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Technical Report

Refueling Emissions from Uncontrolled Vehicles

By

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and

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Standards Development and Support Branch
Emission Control Technology Division
Office of Mobile Sources
Office of Air and Radiation
U. S. Environmental Protection Agency

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I. Background

The Environmental Protection Agency is currently in the process of developing and evaluating a Federal test procedure for the measurement of vehicle refueling emissions. Refueling emissions are of direct concern due to their benzene content and the potential health effects of exposure to gasoline vapors in general. Also, they contribute to ozone formation, and are of particular concern in areas which currently do not meet the National Ambient Air Quality Standards (NAAQS) for ozone.

This report describes EPA's baseline program to measure refueling emissions from uncontrolled vehicles, and to investigate the sensitivity of these emissions to various parameters. An emission factor equation based upon the various parameters will be developed that will be used in making comparisons with the results of other refueling emissions studies. It will then be used to estimate emission factors under a range of conditions.

II. Parameters Affecting Refueling Emissions

As was described by Hochhauser and Campion, the generation of refueling emissions is a complex process "involving non-equilibrium, unsteady state interphase heat and mass transfer in a system where the mode of contact between gas and liquid cannot be easily defined or modeled."[1] It has been shown, however, that fairly good estimates of refueling emissions can be obtained from empirical equations based upon a few, easy to determine parameters.[1,2,3] Those parameters that appear to explain the most variability are: 1) the difference between the temperature of the dispensed fuel and the tank fuel, 2) the temperature of the dispensed fuel, and 3) the fuel volatility. Differences in the physical configuration of vehicles' fuel tanks and fill necks can also affect refueling emissions, but this is a variable that can not be easily quantified. A more complete description of each of these and other parameters considered is given in the following sections.

A. Differences Between Vehicle Tank Temperature and Dispensed Fuel Temperature

A major factor in determining the level of refueling emissions is ΔT, the difference between the temperature of the fuel in the vehicle tank and the dispensed fuel temperature. The addition of fuel that is warmer than the fuel in the vehicle tank in turn warms the tank fuel and vapor space, resulting in the vaporization of additional gasoline and expansion of the vapor mixture. This condition is known as vapor growth. On the other hand, addition of colder fuel to a warmer tank cools the fuel in the tank and some of the vapor present is condensed into liquid. This condition is known as vapor shrinkage. When both fuels are at the same temperature ($\Delta T = 0$) neither vapor growth no vapor shrinkage occurs and the volumetric refueling losses are almost identical to the amount of vapor displaced by the incoming gasoline.

Nearly every previous study dealing with vehicle refueling emissions has recognized the importance of the relationship between ΔT and total refueling emissions.[1,2,4,5,6,7,8,9,10, 11,12] This effect is generally expressed as changes in the ratio of either the volume of vapor displaced, or grams of HC emitted, to the gallons of fuel dispensed. In all cases, an inverse relationship between ΔT and volumetric refueling emissions has been seen as is illustrated in Figure 1 taken from a study by the Stanford Research Institute. In general, the same result holds for the mass of refueling emissions. However, due to the changing constituents of the vapor, at larger negative values of ΔT a positive relationship between ΔT and mass emissions results.[1,2,3,6,9] This "turning over" effect is shown in Figure 2, also taken from the SRI study.

B. <u>Dispensed Fuel Temperature</u>

The temperature of the dispensed fuel (T_D) can exert a distinct impact upon refueling emissions, separate from its use in the determination of ΔT. It has long been known that the amount of vaporization of gasoline varies directly with temperature. This is the reason that mixture enrichment devices are required for cold starting. All other factors being equal, emissions would therefore be lower at colder dispensed temperatures, since less fuel would be vaporized.*

Several of the previous studies have considered the effect of dispensed temperature upon refueling emissions.[1,2,3,4,6] In several of these, the value of ΔT is not separately computed and controlled, so it is difficult to separate the distinct effects that the dispensed fuel temperature has on refueling emissions from its role in vapor growth or shrinkage. Figures 3 and 4, however, show the effect of dispensed fuel temperature, when ΔT is also accounted for, as seen in two of the previous studies.[1,6]

*It is interesting to note that this will not be the case for the temperature of the tank fuel (T_T). Lowering T_T at a constant T_D will create lower values of ΔT, resulting in vapor growth and increased emissions.

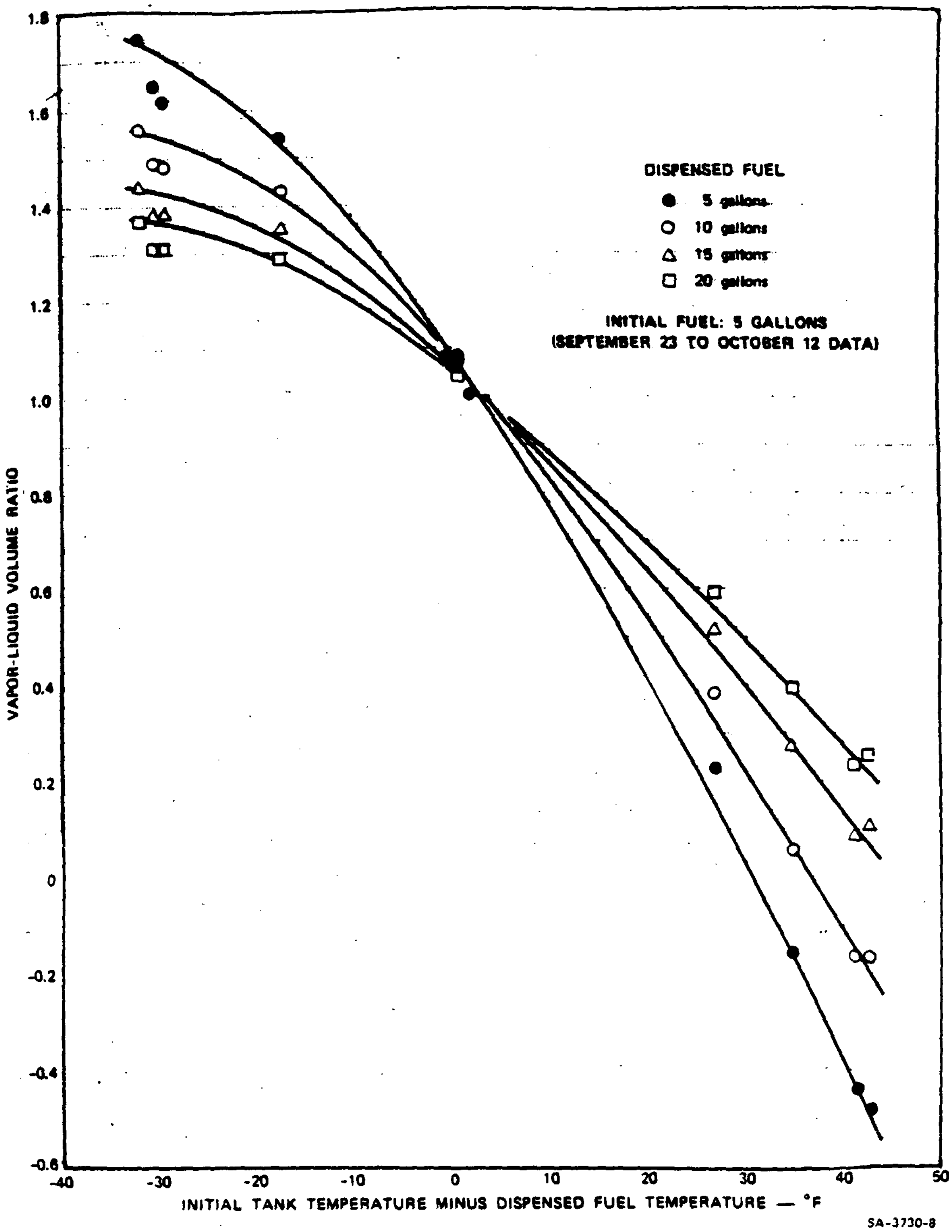

FIGURE 1 VAPOR-LIQUID VOLUME RATIO VERSUS INITIAL ΔT

Source: Stanford Research Institute (9)

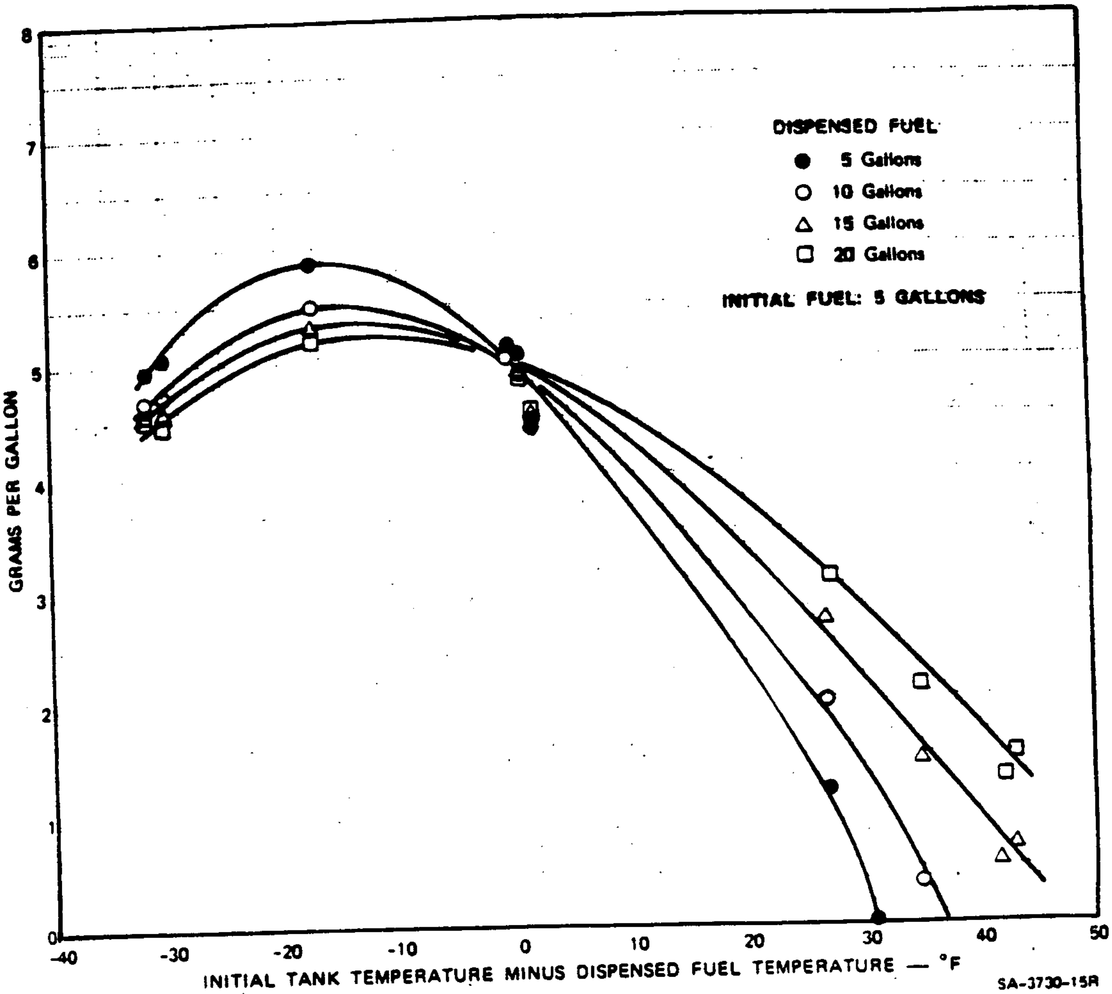

FIGURE 2 GRAMS VAPOR PER GALLON FUEL VERSUS INITIAL ΔT

Source: Stanford Research Institute (9)

EFFECT OF DISPENSED TEMPERATURE

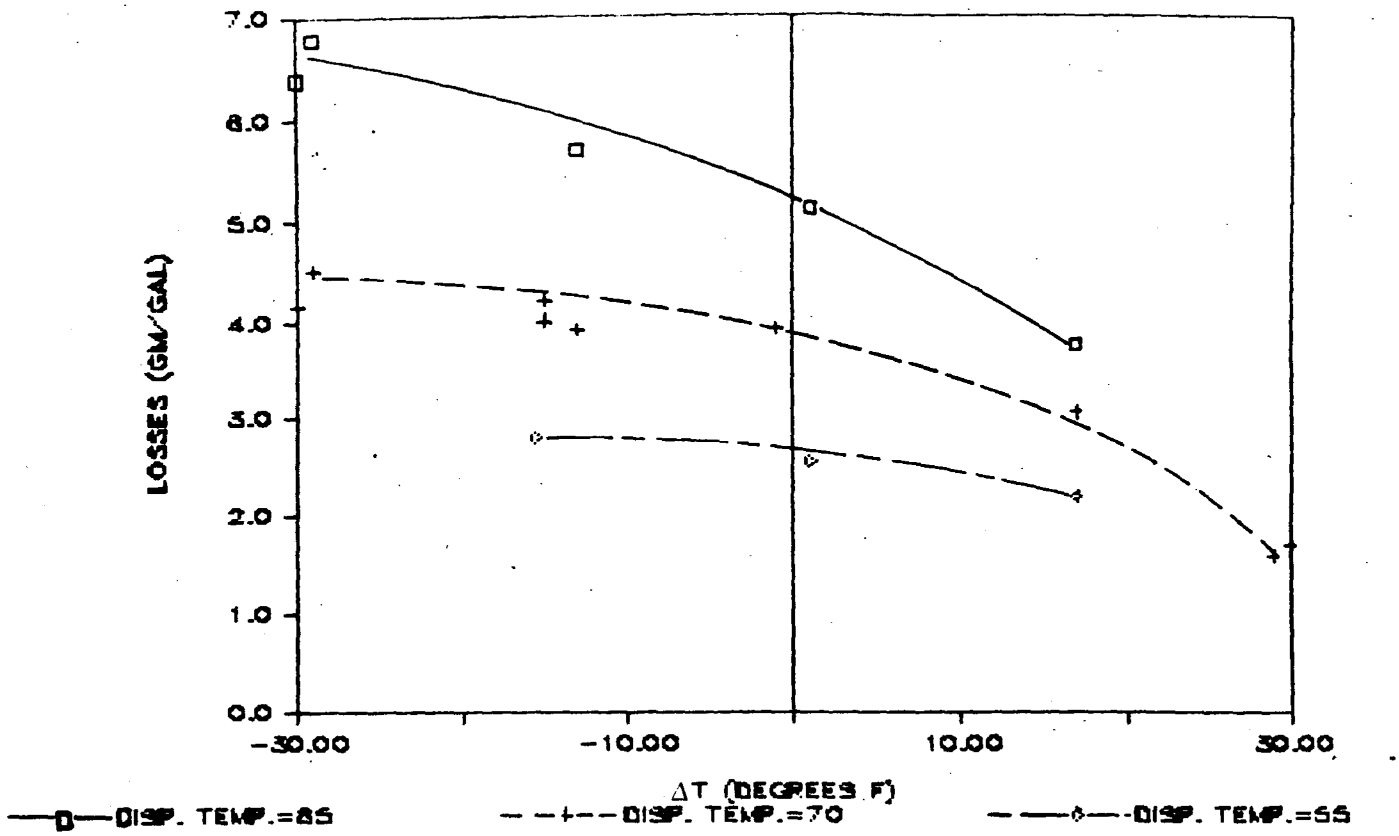

FIGURE 3

Source: EPA Report 75-Gas-6 Part II, August 15,1975, as cited by Scott Environmental (6)

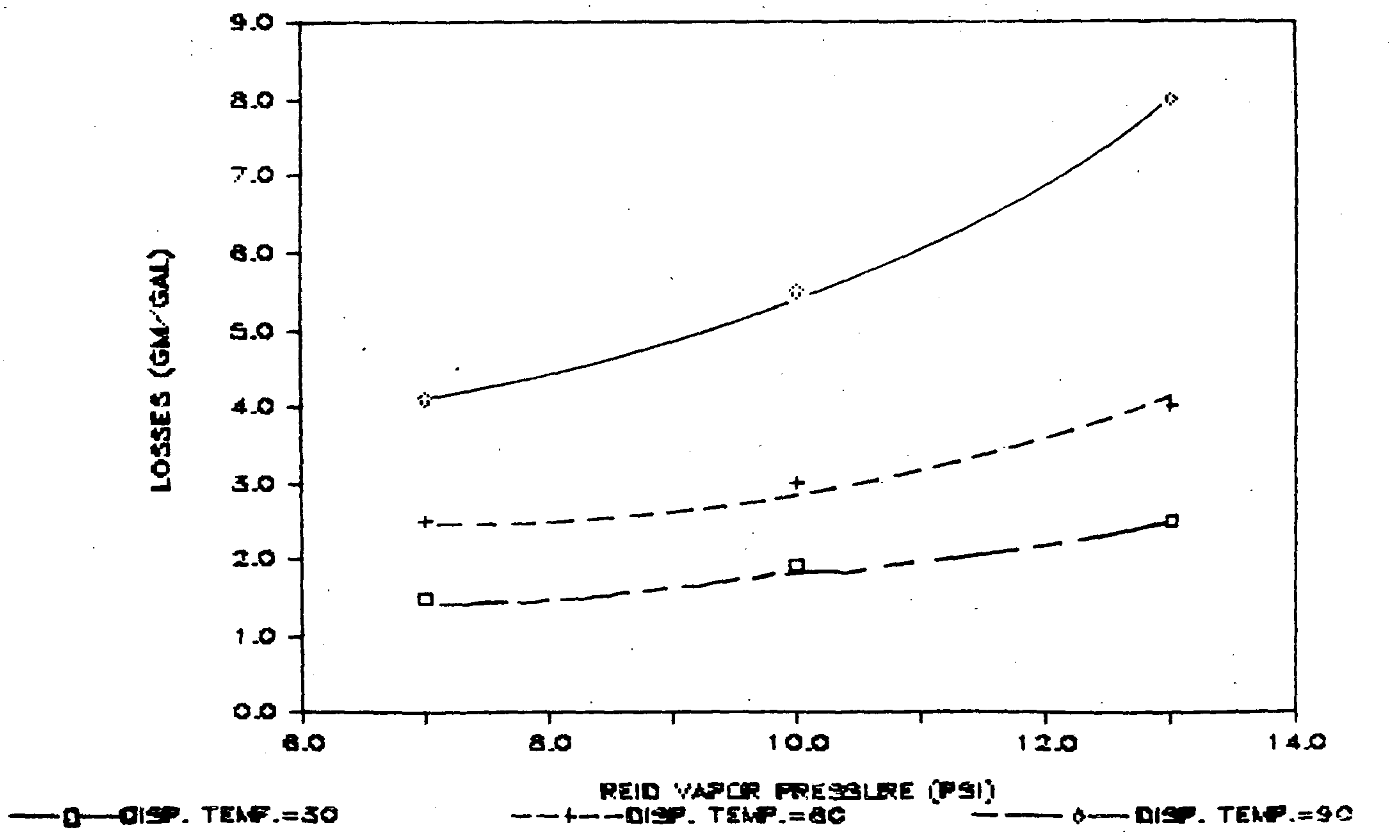

FIGURE 4

Source: EXXON Research & Engineering (5)

C. Fuel Volatility (Reid Vapor Pressure)

RVP is a measure of "front-end" volatility, or the ease of vaporization of gasoline at 100°F; the higher the RVP the greater the vaporization potential. Refueling events occur near this temperature, therefore refueling emission rates should vary with RVP; all other factors being equal, higher RVP fuel yielding higher emissions.

In many of the previous studies, the RVP of the fuel, its effect being recognized, was held constant. Other studies have attempted to explore the relationship between RVP and refueling emissions in a quantitative fashion.[1,2,4,6,9] Figures 5 and 6 show characteristic increases in refueling emissions at a higher RVP.[1,6] This relationship is also noted in other studies.

A few studies have also considered the effect of dispensing a fuel of one RVP into a tank with residual fuel of a different, lower RVP.[3,9] The general result is larger vapor growth as a result of the dispensed fuel vaporizing to increase the hydrocarbon concentration in the tank to the higher vapor pressure of the dispensed fuel.

D. Vehicle Differences

As with any type of emissions, there will be differences in results from different vehicles. In the case of refueling emissions, these differences are primarily related to the vehicle's fuel tank system.

Fuel tanks vary in size, shape, position of the fillpipe (i.e., rear fill or side fill), fill neck design, and internal baffling. Differences in the areas of the evaporative surfaces, effective height of the fillpipe over the evaporative surface and turbulent interactions between the entering fuel and existing vapors are among the most likely causes for the differences that are observed in refueling emissions between vehicles.

