LDGV Evaporative Emissions

Table 12 is a summary of the developed LDGV evaporative emission rates. The low altitude Indolene rates are from Table 7. For pre-1978 model years, the commercial fuel emissions are derived from emission ratios of different fuels. For 1978 and later years, the commercial fuel hot soak emissions are 1.55 grams for the fuel-injected vehicles and 3.98 grams for the carbureted vehicles. The commercial fuel diurnal emissions for 1978 and later years are 9.31 grams.

The high altitude Indolene rates are from Table 9. The low altitude emission ratios of different fuels are also used for the high altitude for the pre-1978 vehicles. For 1978 and later years, the high altitude commercial fuel emissions are derived from the low altitude commercial rates. For example, an altitude factor of 2.59 is used for 1978-81, an emission standard ratio of 1.30 is used for years 1982 and 1983, and the high altitude rates are the same as the low altitude rates for 1984 and later years, as discussed in Section 3.1.2.

Table 12

LDGV Evaporative Emission Rates (gms)

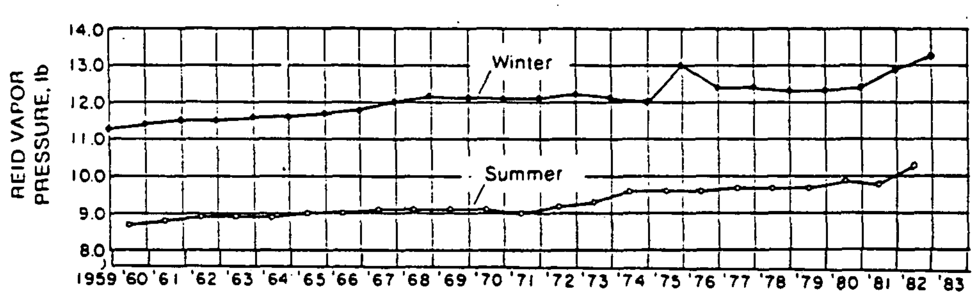
		Hot Soak			Diurnal		
Region	MYR Group	Indol.	Ratio	Comm.	Indol.	Ratio	Comm.
Low Altitude	pre-1971	14.67	1.53	22.45	26.08	1.84	47.99
	1971	10.91	1.48	16.15	16.28	2.37	38.58
	1972-77	8.27	1.49	12.32	8.98	2.62	23.53
	1978-80	2.27		3.98	3.08		9.31
	1981	2.16		3.75	3.08		9.31
	1982	2.06		3.54	3.08		9.31
	1983	1.95		3.31	3.08		9.31
	1984	1.81		3.01	3.08		9.31
	1985-86	1.57		2.50	3.08		9.31
	1987-89	1.36		2.05	3.08		9.31
	1990+	1.25		1.82	3.08		9.31
High Altitude	pre-1971	19.07	1.53	29.18	33.90	1.84	62.38
	1971	14.18	1.48	20.99	21.16	2.37	50.15
	1972-76	14.07	1.49	20.96	17.15	2.62	44.93
	1977	8.27	1.49	12.32	8.98	2.62	23.53
	1978-80	5.88		10.31	7.98		24.11
	1981	5.60		9.71	7.98		24.11
	1982	2.68		4.60	4.00		12.10
	1983	2.54		4.30	4.00		12.10
	1984	1.81		3.01	3.08		9.31
	1985-86	1.57		2.50	3.08		9.31
	1987-89	1.36		2.05	3.08		9.31
	1990+	1.25		1.82	3.08		9.31

Figure 1 (obtained from A DOE survey) shows the trends in fuel volatility from 1959 to 1982. The RVP of the summer grade leaded gasolines was around 9.0 lbs until about 1972, and has been increasing since 1972 to about 10.0 lbs in 1980. The commercial fuel used in EF programs was 11.5 RVP, the average RVP of summer grade unleaded gasolines used around Detroit which is one of the gasoline volatility Class C cities[14] with summer temperature ranges between 60°F and 84°F. The majority of non-California cities were classified as either Class B or Class C in 1983. The average volatility levels of summer grade unleaded gasolines used among the Class B cities such as Dallas are lower (about 10.0 RVP) yet those cities have summer temperature ranges between 65°F and 95°F, which would produce similar amount of diurnal emissions as the 11.5 RVP commercial fuel because of their higher temperatures. Based on this, EPA feels that the commercial fuel evaporative emission rates given in Table 12 are appropriate for 1980 and later calendar years. Because of the lower in-use fuel RVP for pre-1980 calendar years, these commercial fuel evaporative emission rates may not be suitable for use for those calendar years. But the pre-1980 calendar years are not of main concern to most MOBILE3 users.

