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INVESTIGATION OF PASSENGER CAR REFUELING LOSSES

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#12

PREPARED FOR

COORDINATING RESEARCH COUNCIL, INC.

Thirty Rockefeller Plaza
New York, New York 10020

AND

ENVIRONMENTAL PROTECTION AGENCY
OFFICE OF AIR AND WATER PROGRAMS
MOBILE SOURCE POLLUTION CONTROL PROGRAM

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Ann Arbor, Michigan 48105

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SRL 2874 12 0972

Final Report

Investigation of Passenger Car Refueling Losses

Second-Year Program

APRAC Project Number CAPE 9-68
EPA Contract CPA 22-69-68
Scott Project #2874

Prepared for:

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September 1, 1972

by

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SUMMARY

This report documents the results obtained during the second year of a planned three-year program designed to determine the hydrocarbon losses sustained during the refueling of passenger cars. A five-city, four-season field survey and a laboratory study were conducted in parallel. The objectives of the field survey were to observe the magnitude and frequency of spill losses in the service station environment and to record temperatures relevant to the estimation of displaced hydrocarbon losses. The objective of the laboratory study was to measure the magnitude of displaced losses under conditions representative of those observed in the field. The twelve-month investigation obtained data from observations of 7,151 refueling operations in the field and 125 experiments conducted in the laboratory.

Four categories of spill loss were identified. In sequence of possible occurrence they are:

- Prefill drip from the nozzle while it is being handled from the pump to the vehicle
- Spit-back of gasoline from the fuel tank filler pipe resulting from pressure build-up in the vapor space in the fuel tank during an automatic fill
- Overflow from the filler pipe when the amount of gasoline dispensed exceeds the tank capacity (manual fill)
- Postfill drip from the nozzle while it is being handled from the vehicle back to the pump.

A summary of the magnitude and probability of occurrence of one or more spill types is given in the following Table S-1, together with the total and average refill in gallons dispensed.

Table S-1

Total Spill Loss Summary

Four-Season Composite

City	Sample Size	Total Refill gallons	Average Refill, gallons	Average Spill Loss, grams	Loss Prob.	Average Loss, grams/ refill
Los Angeles	1005	11,859.3	11.8	8.6	0.390	3.3
Houston	1287	16,430.2	12.8	17.0	0.373	6.3
Chicago	1234	14,488.2	11.7	9.8	0.260	2.6
New York	1515	15,161.7	10.0	9.5	0.360	3.4
Atlanta	1378	15,905.8	11.5	6.7	0.270	1.8
Composite	6419	73,845.2	11.5	10.6	0.329	3.5

The effect, if any, of the presence of the Scott observer is not known. Service station managers and attendants were told only that a consumer survey of replacement auto parts was to be performed. Despite concealment of the reasons for the survey, it may be prudent to consider the results obtained as reflecting spill loss data closer to a minimum than an average. It should be noted, however, that the spill loss is only about 6% of the total loss.

Dispensing nozzles were instrumented at one station in each city during each season for the purpose of measuring the dispensed fuel and displaced vapor temperatures. These temperature measurements were always made at a station where spill data were not being obtained. A total of 732 refueling operations were conducted with the instrumented nozzles. The fuel and vapor temperature measurements were supplemented with measurements of ambient and underground fuel temperatures.

An investigation of the magnitude of the displaced loss during refueling was conducted in the Scott all-weather room. The displaced loss consists of the displaced vapor loss plus the loss due to any entrained droplets in the displaced vapor. Measurements of the displaced losses for a carefully controlled sample of top fills were compared with those made during a sample of bottom fills controlled in the same way. The losses during the top fills were larger than those sustained during bottom filling, the difference being statistically significant at greater than the 99.5% confidence level. The difference amounted to about 10% at 90°F and 7% at 35°F. The generation of entrained droplets was considered to be precluded in the bottom-fill experiments. Before concluding the difference between top fills and bottom fills to result from the existence of entrained droplets in the top-fill case, however, it should be noted that the bottom-fill technique also precludes any excess fuel vaporization which may result from top filling. Additional experimentation required to resolve this question was beyond the scope of the program and hence was not conducted.