Few of the previous studies on vehicle refueling emissions have specifically addressed the issue of differences between vehicles in terms of emissions. This is due predominantly to the fact that most of these studies were concerned with the efficiency of various control strategies, and the percentage of vapor recovered was of more interest than total emissions. Still, Scott Environmental Technology noted the strong vehicle effect on refueling emissions as evidenced by the increased variability in their results as larger numbers of different type vehicles were used.[6] Stanford Research Institute has

EFFECT OF FUEL VOLATILITY

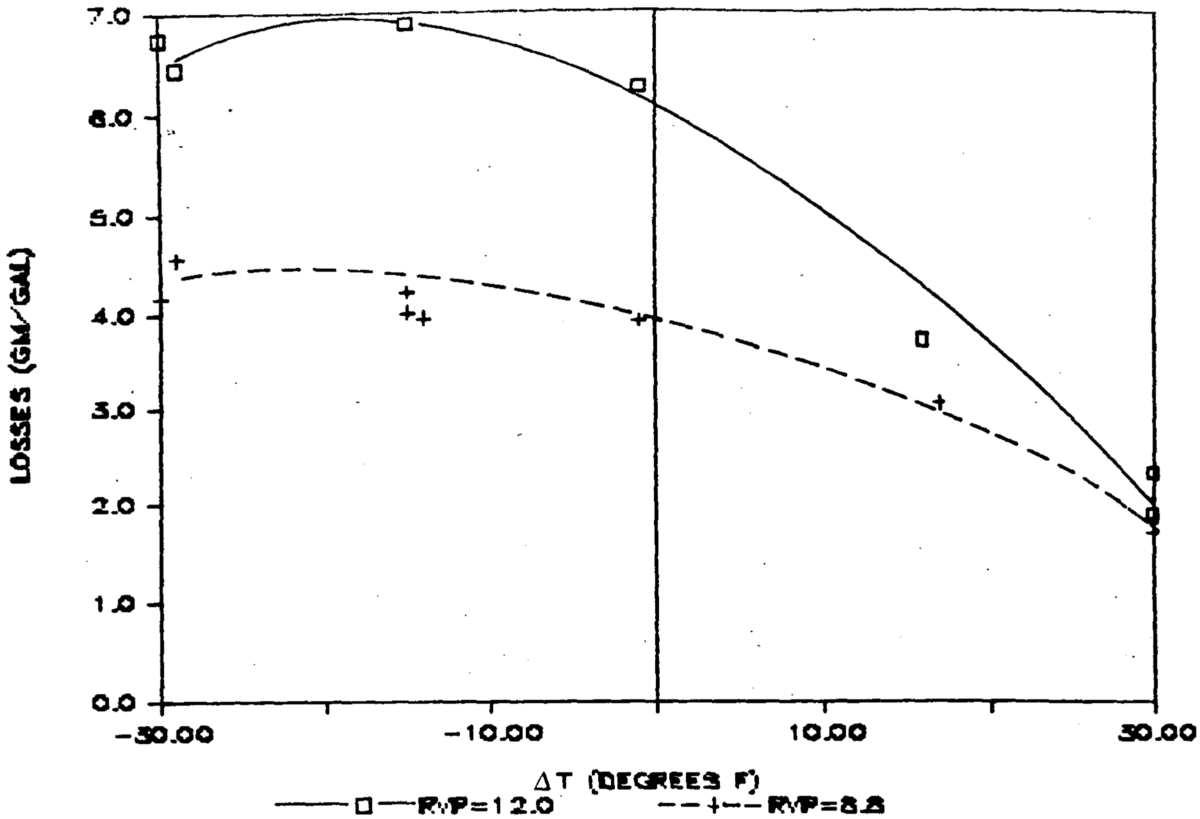

FIGURE 5

Source: EPA Report 75-Gas-6 Part II, August 15,1975, as cited by Scott Environmental (6)

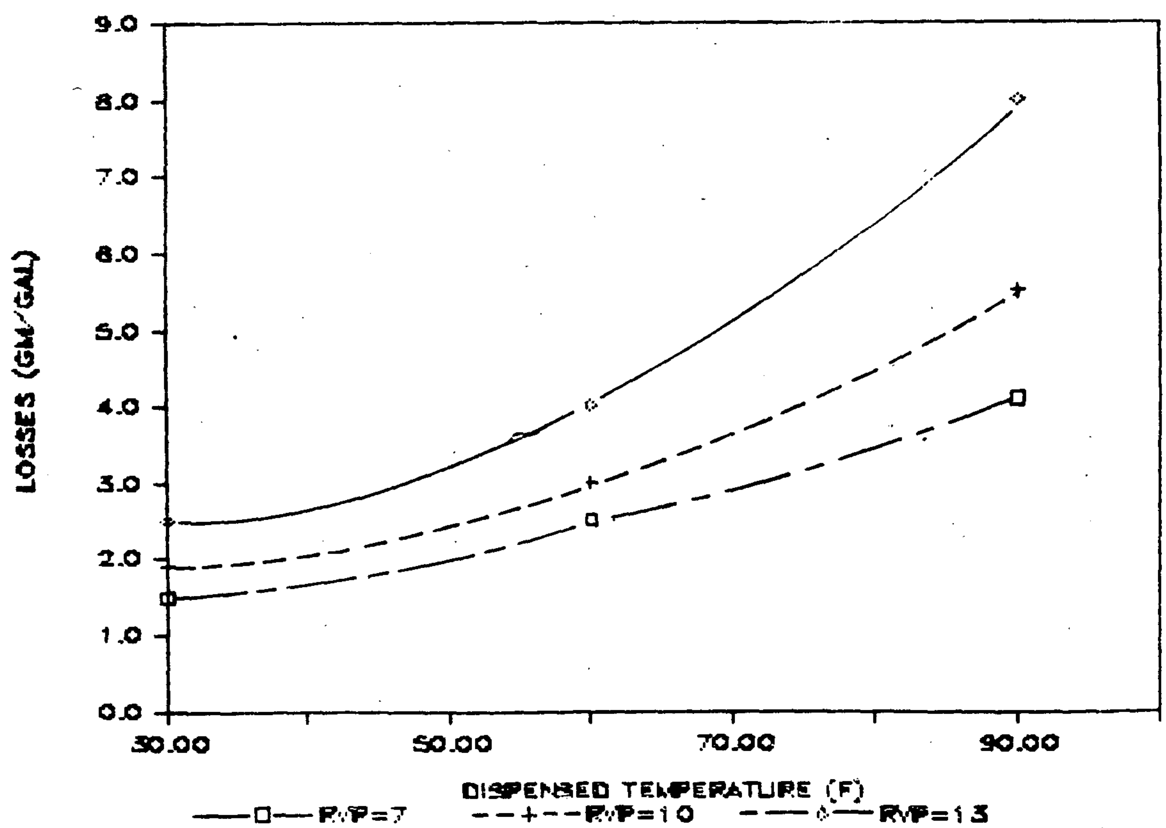

FIGURE 6

Source: EXXON Research & Engineering (5) noted not only changes in emissions between vehicles, but also a change in the shape of the regression line relating refueling losses to ΔT.[9] Also, Exxon Research and Engineering has found average losses at the same test conditions ranging from 4.5 to 5.4 gm/gal depending on the vehicle.[13] Thus, although the previous studies have not specifically addressed the issue of differences between vehicles, its effect has been noted.

E. Other Factors

Several other factors that may have an effect upon refueling emissions have been considered in previous studies. Among these are: fill rate,[1,9] amount of residual fuel in the tank,[3,9] total amount of fill,[1,3,9] position of nozzle in the fill-neck,[9] and ambient temperature.[3,8,9] The magnitude of these effects is much less than that for any of the factors described previously. Therefore, this study has been designed primarily to determine the effects of ΔT, dispensed temperature, and fuel volatility; and any insights that can be obtained about these other effects or differences between vehicles, will be secondary.

III. Baseline Refueling Test Program

A. Vehicles and Test Conditions

Eight vehicles in all have been tested in the baseline program. These consist of six light-duty gasoline vehicles and two light-duty gasoline trucks. The tank sizes vary from vehicle to vehicle, as do the configurations of the tanks and their internal baffling. A listing of the vehicles is given in Table 1.

The majority of the testing was performed on the 1983 Cutlass Supreme, as it was the first vehicle tested. The matrix of parameter conditions under which the Cutlass was tested is shown in Table 2, along with similar but less extensive matrices for the 1984 Escort and the 1983 Reliant. The testing of these vehicles at the various parameter conditions allows for a more complete comparison of the differences in refueling emissions between vehicles. Of particular interest here is the difference in refueling emissions between side-fill and rear-fill vehicles. Of all the vehicles tested, only the 1983 Cutlass Supreme is a rear-fill vehicle, and the future fleet is expected to be dominated by side-fill vehicles.

The remaining vehicles were tested primarily at one set of parameter conditions. By testing several vehicles, an indication of the range of refueling emission rates can be obtained.

Table 1

Vehicles Tested

Year	Make/Model	Tank Vol. (gal)	Comments
1983	Olds. Cutlass Supreme	18.1	Rear fill
1983	Buick Skylark	14.5	
1984	Chevrolet Celebrity	16.4	Fuel Injected
1984	Ford Escort	13.0	
1983	LDT Crown Victoria	18.0	Vertical Tank
1983	Plymouth Reliant	13.0	
1979	Dodge Truck W150	18.0	
1979	Chevrolet 3/4 Ton Pickup	19.6	

Table 2

Refueling Emissions Test Matrix

1983 Oldsmobile Cutlass

Fuel	Dispensed Temperature	Tank Temperature
9.0 RVP	82°F	80, 92, 100, 120°F
	92°F	80, 92, 100, 120°F
11.9 RVP	82°F	80, 92, 100, 120°F
	92°F	80, 92, 100, 120°F
10.0 RVP	92°F	80, 92, 100°F
12.6 RVP	82°F	80, 92, 100°F

1984 Ford Escort

Fuel	Dispensed Temperature	Tank Temperature
9.0 RVP	80°F	82, 92, 100°F
	92°F	92°F
11.9 RVP	66°F	72°F
	80°F	82, 92, 100°F
	92°F	92°F

1983 Plymouth Reliant

Fuel	Dispensed Temperature	Tank Temperature
9.0 RVP	66°F	72°F
11.9 RVP	66°F	72°F
	80°F	82, 92, 100°F
	92°F	92°F

Remaining Vehicles

Fuel	Dispensed Temperature	Tank Temperature
11.9 RVP	80, 92°F	92°F

B. Test Procedure

1. Overview

The refueling emissions tests were performed in the manner outlined in Table 3. The test vehicle was pushed into the Sealed Housing for Evaporative Determination (SHED) "cold", i.e., at ambient temperature. At this point there was a 10 percent fill in the tank. The vehicle's fuel tank was then heated, either by a single or dual heating blankets, to the desired temperature, inside the open SHED.* The purge fan was operating inside the SHED during this time. The dispensed fuel had generally been heated to its desired temperature previously.

At the end of the heating phase, the heating blankets were unplugged, the fuel nozzle was inserted into the fuel neck, the mixing fans were started, and the SHED was sealed. A background reading was then taken inside the sealed SHED before the refueling began. The refueling was then performed by turning on the fuel cart from outside the SHED. The refueling ended at a 95 percent fill, either when the nozzle had automatically shut off, or when it was shut off manually outside the SHED. The first method led to some problems with spillage, so in the later testing only manual shutoff was used.

Temperature sensors were located at three points inside the tank, in the fuel cart, and at various other places in the testing setup, and values were recorded approximately every two minutes throughout the test. The measurements of refueling emissions were made with the use of a Flame Ionization Detection device.

2. Effects of Vehicle Preconditioning

As was described in the previous section detailing the test conditions, the vehicle's fuel tanks were heated either by single or dual blankets. The earliest tests on the 1983 Cutlass were the only ones where a single blanket was used. Heating of the fuel tank was done with the general constraint that vapor and liquid temperatures not be allowed to differ by more than 6°F. Under these conditions, the time required to heat the tank to the desired temperature was in many cases excessive, i.e., an average of three hours to reach a tank temperature of 100°F. Also, since the tank was only heated from below, temperature stratification occurred inside the tank,

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* In a few of the tests the vehicle was driven on a road circuit before the refueling, heating the vehicle's fuel tank in the process.

Table 3

Test Sequence

1. Drain and refuel tank to 10 percent of fuel capacity.
2. Push vehicle into shed.
3. Connect heat blankets and thermocouples.
4. Heat vehicle tank to desired temperature.
5. Insert fuel nozzle.
6. Close shed and start mixing fans.
7. Take initial sample reading (using FID).
8. Refuel tank to 95 percent of fuel capacity.
9. Check for spills and nozzle shutoff.
10. Take final sample reading (using FID).
11. Disconnect heat blankets and thermocouples.
12. Remove vehicle from shed.

with the vapor temperature lagging behind the liquid temperature by several degrees. At the time of refueling, it was unclear as to whether an equilibrium existed in the vehicle's fuel tank.

The use of dual heating blankets (the second blanket being used to heat the top of the fuel tank) drastically reduced the heating time required, and alleviated the problem of temperature stratification in the fuel tank. This approach was therefore adopted as the standard tank heating procedure.

Figures 7, 8, and 9 show the results of the refueling tests for various methods of vehicle preconditioning. These data are solely from tests on the 1983 Cutlass, at a constant RVP and dispensed temperature in each case. Figure 7 gives a comparison of the results when the vehicle was heated by a single blanket, heated by dual blankets, or driven on a road circuit. Figure 8 shows further results when the vehicle was heated by dual blankets compared to when it was driven on a road circuit. Finally, Figure 9 shows the results of tests in which the vapor and fuel temperatures inside the vehicle's fuel tank were permitted to differ markedly.

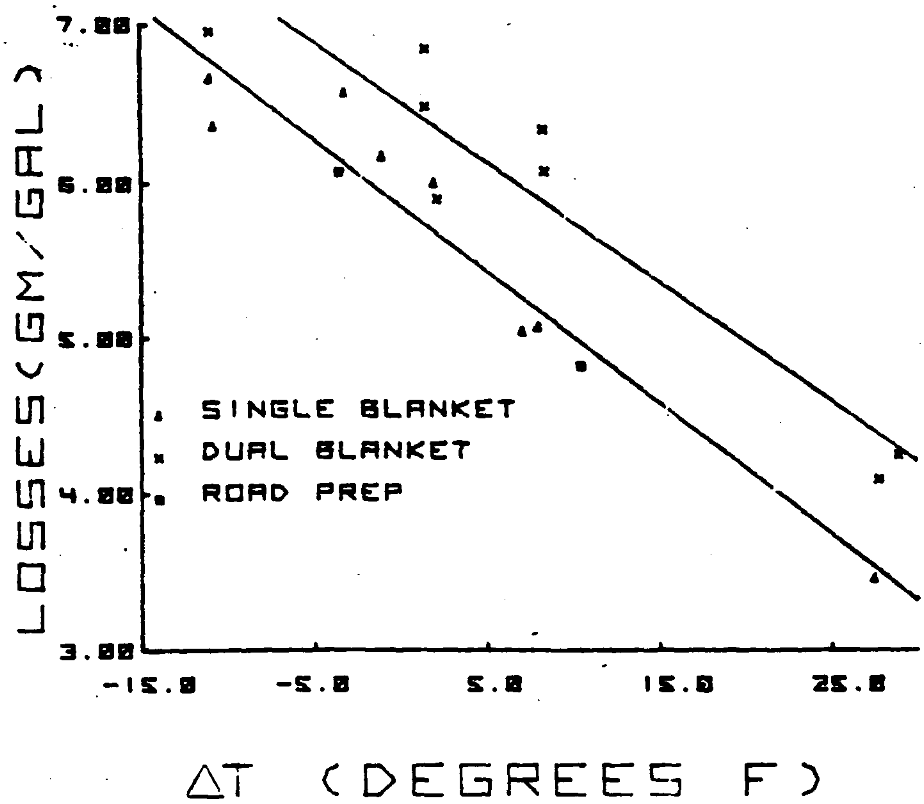
Several conclusions can be drawn from these test results. Refueling emissions were lower by approximately 0.7 gm/gal when under single blanket heating versus dual blanket heating. Large differences in the fuel tank liquid and vapor temperatures may affect refueling emissions, with lower emissions resulting when the vapor temperature lags behind the liquid temperature. The results from the road circuit tests appear to fit better with the single blanket tests, but half of these also fit with the dual blanket tests fairly well.**

It is unclear how much of the difference between the single and dual blanket test results can be explained by the temperature stratification in the vehicle's fuel tank, and what must be explained by other factors. Because of its heating time advantages, and the question of tank equilibrium, dual blanket heating was used in the actual baseline testing. The results from the tests on the vehicle prepared on the road circuit, which are taken to represent a real-life situation, suggest that the dual blanket heating procedure may yield slightly conservative, but generally accurate, estimates of refueling emissions in real life situations.

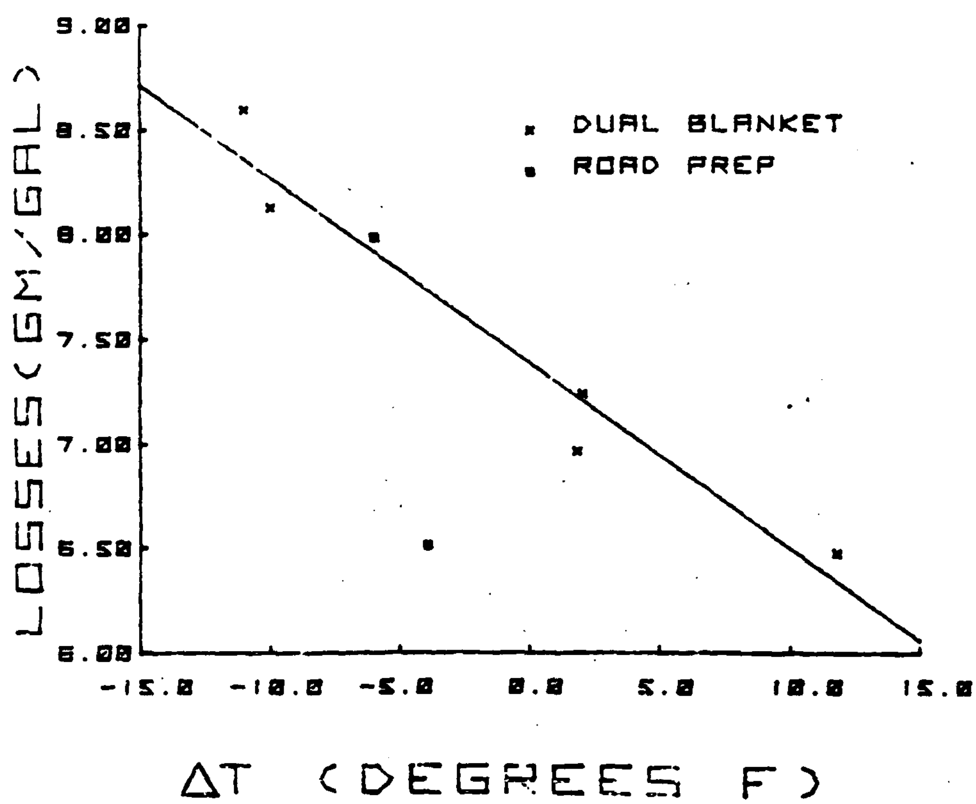
** When 90 percent confidence intervals for the regression lines are used.

VEHICLE PRECONDITIONING EFFECTS

RVP=9.0 DISP.TEMP.=92



RVP=10.0 DISP.TEMP.=92



FIGURES 7 and 8

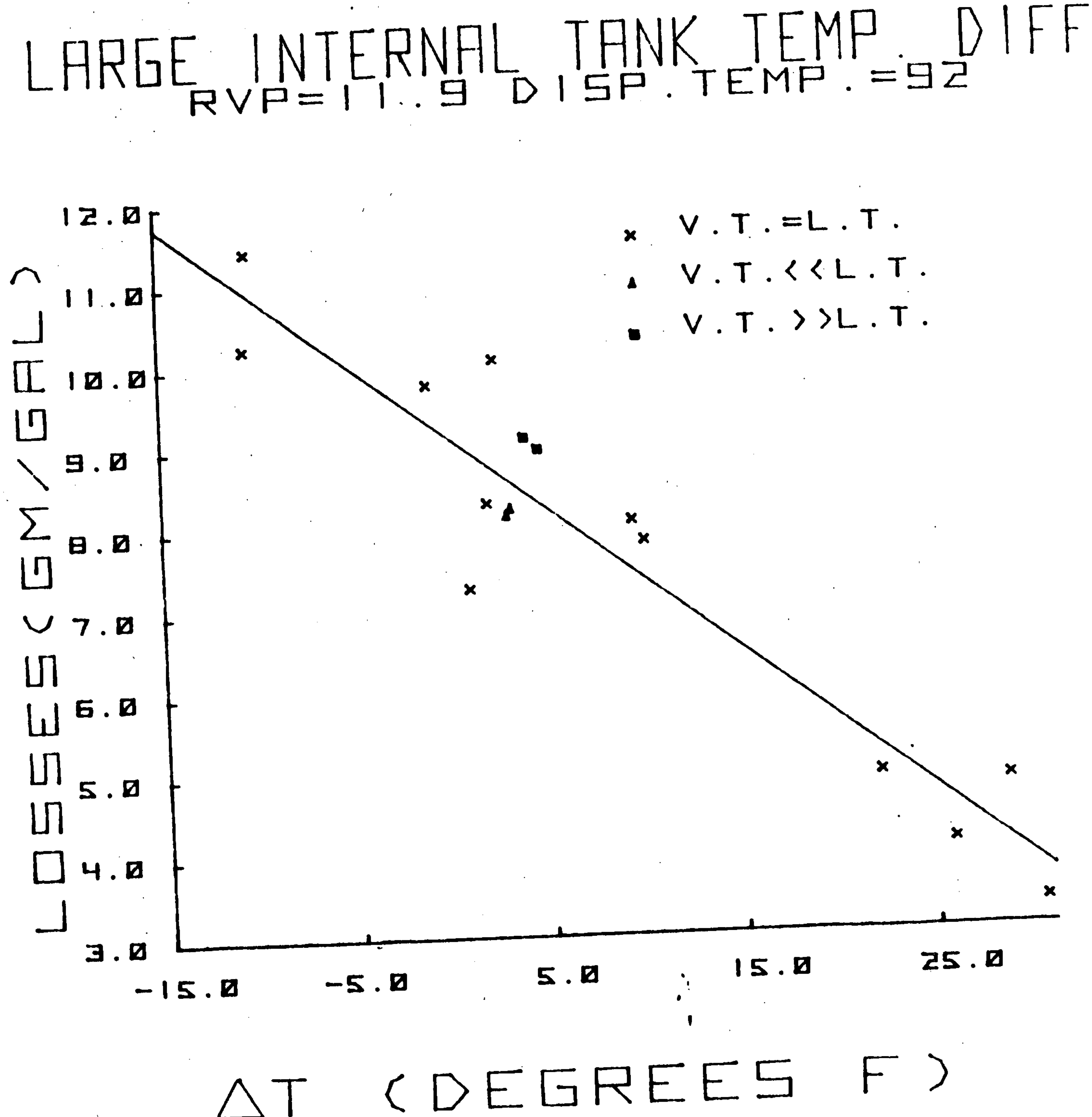

LARGE INTERNAL TANK TEMP DIFF
RVP=11.9 DISP.TEMP.=92
V.T.=L.T.
V.T.<<L.T.
V.T.>>L.T.
LOSSES (GM/GAL)
12.0
11.0
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
-15.0
-5.0
5.0
15.0
25.0
ΔT (DEGREES F)

FIGURE 9

C. Test Results

1. Summary

It has been found that the refueling emissions, in grams of HC per gallon of fuel dispensed, can be estimated accurately by a multiple linear regression model relating refueling emissions to the difference between vehicle tank temperature and dispensed fuel temperature (ΔT), the dispensed fuel temperature, and the fuel volatility. The effects of vehicle configuration were explored and found to be of some significance.* The following general conclusions can be reached from the results.

a) lower tank temperatures, relative to the dispensed fuel temperature, yield higher emissions,

b) higher dispensed temperatures yield higher emissions,

c) higher RVP dispensed fuel yields higher emissions; and,

d) vehicle configuration can have a significant impact on refueling emissions.

A more detailed look at each of these factors follows.

2. Parameter Effects

a. Differences Between Vehicle Tank Temperature and Dispensed Fuel Temperature

Due to the phenomena of vapor shrinkage and vapor growth the difference between the tank temperature and the dispensed fuel temperature has a significant impact upon refueling emissions. This difference is defined herein as $T_T - T_D$ and will be referred to as ΔT. The tank temperature, T_T, is measured as the liquid temperature in the vehicle fuel tank.