Figure 1

Trends in RVP, Leaded Gasoline
1959-82

Source: DOE, "Motor Gasolines"



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14 The American Society for Testing Materials (ASTM) recommends maximum gasoline volatility levels for different cities based on their summer temperatures. Warm cities such as Phoenix, Dallas have lower recommended RVP maximums. The recommended maximum volatility levels for summer fuel in 1983 are 9.0 in New Mexico (Class A), 10.0 in Dallas (Class B), 11.5 in Detroit (Class C), and 13.5 in cities of Alaska (Class D). These recommended fuel maximum volatility levels are intended to prevent or reduce problems such as vapor lock in vehicles.

4.0 OTHER VEHICLE TYPES

LDGV evaporative emission rates obtained from the previous section are used as the basis to derive evaporative emission rates for other gasoline powered vehicles.

4.1 Light-Duty Gasoline Class 1 Trucks

Limited Indolene evaporative emission test data from LDGTls are available from EF programs. The LDGTl data are not significantly different from the LDGV data, and the evaporative emission standards for these two vehicle classes are exactly the same. Therefore, low altitude LDGV evaporative emission rates on both the Indolene and commercial fuels are also used for LDGTls. The only difference between these two vehicle classes is the fuel injection sales projections. As can be seen from Attachment 5, LDGTl fuel injection sales were projected to begin in the year of 1984 and continue at a different percentage until the year of 1988. Therefore, the LDGTl hot soak rates between the years of 1981 and 1987 are slightly different from the LDGV rates.

The high altitude LDGV evaporative emission rates on both the Indolene and commercial fuels for pre-1984 model years are also used for high altitude LDGTl emission rates. For 1984 and later years, the high altitude LDGTls have a SHED 2.6 grams/test emission standard, while the low altitude LDGTls have the same evaporative emission standard (SHED 2.0 grams/test) as the LDGVs. Therefore, in parallel to the LDGV relationships the high altitude emission rates for 1984 and later trucks, Indolene or commercial fuel, are the low altitude rates multiplied by an emission standard ratio of 1.30.

Table 13 is a summary of the LDGTl evaporative emission rates.

Table 13

LDGT1 Evaporative Emission Rates (gms)

Region	MYR Group	Hot Soak Indol.	Hot Soak Ratio	Hot Soak Comm.	Diurnal Indol.	Diurnal Ratio	Diurnal Comm.
Low Altitude	pre-1971	14.67	1.53	22.45	26.08	1.84	47.99
	1971	10.91	1.48	16.15	16.28	2.37	38.58
	1972-77	8.27	1.49	12.32	8.98	2.62	23.53
	1978-80	2.27	-	3.98	3.08	-	9.31
	1981-83	2.27		3.98	3.08		9.31
	1984	2.09		3.59	3.08		9.31
	1985	1.90		3.20	3.08		9.31
	1986	1.72		2.81	3.08		9.31
	1987	1.56		2.47	3.08		9.31
	1988-89	1.36		2.05	3.08		9.31
	1990+	1.25		1.82	3.08		9.31
High Altitude	pre-1971	19.07	1.53	29.18	33.90	1.84	62.38
	1971	14.18	1.48	20.99	21.16	2.37	50.15
	1972-76	14.07	1.49	20.96	17.15	2.62	44.93
	1977	8.27	1.49	12.32	8.98	2.62	23.53
	1978-81	5.88	-	10.31	7.98	-	24.11
	1982-83	5.88		10.31	4.00		12.10
	1984	2.71		4.67	4.00		12.10
	1985	2.47		4.16	4.00		12.10
	1986	2.23		3.65	4.00		12.10
	1987	2.02		3.21	4.00		12.10
	1988-89	1.76		2.67	4.00		12.10
	1990+	1.62		2.37	4.00		12.10

4.2 Light-Duty Gasoline Class 2 Trucks

There are very few LDGT2 test data in the EF programs. For pre-1979 model years, LDGTs with gross vehicle weight (GVW) over 6,000 lbs. were classified as HDGVs. Therefore, the emission rates and standards for LDGT2s for pre-1979 model years are the same as those for HDGVs. Since LDGT2s have the same evaporative emission standards as LDGT1s for 1979 and later years, the same emission rates are used.