A total of 103 top-fill experiments yielded data on a large number of controlled experimental variables. Regression analyses were conducted on these data and a regression model for estimating the displaced loss was developed. The model is of the form

$$L_D' = \exp\,(a + b\cdot\overline{T}_{DF} + c\cdot\overline{T}_V + d\cdot\overline{T}_V\cdot RVP),$$

where

L'_D = Estimate of the displaced loss, gms/gallon

$\overline{T}_{DF}$ = Average dispensed fuel temperature, ^oF

$\overline{T}_V$ = Average displaced vapor temperature, ^oF

RVP = Reid vapor pressure, psi

a = −0.02645

b = 0.01155

c = −0.01226

d = 0.00246.

This model should not be used, however, for extrapolations to temperatures above 90°F.

Using published values of the average RVP for the fuels used in each of the sampled cities during each season and the 732 sets of dispensed fuel and displaced vapor temperature measurements as inputs to the regression model, an average composite displaced loss of 57.4 grams per refueling operation was obtained. Caution must be observed in the use of that number, however, since the 732 sets of temperature measurements do not constitute a statistically representative sample over all seasons or over the full service station day.

It does provide a basis, however, for obtaining an estimate of the magnitude of the refueling loss problem. When the average displaced loss of 57.4 grams per refill is divided by the average observed refill quantity, 11.5 gallons per refill, one obtains an estimated displaced loss of 5.0 grams per gallon. Similarly, the average total spill loss of 3.5 grams per refill amounts to 0.3 grams per gallon. The total refueling loss, for the sample data, thus amounts to 5.3 grams per gallon of dispensed gasoline.

Using an average fuel consumption datum of 13.4 miles per gallon published in National Petroleum News, the total refueling loss may be expressed as 0.396 grams of hydrocarbons per mile. It is of interest to contrast that result with the 1975-76 Federal Standard for exhaust emissions, which limits the unburned hydrocarbons to 0.41 grams per mile, and with the average value of unburned hydrocarbons in the exhaust of uncontrolled vehicles of about 10 grams per mile.

1.0 INTRODUCTION

1.1 THE PROBLEM

The automobile has long been recognized as a major source of the hydrocarbons in the air over our cities. Past and present investigations have measured the emissions of hydrocarbons in the automobile's exhaust gas, from the escape of combustion gases which blow by the piston rings, and from evaporation of gasoline from the vehicle's fuel system.

A source of hydrocarbon loss which had received little attention is the refueling of passenger cars. The losses encountered during refueling operations may include:

1. Displaced fuel tank vapor
2. Entrained fuel droplets in the displaced vapor
3. Liquid spillage from the tank
4. Liquid spillage from the nozzle.

Of these four loss sources, only the first (displaced fuel tank vapor) has been estimated for passenger cars.

In May, 1967, estimates of the displaced vapor loss from vehicle fuel tanks throughout the state of California were presented to the California Air Resources Board by six independent sources. These estimates placed the loss at a mean value of approximately 124 tons/day. Although the estimates varied somewhat, they were in surprisingly good general agreement, as shown in Table 1-1.

Table 1-1

Displaced Vapor Loss Estimates
for the State of California - May 1967

Bay Area Air Pollution Control District	140 Tons/Day
Los Angeles County Air Pollution Control District	133 Tons/Day
Chevron Research Company	132 Tons/Day
California State Department of Public Health	130 Tons/Day
General Motors Corporation	128 Tons/Day
Atlantic Richfield Company	80 Tons/Day

During the filling of vehicle fuel tanks, the splashing of the fuel accelerates vaporization and also produces small droplets which may be lost by entrainment. While little work had been done on this phenomenon in passenger vehicle fuel tanks, a considerable amount of work was done by the petroleum industry on the splash filling of petroleum tanks and transportation equipment (References 1, 2, and 3).

It was stated in Reference 3 that faulty design or poorly-conducted refueling operations could result in entrainment losses two to three times greater than the loss due to displaced vapor. It would not be prudent, however, to extrapolate this conclusion to automotive fuel tanks because of the differences in the tank sizes, refueling apparatus, and other equipment. A number of methods have been proposed for measuring the losses experienced in filling petroleum tanks (Reference 4). However, the accuracy of these methods was estimated to be only ±25%.

A frequent cause of liquid spillage is overfilling of the tank, resulting in fuel being forced back up the fuel fill pipe. It should be recognized, however, that some vehicles will "spit-back" liquid fuel even before the tank is full.

It is apparent from this brief discussion that, although the sources of passenger car refueling losses were recognized, little was known about the magnitudes of the losses and their occurrence frequencies. Before a meaningful assessment of the importance of these losses could be made, it was necessary to observe refueling operations in the field to determine the magnitudes and frequency of occurrence of those losses for a representative sample of service stations.