Figure 10 shows a plot of refueling emissions against ΔT. The general trend of higher emissions at lower ΔT values, representing more vapor growth, is apparent even when other factors such as dispensed temperature and fuel volatility are not considered. Very few tests were run at negative values of ΔT, and none below $\Delta T= -12$, so the turnover in the

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* The results of all of the valid tests performed on each vehicle are summarized in Appendix A. This includes the special tests run on the Cutlass in addition to the primary baseline testing.

REFUELING LOSSES vs. $T_{TANK}-T_{DISPENSED}$

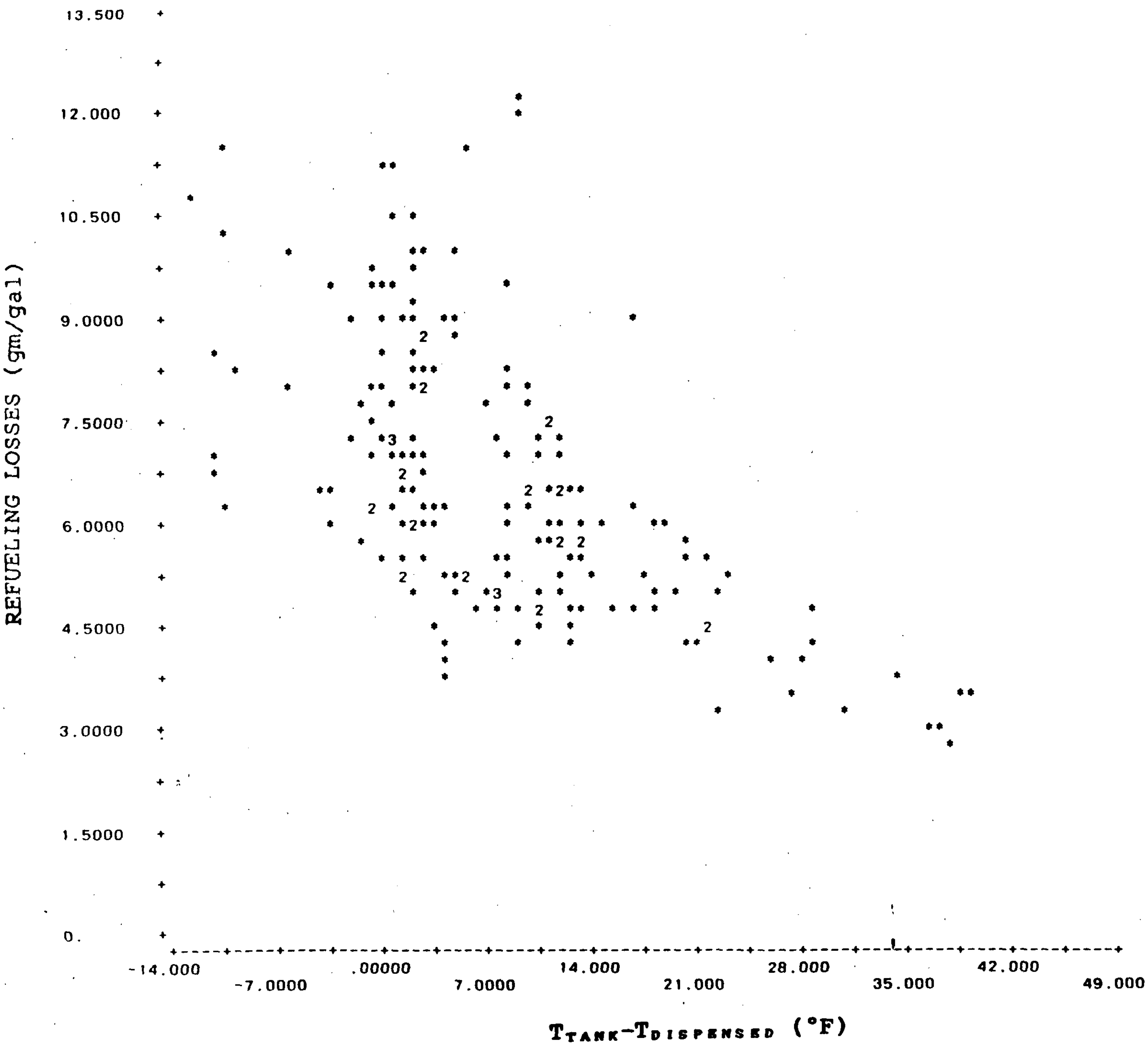


FIGURE 10

relationship between ΔT and mass emissions noted earlier from other studies is not seen here.

b. Dispensed Fuel Temperature

Figures 11 and 12 illustrate the effect that the dispensed fuel temperature can have upon refueling emissions. These plots are separated by fuel volatility, and the refueling emissions values are plotted against ΔT in order that the effects of dispensed temperature can be separated from these other parameters. The values plotted at each ΔT are the mean responses, along with the standard deviation of the observed test results (where applicable) for a range of ΔTs centered at that point. A smaller standard deviation at a given point in these plots will not necessarily mean a more precise point, as the same number of tests were not performed at each point. They are presented here solely to give an indication of the variation in the test results.

The figures indicate in general that higher dispensed temperatures will yield higher refueling emissions. This is especially true at values of ΔT around 0F° where a 10°F change in T_D produces a 1 gm/gal change in emissions, with the effect being less notable at higher values of ΔT, where all values tend to converge. These results are consistent with those seen in previous studies.

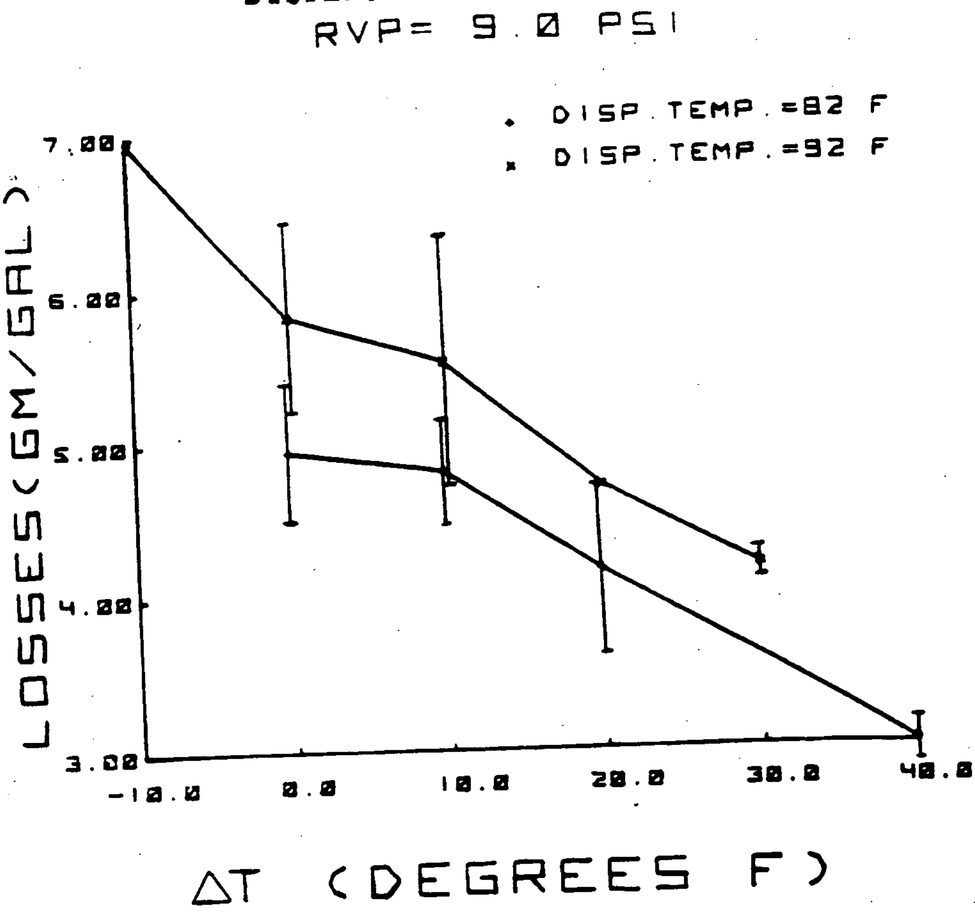
c. Fuel Volatility (Reid Vapor Pressure)

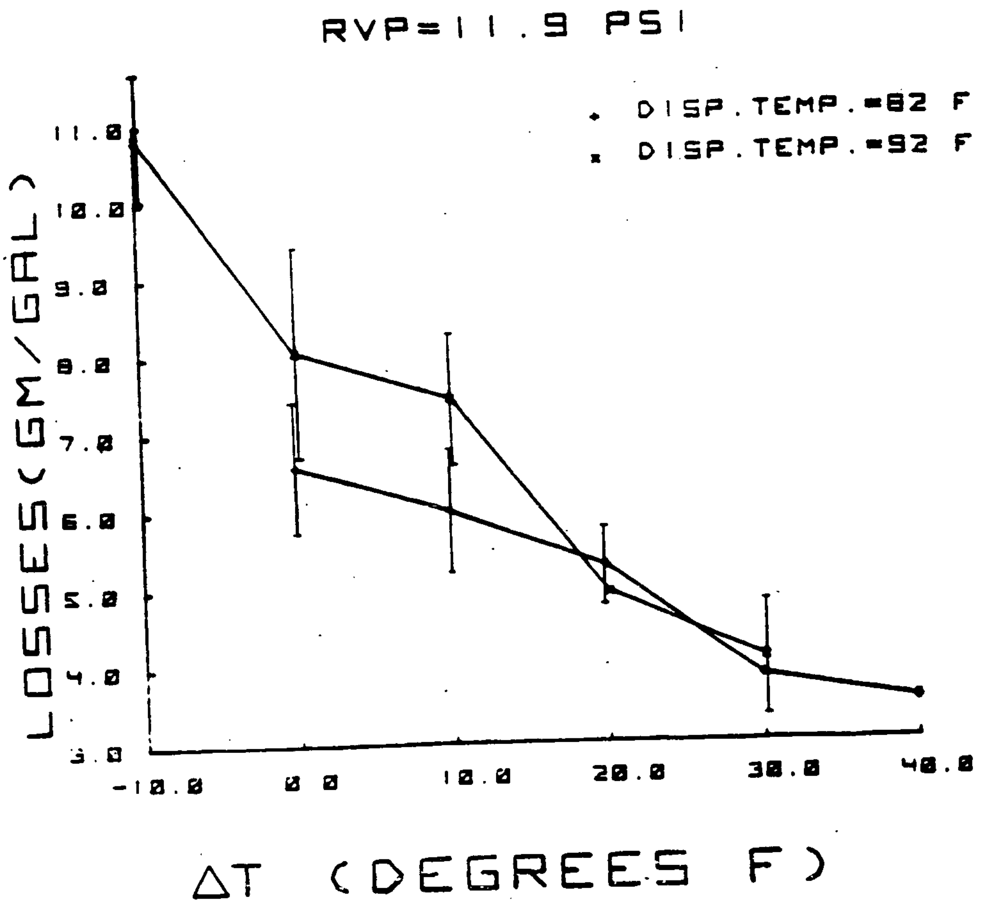
Figures 13 and 14 illustrate the effect that the fuel volatility can have upon refueling emissions. The form of these plots is the same as in those used to illustrate the effect of dispensed fuel temperature, only here the dispensed fuel temperature is held constant as opposed to the fuel volatility being fixed previously.

These figures give a clear indication that a higher fuel volatility, denoted by a higher RVP, will yield higher refueling emissions, as was seen in other studies. As with the dispensed fuel temperature, this effect is more noticeable at low values of ΔT.

Several tests were run where a fuel with a lower volatility than the dispensed fuel was placed in the vehicle's fuel tank. This represents the case in which a vehicle's fuel weathers and loses some of its volatility between refuelings. The expected result, as described in the SRI study, is higher emissions resulting from vaporization of the dispensed fuel to increase the hydrocarbon concentration in the fuel tank to the higher vapor pressure at the dispensed fuel. The results from these tests are shown in Figure 14 as the three single points*, and reaffirm the results in the SRI study.[2]

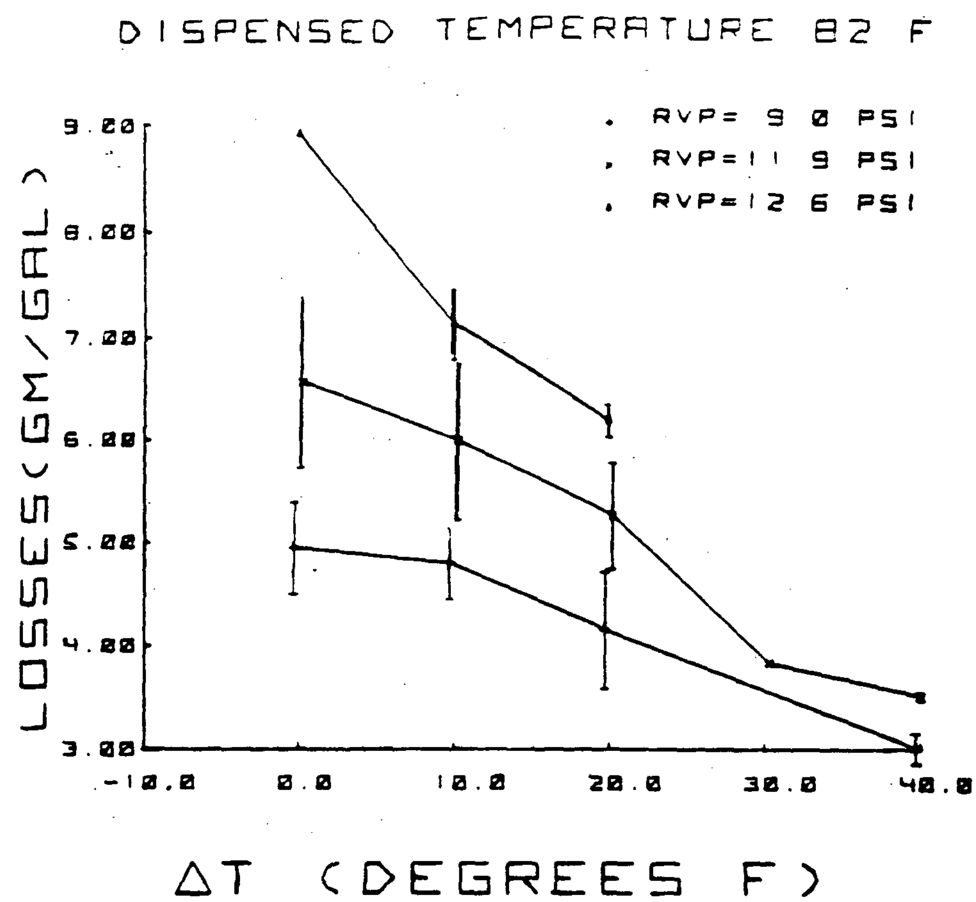
DISPENSED TEMPERATURE EFFECTS

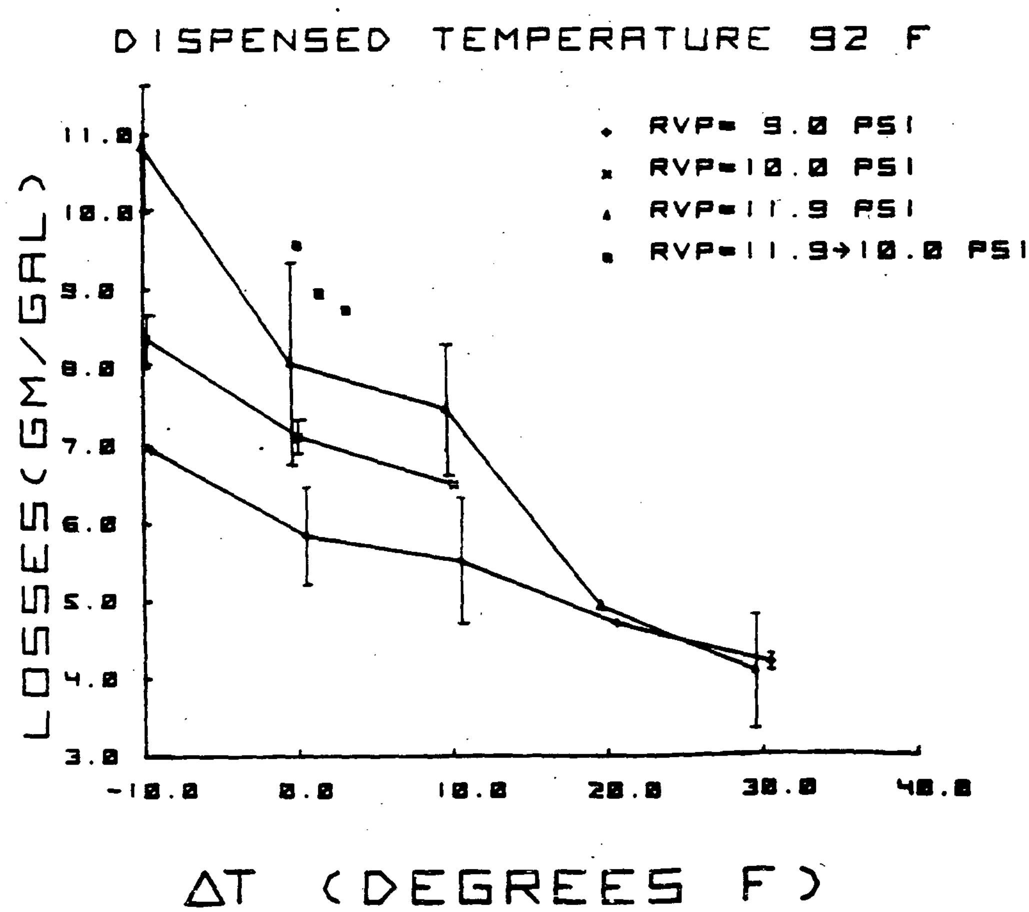




FIGURES 11 and 12

FUEL VOLATILITY EFFECTS





FIGURES 13 and 14

d. Other Parameters

It has been suggested that other parameters, such as ambient temperature and fuel dispensing rate may influence refueling emissions. In this particular testing program, it appears that the time required to heat the vehicle's fuel tank and the dispensing rate of the fuel may be of some significance. The design of this program, however, has made any significant analysis of these effects virtually impossible. Thus, although the presence of these effects are recognized, they cannot be determined here. Also, in comparison to the effects due to ΔT, the dispensed fuel temperature, fuel volatility, and vehicle configuration (discussed in the next section), these other effects are of much lesser significance.

3. Differences in Vehicles and Vehicle Configuration

For most of the vehicles tested, there is insufficient data to do independent parameter analyses. Therefore, a multiple linear regression has been fit using all of the data, and the residuals, the actual values minus the values predicted by the regression equation, have been examined.. The different patterns in the residuals from vehicle to vehicle can give an indication of the vehicle effects. Figures 15-22 show the residuals plotted against the predicted values for each vehicle individually, all plotted at the same scale.

Of particular interest in these residual plots are the residuals associated with the LTD Crown Victoria, the Escort, and the Reliant. The residuals associated with the LTD are quite extreme, higher than those associated with any of the other vehicles aside from a few tests on the 1983 Cutlass. This may be due to the LDT's unique fuel tank configuration; its height dimension being larger than its width, with almost no drop in the fill neck. This configuration is atypical of the automotive fleet, and the results from the tests on the LTD would skew the prediction equation derived from the multiple linear regression model. Thus, although the LTD shows the potential range in refueling emission rates, its test results have not been used in formulating the prediction equation to be used here.