Table 14 is a summary of the LDGT2 evaporative emission rates. Note that for the hot soak rates, the LDGT2 fuel injection sales projections are the same as the LDGT1s. For high altitude 1984 and later vehicles, the emission rates are the low altitude rates multiplied by an emission standard ratio of 1.30.

Table 14

LDGT2 Evaporative Emission Rates (gms)

Region	MYR Group	Hot Soak Indol.	Hot Soak Ratio	Hot Soak Comm.	Diurnal Indol.	Diurnal Ratio	Diurnal Comm.
Low Altitude	pre-1979	18.08	1.53	27.66	42.33	1.84	77.89
	1979-80	2.27	-	3.98	3.08	-	9.31
	1981-83	2.27		3.98	3.08		9.31
	1984	2.09		3.59	3.08		9.31
	1985	1.90		3.20	3.08		9.31
	1986	1.72		2.81	3.08		9.31
	1987	1.56		2.47	3.08		9.31
	1988-89	1.36		2.05	3.08		9.31
	1990+	1.25		1.82	3.08		9.31
High Altitude	pre-1979	23.50	1.53	35.96	55.03	1.84	101.26
	1979-81	5.88	-	10.31	7.98	-	24.11
	1982-83	5.88		10.31	4.00		12.10
	1984	2.71		4.67	4.00		12.10
	1985	2.47		4.16	4.00		12.10
	1986	2.23		3.65	4.00		12.10
	1987	2.02		3.21	4.00		12.10
	1988-89	1.76		2.67	4.00		12.10
	1990+	1.62		2.37	4.00		12.10

4.3 Heavy-Duty Gasoline Vehicles

MOBILE2 used 12.90 grams for hot soak emissions and 31.90 grams for diurnal emissions for the evaporative emission rates of pre-1985 uncontrolled HDGVs (also pre-1979 LDGT2s) in the low altitude non-California region. These emission rates were derived from nine in-use heavy-duty vehicles.[15] There are no new in-use test data available since MOBILE2. However, in comparison with LDGV Indolene evaporative emission rates for the no-standard era (pre-1971), the hot soak of 12.90 grams is lower than that of 14.67 grams from the LDGVs. This seems to be unreasonable as HDGVs generally have larger carburetors and experience more severe usage than the LDGVs.

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15 Memo on "Quantity of Evaporative HC Emissions from Heavy-Duty Vehicles" from Michael W. Leiferman to Marcia Williams, May 11, 1977.

Test data submitted by GM for the HDGV evaporative emission rulemaking[16] have shown an average full-SHED hot soak emissions of 18.08 grams and diurnal emissions of 42.33 grams based upon Indolene fuel. These results were obtained from testing of two uncontrolled vehicles, one a heavy-duty pick-up, and one C-7 series tractor. These data were submitted with the intention to show a good correlation between the GM proposed component test procedure and the EPA proposed "full-SHED" test procedure for HDGV engine certifications. These emission rates appear to be reasonable, in comparison with the LDGV rates from the precontrolled period. The higher rate of hot soak emissions of HDGVs (18.08 vs. 14.67 grams from LDGVs) can be attributed to their larger carburetors and more variable operating temperatures. The higher rate of diurnal emissions (42.33 vs. 26.08 grams from LDGVs) can be attributed to the fact that HDGVs have larger fuel tanks. Therefore, these rates of 18.08 and 42.33 grams are used as the Indolene rates for low altitude pre-1985 HDGVs and pre-1979 LDGT2s. The corresponding high altitude Indolene emission rates are the low altitude Indolene emissions multiplied by the altitude factor of 1.30.