1.2 PROGRAM BACKGROUND

With mutual concern for the foregoing problem, meetings were held by the Air Pollution Research Advisory Committee (APRAC) of the Coordinating Research Council (CRC) and the National Air Pollution Control Administration of the U.S. Department of Health, Education, and Welfare (now the Office of Air and Water Programs of the Environmental Protection Agency) to initiate an investigation of passenger car refueling losses. This problem fell within the scope of the newly created APRAC-CAPE-9 Committee which was charged with studies of refueling losses in general.

On December 18, 1968 Scott Research was awarded a contract to conduct an "Investigation of Passenger Car Refueling Losses".

1.3 FIRST-YEAR PROGRAM

The first-year program was conducted in two phases. The first phase was an experimental study carried out in the laboratory to determine the amount of the losses from displaced vapor and spillage. The second phase was a field survey of service stations to determine the frequency of occurrence of gasoline spills. The laboratory study was initiated upon award of the contract; go-ahead for the field survey was subsequently received on April 16, 1969.

The laboratory study yielded information on the effect of fuel tank configuration, fill rate, vapor pressure, and fuel and vapor temperatures on the displaced losses. Additional data were obtained on the average spill loss for different fuel tank configurations filled at different fueling rates. The minimum, maximum, and average amounts of nozzle drip were determined by measurement. In order to carry out the laboratory study Scott constructed two enclosures: (1) a full-sized SHED (acronym for Sealed Housing for Evaporative Determinations) to collect spillage from an entire automobile, and (2) a MINI-SHED to collect displaced losses from fuel tanks alone. Measurements of the hydrocarbon concentrations in both SHEDs were made with a flame ionization detector (FID).

The field survey was carried out in two parts. The first part utilized Scott employees who filled out a questionnaire each time they refueled their automobiles. The questionnaires were filled out without the knowledge of the attendant. In the second part, Scott technicians surveyed several stations in the San Bernardino area for spillage and nozzle drip under the guise of determining the average amount of gasoline per fill. A coded data form allowed the technician to record number of spills and nozzle drips without an attendant's knowledge.

Significant factors contributing to individual and overall refueling losses were examined and discussed in the first-year report, but the scope of the first-year program was limited to the results of exploratory laboratory tests and a small sample of survey observations (Reference 5).

1.4 SECOND-YEAR PROGRAM

The CAPE-9 Committee concluded that an expanded field survey was necessary to supplement the relatively small sample size on which the results of the first-year program were based. Improvements in the techniques and equipment used to measure displaced losses and the development of a mathematical model for estimating displaced losses were also desired. On November 19, 1969, the CRC requested Scott to propose a one-year extension to the original program. Scott responded on December 16, 1969, and program go-ahead was received on June 30, 1970.

Refueling operations were observed in five major cities during each of the four seasons. The scope of the survey was expanded to acquire data on additional variables identified as having possible effects on refueling losses. The effects of gasoline volatility (as Reid vapor pressure (RVP)), dispensed fuel and fuel tank temperature, displaced vapor and ambient temperature, fuel tank filler pipe configuration, and refueling procedures were studied in the laboratory. The data from the field survey and the laboratory study were integrated in the analysis phase and a refueling loss model was developed.

1.5 THIRD-YEAR PROGRAM

Program go-ahead for the third and final year of effort was received on June 29, 1972. Field and laboratory effort during the third year will be devoted to the collection of data necessary to establish the operational and statistical relationships between the variables of interest in order that a mathematical model can be developed for estimating refueling losses over an air quality region (see Section 5).

2.0 APPROACH TO SECOND-YEAR PROGRAM

The sources of refueling losses were first identified and the effects of variables which relate to the magnitude of displaced losses were measured in the laboratory. Spillage and temperature data related to displaced losses were gathered at service stations in five different cities. Total refueling losses were then calculated from these data.

2.1 SOURCES OF REFUELING LOSSES

From the results of the first-year pilot program, two primary categories of refueling loss were identified.

2.1.1 Liquid Spillage

Liquid spillage was traced to four origins. In sequence of possible occurrence they are:

- Prefill drip from the nozzle while it is being handled from the pump to the vehicle
- Spit-back of gasoline from the fuel tank filler pipe resulting from pressure build-up in the vapor space in the fuel tank during the fill
- Overflow from the filler pipe when the amount of gasoline dispensed exceeds the tank capacity
- Postfill drip from the nozzle while it is being handled from the vehicle back to the pump.