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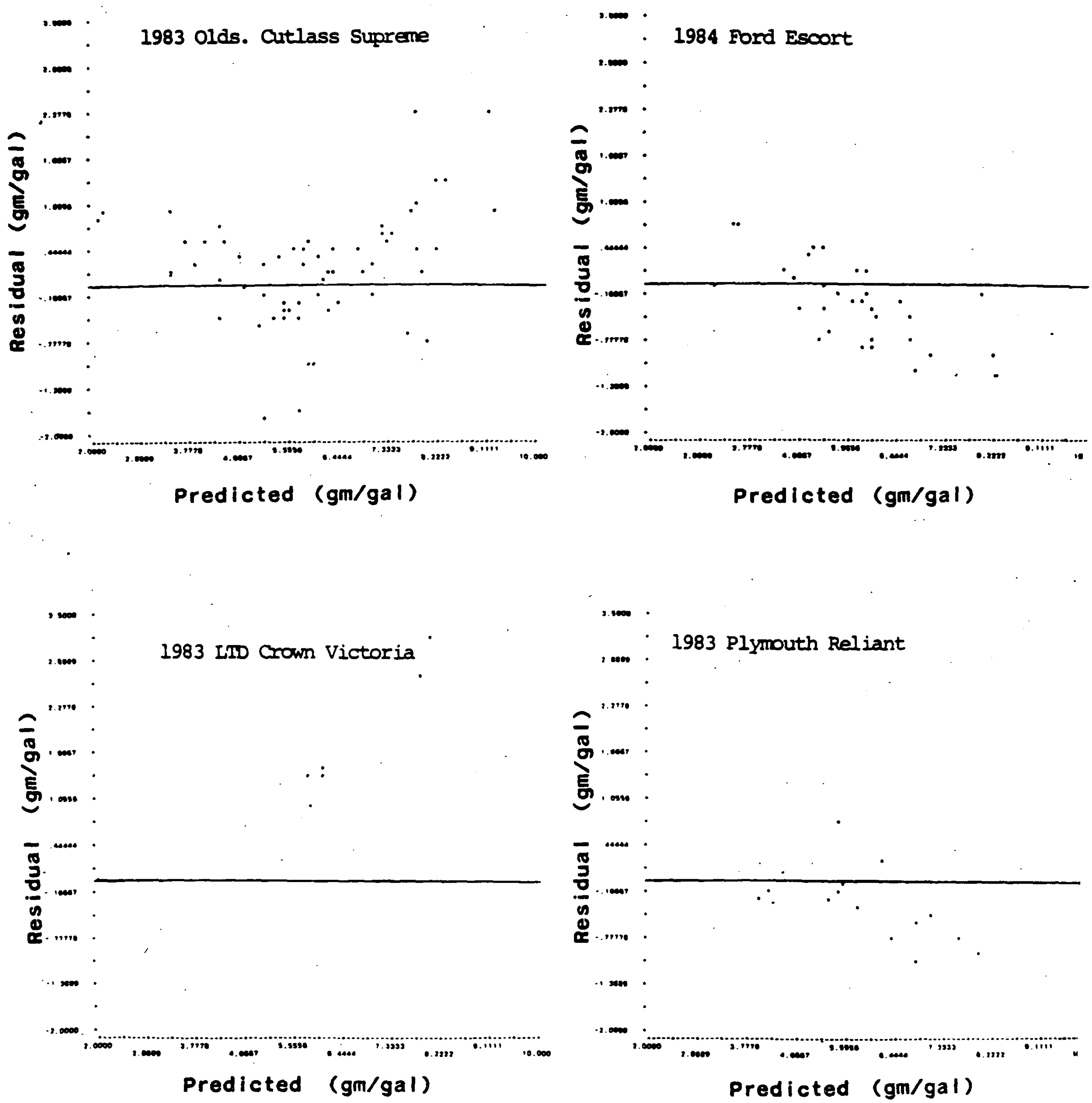
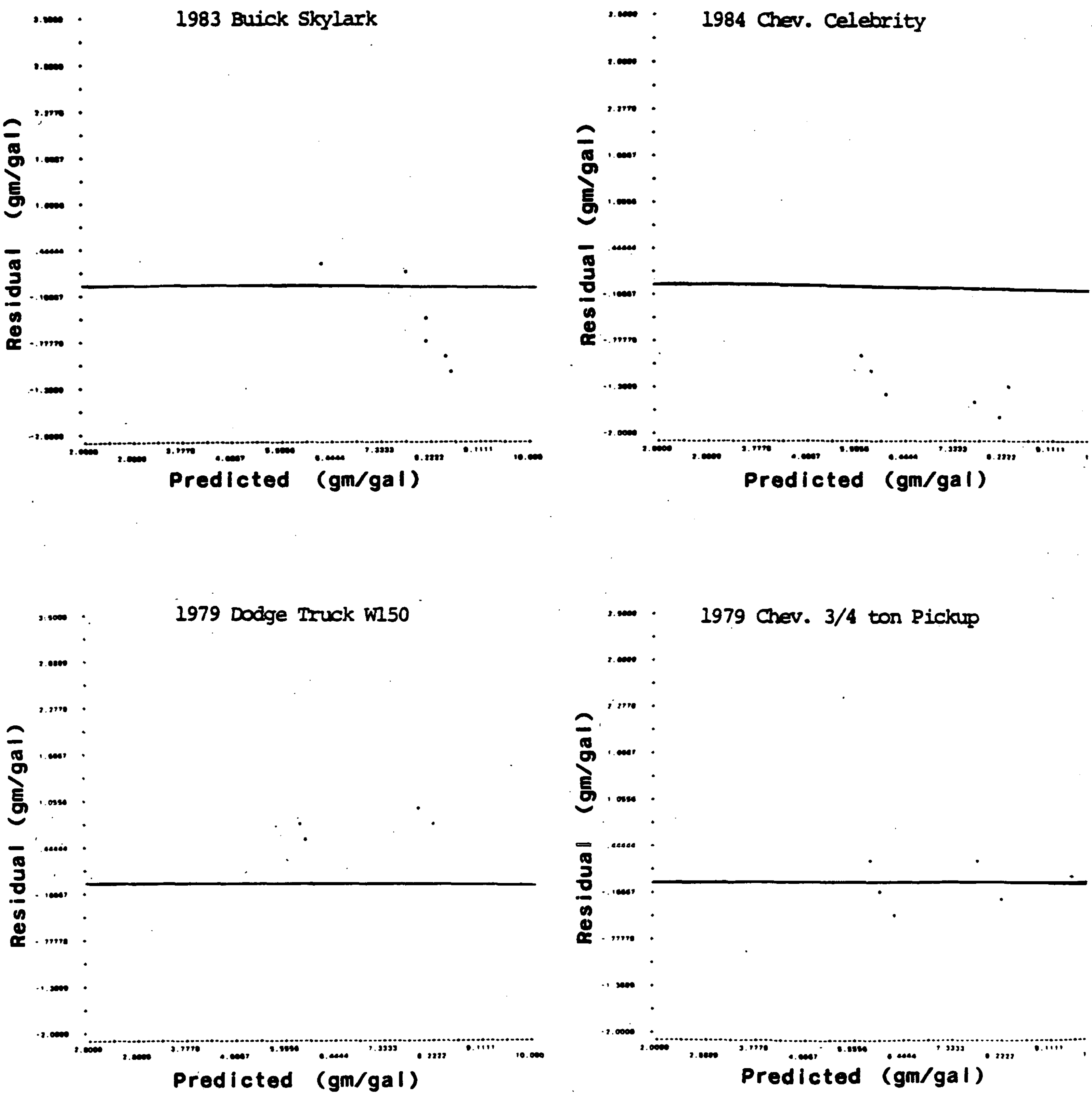
* The results are also listed in Appendix A under the heading Fuel Weathering Tests.



FIGURES 15-18 RESIDUAL PLOTS BY VEHICLE



FIGURES 19-22 RESIDUAL PLOTS BY VEHICLE

The residual plots associated with the Escort and Reliant both show a distinct pattern of underestimation of refueling losses (positive residuals) at low predicted values, and overestimation of higher predicted values. This would indicate that the fitted model here, dominated by data from the rear-filled 1983 Cutlass, may not be the most accurate for other vehicles, particularly side-filled vehicles which have a large vertical drop in the fill neck.

A further comparison can be made by fitting a multiple linear regression model, based upon the same parameters as discussed before, for the Cutlass test results and for the Escort test results. These are the only two vehicles that have large enough data bases to make reasonable parameter estimates. The resulting fitted models are as follows:

Cutlass: Refueling Loss (gm/gal) =

$$-5.584 - 0.114[\Delta T(°F)] + 0.0857[T_D(°F)] + 0.520[RVP(psi)]$$

$$R^2 = 0.856$$

Escort: Refueling Loss (gm/gal) =

$$-6.687 - 0.039[\Delta T(°F)] + 0.081[T_D(°F)] + 0.545[RVP(psi)]$$

$$R^2 = 0.912$$

The resulting equation indicates that the primary differences in refueling emission between these vehicles lies in the amount of vapor shrinkage or vapor growth that occurs during the refueling event. These processes would naturally be related to vehicle configuration, so this result appears reasonable.

A few more insights can be gained from an examination of the residual plots. Aside from the Celebrity whose residuals are consistently negative, although not as extreme as those for the LTD, the residuals for all vehicles generally fall within $\pm$ 1 gm/gal. This includes the test results from the two light-duty trucks which agree well with the prediction equation, even though it is based primarily upon automobile tests.

In summary, it is clear that differences do exist from vehicle to vehicle. Nevertheless, an equation based upon all of the data, except the LTD tests for reasons as noted before, appears to work well on average.

4. <u>Prediction Equation</u>

a. <u>Fitted Model</u>

A primary goal of this study has been to develop an emission factor equation based upon the parameters that affect refueling emissions. This has been achieved by fitting a multiple linear regression model with the data from seven of the eight vehicles tested.*

The prediction equation developed for refueling emissions from an uncontrolled vehicle is given as follows:

$$\text{Refueling Loss (gm/gal)} = -5.909 - 0.0949[\Delta T(^\circ F)] + 0.0884[T_D(^\circ F)] + 0.485[RVP(psi)]$$

$$R^2 = 0.786$$

$$MSE = 0.732$$

This equation will be used to estimate emission factors under a range of conditions, and also will be compared with results from other refueling emission studies. The range of conditions over which actual tests were made is given below:

T_D = 66–68°F; RVP = 9.0–11.9 psi; ΔT = 0 to 10°F
T_D = 78–85°F; RVP = 9.0–12.6 psi; ΔT = −2 to 40F°
T_D = 88–95°F; RVP = 9.0–11.9 psi; ΔT = −12 to 32F°

1. Coefficients

Each of the parameters included in the regression model is statistically significant at a confidence of 99.9 percent, i.e., there is less than a 0.1 percent probability that any of the three parameters has no effect upon refueling emissions. The magnitude of the effects due to each parameter is given by the associated coefficient in the regression equation. A 10F° increase in ΔT will lower refueling emissions by nearly 1 gm/gal; a 10°F increase in T_D will increase refueling emissions nearly 1 gm/gal; and a 1 psi increase in RVP will increase refueling emissions nearly 0.5 gm/gal.

There was some consideration as to whether a linear model is sufficient to explain the data over the range of conditions where the regression equation is applicable. A look at the residuals (actual gm/gal minus predicted gm/gal) can give an indication as to whether the assumption of linearity is appropriate. Figures 23-26 show the residuals plotted against the predicted values and against each independent parameter. The residual scatter in these plots appears random, and no systematic trends are evident, which would indicate significant nonlinearity. Also, several other forms of the regression were considered in which interaction and nonlinear terms were included. These are presented in Table 4, along with the associated R^2. The R^2 value is a measure of a model's

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* Does not include testing on the LTD or the special tests on the 1983 Cutlass (single blanket, etc.)

Table 4

Alternative Formulations of Regression Model

Form of Model	R^2
Gm/Gal =	
1) $\exp\,[\alpha_0+\alpha_1(T_T)+\alpha_2(RVP)+\alpha_3(T_D)(T_T)+\alpha_y(T_D)(RVP)]$	.805
2) $\exp\,[\alpha_0+\alpha_1(T_T)+\alpha_2(T_D)+\alpha_3(RVP)]$	.823
3) $\alpha_0+\alpha_1(T_D)+\alpha_2(T_D)(T_T)+\alpha_3(T_D^2)(T_T^2)$	.613
4) $\alpha_0+\alpha_1(\Delta T)+\alpha_2(\Delta T^2)+\alpha_3(T_D)+\alpha_y(RVP)$	.790
5) $\alpha_0+\alpha_1(\Delta T)+\alpha_2(T_D)+\alpha_3(RVP)$	.786

RESIDUAL VALUES vs. PREDICTED VALUES

Fitted Model   All Vehicles

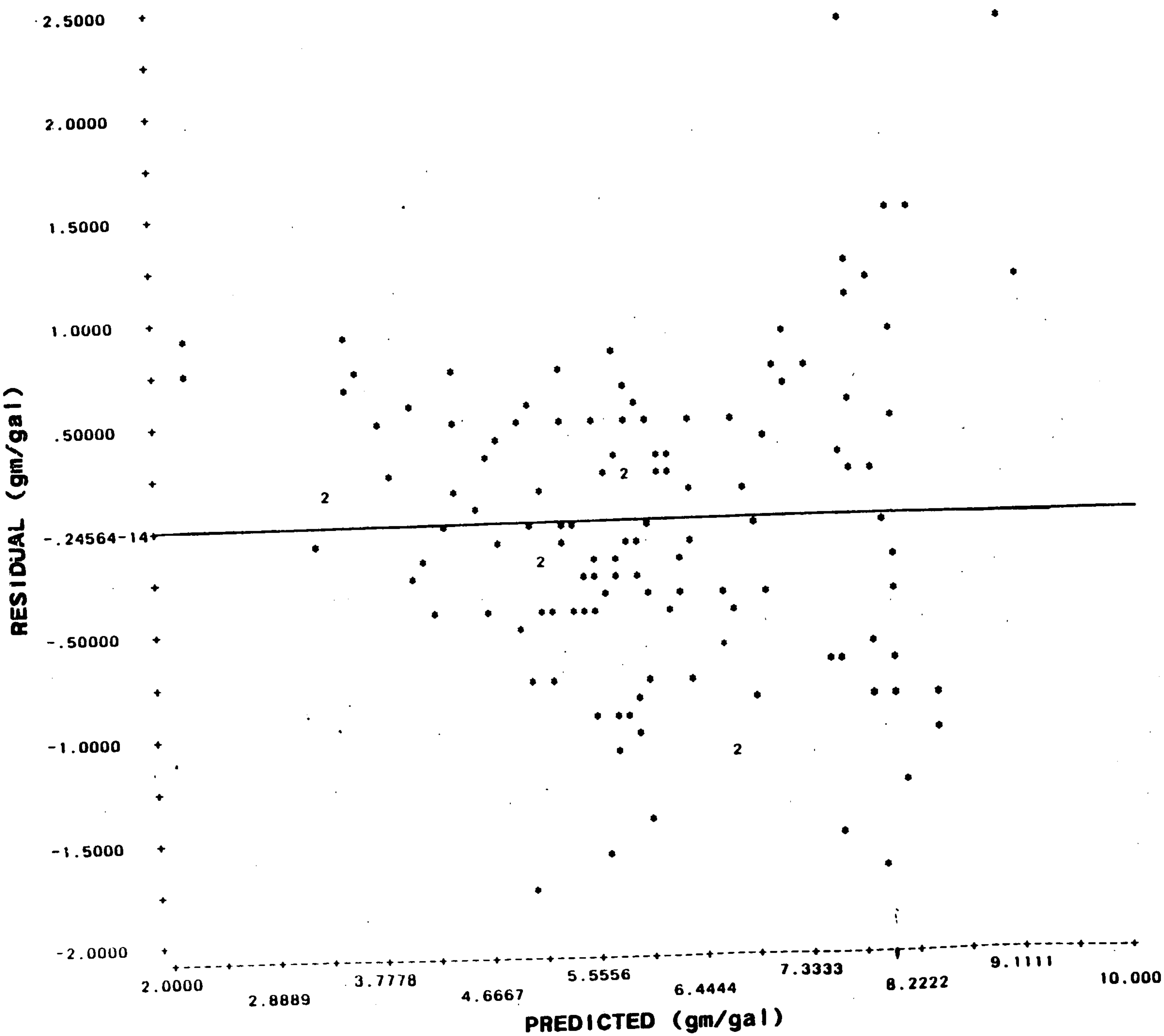
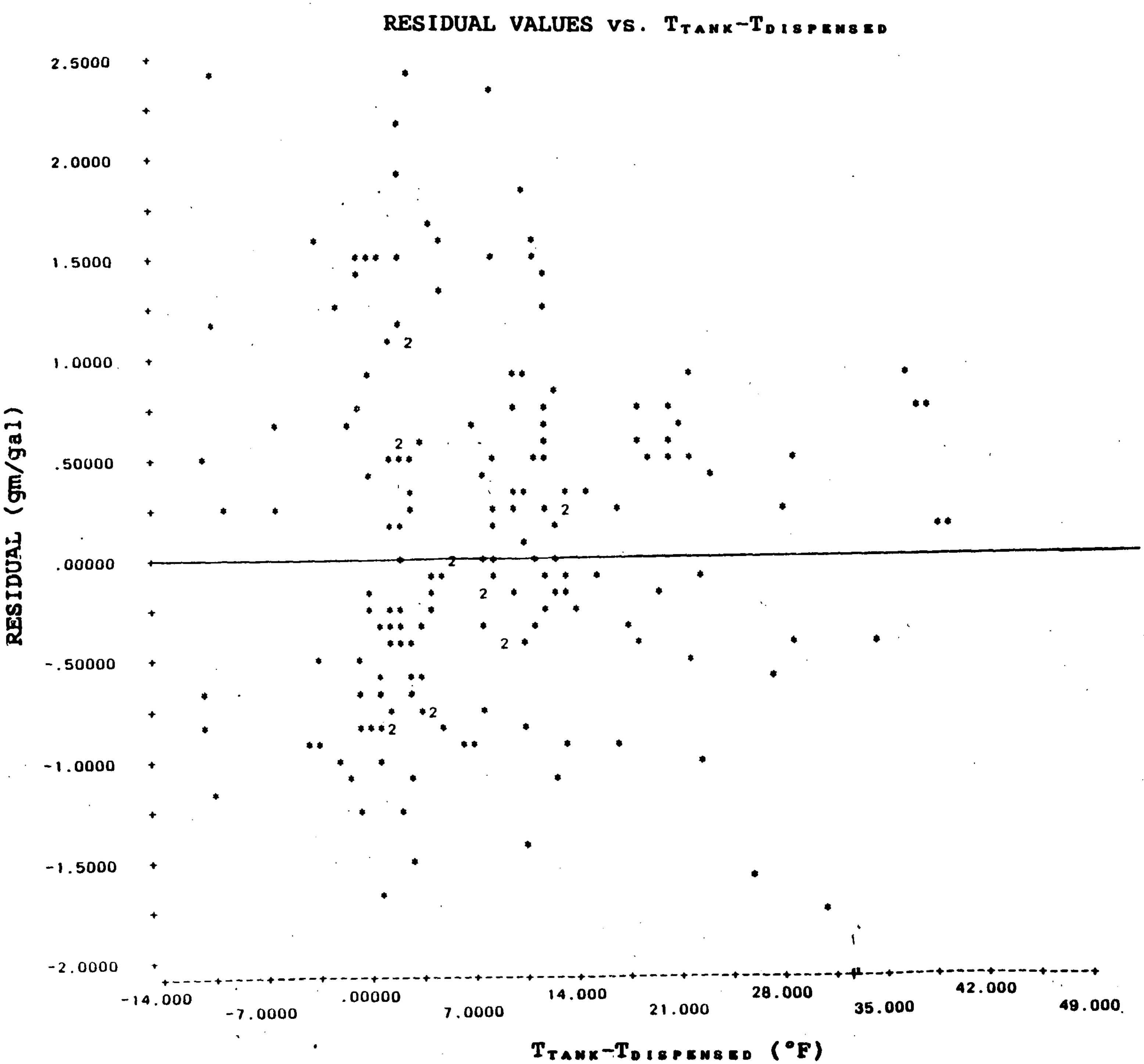
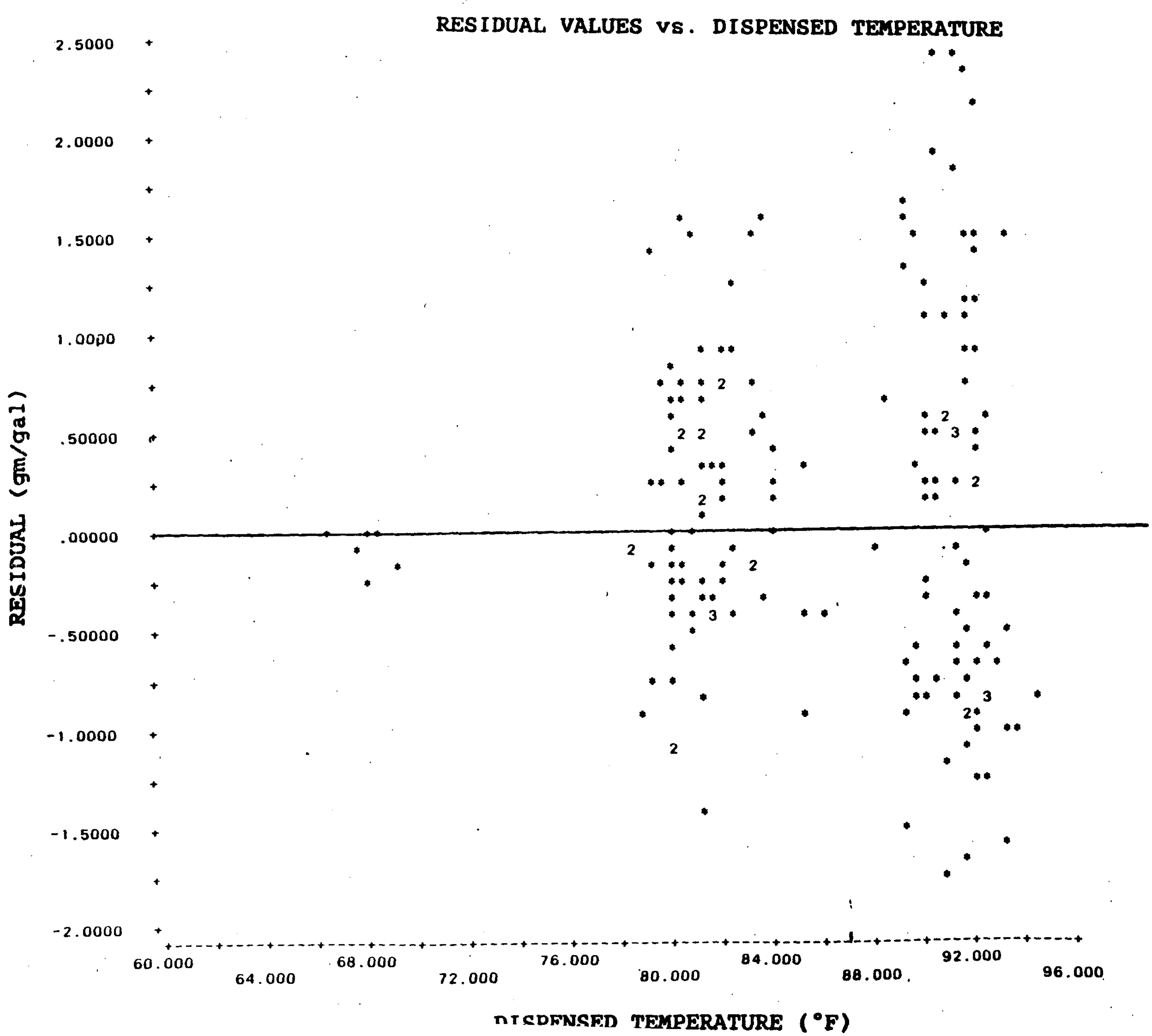
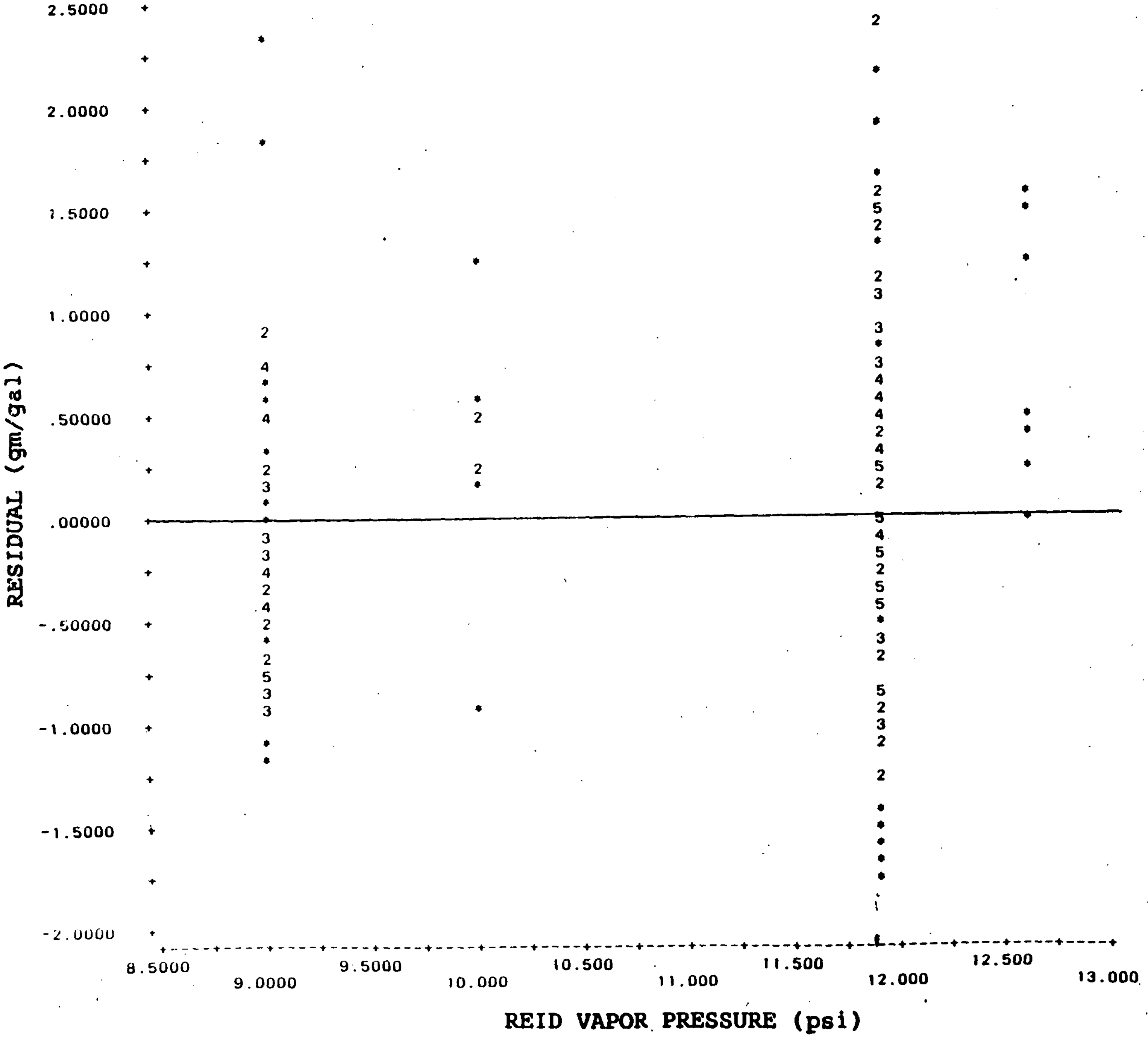


FIGURE 23


RESIDUAL VALUES VS. TTANK-TDISPENSED
RESIDUAL (gm/gal)
2.5000
2.0000
1.5000
1.0000
.50000
.00000
-.50000
-1.0000
-1.5000
-2.0000
-14.000
-7.0000
.00000
7.0000
14.000
21.000
28.000
35.000
42.000
49.000
TTANK-TDISPENSED (°F)


RESIDUAL VALUES vs. DISPENSED TEMPERATURE
RESIDUAL (gm/gal)
2.5000
2.0000
1.5000
1.0000
.50000
.00000
-.50000
-1.0000
-1.5000
-2.0000
60.000
64.000
68.000
72.000
76.000
80.000
84.000
88.000
92.000
96.000
DISPENSED TEMPERATURE (°F)

RESIDUAL VALUES vs. FUEL VOLATILITY



ability to predict trends that are presented in the data. These results show that the linear model is sufficient to model the baseline refueling data, and its simpler form makes it easier to interpret.