The emission rates for 1985 and later model year vehicles for low and high altitude (at SHED standards of 3.0/4.0 grams/test) are estimated from LDGV emission rates for the SHED standard of 2.0 grams/test. The HDGV emissions are calculated from the LDGV emissions and the ratio of the HDGV standards to the LDGV standard. For example, since the HDGV 3.0 grams/test standard is a factor of 1.5 in comparison with the LDGV 2.0 grams/test standard, the assumption is that the ratio of the emissions will be the same as the ratio of the standards. Therefore, the evaporative emission rates for HDGV 3.0 gram standard are those for the LDGVs multiplied by 1.5. Similarly, the rates for HDGVs 4.0 gram standard are those for the LDGVs multiplied by 2.0. This methodology is used to derive HDGV evaporative emission rates, for both Indolene and commercial fuels. The derived two ratios are then weighted by their respective GVW sales fractions for HDGV in 1987[17], which are estimated to be 81.5 percent for the under 14,000 lb. weight classes and 18.5 percent for the over 14,000 lb. weight classes. No fuel injection sales are assumed for HDGVs. The resultant low altitude emission rates are 3.62 grams for hot soak and 4.90 grams for diurnal on the Indolene fuel, and 6.34 grams for hot soak and 14.83 grams for diurnal on the commercial fuel.

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16 "Summary and Analysis of Comments to the Notice of Proposed Rulemaking: Evaporative Emission Regulation and Test Procedure for Gasoline-Fueled Heavy-Duty Vehicles," Standards Development and Support Branch, US EPA Docket #OMSAPC-79-1.

17 "Historical and Projected Emissions Conversion Factor and Fuel Economy for Heavy-Duty Trucks, 1962-2002," Energy and Environmental Analysis, Inc., prepared for Motor Vehicle Manufacturers Association, December 1983.

The derived Indolene fuel evaporative emissions for 1985 and later HDGVs under different emission standards (SHED 3.0, SHED 4.0, and SHED 3.0/4.0) are listed in Table 15. Additional test data were available from the HDGV evaporative emission rulemaking. These data were submitted by Ford in support of a proposed 3.0 gram standard for HDGVs under 12,000 GVW classes. With inertia test weight settings between 6,250 to 7,000 lbs., which are equivalent to GVW's of 12,500 to 14,000 lb. HDGVs, two F-350 vehicles with a total of 51 tests had an average total Indolene evaporative emissions of 2.70 grams. (Note, from Table 15, that the estimated total emissions for the 3.0 gram standard are 8.03 grams.) Two C-700 vehicles, which were the representative vehicles for the over 14,000 lb. HDGV classes, with 65 tests, had an average total evaporative emissions of 3.70 grams. (The estimated total emissions for the 4.0 gram standard from Table 15 are 10.70 grams.) These results show lower emission levels in comparison with the estimated Indolene rates from Table 15. However, since these results were submitted to be representative of vehicles at certified levels, they are expected to be lower than the in-use evaporative emission rates. Therefore, the derived Indolene emission rates presented in Table 15 are considered to be reasonable.

Table 15

Low Altitude Indolene Evaporative Emissions (gms)
for 1985 and Later* HDGVs

Standard	Hot Soak	Diurnal	Total
SHED 3.0	3.41	4.62	8.03
SHED 4.0	4.54	6.16	10.70
SHED 3.0/4.0	3.62	4.90	8.52

* The proposed Indolene emission rates are those for the SHED 3.0/4.0 split standards.

The MOBILE3 commercial fuel evaporative emission rates for pre-1985 HDGVs are derived from the Indolene rates (for example, the low altitude 18.08 grams for hot soak and 42.33 grams for diurnal) and the commercial to Indolene emission ratios of precontrolled LDGVs (1.53 for hot soak and 1.84 for diurnal). For 1985 and later years, the commercial fuel evaporative emission rates for the HDGV 3.0/4.0 split standards are derived the same way as the Indolene rates, that is, scaled from LDGV emission rates by the ratio of HDGV and LDGV emission standards, then weighted by the HDGV GVW sales fractions. Table 16 is a summary of the HDGV evaporative emission rates. High altitude commercial fuel emission rates are the low altitude rates multiplied by an altitude factor of 1.30.