2.1.2 Displaced Losses

Displaced losses were traced to vapor displaced from the tank in a volume approximately equal to the volume of gasoline dispensed and, under certain conditions, to small droplets entrained in the vapor.

2.2 LABORATORY STUDY

Displaced losses were measured directly in the laboratory under controlled conditions in which the values of 15 variables were varied (see Table 3-1). The measured losses were then regressed on those variables to provide a statistical estimate of displaced losses as a function of the significant variables.

2.3 FIELD SURVEY

The contribution of each spill source to the total refueling loss was determined from a large sample of direct observations made at service stations selected by the CAPE-9 Committee to be a representative sample. The magnitude and frequency of spillage losses were assessed by trained technicians. Variables significant to the magnitude of displaced losses were measured and recorded on a strip-chart recorder. Regression analyses were conducted to determine the existence of any significant relationships between measured parameters.

2.4 MODELING STUDY

The laboratory and field survey data were integrated and a Scott regression model for estimating refueling losses on a grams-per-gallon basis was developed. The regression model was then embedded in a general functional model to illustrate the proposed approach to the estimation of refueling losses over a region for a given unit of time. The development of the regional model is an objective of the third-year program.

3.0 LABORATORY STUDY

The procedures developed during the first-year program for measuring losses in the large SHED succeeded in accounting for about 75% of the known gasoline losses. The first objective of the second-year laboratory program, therefore, was to develop improved procedures and measurement techniques to permit essentially 100% accountability of evaporated hydrocarbons. This objective was successfully attained, as discussed in 3.2.2 below.

Displaced hydrocarbon losses were measured under carefully controlled conditions in the Scott all-weather room in accordance with the experimental plan shown in Table 3-1. The experimental program was designed to test all controlled variables for significance and to test some variables for interaction. Measured hydrocarbon losses were regressed on the variables shown in Table 3-1, the significant variables were identified, and various exponential regression estimates of the displaced losses as a function of those variables were computed.

Demonstration of the existence of entrained droplets in the displaced vapor was attempted by making loss measurements over a controlled set of variables during top fills and the corresponding set during bottom fills. (Entrained droplet loss is considered not to exist during bottom fills.) The experimentally-determined losses were regressed on the variables of interest and statistical tests of the significance of the difference between top-fill losses and bottom-fill losses were made.

3.1 MEASUREMENT OF DISPLACED LOSSES

Displaced losses were collected in the MINI-SHED and the resulting hydrocarbon concentrations measured by the flame ionization

Table 3-1
Experimental Plan

Design	Exp. Group No.	Pipe: Dia. In.	Pipe: Lgth. In.	Pipe: Device	Pipe: Entr. Deg.	Tank: Shape	Tank: Vent	Operation: Dpth. In.	Operation: Noz Deg	Operation: Rate GPM	Operation: Fill Gal.	Operation: % Comp	Operation: Fill Method	Temp.: Amb.* °F	Temp.: Disp Fuel °F
Reference	301	1.38	10	None	18	1	Tube	6	30	10.0	10.0	100	Splash	60	60
Tests For Significance	302	1.50													
	303	1.38	5												
	304		22												
	305		10	Casc.											
	306			None	45										
	307				75										
	312				18		None								
	313						Tube	3							
	314							6	120						
	315								30	5.3					
	316									12.3					
	317									10.0	5.0				
	318										20.0				
	319										10.0	50			
Temperature and Volatility Interaction	321	1.38	10	None	18	1	Tube	6	30	10.0	10.0	100	Splash	35	60
	322													35	35
	323													60	35
	324													90	60
	326													90	90
	327													60	60
	328													60	35
	329													90	60
	330													90	90
	331													35	60
	333													35	35
Vapor Only Duplicates	320	1.38	10	None	18	1	Tube	6	30	10.0	10.0	100	Subsur	60	60
	335													35	35
	325													90	60
	336													90	90
	332													35	60
	334													35	35
Tank No. 2 Duplicates	308	1.38	22	None	18	2	Tube	6	30	10.0	10.0	100	Splash	60	60
	309				45										
	310			Tube											
	311			None	75										
	337				90										

* Approximately equal to initial fuel tank temperature

detection (FID), method. Losses were calculated in accordance with the procedures specified in SAE Recommended Practice J171.