2. Variability

There is a large amount of variability in the results from the refueling emission tests; values ranged from under 3.0 gm/gal to over 11.0 gm/gal. Nearly 80 percent of this variation is explained by the three parameters: T_D, ΔT, and RVP, as indicated by the R^2 value associated with the regression model. However, a fair amount of variability remains unexplained as shown by the mean squared error value of 0.557 gm/gal.

Much of the remaining variability is due to the differences in vehicles as discussed before, but other factors are also involved. Several parts of the test procedure are subject to certain degrees of error, and can therefore lead to test variability. The first of these involves the heating of the fuel tank in the vehicle as mentioned before. What effect the heating rate may have is unclear. The same can also be stated for the dispensing rate of the fuel. The heating of the dispensed fuel in the fuel cart also varies somewhat, and could very possibly slightly affect the RVP of the fuel.

All of the above effects are generally negligible, however, in comparison to the effects caused by even a small fuel spill or spitback at the end of a refueling. Tests in which spills estimated at over 1/2 of a cup occurred were generally voided, except where no significant effect was noted. However, even a spill as small as 1 1/2 tablespoon could generate a one gram per gallon increase in emissions if it were to completely evaporate.* The concern over spills was large enough to change the test procedure used in this program to call for manual shutoff of the dispensed fuel. Also, the effect is large enough to warrant being considered in determining the total emission factor. This will be discussed more in the sections dealing with the refueling emission factor.

b. <u>Comparisons to Results from Other Studies</u>

The prediction equation derived here can be: 1) used to make comparisons with the results measured from other studies, and 2) compared to prediction equations derived elsewhere. A brief summary of the results from other studies, and how they compare to those in this study, is given in Table 5. Overall the results of this study are in good agreement with past work.

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* Using 10 grams/tablespoon and assuming a 15 gallon refueling.

Table 5

Summary of Results from Previous Studies

Year	Study	T_D(°F)	ΔT(°F)	RVP(psi)	Comments & Relation to Current Study
1975	Scott	55-70	-30 to 30	8.8, 12.0	Laboratory study;(lab)similar effects seen for RVP, T_D, and ΔT; resulting gm/gal 0-0.5 gm/gal lower
1975	Scott (station)	80-85	-20 to 30	8.0-8.8	Field study of 4 Stage II Recovery Systems on vehicles at a service station ; some baseline testing done; mean values from baseline results agree well with predictions from this study.
1975	CAPE9	30-90	-40 to 40	7-13	Performed in SCOTT mini-shed on vehicle tanks; no tests of positive ΔTs at higher T_Ds; can only compare with current study at around ΔT=0F°; agreement is good in this range.

Table 5 (cont'd)

Summary of Results from Previous Studies

Year Study	Study	T_D(°F)	ΔT(°F)	RVP(psi)	Comments & Relation to Current
1975	SRI	68-85	-30 to 45	6.9-8.6(10.6)	Tests at a station on a vehicle fuel tank; comprehensive tests looking at many independent variables that affect refueling emissions; good general agreement with current study; slightly low at low ΔTs and higher at high ΔTs.
1976	ER&E	10-100	-20 to 10	7-13	Fuel tank tested in controlled environment; vapors collected in Tedlar bag; yields results 1-1.5 gm/gal lower at 0° ΔT, nearly equal at 10° ΔT.
1976	Union	75-85	-20 to 30	8.8-9.0	Tested random vehicles at a refueling station; 29 used for baseline results; estimates 1 gm/gal lower at 0° ΔT, approximately equal at ΔT 10°

Table 5 (cont'd)

Summary of Results from Previous Studies

Year	Study	T_D(°F)	ΔT(°F)	RVP(psi)	Comments & Relation to Current Study
1978	ER&E	85	-1	9.1	Looking at efficiency of an onboard control system on 3 vehicles. Baseline estimates .7-1.6 gm/gal lower than predicted by current study.
1978	Mobil	82-85	0	8.2-12.0	Tests on a single vehicle. Good agreement with predicitons from current study.

In order to estimate the results from other studies using the prediction equation, information is required on the test conditions: fuel RVP, tank temperature, and dispensed fuel temperature. Also the refueling losses need to be reported in total grams per gallon of refill, or in a form that can be readily converted to this form. Only a few of the previous studies met all of these criteria.

In their tests involving Stage II vapor recovery vapor balance systems at a retail gasoline station, Scott Environmental arrived at estimates for uncontrolled emissions.[6] Their study involved two phases of testing: the first on thirty control vehicles at a service station and the second on random vehicles. For each phase, two series of vehicles were tested. Average RVP and dispensed temperature are only provided for the two series in the second phase of testing. These two series yielded baseline emissions of 5.505 and 5.593 gm/gal. The average for the other factors are also given for these two series; RVP = 8.0286 and 8.6440, dispensed temperature = 81.265 and 81.0196 °F, and tank temperature = 81.867 and 82.0796 respectively. Using these conditions and the regression equation derived in this report, estimates of 5.109 and 5.352 gm/gal are obtained. These are slightly lower than obtained by Scott, but still well within the range of uncertainty in the data.[6]

In a study done by the Mobil Research and Development Corporation in 1978 a series of refueling emission tests were run on a 1978 Pontiac Sunbird. During these tests the vehicle was equipped with an onboard control system, so the total HC emissions given is the sum of the HC collected in the canister and the refueling emissions measured in the SHED. These tests were performed in a SHED, in the same general manner as the test in this study, with the only exception being that the vehicle was preconditioned by driving and not just heating of the fuel tank.[13]

The Sunbird was tested at the following conditions: dispensed temperature = 82-85°F, ΔT = 0F°, and RVP ranging from 8.2 to 12.0lbs. The resulting losses, along with the estimates from this study are given below. The equation derived in this report is not strictly applicable at RVP levels under 9.0, but the estimates are given here regardless. Mean estimates from this study are generally on the high end of the ranges given by Mobil, but also note the variability in their test results.

RVP	# Tests	Total HC (gm/gal)	This Study*
8.2-8.5	8	3.72-6.82	5.52
8.6-9.0	10	4.2-5.60	5.74
10.3-10.6	3	5.9-7.1	6.54
11.2-11.4	3	5.5-7.0	6.95
11.8-12.0	3	7.0-7.2	7.24

The Stanford Research Institute study involved tests on a 26-gallon General Motors and a 26-gallon Ford fuel tank used in 1973-4 vehicles, at a service station. The results from the tests on the GM tank at a fill rate of 5.3 gallons per minute and a fill of 20 gallons are given below along with this study's estimates at the given conditions.[9] These tests represent those most similar to this study's testing. Where the conditions fall within the ranges for which the EPA equation is applicable, the agreement is good, generally within .50 gm/gal. Only when the equation is extrapolated far beyond its applicable range is there a significant disagreement with the SRI results, illustrating the dangers of such extrapolation.

			GM/GAL		
ΔT	T_D	RVP	SRI[2]	This Study	Difference
-17	79.5	8.5	5.13	6.85	1.72
0	80	8.5	5.03	5.28	.25
1	80	8.5	4.82	5.19	.37
2	78	8.5	4.52	4.92	.40
27	76	8.5	3.07	2.37	-.70
35	79	8.5	2.09	1.88	-.21
41.5	79.5	8.5	1.26	1.30	.04
43	77	8.5	1.42	0.94	-.48

Exxon Research and Engineering performed a series of tests on 3 vehicles in 1978, in order to determine the efficiency of an onboard control system.[13] The vehicles tested were: a 1978 Caprice, a 1978 Pinto, and a 1978 Chevette, and the test conditions were: $\Delta T = -1F°$, $T_D = 85°$ F, and RVP = 9.1 psi. The resulting averages for each vehicle, along with predicted values from this study are given below.

	GM/GAL	
Vehicle	ER&E[13]	This Study
Caprice	4.9	6.1
Pinto	4.5	6.1
Chevette	5.4	6.1

* Using 83.5°F and mid-range of RVP interval.

In this case, the results from this study appear to significantly overestimate the Exxon results, especially for the Pinto. The testing on these vehicles was performed with a prototype refueling canister on each vehicle, and the tests were part of a larger test sequence including measurements of evaporative and exhaust emissions. These differences and consideration of the fact that a comparison is being made between individual vehicles and one case and a population average in the other case can explain some of the discrepency in the results. Also, these vehicles are older and of a different fuel tank design than those tested here.

Four prediction equations that consider factors other than ΔT have been found in the relevant literature. One of these has a correlation coefficient, r, of only 0.25 associated with it, so it has not been included in the analysis here.[4] The remaining equations, and associated parameter regions where they are applicable are given below.

CAPE9(EPA)[3]

$$gm/gal = \exp[-0.091703 + 0.0011521(RVP)(T_D) - 0.0012605(T_T) + 0.054094(RVP) + 0.00010725(T_D)(T_T)]$$

$R^2 = 0.945$	SE = 5.6%	
RVP = 7 psi	T_D = 50 to 90 °F	T_T = 50 to 90 °F
RVP = 10 psi	T_D = 40 to 80 °F	T_T = 40 to 80 °F
RVP = 13 psi	T_D = 30 to 70 °F	T_T = 30 to 70 °F

Exxon Research and Engineering Co.[1]

$$gm/gal = \exp[-1.23 + 0.0185(T_D) + 0.00170(T_T) + 0.118(RVP)]$$

$R^2 = 0.951$ SE = 12.4%
RVP = 7 to 13 psi
T_D = 10 to 100 °F
T_T = 30 to 90 °F
ΔT > -20 °F

Union Oil[2]

$$gm/gal = -15.178+0.1503(T_D)+0.002523(T_D)(T_T)-0.0000002099(T_D)^2(T_T)^2$$

$R_2 = 0.5740$ SE = 0.3873 gm/gal
RVP = 8.8 to 9.0 psi
T_D = 75 to 85 °F
T_T = 70 to 115 °F

The equations determined in the CAPE-9, Exxon and Union studies are based upon 140, 43, and 29 tests, respectively.[1, 2,3] The testing done in the CAPE-9 and Exxon studies was performed on a vehicle tank in a laboratory setting.[1,3] Union performed its testing on vehicles refueling at a retail gasoline station.[2]

As is readily apparent, the form of these three equations differ among themselves, and from the equation derived in this study. This makes a direct comparison of the results somewhat difficult. Figure 27, however, shows plots of refueling losses versus for each equation and the Stanford results, at a dispensed temperature of 79°F and an RVP of 8.5 psi. An RVP of 8.5 psi is slightly out of the applicable ranges for the Union results and those derived here, but the figure is still useful for comparison. Figure 28 shows a further comparison of this study's results to earlier work by EPA as cited in the Scott study.[6] This is shown in a separate figure as the conditions are slightly different from those show for the other studies.

Figures 27 and 28 show very good general agreement between the results from the CAPE 9, Stanford, the earlier work by EPA, and this study, over their applicable ranges of ΔT. The studies by Union and Exxon yield somewhat lower estimates of refueling losses at negative values of ΔT, but their results are not radically different. All in all, considering the differences in testing apparatus and procedures, the results from the various studies tend to confirm each other and the results derived here.

Considering the results from these studies, it appears that the prediction equation derived in this report generally provides reasonably accurate estimates of refueling emissions based upon the given parameters within its applicable parameter ranges. Therefore, there should be no problem in using it to determine average emission factors and to determine control system designs and efficiencies.

IV. Calculation of Nationwide Emission Factors

A. Introduction

Analysis of the baseline test data has yielded an equation that can be used to calculate emission factors representative of various ΔT, T_D, and RVP conditions within the approximate limits of the values for the original test parameters (see section III C 4). Given this ability to determine emission rates for different conditions, it then becomes necessary to determine the most representative conditions in order to calculate a refueling emission factor that will accurately reflect national uncontrolled in-use emissions levels. Because the conditions that determine

COMPARISON of EPA RESULTS to OTHER STUDIES

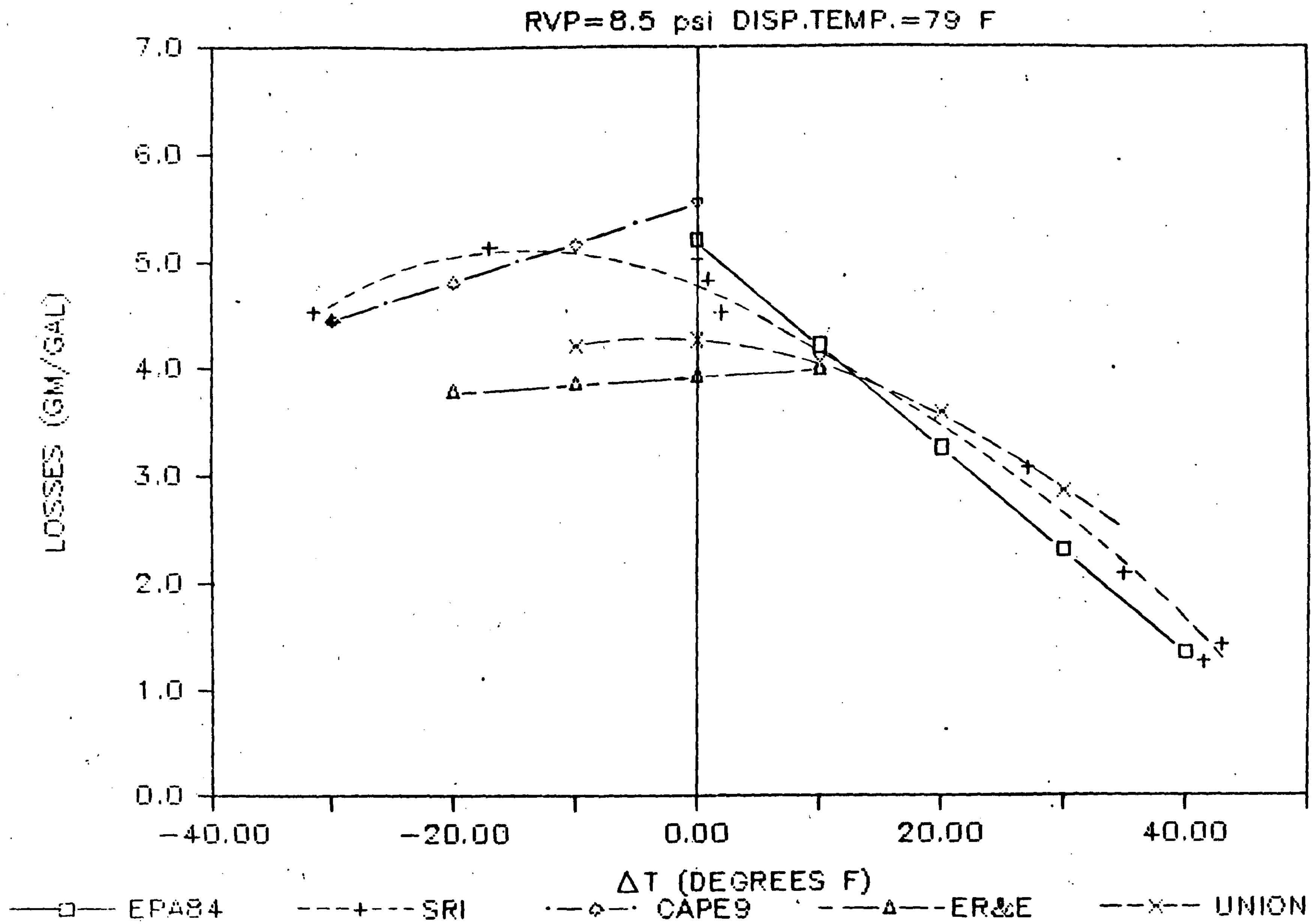

FIGURE 27

COMPARISON of EPA RESULTS to SCOTT STUDY

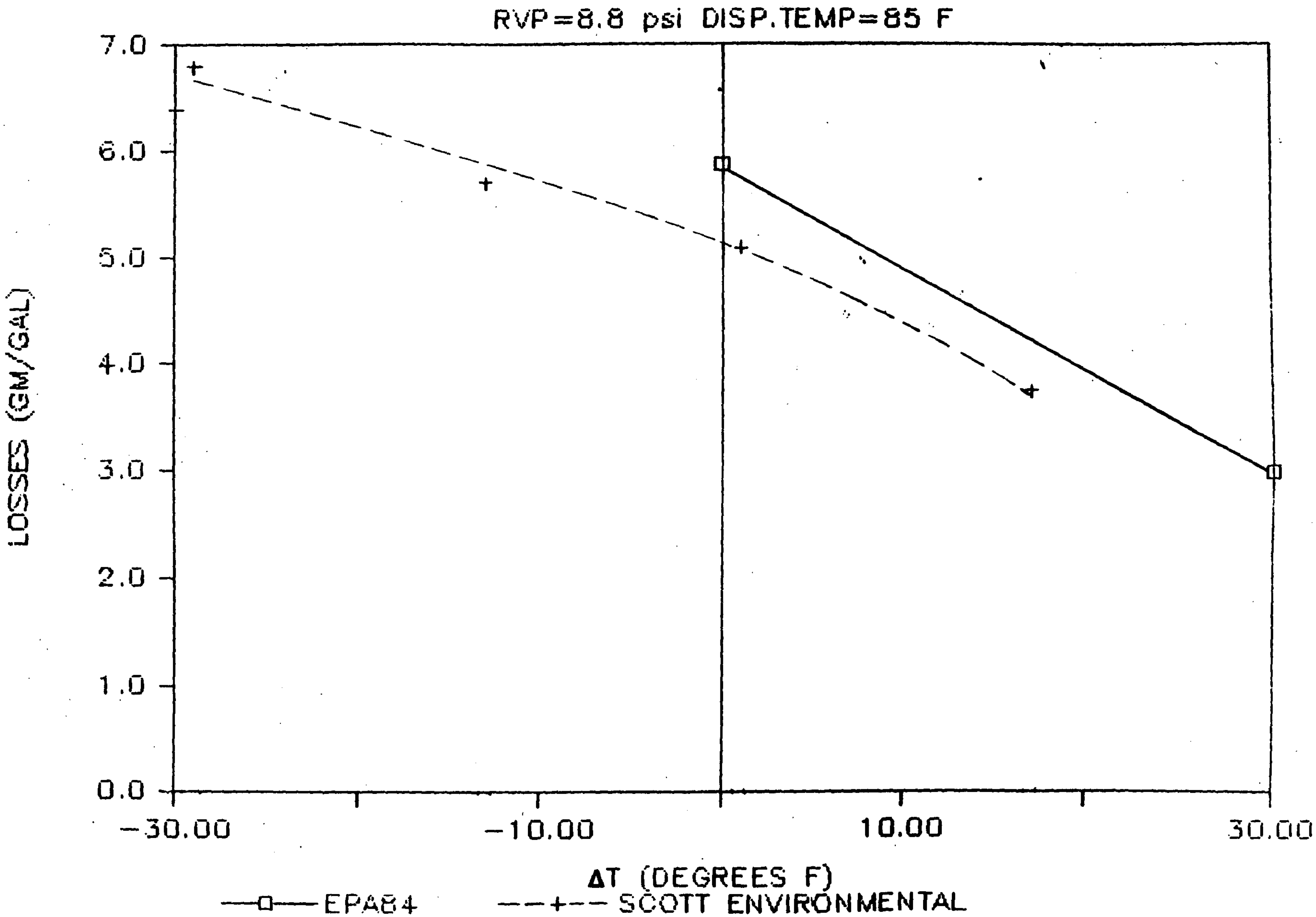

FIGURE 28

emission rates (basically temperature and volatility of the fuel) vary from region to region and from season to season within a given region, it will be necessary to identify regional and seasonal temperatures and fuel characteristics and then to apply the appropriate averaging to determine national emission factors. It is also important to examine seasonal emission factors to ensure that summer and winter emissions are not significantly different from the annual average value.