Table 16

HDGV Evaporative Emission Rates (gms)

		Hot Soak			Diurnal		
Region	MYR Group	Indol.	Ratio	Comm.	Indol.	Ratio	Comm.
Low Altitude	pre-1985	18.08	1.53	27.66	42.33	1.84	77.89
	1985+	3.62		6.34	4.90		14.83
High Altitude	pre-1985	23.50	1.53	35.96	55.03	1.84	101.26
	1985+	4.71		8.24	6.38		19.28

Attachment 1

Summary of Indolene Evaporative Data Base*
Number of Vehicles Tested
(Including Tampered Vehicles)

Model Year	Low Altitude Non-California	California	High Altitude Non-California
Pre-1970	-	102	-
1970	-	13	-
1971	-	21	21
1972	-	20	20
1973	-	20	20
1975	-	20	20
1977	36	-	32
1978	49	50(50)	49
1979	75	49(49)	75
1980	-	100(61)	45
1981	175	157(43)	64
1982	25	-	4
1983	47	-	-
Total	407	552(203)	350

* Data obtained from CARB are indicated in parentheses.

Attachment 2

List of Tampered Vehicles

Veh ID*	MYR	MFG	Mileage (Miles)	Indolene Emissions (gms) Hot Soak	Indolene Emissions (gms) Diurnal	Tampering Characteristic
Federal Region						
4055	1981	GM	67,375	1.98	0.70	Misrouted vacuum line & missing gas cap
4086	1981	Ford	74,475	2.44	4.97	Disconnected vacuum line
4095	1981	Ford	84,454	10.89	10.73	Missing canister
4143	1981	Toyota	63,747	9.91	1.88	Disconnected vacuum line
4315	1983	Ford	19,286	0.36	7.82	Disconnected vacuum line
California Region						
204	1980	Ford	5,458	0.94	14.28	Disconnected vacuum line
High Altitude Region						
158	1980	GM	14,577	11.37	3.75	Disconnected vacuum line
188	1980	GM	12,418	3.00	4.77	Disconnected vacuum line
220	1980	Toyota	5,920	2.70	6.29	Disconnected vacuum line
16	1981	GM	6,474	3.33	1.19	Disconnected vacuum line

* Only one Federal vehicle (#4315) was a fuel-injected vehicle, all others were carbureted vehicles.

Attachment 3

Low Altitude 1981 and Later LDGV Sample Distributions*
(Untampered Vehicles)

MYR	Carbureted	Fuel-Injected
1981	168(43)	3(2)
1982	0	25(25)
1983	11(10)	35(35)
Total	179(53)	63(62)

* Vehicles tested with both Indolene and commercial fuels are indicated by parentheses.

Attachment 4

Evaporative Emission Control System Diagnosis

Problem	Number of Vehicles Carbureted	Fuel-Injected
Canister saturated with fuel*	18	3
Canister broken	1	0
Canister filter dirty	6	0
Purge valve disconnected	1	0
Purge valve leaked vacuum	5	0
Purge valve was sticking	10	0
Vacuum line plugged	1	0
Vacuum line damaged	3	0
Vent line damaged	1	1
Non-OEM gas cap	1	1
Inoperative vacuum control valve	7	0
Overall**	40	5

* Among these vehicles with saturated canisters, 20 were found to have purge control problems, such as sticking purge valves, etc.

** Vehicles that had one or more problems.

Attachment 5

Fuel Injection Projections

To account for different hot soak emission rates due to vehicles' fuel delivery types, it is necessary to use sales projections on fuel injection for LDGVs and LDGTs. The following is a summary of the fuel injection projections with all manufacturers combined.

VEH TYPE	MYR Group	Percent of Fuel Injection Projection
LDGVs	1981	9.4
	1982	18.3
	1983	27.6
	1984	40.0
	1985-86	61.0
	1987-89	79.5
	1990+	88.8
LDGT1s & LDGT2s	1981-83	0.0
	1984	16.0
	1985	32.0
	1986	48.0
	1987	62.0
	1988-89	79.5
	1990+	88.8

The LDGV projections[1] are obtained from separate estimations on 1982, 1983, 1984, 1985, 1987, and 1990 model years. The sales projections for LDGT1s and LDGT2s combined[2] are obtained from years 1983, 1987, and 1995, with the growth between the years of 1984 and 1987 assumed to be linear, and the same projections as LDGVs assumed for 1988 and later years.

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1 Letter from Energy and Environmental Analysis, Inc. to Phil Lorang of Technical Support Staff, November 28, 1983.

2 Dana Jones and LeRoy H. Lindgren, "Automotive Technological Projections Based on U.S.A. Energy Conservation Policies," December 17, 1983.