3.1.1 MINI-SHED

The SHED (acronym for Sealed Housing for Evaporative Determinations) was originally proposed by the U.S. Department of Health, Education and Welfare (DHEW) in February, 1967 (Reference 6). The function of the SHED was to capture evaporative emissions from the total passenger car for subsequent mass determinations.

An abbreviated version of the full-size SHED, the MINI-SHED is designed to collect hydrocarbon losses from vehicle fuel tanks. The net volume enclosed by the nylon reinforced vinyl skin is 150.3 cubic feet with two fuel tanks inside. Gasoline may be dispensed from the Scott Fuel Conditioning System into either tank, using a hose passing through a sealed bulkhead fitting in the aluminum floor. Tank liquid, vapor space, dispensed gasoline, and ambient temperatures are measured with thermocouples. The absence of any enclosure pressure differential is ensured by monitoring with a slant-tube water manometer.

All gasoline management can be accomplished outside the apparatus, with the exception of inserting the nozzle in the fill pipe and capping the tank. The actual refueling operation is accomplished by reaching through vinyl glove fittings in the wall of the MINI-SHED. The hydrocarbon concentration resulting from the displaced vapor and entrained droplets is measured with the FID and recorded on chart paper.

Under test conditions, the MINI-SHED was placed in the environmental chamber where the refueling operations were performed.

The fuel conditioning system was used to dispense gasoline at the temperatures specified in the experimental plan. The FID and the temperature recorder were protected in a control room adjacent to the environmental chamber.

Two passenger car fuel tanks are arranged in the MINI-SHED so that they can be refueled by a technician standing outside the sealed enclosure. Gasoline from the Scott Fuel Conditioning System is delivered through a hose and the rate of top-fill delivery is controlled by the nozzle. Subsurface fills are performed through fittings in the bottom of each tank. Valves are provided to control manually the rate of subsurface delivery. Thermocouples are located so as to measure the temperatures of the enclosed volume and the dispensed gasoline, vapor space, liquid contents, and filler pipe entrance of each tank. A sample probe connected to the FID is located in the center of the MINI-SHED. A circulating fan is provided on the floor of the enclosure to ensure a uniform concentration of hydrocarbons throughout the enclosure

Figure 3-1 shows the arrangement of these components. Necessary channels for temperature measurements during each fill are provided on a continuous strip-chart recorder. Operation of the circulation fan was found to be necessary to ensure a uniform hydrocarbon concentration throughout the enclosure. A water seal is provided at the bottom of the MINI-SHED to prevent loss of hydrocarbons from the enclosure.

3.1.2 Procedures

Displaced losses were collected in the MINI-SHED while filling fuel tanks under specified experimental conditions. The net hydrocarbon