There are two basic uses of a refueling emission factor: (1) to calculate air quality effects and (2) to determine health risk due to exposure to the pollutant in question. The air quality effect of VOC from refueling emissions consists of the role these emissions play in ozone formation. Ozone formation tends to be a seasonal phenomenon, with most NAAQS violations occurring during the spring and summer months, i.e, May through September. The emission factor used in air quality calculations should therefore appropriately reflect the conditions that are found during the ozone season.

In addition to their role as ozone precursors, refueling emissions may also have environmental health effects. Benzene, a known human carcinogen, is present in small amounts in gasoline. In addition, recent studies have indicated that other species of VOC contained in refueling emissions are possible carcinogens.[15] Although the effect on humans is not fully known, refueling emissions may pose a health risk to service station employees, self-service gasoline customers, and persons residing near service stations. Because such exposure risk represents a year-round problem, the emission factor used in determining health risk should represent average annual conditions, although if there are significant seasonal variations the additional risk posed by these variations would have to be evaluated.

The remainder of this report will begin with a discussion of the total emission factor, which includes both spillage and displacement losses. An appropriate spillage emission factor will be selected. The process for developing the displacement emission factor will then be described in detail, including the methodology used, sources of data, selection of seasonal scenarios for air quality and environmental health effects, determination of representative temperature and fuel volatility parameters and emission factors for these scenarios. The question of seasonal differences in the emission factor will also be addressed. Finally, a representative national emission factor for refueling will be presented.

B. Description of Refueling Emission Factors

There are two types of refueling losses that comprise a total refueling emission factor. These are spillage of liquid gasoline during the course of the refueling operation and displacement losses, or the vapor that is forced out the fillpipe during refueling. Displacement losses occur during every refueling operation, while spillage or "spitback" is a more infrequent occurrence.

1. Spillage Losses

A varying portion of the total refueling loss results from the spillage of liquid gasoline during the refueling process. The amount of such spillage can vary from a few drops on the side of the car or pavement as the fueling nozzle is withdrawn from the fillpipe to a cup or more spurting out on the ground as a result of "spitback" due to poor fillneck design or a malfunctioning fuel nozzle. Probably the majority of spills are less extreme, coming about as a result of motorists or service station attendants attempting to "top off" the vehicle tank by restarting the nozzle after automatic shutoff has occurred. Such spills are normally not large, on the order of a tablespoon or so. A spill of one tablespoon leaves a 9 to 10 inch diameter circular spot on the service station pavement and results in emissions of about 10 grams. Thus on a 10 gallon fill, the spillage would equal about one gram per gallon of fuel dispensed. Larger spills such as those accompanying spitbacks or nozzle malfunctions can lead to significantly higher emissions. A one-half cup spill for the same 10 gallon fill leads to emissions of about 8 grams per gallon. Thus, overall, spills are of concern.

Of course not every fillup, or even every attempt at "topping off" results in a fuel spill and different amounts of fuel are spilled each time. Unfortunately very few data are available regarding either the quantity or the estimated frequency of fuel spills, and there is considerable variance in the existing estimates. EPA's emission factor document (AP-42) presents a value of about 0.30 grams per gallon based on a comprehensive study conducted by Scott Research Laboratories in the early 1970's.[16] However, an in-depth review of this study reveals the authors belief that the spillage rate estimates should be viewed as minimum values, rather than averages, due to the presence of observers, the technique used to estimate spill amounts, and the fact that the stations studied were primarily full serve rather than self serve.[17] However, another EPA contractor report cited an estimate of 1.36 grams per gallon, and a 1980 Calfornia study conducted by the South Coast Air Quality Management District provided information which indicated an average spillage rate of about 0.80 grams per gallon for uncontrolled nozzles.[18,19]. It should be noted that the latter study included the brief period of fuel shortages in 1979, which may have encouraged an abnormal amount of "topping off" of fuel tanks and hence slightly higher than normal spillage. The wide variation in the available data on spillage rates (more than a factor of four among the three studies) is of some concern. While there appears to be good reason for the variation, the data is inadequate to allow determination of a revised emission factor. In the absence of more definitive information on this topic, the .30 grams/gallon rate contained in AP-42 seems to represent the best available estimate of the spillage emission factor, so this value will be used in this analysis. The remainder of the discussion will focus on the displacement emission factor, but it should be noted that the emission factor for spillage must be added to the displacement emission factor in order to arrive at a total refueling emission factor.

2. <u>Displacement Losses</u>

As discussed earlier, there are three primary factors and several secondary factors that determine the displacement emission rate for refueling operations. The primary factors are (1) the dispensed temperature (T_D) of the gasoline (2) the Reid Vapor Pressure (RVP) of the gasoline and (3) ΔT, or the difference between the temperature of the residual gasoline in the vehicle tank (T_T) and the dispensed temperature of the gasoline used to refill the tank (ie. $T_T - T_D$). To develop emission factors for refueling operations, it will be necessary to look at these parameters on a seasonal and national basis. The most significant of the secondary factors are fuel tank configuration differences, the effects of which have been described in sections II and III above, and differences between the RVP of the dispensed fuel and the residual fuel in the tank, due to weathering of the tank fuel.

C. <u>Calculation of Displacement Emission Factors</u>

This section will derive nationwide average values for the three major determinants, ΔT, T_D, and RVP, from which the uncontrolled displacement emission factors for several scenarios will then be calculated.

1. <u>Methodology</u>

Overall, the methodology used in this process is to weight the available regional temperature and RVP data by regional highway fuel consumption to determine average national values for the appropriate time periods for each scenario to be evaluated. These average values can then be used with the multiple linear regression equation developed earlier to calculate representative emission factors. The available data indicate that there is a considerable amount of regional and seasonal variation in the the temperature and RVP parameters, making such a weighting process necessary. Also, the fuel consumption pattern is far from uniform throughout the U. S. and the available data are not all aggregated at the same levels. Fuel consumption and RVP data are available on a monthly state-by-state basis while ΔT and T_D data are available only on a monthly regional basis. The methodology used to aggregate and weight these parameters will be discussed following a brief description of the sources of the fuel temperature, RVP and fuel consumption data that were used.

2. Sources of Data

a. Fuel Temperature

Dispensed temperature and ΔT data used for calculating emission factors are available from a 1975 gasoline temperature survey conducted for the American Petroleum Institute (API) by the Radian Corporation.[20] The year 1975 is considered to be a representative year in terms of temperature, since the average annual ambient temperature was within one degree of the 30 year mean. The study surveyed 56 U.S. gasoline stations located in 22 cities; these were grouped into six geographic regions. The six regions and the locations for the stations surveyed are shown in Figure 29, and the monthly ΔT and T_D values from the survey are shown in Appendix B.

Not all of the stations reported data for all months of the year, resulting in a few gaps in the data. The most serious of these gaps occurred in the Pacific Northwest (region 6 in Figure 29) where ΔT data were reported only for the month of May. Since the Pacific Northwest accounts for only about 3.5 percent of the gasoline consumed for highway use in the U.S., it was concluded that this region could be omitted from the analysis without seriously affecting the accuracy of the results. Alaska and Hawaii were also omitted from the study, since no ΔT or T_D data were available from these states. Other minor gaps of a month or so in ΔT and T_D data, primarily in the North Central U.S. and the Far West (regions 4 & 5), were filled by points interpolated from the existing data.

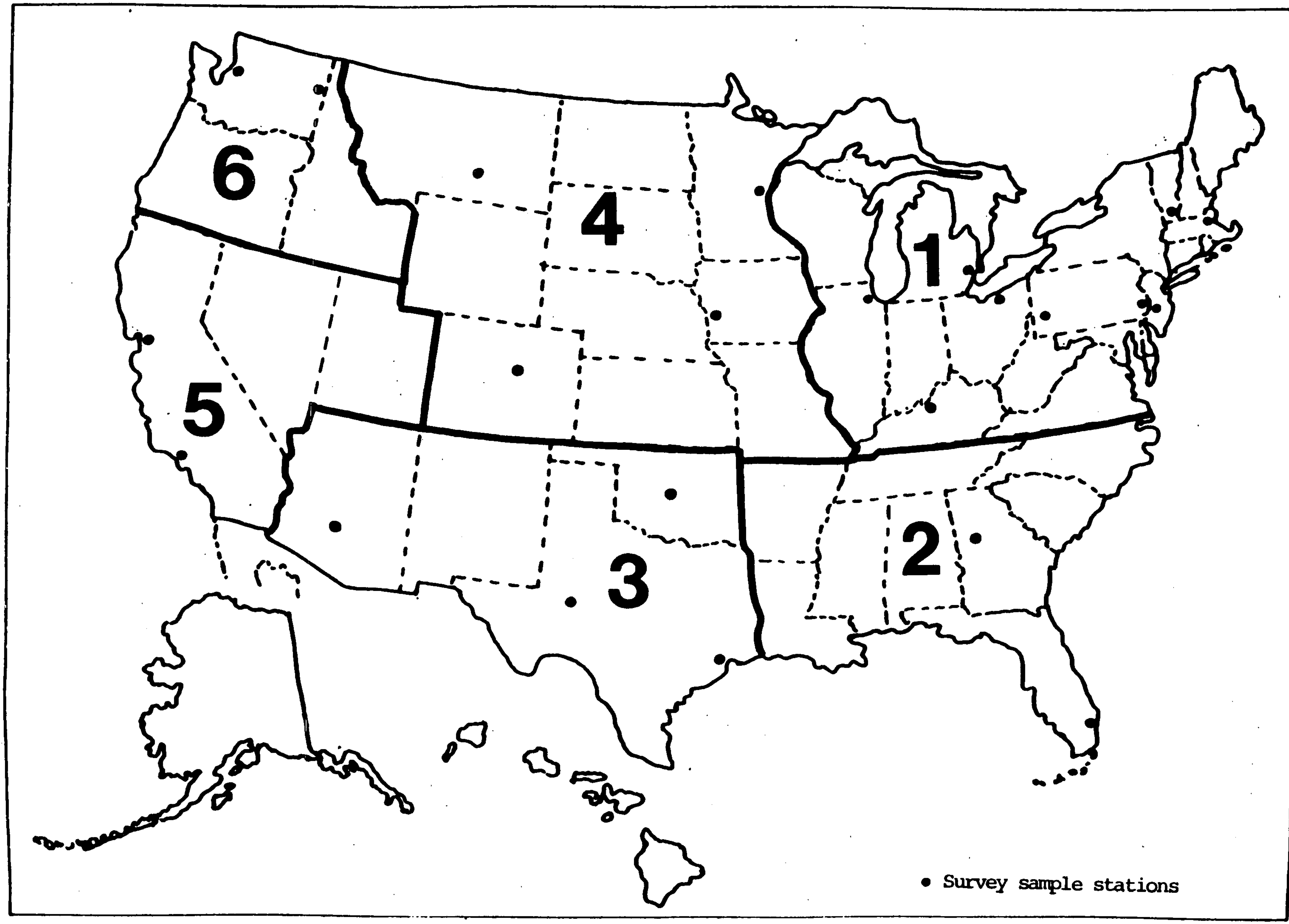

Figure 29

b. Nationwide Fuel Consumption

Nationwide fuel consumption (gasoline) by state was taken from the 1983 version of the DOT/FHwA publication entitled Highway Statistics - Table MF-26. This table contains estimates of monthly gasoline consumption for each state and the District of Columbia. Table MF-26 is shown in Appendix B.

To allow for further calculations, the monthly state fuel consumption figures were summed for each region thus providing monthly regional fuel consumption values.

c. RVP

The RVP data were taken from 1983 ASTM maximum specifications for the U.S.[21] The maximum specifications were used rather than current actual levels on the assumption that recent increases in RVP would continue and that by 1989 in-use RVP levels would be essentially at the maximum values specified by ASTM. This is already the case in some areas of the country. The RVP values for each state and month are also shown in Appendix B.

To get the RVP data on the same level of aggregation as the temperature data, the state RVP data was divided into the same regions as the temperature data and then consumption weighted to get weighted RVP for each region in each month.

3. Air Quality and Health Effects Scenarios

To facilitate assessment of seasonal variation in the emission rates, five seasonal air quality and health effects scenarios were established and ΔT, T_D, and RVP values were calculated for each. The first scenario is simply the annual average value for the nation or region. Two additional six-month scenarios were chosen to represent warm weather versus cold weather conditions. "Winter" is comprised of the months October through March, while "Summer" consists of the months April through September. Two additional scenarios were chosen to represent the months in which most ozone violations occur. These include a "Five Month" scenario (May through September), and a "Two Month" scenario for the two peak ozone violation months (July and August).

4. Consumption Weighting Calculation

In order to calculate national average ΔT, T_D, and RVP values for the five scenarios mentioned above, monthly regional data were consumption-weighted by the regional fuel consumption values for the months in question. As explained earlier, monthly state RVP and fuel consumption values were aggregated on the same monthly regional basis as the T_D and ΔT data. The generalized equation for calculating consumption weighted values for each scenario is as follows:

$$\Delta T = \frac{\sum_{R,M=1}^{n} (\Delta T_{R,M})(FC_{R,M})}{FC_{Total}}$$

Where R = region number from Figure 29

M = month number (of the seasonal scenario, not necessarily of the calendar year)

n = number of months and number of regions evaluated in a given scenario

$\Delta T_{R,M}$ = temperature differential (ΔT) for region R during month M

$FC_{R,M}$ = fuel consumption for region R during month M

FC_{Total} = total national fuel consumption (less region 6, Alaska and Hawaii).

The key parameter shown in the equation above is ΔT. The consumption weighted values for the other two key parameters for any given scenario can be determined by substituting the appropriate monthly T_D and RVP values in the equation above. This can be done for each of the scenarios mentioned above to get the appropriate values of the key parameters for use in the refueling emission equation.

The results of these weighting calculations are shown in Table 6. Regional and national average ΔT, T_D and RVP information is presented for five scenarios: annual average, summer, winter, five month ozone season and two month peak ozone season. Regional fuel consumption values used in the the weighting calculations and percentages of total fuel consumption for each region are also shown for comparison purposes. As explained above, Region 6 (Pacific Northwest) has been omitted, as have Alaska and Hawaii. As would be expected, T_D, RVP and ΔT values vary both seasonally and from region to region for any given season. Reasons for this variability are discussed below.

As can be seen from the table, dispensed fuel temperatures vary seasonally and from region to region. This is due largely to climatic factors such as ambient temperature and the amount of solar radiation. Other relevant variables include the volume and depth of the underground service station tanks, layout of the fuel piping, composition of the surface over the tanks and associated piping (e.g. concrete, asphalt, grass) and

Table 6

Weighted Temperature and RVP Parameters

SCENARIO:	Nat'l Avg.	REGION: 1 N.East	2 S.East	3 S.West	4 N.Cent.	5 Far W.
Average Annual						
Fuel Consumpt. (gal x 10^6)	96,050.4	41,658.5	20,381.2	11,977.6	10,225.6	11,807.6
% Total	100.0	43.4	21.2	12.5	10.6	12.3
RVP (PSI)	12.6	13.3	12.4	11.4	12.6	11.7
Δ T (°F)	+4.4	+5.7	+4.0	+3.7	+5.5	+0.1
T_D (°F)	68.9	62.3	81.8	70.5	66.2	70.5
Summer (Apr-Oct)						
Fuel Consumpt. (gal x 10^6)	51,846.3	22,815.1	10,689.0	6,232.4	5,690.2	6,419.7
% Total	100.0	44.0	20.6	12.0	11.0	12.4
RVP (PSI)	11.5	12.2	11.4	10.1	11.2	10.5
Δ T (°F)	+8.8	+10.7	+6.8	+7.6	+11.7	+3.9
T_D (°F)	76.2	70.7	86.7	78.6	74.3	77.2
Winter (Oct-Mar)						
Fuel Consumpt. (gal x 10^6)	44,204.4	18,843.5	9,692.1	5,745.3	4,535.5	5,388.0
% Total	100.0	42.6	21.9	13.0	10.3	12.2
RVP (PSI)	13.9	14.6	13.4	12.8	14.3	13.3
Δ T (°F)	-0.8	-0.3	+0.9	-0.4	-2.4	-4.4
T_D (°F)	60.3	52.0	76.4	61.8	56:1	62.4

Scenario	Nat'l Avg.	1 N.East	2 S.East	3 S.West	4 N.Cent.	5 Far W.
Ozone - 5 Mo. (May-Sept)						
Fuel Consumpt. (gal x 10^6)	43,995.8	19,459.4	8,956.0	5,244.4	4,869.8	5,466.2
% Total	100.0	44.2	20.4	11.9	11.1	12.4
RVP (PSI)	11.3	12.0	11.2	9.9	10.9	10.3
Δ T (°F)	+9.4	+11.5	+7.5	+7.1	+12.1	+5.1
T_D(°F)	78.8	73.8	88.0	80.8	79.0	79.0
Ozone - 2 Mo. (Jul-Aug)						
Fuel Consumpt. (gal x 10^6)	18,664.7	8,326.2	3,760.0	2,147.7	2,103.0	2,327.8
% Total	100.0	44.6	20.1	11.5	11.3	12.5
RVP (PSI)	10.9	11.5	10.9	9.8	10.5	10.0
Δ T (°F)	+9.9	+12.5	+8.2	+7.0	+13.3	+3.2
T_D (°F)	82.7	78.0	90.5	83.5	86.5	83.0

protection from solar radiation for the tank system. Although there is a strong correlation between ambient temperature (T_A) and dispensed temperature, variation exists due to these other factors. In general, the Radian study for API shows the average dispensed temperature parallels the average ambient temperature curve, with a positive offset (i.e., T_D is always higher than T_A). The amount of the offset varies seasonally and regionally, undoubtedly due to climatic differences.

The RVP values shown in the table are ASTM maximum recommended values. Figure 30 shows the average seasonal and regional variation in these ASTM RVP values and the resulting national averages for winter and summer. The regions by which these data are aggregated are those shown in Figure 29. ASTM assigns each state a "volatility class" and specifies maximum recommended monthly RVP limits based on the climatic and topographic factors. The five volatility classes are designated A, B, C, D, and E, corresponding to maximum RVP limits of 9, 10, 11.5, 13.5, and 15 psi, respectively. In addition, a number of states have formally adopted RVP limits similar to the ASTM recommended levels.[22] Particularly noteworthy is California, where RVP is limited to 9 psi during the months of the highest ozone concentrations in order to decrease VOC emissions.

In-use RVP is essentially determined by the gasoline refiners, subject to state laws and voluntary compliance with the ASTM recommended limits. RVP varies seasonally as well as regionally, based primarily on how the climate and topography of an area affect vehicle operation. For example, RVP is higher in the winter to assist in cold starting but decreases in summer to avoid vehicle driveability problems such as vapor lock. RVP values are generally higher for the northeastern U.S. than the southeastern U.S. In general, for any given season or area, RVP is higher as ambient temperature for any given month decreases. The overall trend in in-use RVP has been toward higher and higher values in recent years, due to changes in vehicle design and gasoline refining practices, leading to the conclusion that by 1990 the in-use values will approximate the ASTM maximum limits.

The final factor, ΔT, also varies seasonally, with positive values being more predominant in the summer and negative values more prevalent in winter. Although there is a certain amount of regional variation, the seasonal values are very similar for all areas of the country.

There is also a certain amount of diurnal variation that affects ΔT values, which explains the presence of some

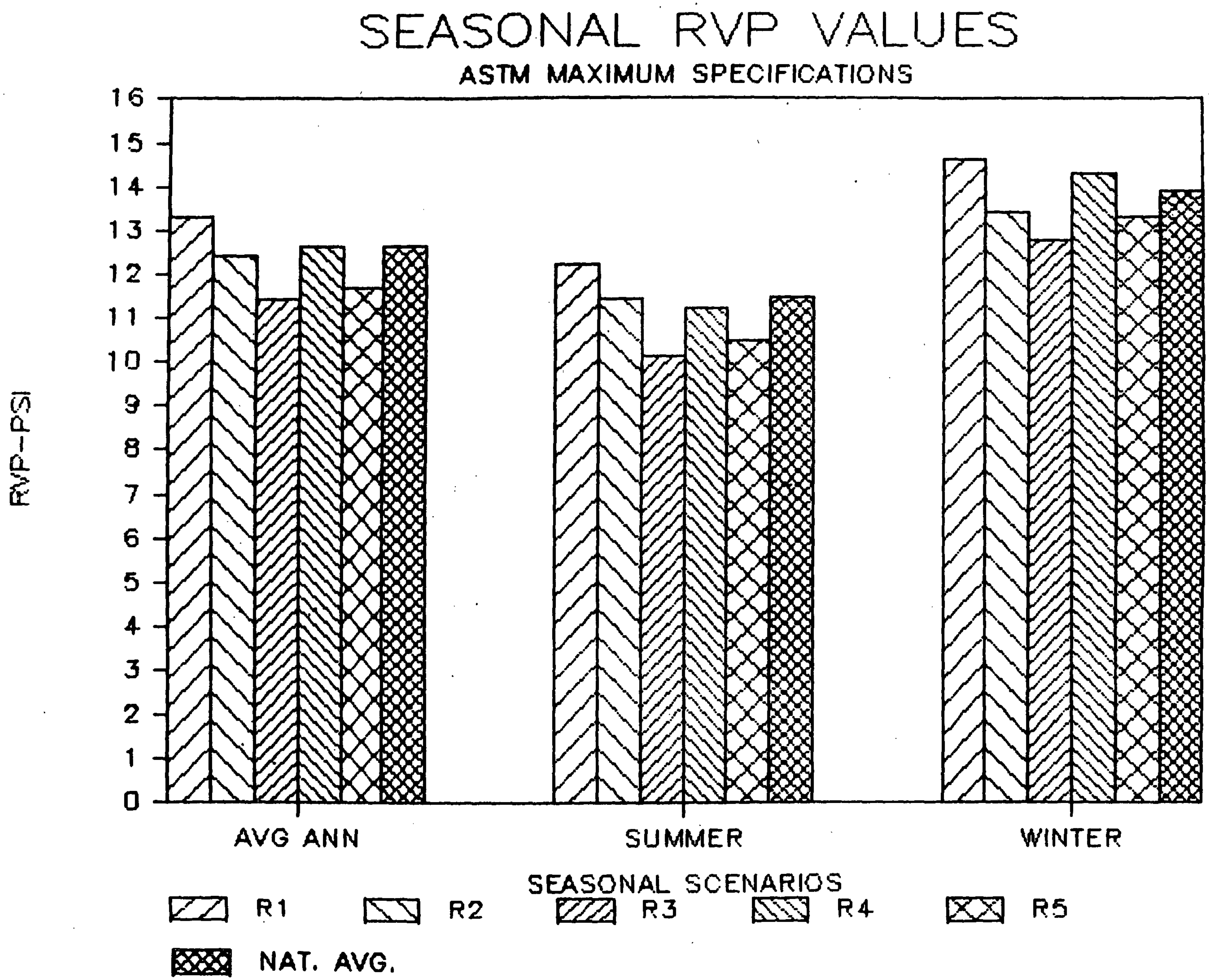
SEASONAL RVP VALUES
ASTM MAXIMUM SPECIFICATIONS
RVP-PSI
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
AVG ANN
SUMMER
WINTER
SEASONAL SCENARIOS
R1
R2
R3
R4
R5
NAT. AVG.

Figure 30

negative values in the summer and positive values in the winter. T_D is more stable than T_T due to the insulating effect of the ground in which the service station storage tanks are buried. Since vehicle tank temperatures follow ambient temperatures more closely, the likelihood is strong that T_T will be lower for those vehicles fueled in the morning, resulting in negative, or at least less positive, ΔT values. Conversely, diurnal heating would likely result in higher T_T values in the afternoon, resulting in positive ΔTs. The distance a car is driven before refueling also affects T_T (T_T increases with distance driven, up to a point) which in turn affects ΔT. Since these diurnal effects are recurring and ongoing, one would expect the differences between summer and winter ΔTs to be caused by climatic and not diurnal variations.

5. Emission Rates

Given the weighted regional and national average T_D, ΔT and RVP values in Table 6 for each of the five scenarios under consideration, we are now prepared to calculate the emission rates for each of the scenarios and to assess how the variation in the key parameters affects emission rates. These emission rates for the different scenarios are calculated quite simply by substituting the T_D, ΔT and RVP values of Table 6 into the multiple linear regression relationship developed earlier (given below) and solving for the emission rate (ER).

$$ER = -5.909 - 0.0949\Delta T + 0.0884\ T_D + 0.485\ RVP$$

The results of these calculations for each of the five scenarios are shown in Table 7. This emission rate data can be compared regionally within each scenario and between the various scenarios on a seasonal basis for each region and nationally.

Turning first to the regional evaluation within each scenario, several points should be noted. First, overall, the regional values for each scenario are relatively uniform given the variation seen in the key parameters of Table 6. All values fall within $\pm$ 10 percent of the national average for that scenario, with the exception of the southeastern U.S (Region 2). In each of the five scenarios the emission rate expected in the Southeast exceeds the national average for that scenario by between 16 and 19 percent. The higher emission rates in the southeastern US apparently occur because of the 10 to 16F° higher dispensed temperatures encountered there, as compared to the national average. Simply by using the coefficient for T_D in the emission rate equation, it can be

Table 7
Displacement Emission Factors 1/

SCENARIO:	Nat'l Avg.	REGION: 1 N.East	2 S.East	3 S.West	4 N.Cent.	5 Far W.
Average Annual	5.9	5.5	7.0	5.5	5.5	6.0
Summer (Apr-Sep)	5.6	5.2	6.6	5.2	5.0	5.6
Winter (Oct-Mar)	6.2	5.8	7.2	5.8	6.2	6.5
Ozone-5 mo. (May-Sep)	5.6	5.3	6.6	5.4	5.2	5.6
Ozone-2 mo. (Jul-Aug)	5.7	5.4	6.6	5.6	5.6	6.0

1/ Displacement losses only - a spillage factor must be added to derive a total refueling emission factor.

determined that the 10 to 16F° difference in T_D results in an increase of 0.9 to 1.4 g/gal in the emission for the various scenarios. This easily accounts for the significantly higher emission rate in the this region.

Climatological differences offer the most likely explanation for the higher dispensed temperatures in the Southeast. As explained earlier, the average T_D value generally follows the trend of the annual average ambient temperature curve for any given region, but there is always a positive offset (i.e., the T_D value is greater than the average ambient temperature), probably because of solar heat gain and the thermal storage effect of the ground, which in turn are modified by the other factors noted above in section C-4. The magnitude of the offset varies during the course of the year for most regions, particularly where the ground may be frozen during the winter months. In such areas T_D may approach the ambient temperature in the Spring, when the ambient temperature rises relatively quickly while the soil temperature increases more gradually. The offset for the Southeast, on the other hand, is relatively constant throughout the year, likely because over most of the area the ground never freezes and because of greater solar gains and higher ambient temperatures, particularly during the Winter months.

Second, comparing the seasonal (summer and winter) emission rates to the average annual rates for each region, all the emission rates are within +10 percent of the average annual value except for the North Central U.S. In this case the seasonal variation is on the order of 12-13 percent, due to slightly greater seasonal variation in the absolute values of the key parameters. This relatively small seasonal variation in the emission factors is likely due to the existence of offsetting factors in the conditions that determine both Winter and Summer emission rates. In the Winter months, RVP's are high and ΔT values tend to be more negative than during the Summer. Both of these trends would tend to increase emissions, but they are offset by lower dispensed temperatures, which tend to decrease emissions. Conversely, during the Summer dispensed temperatures are higher, which would increase emissions, but the higher temperatures are offset by lower RVP's and positive ΔT values, both of which tend to decrease emissions.

Third, comparing the two ozone scenarios to the average annual scenario, the emission rates for all five regions and the national average do not vary by more than 10 percent. In this case the average annual values for each region exceed the ozone scenario values in a range of 0 to about 6 percent. So overall there is good agreement between the average annual emission rates and the emission rates expected in the ozone prone months. This is true for all regions and on a national level.

6. Effects of Fuel Weathering

In addition to the three primary factors discussed above, fuel weathering also affects refueling emission rates. Fuel tank weathering results in a difference in RVP between the dispensed fuel and the residual fuel in the vehicle tank, with fuel in the tank losing volatility due to the evaporation of lighter ends in the gasoline. The very limited amount of baseline testing that was done with lower RVP fuel in the vehicle tank indicates that an increase in emissions, on the order of a gram per gallon, resulted from an RVP difference of approximately 1.9 psi between the tank and the dispensed fuel (see Section III.C.). This general phenomenon was also observed in the SRI study.[2] Unfortunately, neither the EPA nor the SRI data are adequate to fully characterize the effect of the RVP difference, although they do show the direction and give a rough idea of the magnitude of the change.

In order to be able to include the effect of tank fuel weathering in the emission rate calculation, one would also need to know the average amount of in-use weathering that occurs between refuelings, in addition to the effect of the resultant difference in RVP values on the refueling emission rate. This includes both the different vehicle and fuel effects. Since neither of these variables can be determined with any certainty at this time, the effect of tank weathering has not been included in the emission factor calculation. Although refueling emissions may thus be somewhat understated, this effect may be partially offset by the method of RVP determination for the calculation. Use of the ASTM maximum RVP limits represents EPA's best judgment of future RVP levels. However, if in-use RVP levels should be lower than these maximum values, the resulting decrease in the emission factor would tend to be at least partially offset by an increase in refueling emissions due to fuel weathering.

D. Conclusions

At the beginning of this investigation it was felt that it might be necessary to develop both a seasonal emission factor for air quality calculations and an average annual emission factor for health exposure risk calculations. However, the relative uniformity of the seasonal emission factors indicates that the average annual values can be used for both purposes without introducing any significant error into the air quality calculations. If only air quality calculations were involved, it might be more appropriate to use only a summer emission factor, although by so doing two important "by-products" of the air quality calculation, the emissions inventory calculation and the calculated lifetime emissions reduction per vehicle, would both be understated. An annual average would be more appropriate for these latter two purposes as well as for health exposure risk calculations.

On the other hand, use of an average annual emission rate for air quality determinations may theoretically overstate the air quality benefits somewhat. The difference between the summer and average annual emission factors is relatively small (less than 5 percent), however, and any differences in air quality calculations, i.e. SMSAs brought into compliance or percent change in air quality, would likely disappear in the roundoff of the EKMA model. Thus in practical terms, it would likely be very difficult to see any differences in the air quality outputs resulting from the use of the average annual values, whereas there are real advantages to its use in terms of emissions inventory, lifetime emissions and cost-effectiveness calculations.

Finally, it does not appear that there will be a need for seasonal emission factors for health effects purpose as a result of changes in the amount of benzene and other potentially hazardous species in the total VOC emitted. Such emissions are a function of the percentage of the hazardous pollutant present in liquid gasoline and the same temperature considerations that affect the basic VOC emission rate. In order to have significant seasonal variation in the emissions of these hazardous species, then, either the seasonal percentage of these species in the liquid gasoline would have to vary significantly or, since such emissions are normally expressed as a percentage of total VOC emissions, winter and summer VOC emission factors would have to differ significantly from the annual average. As stated above, the latter condition is not the case. Correspondingly, the 1983/84 NIPER gasoline surveys show no significant difference between the winter and summer benzene percentages in liquid gasoline. For these surveys average summer and winter benzene fractions in the liquid gasoline averaged about 1.3 percent.[23,24] Similar data are not available for other potentially hazardous species, but there is no reason to believe that the liquid fraction of these species varies regionally or seasonally. Therefore it is reasonable to conclude that seasonal differences in the emission factors will not necessitate separate emission factors for either health effects or air quality purposes.

For these reasons, it was decided to use the average annual displacement value of 5.9 grams per gallon for all calculations. Adding 0.3 grams per gallon for spillage results in a national average refueling emission factor of 6.2 grams per gallon.

Appendix A

BASELINE TEST RESULTS

1983 Oldsmobile Cutlass Supreme

Dispensed Temperature = 82°F 3 RVPs

Test	RVP	T(°F)	Disp. Temp(°F)	Losses (gm/gal)	Liq. Temp(°F)	Vap. Temp(°F)	Disp. Gals	Losses (gms)	Disp. Time (min.)	Heat Time (min.)
845638	9.0	1.5	80.5	5.209	82.0	83.0	14.8	77.1	2.52	28.00
845639	9.0	0.	82.0	5.456	82.0	83.0	14.7	80.2	2.53	24.00
845637	9.0	10.8	82.0	5.021	92.8	93.9	14.6	73.3	2.58	52.00
845632	9.0	8.1	83.9	5.308	92.0	92.5	14.6	77.5	2.67	50.00
845636	9.0	22.0	81.0	4.407	103.0	102.0	15.0	66.1	2.63	36.00
845631	9.0	18.5	83.5	4.632	102.0	100.5	15.5	71.8	2.70	37.00
845628	9.0	36.7	82.3	3.115	119.0	116.0	14.8	46.1	3.00	74.00
845630	9.0	37.0	82.0	2.918	119.0	117.0	14.6	42.6	2.58	67.00
850113	9.0	12.0	80.5	4.934	92.5	92.3	15.1	74.5	1.97	42.00
850114	9.0	7.7	83.3	4.934	91.0	93.0	15.1	74.5	1.98	32.00
850115	9.0	12.3	80.0	4.331	92.3	93.4	15.1	65.4	1.98	30.00
850117	9.0	11.9	79.8	5.126	91.7	90.5	15.1	77.4	2.02	48.00
851354	9.0	2.3	81.7	5.060	84.0	82.5	15.0	75.9	1.98	28.00
851355	9.0	1.5	81.5	5.133	83.0	82.5	15.0	77.0	1.97	32.00
845950	11.9	-1.1	81.0	7.831	79.9	82.5	14.8	115.9	3.30	24.00
845951	11.9	-.8	83.0	8.074	82.2	83.0	14.8	119.5	3.42	24.00
845945	11.9	11.0	81.0	6.490	92.0	92.3	14.7	95.4	3.25	60.00
845947	11.9	10.0	83.2	6.133	93.2	92.5	15.0	92.0	3.33	46.00
850057	11.9	10.0	82.0	6.395	92.0	93.0	15.2	97.2	1.98	46.00
850104	11.9	11.1	80.8	5.947	91.9	93.0	15.0	89.2	2.00	45.00
845943	11.9	17.0	85.0	4.842	102.0	102.0	14.6	70.7	3.35	35.00
845944	11.9	21.7	80.8	4.432	102.5	102.0	14.8	65.6	3.13	40.00
845946	11.9	20.5	83.0	5.743	103.5	103.0	14.8	85.0	3.33	37.00
850105	11.9	17.2	83.8	5.327	101.0	102.5	15.0	79.9	2.05	39.00
850106	11.9	18.0	81.8	5.007	99.8	98.5	14.9	74.6	1.97	39.00
845941	11.9	34.0	86.0	3.830	120.0	118.3	15.3	58.6	3.50	68.00
845942	11.9	39.5	82.0	3.500	121.5	118.0	14.6	51.1	3.27	61.00
845948	11.9	38.8	81.2	3.514	120.0	118.5	14.8	52.0	3.23	72.00
845642	12.6	-2.0	82.5	8.938	80.5	83.0	14.5	129.6	3.62	25.00
845641	12.6	7.5	84.0	7.366	91.5	92.5	14.5	106.8	3.58	48.00
845627	12.6	8.2	84.0	6.892	92.2	92.5	14.8	102.0	3.83	60.00
845294	12.6	16.6	84.0	6.290	100.6	102.0	14.5	91.2	3.68	39.00
845625	12.6	19.0	81.0	6.081	100.0	101.0	14.9	90.6	3.38	41.00

Dispensed Temperature = 92°F 3 RVPs

Test	RVP	T(°F)	Disp. Temp(°F)	Losses (gm/gal)	Liq. Temp(°F)	Vap. Temp(°F)	Disp. Gals	Losses (gms)	Disp. Time (min.)	Heat Time (min.)
845289	9.0	-11.0	91.0	6.952	80.0	81.8	14.5	100.8	2.88	26.00
845290	9.0	8.3	92.0	6.324	100.3	101.0	14.2	89.8	2.95	38.00
845280	9.0	29.0	91.0	4.257	120.0	119.0	14.8	63.0	2.78	67.00
845292	9.0	27.8	91.2	4.097	119.0	116.0	14.5	59.4	2.82	67.00
850110	9.0	1.5	90.5	6.470	92.0	92.5	14.9	96.4	2.05	34.00
850111	9.0	1.5	90.5	6.831	92.0	93.5	15.4	105.2	2.07	34.00
850112	9.0	2.2	90.0	5.887	92.2	94.2	15.1	88.9	2.00	36.00
851356	9.0	15.2	88.0	4.700	103.2	100.0	15.0	70.5	2.00	44.00
851357	9.0	8.4	92.0	6.060	100.4	97.0	15.1	91.5	2.05	32.00

845931	11.9	-10.5	92.0	10.250	81.5	81.5	15.2	155.8	4.52	32.00
845932	11.9	-10.3	91.3	11.431	81.0	83.0	15.3	174.9	4.53	24.00
845935	11.9	2.0	90.0	8.307	92.0	91.5	15.0	124.6	3.98	46.00
845937	11.9	1.0	91.0	7.270	92.0	93.0	15.2	110.5	3.77	53.00
850054	11.9	2.5	90.5	10.060	93.0	90.8	14.9	149.9	3.08	40.00
850053	11.9	-1.0	93.0	9.765	92.0	92.0	15.3	149.4	3.28	42.00
845938	11.9	9.5	92.0	8.066	101.5	102.5	15.2	122.6	4.22	40.00
845939	11.9	10.1	91.8	7.815	101.9	103.0	15.1	118.0	4.22	39.00
845933	11.9	22.1	92.0	4.921	114.1	109.9	15.1	74.3	4.05	67.00
845936	11.9	30.6	90.9	3.311	121.5	119.0	14.8	49.0	3.60	65.00
850055	11.9	25.9	93.0	4.066	118.9	117.8	15.2	61.8	2.55	49.00
850056	11.9	28.8	91.2	4.821	120.0	117.2	15.1	72.8	2.32	58.00
845956	10.0	-11.0	91.0	8.597	80.0	82.3	14.9	128.1	3.48	21.00
845957	10.0	-10.0	90.0	8.128	80.0	83.0	14.9	121.1	3.43	24.00
845954	10.0	1.8	90.2	6.966	92.0	93.0	14.8	103.1	3.33	48.00
845955	10.0	2.0	90.0	7.240	92.0	92.3	15.0	108.6	3.42	48.00
845953	10.0	11.8	90.8	6.479	102.6	102.0	14.6	94.6	3.33	35.00

Single Blanket Data

845107	9.0	-10.8	90.8	6.353	80.0	78.0	15.0	95.3	2.85	36.00
845276	9.0	-11.0	90.0	6.651	79.0	76.0	14.6	97.1	2.83	42.00
845102	9.0	2.0	90.0	5.980	92.0	86.5	15.0	89.7	2.93	96.00
845103	9.0	-1.0	92.7	6.153	91.7	86.0	15.0	92.3	2.97	178.00
845109	9.0	-3.2	93.2	6.554	90.0	84.0	14.8	97.0	2.93	74.00
845105	9.0	7.1	91.6	5.027	98.7	95.6	15.0	75.4	2.93	212.00
845106	9.0	8.0	91.5	5.060	99.5	96.4	14.9	75.4	2.80	173.00
845275	9.0	27.5	92.5	3.453	120.0	114.0	15.0	51.8	2.87	306.00

Road Prep Data

845286	9.0	10.5	92.5	4.815	103.0	105.9	14.6	70.3	-	182.00
845287	9.0	-3.5	92.0	6.060	88.5	90.0	13.4	81.2	2.60	172.00
845961	10.0	-6.0	92.0	7.985	86.0	87.5	13.5	107.8	3.15	185.00
845959	10.0	-3.9	91.6	6.514	87.7	88.7	14.2	92.5	3.22	159.00

Dispensed Fuel RVP = 11.9 Tank Fuel RVP = 10.0

850904	11.9	0.0	92.0	9.566	92.0	88.0	14.5	138.7	2.27	16.00
850913	11.9	3.1	90.8	8.731	93.9	90.3	14.5	126.6	2.25	19.00

Large Vapor-Liquid Temperature Differences

850885	11.9	3.2	90.8	8.220	94.0	86.8	15.0	123.3	2.07	16.00
850887	11.9	3.0	91.0	8.140	94.0	87.0	15.0	122.1	2.10	16.00
850901	11.9	4.7	89.0	8.947	93.7	104.0	15.0	134.2	2.10	36.00
850902	11.9	4.0	89.0	9.093	93.0	102.5	15.0	136.4	2.07	34.00

1984 Ford Escort

Dispensed Temperature = 80°F 2 RVPs

851161	9.0	3.7	80.0	4.456	83.7	83.0	10.3	45.9	4.46	17.00
851162	9.0	4.0	79.0	4.308	83.0	83.0	10.4	44.8	1.37	16.00
851163	9.0	9.3	80.7	4.269	90.0	91.9	10.4	44.4	1.37	28.00
851165	9.0	12.5	81.0	4.574	93.5	92.5	10.8	49.4	1.43	32.00
851164	9.0	21.2	80.3	4.221	101.5	101.8	10.4	43.9	1.43	40.00
851166	9.0	22.5	78.5	3.159	101.0	102.5	10.7	33.8	1.42	44.00
851213	9.0	10.5	81.0	4.673	91.5	91.7	10.4	48.6	1.37	28.00
851214	9.0	20.5	80.5	4.346	101.0	101.0	10.4	45.2	1.35	42.00
850304	11.9	1.5	81.2	6.091	82.7	84.0	11.0	67.0	1.47	25.00
850012	11.9	12.0	80.0	5.750	92.0	94.0	10.8	62.1	1.42	57.00
850014	11.9	12.7	80.3	5.606	93.0	94.0	10.9	61.1	1.43	56.00
850311	11.9	2.7	80.0	5.595	82.7	82.3	11.1	62.1	1.45	32.00
850314	11.9	11.8	81.2	5.694	93.0	92.7	11.1	63.2	1.45	50.00
850312	11.9	11.1	81.0	5.654	92.1	92.2	10.7	60.5	1.40	52.00
850313	11.9	13.4	79.1	5.455	92.5	91.8	11.2	61.1	1.47	58.00
850013	11.9	3.7	80.0	6.255	83.7	83.9	11.0	68.8	1.43	24.00
850303	11.9	3.7	80.0	5.991	83.7	84.0	11.6	69.5	1.45	25.00
850011	11.9	13.3	79.6	5.890	92.9	93.0	10.9	64.2	1.45	50.00
850310	11.9	4.5	78.5	6.279	83.0	83.7	10.4	65.3	1.38	28.00
850309	11.9	12.0	80.5	6.077	92.5	95.0	10.4	63.2	1.43	45.00
850307	11.9	22.0	80.5	5.390	102.5	103.0	10.5	56.6	1.43	40.00
850308	11.9	23.0	80.0	5.202	103.0	105.0	10.4	54.1	1.40	38.00
851160	11.9	20.2	80.0	5.567	100.2	102.0	10.4	57.9	1.38	42.00

Dispensed Temperature = 90°F 2 RVPs

851167	9.0	8.9	85.0	4.740	93.9	94.5	10.4	49.3	1.40	32.00
851168	9.0	4.5	89.5	5.221	94.0	93.2	10.4	54.3	1.42	30.00
851169	9.0	4.8	89.7	5.115	94.5	91.0	10.4	53.2	1.38	32.00
851211	9.0	6.0	89.0	4.875	95.0	96.0	10.4	50.7	1.38	30.00
846446	11.9	2.0	92.5	7.903	94.5	98.2	11.3	89.3	1.63	26.00
846447	11.9	.7	92.3	7.228	93.0	98.0	11.4	82.4	1.63	21.00

Dispensed Temperature = 66°F

850305	11.9	7.5	66.5	5.029	74.0	73.9	10.5	52.8	1.35	6.00
850306	11.9	5.0	67.5	5.286	72.5	72.0	10.5	55.5	1.37	5.00

1983 Plymouth Reliant

851151	11.9	2.5	80.0	6.265	82.5	84.3	9.8	61.4	1.32	16.00
851150	11.9	1.7	81.8	6.640	83.5	84.0	10.0	66.4	1.32	16.00
851152	11.9	10.0	81.0	6.439	91.0	89.0	9.8	63.1	1.30	32.00
851153	11.9	19.3	80.0	4.969	99.3	97.5	9.6	47.7	1.28	44.00
851154	11.9	14.1	79.9	5.316	94.0	94.0	9.5	50.5	1.48	32.00
851155	11.9	18.0	81.0	6.109	99.0	99.7	10.1	61.7	1.37	38.00
845486	9.0	1.5	90.5	5.577	92.0	86.5	10.4	58.0	1.92	38.00
845487	9.0	-1.5	91.5	5.677	90.0	87.0	9.9	56.2	1.87	38.00
845492	11.9	3.0	89.0	6.839	92.0	88.3	11.2	76.6	3.12	42.00
845493	11.9	1.3	91.0	7.036	92.3	89.5	11.2	78.8	3.17	43.00
851157	9.0	4.3	68.0	3.763	72.3	73.2	9.7	36.5	1.30	6.00
851156	9.0	4.0	69.0	3.939	73.0	72.0	9.8	38.6	1.32	4.00
851159	11.9	5.5	68.0	5.299	73.5	77.5	9.7	51.4	1.28	12.00
851246	11.9	5.6	68.3	5.323	73.9	78.0	9.9	52.7	1.30	14.00

1983 Buick Skylark

846410	11.9	2.7	90.5	7.925	93.2	92.2	13.4	106.2	3.75	28.00
846413	11.9	13.0	85.0	6.471	98.0	91.0	13.6	88.0	2.32	28.00
846454	11.9	-.9	94.3	7.540	93.4	91.9	13.7	103.3	2.15	26.00
846453	11.9	-2.0	93.5	7.353	91.5	90.0	13.6	100.0	2.05	23.00
846412	11.9	.5	92.0	7.365	92.5	90.6	13.7	100.9	2.05	20.00
846452	11.9	.5	92.0	7.708	92.5	94.3	12.0	92.5	1.80	19.00

1984 Chevrolet Celebrity

850205	11.9	12.7	80.0	4.632	92.7	92.2	13.6	63.0	1.78	44.00
850209	11.9	10.7	81.0	4.596	91.7	92.0	13.6	62.5	1.78	38.00
850208	11.9	13.2	78.8	4.706	92.0	92.1	13.6	64.0	1.85	40.00
850207	11.9	.7	91.8	6.333	92.5	96.0	13.8	87.4	1.95	58.00
850206	11.9	-.5	92.5	6.876	92.0	94.5	13.7	94.2	1.95	38.00
850204	11.9	2.6	89.4	6.080	92.0	94.0	13.8	83.9	1.93	36.00

1983 LDT Crown Victoria

850400	11.9	11.2	80.8	7.448	92.0	95.0	15.4	114.7	2.02	58.00
850401	11.9	11.8	79.2	7.200	91.0	94.0	14.5	104.4	1.90	51.00
850402	11.9	11.0	80.5	7.558	91.5	94.2	15.4	116.4	2.05	42.00
850404	11.9	1.0	90.8	11.166	91.8	95.4	15.7	175.3	2.30	34.00
850405	11.9	1.8	90.0	10.500	91.8	94.2	15.6	163.8	2.25	36.00

1979 Chevrolet 3/4 Ton Pickup

850689	11.9	14.5	81.7	6.048	96.2	92.0	16.6	100.4	2.33	32.00
850690	11.9	13.2	82.3	5.813	95.5	93.0	16.6	96.5	2.27	28.00
850691	11.9	10.3	82.3	5.795	92.6	93.5	16.6	96.2	2.30	28.00
850686	11.9	-.1	91.8	7.916	91.7	93.2	16.7	132.2	2.43	38.00
850688	11.9	2.6	89.7	7.964	92.3	93.5	16.6	132.2	2.58	32.00

1979 Dodge Truck W150

850990	11.9	12.5	80.0	6.593	92.5	94.0	18.2	120.0	2.47	46.00
850991	11.9	12.0	80.0	6.456	92.0	92.7	18.0	116.2	2.38	42.00
850987	11.9	2.1	91.7	8.984	93.8	95.0	18.3	164.4	3.30	30.00
850988	11.9	.2	91.8	8.950	92.0	91.8	18.0	161.1	2.78	40.00

Appendix B

Fuel Consumption Weighting Data

HIGHWAY USE OF GASOLINE BY MONTHS - 1983 1/

COMPILED FOR THE CALENDAR YEAR
FROM AN ANALYSIS OF MOTOR-FUEL USE

(THOUSANDS OF GALLONS)

TABLE MF-25
NOVEMBER 1984

STATE	TAX RATE ON DECEMBER 31 (IN CENTS PER GALLON) 2/	JANUARY	FEBRUARY	MARCH	APRIL	MAY	JUNE	JULY	AUGUST	SEPTEMBER	OCTOBER	NOVEMBER	DECEMBER	TOTAL	CHANGE FROM 1982 GALLONS	CHANGE FROM 1982 PERCENT
ALABAMA	11	117,782	127,036	149,091	146,978	168,900	168,482	169,089	171,470	181,839	149,812	146,282	182,662	1,812,442	23,807	1.3
ALASKA	8	16,730	16,232	10,932	16,119	11,982	10,723	8,349	23,070	19,820	9,410	10,630	12,332	182,042	-10,869	-5.6
ARIZONA	12	112,280	107,070	114,734	120,192	120,690	110,210	121,972	122,273	102,277	110,806	113,427	110,026	1,378,067	78,603	8.8
ARKANSAS	9.5	83,363	88,178	83,874	92,339	100,278	99,400	110,934	103,048	98,278	87,914	82,772	81,204	1,009,061	6,659	0.6
CALIFORNIA	9	744,721	737,242	830,199	862,252	934,900	961,622	1,022,922	1,067,299	938,976	912,471	830,190	848,187	10,604,667	284,273	2.7
COLORADO	12	107,317	91,728	115,179	112,950	110,902	124,700	139,063	139,798	116,426	115,649	100,102	90,283	1,300,048	-50,104	-3.8
CONNECTICUT	14	84,609	88,371	97,792	102,400	110,790	113,155	135,386	124,860	115,920	125,640	90,090	80,598	1,277,382	28,240	2.3
DELAWARE	11	17,067	18,278	21,797	23,257	27,146	29,770	33,020	32,787	27,689	24,860	22,833	24,289	302,680	26,793	9.7
DIST. OF COL.	14.8	11,263	11,214	13,689	13,380	14,952	14,016	16,273	16,042	14,307	14,646	13,176	13,177	166,943	-708	-0.4
FLORIDA	9.7	382,860	374,033	481,987	416,736	406,928	393,666	423,500	418,700	379,432	409,864	400,392	442,782	4,908,858	167,817	3.5
GEORGIA	7.8	200,463	208,019	253,616	252,304	250,796	243,918	251,079	250,070	229,422	235,029	229,911	241,885	2,843,518	88,763	3.2
HAWAII	8.8	22,388	22,102	28,063	24,884	24,776	24,202	27,807	28,200	26,553	29,320	24,798	24,078	300,198	756	0.3
IDAHO	14.5	24,947	26,662	32,098	33,969	37,126	39,558	43,023	44,493	38,807	36,206	31,644	29,132	418,862	10,212	2.5
ILLINOIS	11	264,990	274,394	341,231	366,303	410,137	406,173	420,192	437,760	393,122	395,014	353,789	338,692	4,401,767	117,070	2.7
INDIANA	11.1	112,661	149,206	183,296	202,595	225,949	228,205	247,202	243,671	200,069	200,287	189,118	184,783	2,381,122	44,872	1.9
IOWA	13	68,349	80,858	102,383	100,866	124,382	126,783	137,074	143,140	116,914	111,763	106,124	96,397	1,314,953	34,691	2.7
KANSAS	10	84,563	61,091	90,700	92,416	102,716	103,003	118,920	118,387	103,443	104,930	94,958	91,991	1,164,206	16,970	1.5
KENTUCKY	10	216,200	97,360	122,305	134,491	130,744	138,211	155,137	148,078	132,201	143,483	127,846	129,831	1,684,817	11,147	0.7
LOUISIANA	8	164,911	150,930	174,407	179,103	184,282	173,071	180,481	184,042	160,276	177,044	171,041	167,032	2,093,158	16,707	0.8
MAINE	16	30,148	27,067	37,017	37,030	42,239	48,226	58,680	58,130	48,736	46,461	34,889	32,861	502,262	12,011	2.4
MARYLAND	13.5	113,317	120,846	141,417	152,602	160,751	164,189	181,326	190,601	161,483	162,944	148,180	148,450	1,858,244	5,842	0.3
MASSACHUSETTS	11	152,616	145,738	172,760	174,116	189,848	197,621	221,023	227,533	197,046	195,420	187,150	176,501	2,207,877	34,231	1.6
MICHIGAN	13	220,514	220,264	243,384	274,206	321,671	319,590	306,708	306,289	314,235	325,013	289,165	225,060	3,537,119	-92,492	-2.5
MINNESOTA	16	131,462	124,990	145,522	154,951	166,810	163,344	173,977	180,361	157,522	161,609	144,313	142,561	1,847,470	97,305	5.6
MISSISSIPPI	9	75,527	80,402	90,833	90,660	104,092	103,300	105,980	106,889	89,405	85,419	92,208	91,230	1,115,722	12,026	1.1
MISSOURI	7	149,709	148,076	184,353	200,813	224,913	220,615	241,888	244,868	269,670	215,604	198,792	185,481	2,424,622	56,025	2.4
MONTANA	15	22,682	26,859	29,396	27,911	39,714	41,946	50,362	51,690	38,899	32,989	32,952	24,161	418,919	12,457	3.1
NEBRASKA	15.5	42,672	44,789	54,822	56,214	63,856	67,076	72,225	72,225	62,774	62,068	55,086	52,617	705,324	-8,021	-1.1
NEVADA	12	30,882	31,879	35,619	35,804	41,230	43,791	47,925	47,646	41,609	39,891	34,086	34,310	464,380	761	0.2
NEW HAMPSHIRE	14	20,163	20,062	29,328	27,139	34,267	32,904	39,262	44,367	34,793	34,526	33,086	29,085	394,044	12,041	3.2
NEW JERSEY	8	230,216	233,126	270,310	264,167	288,417	286,476	298,063	301,997	223,102	289,306	273,220	277,099	3,233,370	171,761	5.6
NEW MEXICO	11	29,008	83,602	59,441	37,071	73,720	78,020	49,252	80,883	73,322	39,804	64,396	60,368	716,364	596	0.1
NEW YORK	8	319,269	321,761	380,068	397,947	472,388	480,120	559,853	550,177	476,693	472,070	416,408	394,039	5,251,098	-87,764	-1.6
NORTH CAROLINA	12	205,202	180,760	211,044	240,715	246,980	247,912	201,241	269,700	234,006	246,168	226,391	214,994	2,703,990	66,781	2.6
NORTH DAKOTA	13	20,725	19,167	24,564	28,093	28,861	32,073	35,732	33,669	31,028	28,494	23,081	26,008	320,806	-6,221	-1.9
OHIO	12	297,014	309,816	361,845	381,156	402,062	396,204	411,607	414,336	377,027	380,762	340,422	346,894	4,435,138	39,840	0.9
OKLAHOMA	6.5	124,807	114,114	135,802	153,120	162,378	182,028	170,398	172,247	144,729	188,092	148,872	120,688	1,770,443	-26,178	-1.5
OREGON	8	79,535	77,211	95,949	93,982	102,059	106,470	111,347	112,392	101,710	97,646	90,864	91,609	1,161,074	-709	-0.1
PENNSYLVANIA	12	270,840	279,039	339,977	380,949	381,404	376,261	404,974	416,848	385,260	383,978	383,977	342,834	4,288,428	42,122	1.0
RHODE ISLAND	13	20,418	22,168	26,838	25,561	29,993	30,199	34,729	38,004	29,928	31,469	28,390	27,480	343,169	-3,467	-1.0
SOUTH CAROLINA	13	98,644	108,091	119,846	127,206	139,986	132,270	182,499	143,070	115,960	130,492	110,339	110,313	1,494,774	21,652	1.5
SOUTH DAKOTA	13	16,738	18,724	20,801	24,114	29,220	35,553	39,150	38,760	29,045	26,073	22,918	21,430	323,406	-7,891	-2.3
TENNESSEE	9	150,284	157,846	179,090	186,767	190,430	194,010	213,319	215,324	180,065	207,249	176,902	171,718	2,239,771	-23,422	-1.0
TEXAS	5	613,806	500,340	692,222	677,616	706,010	705,206	717,370	713,322	665,253	693,845	661,304	590,049	8,115,147	145,592	1.8
UTAH	11	41,364	36,065	53,452	55,376	54,082	62,918	80,103	82,341	62,297	57,027	41,707	51,000	658,622	6,394	1.0
VERMONT	13	14,233	16,179	17,641	16,049	20,982	18,634	24,324	25,763	22,162	22,087	14,794	18,626	231,684	1,916	0.8
VIRGINIA	11	170,309	167,091	195,819	201,252	217,093	221,797	230,134	238,630	211,640	214,866	187,530	197,837	2,478,414	51,195	2.1
WASHINGTON	16	120,157	127,020	150,057	151,843	160,488	167,329	180,144	181,814	164,350	162,072	149,972	148,416	1,887,140	69,827	3.9
WEST VIRGINIA	10.5	48,886	49,090	61,953	66,634	69,903	71,070	72,862	72,861	67,179	69,814	64,765	62,196	778,432	-14,845	-1.9
WISCONSIN	15	106,463	117,719	135,654	142,714	172,477	183,163	200,877	200,920	174,080	169,044	150,154	140,996	1,987,939	22,274	1.2
WYOMING	8	17,859	16,243	25,827	26,130	26,669	33,131	39,813	36,031	30,862	23,231	19,241	18,830	309,027	-14,313	-4.4
TOTAL	9.78	6,037,033	6,695,781	7,961,493	8,169,474	8,909,662	8,886,639	9,668,171	9,760,349	8,533,021	8,605,620	7,959,225	7,856,376	99,964,516	1,480,638	1.5
PERCENTAGE	-	6.04	6.70	7.97	8.17	8.91	8.92	9.67	9.76	8.54	8.60	7.96	7.86	100.00	-	-

1/ THIS TABLE IS ONE OF A SERIES (MF-21 THROUGH MF-25) GIVING AN ANALYSIS OF MOTOR-FUEL CONSUMPTION. THEY ARE BASED ON REPORTS FROM STATE MOTOR-FUEL TAX AGENCIES. IN THESE TABLES GASOHOL IS INCLUDED WITH GASOLINE. IN ORDER TO MAKE THE DATA UNIFORM AND COMPLETE, ESTIMATES OF NONHIGHWAY USE HAVE BEEN MADE IN SOME CASES BY THE FEDERAL HIGHWAY ADMINISTRATION. THE RESULTING GALLONAGES DIFFER IN MANY INSTANCES FROM THE UNADJUSTED DATA RECORDED IN TABLE MF-2. IN ORDER TO APPROXIMATE ACTUAL USE, THE MONTHLY DISTRIBUTIONS WERE ESTIMATED BY THE FEDERAL HIGHWAY ADMINISTRATION USING TRAVEL DATA. THE ENTRIES IN TABLE MF-25 WILL NOT AGREE WITH THOSE IN TABLE MF-33GA. TABLE MF-25 SHOWS HIGHWAY USE ONLY WHILE TABLE MF-33GA REFLECTS GROSS GALLONS OF GASOLINE REPORTED BY WHOLESALE DISTRIBUTORS TO THE STATE TAXING AGENCIES EACH MONTH.

2/ FOR TAX RATES AS OF JANUARY 1, 1983 AND FOR RATE CHANGES DURING THE YEAR SEE TABLE MF-121T. STATES WITH VARIABLE RATES ARE ALSO IDENTIFIED IN TABLE MF-121T.

1	ST	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
2	AK	15.0	15.0	15.0	15.0	15.0	13.5	13.5	13.5	15.0	15.0	15.0	15.0
3	AL	13.5	13.5	13.5	11.5	11.5	11.5	11.5	10.0	11.5	11.5	13.5	13.5
4	AR	15.0	13.5	13.5	11.5	11.5	11.5	10.0	10.0	11.5	13.5	13.5	15.0
5	AZ	13.5	13.5	11.5	10.0	10.0	9.0	9.0	9.0	9.0	10.0	11.5	13.5
6	CA	13.5	13.5	13.5	11.5	11.5	10.0	10.0	10.0	10.0	11.5	13.5	13.5
7	CO	15.0	15.0	13.5	11.5	11.5	10.0	10.0	10.0	10.0	11.5	13.5	15.0
8	CT	15.0	15.0	15.0	13.5	13.5	11.5	11.5	11.5	11.5	13.5	15.0	15.0
9	DC	15.0	15.0	13.5	13.5	11.5	11.5	11.5	11.5	11.5	13.5	15.0	15.0
10	DL	15.0	15.0	15.0	13.5	13.5	11.5	11.5	11.5	11.5	13.5	15.0	15.0
11	FL	13.5	13.5	13.5	11.5	11.5	11.5	11.5	11.5	11.5	11.5	13.5	13.5
12	GA	13.5	13.5	13.5	11.5	11.5	11.5	11.5	10.0	11.5	11.5	13.5	13.5
13	IA	15.0	15.0	15.0	13.5	11.5	11.5	11.5	11.5	11.5	13.5	15.0	15.0
14	ID	15.0	15.0	13.5	13.5	11.5	10.0	10.0	10.0	10.0	11.5	13.5	15.0
15	IL	15.0	15.0	15.0	13.5	11.5	11.5	11.5	11.5	11.5	13.5	13.5	15.0
16	IN	15.0	15.0	15.0	13.5	13.5	11.5	11.5	11.5	11.5	13.5	15.0	15.0
17	KS	15.0	15.0	13.5	11.5	11.5	10.0	10.0	10.0	10.0	11.5	13.5	15.0
18	KY	15.0	15.0	13.5	13.5	11.5	11.5	11.5	11.5	11.5	13.5	15.0	15.0
19	LA	13.5	13.5	13.5	11.5	11.5	11.5	11.5	10.0	11.5	11.5	13.5	13.5
20	MA	15.0	15.0	15.0	13.5	13.5	11.5	11.5	11.5	13.5	13.5	15.0	15.0
21	MD	15.0	15.0	15.0	13.5	13.5	11.5	11.5	11.5	11.5	13.5	15.0	15.0
22	ME	15.0	15.0	15.0	13.5	13.5	11.5	11.5	11.5	13.5	13.5	15.0	15.0
23	MI	15.0	15.0	15.0	13.5	13.5	11.5	11.5	11.5	13.5	13.5	15.0	15.0
24	MN	15.0	15.0	15.0	13.5	13.5	11.5	11.5	11.5	11.5	13.5	15.0	15.0
25	MO	15.0	15.0	13.5	13.5	11.5	11.5	10.0	10.0	11.5	13.5	13.5	15.0
26	MS	13.5	13.5	13.5	11.5	11.5	11.5	11.5	10.0	11.5	11.5	13.5	13.5
27	MT	15.0	15.0	15.0	13.5	11.5	10.0	10.0	10.0	11.5	13.5	15.0	15.0
28	NB	15.0	15.0	15.0	13.5	11.5	10.0	10.0	10.0	10.0	11.5	13.5	15.0
29	NC	15.0	13.5	13.5	13.5	11.5	11.5	11.5	10.0	11.5	13.5	13.5	15.0
30	ND	15.0	15.0	15.0	13.5	13.5	11.5	10.0	10.0	11.5	13.5	15.0	15.0
31	NH	15.0	15.0	15.0	13.5	13.5	11.5	11.5	11.5	13.5	13.5	15.0	15.0
32	NJ	15.0	15.0	15.0	13.5	13.5	11.5	11.5	11.5	13.5	13.5	15.0	15.0
33	NM	13.5	13.5	11.5	10.0	10.0	9.0	9.0	9.0	10.0	11.5	13.5	13.5
34	NV	15.0	13.5	11.5	11.5	10.0	10.0	10.0	10.0	10.0	10.0	11.5	13.5
35	NY	15.0	15.0	15.0	13.5	13.5	11.5	11.5	11.5	13.5	13.5	15.0	15.0
36	OH	15.0	15.0	15.0	13.5	13.5	11.5	11.5	11.5	11.5	13.5	15.0	15.0
37	OK	15.0	13.5	13.5	11.5	11.5	10.0	10.0	10.0	10.0	11.5	13.5	15.0
38	OR	15.0	15.0	13.5	13.5	13.5	11.5	10.0	10.0	11.5	13.5	13.5	15.0
39	PA	15.0	15.0	15.0	13.5	13.5	11.5	11.5	11.5	13.5	13.5	15.0	15.0
40	RI	15.0	15.0	15.0	13.5	13.5	11.5	11.5	11.5	13.5	13.5	15.0	15.0
41	SC	13.5	13.5	13.5	13.5	11.5	11.5	11.5	10.0	11.5	13.5	13.5	13.5
42	SD	15.0	15.0	15.0	13.5	11.5	10.0	10.0	10.0	10.0	11.5	13.5	15.0
43	TN	15.0	13.5	13.5	13.5	11.5	11.5	11.5	10.0	11.5	13.5	13.5	15.0
44	TX	13.5	13.5	11.5	11.5	10.0	10.0	10.0	10.0	10.0	11.5	13.5	13.5
45	UT	15.0	15.0	13.5	13.5	11.5	10.0	10.0	10.0	10.0	11.5	13.5	15.0
46	VA	15.0	15.0	13.5	13.5	11.5	11.5	11.5	11.5	11.5	13.5	15.0	15.0
47	VT	15.0	15.0	15.0	13.5	13.5	11.5	11.5	11.5	13.5	13.5	15.0	15.0
48	WI	15.0	15.0	15.0	13.5	13.5	11.5	11.5	11.5	11.5	13.5	15.0	15.0
49	WN	15.0	15.0	15.0	13.5	13.5	11.5	11.5	11.5	11.5	13.5	15.0	15.0
50	WV	15.0	15.0	15.0	13.5	13.5	11.5	11.5	11.5	11.5	13.5	15.0	15.0
51	WY	15.0	15.0	15.0	13.5	11.5	10.0	10.0	10.0	10.0	11.5	13.5	15.0
52	HA	11.5	11.5	11.5	11.5	11.5	11.5	11.5	11.5	11.5	11.5	11.5	11.5

1	REGN	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
2	1-NE	-10.3	0.2	8.2	6.3	14.5	15.6	15.9	9.1	1.7	3.4	0.2	-5.4
3	2-SE	1.9	5.4	7.4	3.4	7.4	6.1	3.5	13.0	7.4	2.4	-7.8	-3.5
4	3-SW	3.4	-8.2	5.4	10.3	11.6	10.0	4.9	9.1	-.8	2.7	-4.8	-1.9
5	4-NC	0.2	-9.0	-11.3	9.3	7.6	19.3	15.5	11.2	6.3	2.1	-3.4	6.1
6	5-FW	-3.7	-3.2	-4.0	-2.9	11.9	3.7	0.0	6.3	3.9	1.1	-11.3	-5.9

1	REGN	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
2	1-NE	43	45	48	53	66	74	78	78	72	66	59	46
3	2-SE	69	74	73	80	84	87	90	91	88	85	83	73
4	3-SW	54	57	61	67	76	82	83	84	79	76	67	54
5	4-NC	50	51	41	47	63	74	88	85	83	75	63	52
6	5-FW	54	57	62	67	72	77	83	83	79	74	67	58
7	6-NW	999	48	49	53	59	63	999	73	71	60	49	42

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