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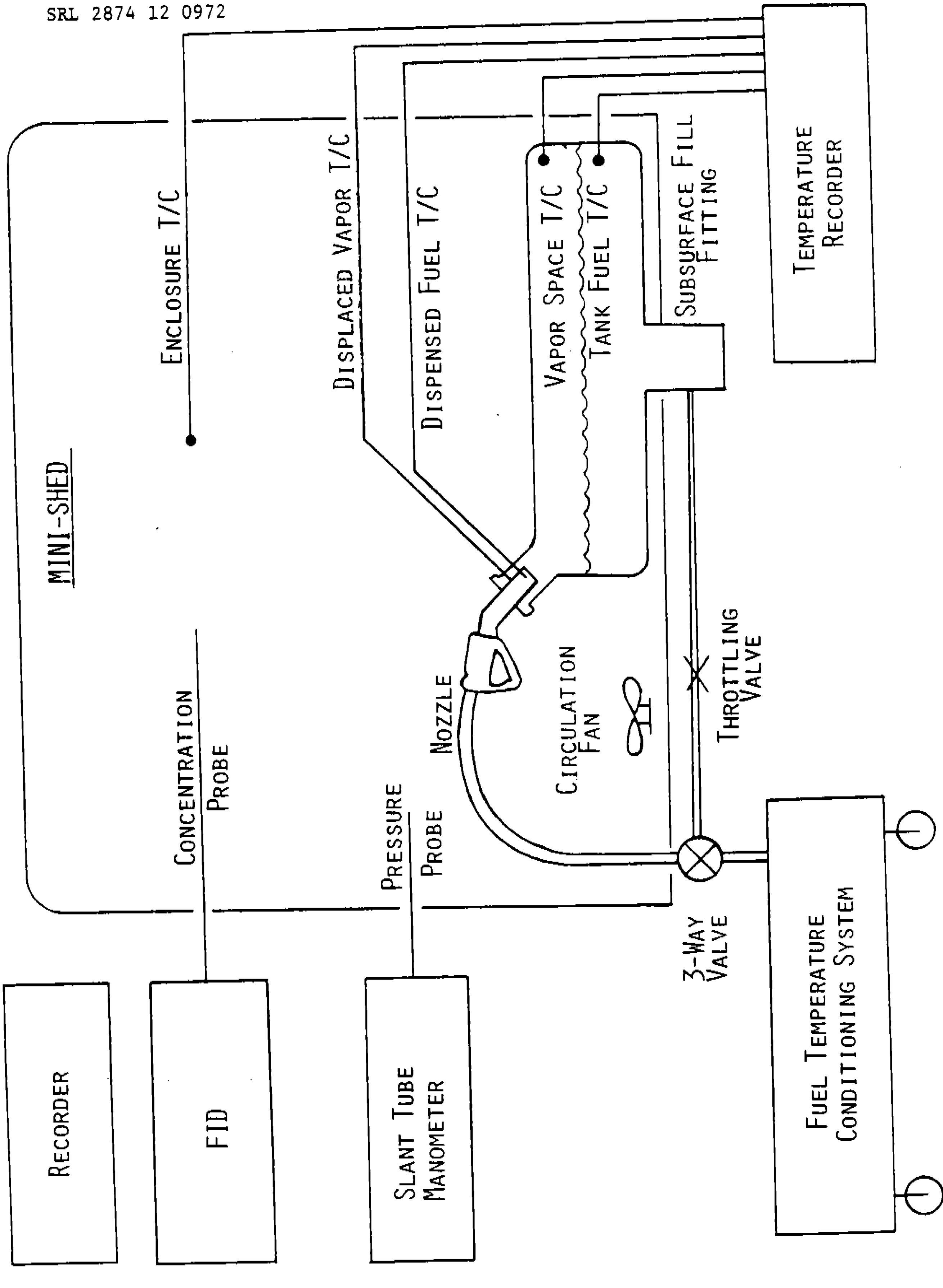

Figure 3-1 Mini-Shed with Associated Displaced Loss Measurement Apparatus

concentration increase over the initial background concentration was measured with the FID. The test procedures for these measurements are summarized as follows:

1. Establish specified temperatures
2. Purge residual hydrocarbons from MINI-SHED
3. Seal MINI-SHED
4. Turn on temperature and FID recorders
5. Calibrate FID with propane in air
6. Record background concentration
7. Uncap fuel tank
8. Dispense gasoline as specified in the experimental design (void if spit-back occurs)
9. Cap fuel tank
10. After stabilization, record final concentration
11. Recalibrate FID.

3.1.3 Gasoline Sample Analyses

Gasoline samples were analyzed by an independent laboratory. Fuel inspection data for three of the gasoline blends are presented in Appendix A. Reid vapor pressure measurements for each of 13 samples are presented in Appendix B. These data indicated weathering of the fuel had occurred because the same batch of fuel had been used over a period of several days. The weathering was most severe during the initial refueling tests, as indicated by RVP measurements of fuel samples. High-temperature tests were therefore scheduled last in order to preserve volatility as much as possible. It should also be noted that the desired RVP range was not obtained for the additional reason that ordered fuels did not have the RVP specified.

3.2 MINI-SHED VALIDATION

Experiments were performed to validate the usage of the MINI-SHED apparatus for determining refueling losses. The enclosed mixture was checked for homogeneity and the FID was checked for accurate response. The traversing apparatus used to conduct this phase of the laboratory study is shown in Figure 3-2.

3.2.1 Homogeneity of Enclosed Mixture

Determination of the gram weight of evaporated hydrocarbons must be computed from point measurements of temperature, pressure, and concentration inside the MINI-SHED. In order to ensure that these point measurements are uniform throughout the enclosure, it is necessary to detect any variation from a homogeneous mixture.

In the search for possible variations, temperature and concentration probes were moved in a three-axis traverse through the enclosure after tank refueling. Although no variation was detected in temperature, evidence of non-uniform hydrocarbon concentrations was found in the FID records.

An example of such a record is shown in Figure 3-3. With no air circulation, the hydrocarbon concentration varied throughout the enclosure between extremes of 960 to 1630 parts per million, as propane, after a typical fill of 10 gallons. The greatest concentration was found at the bottom of the MINI-SHED.

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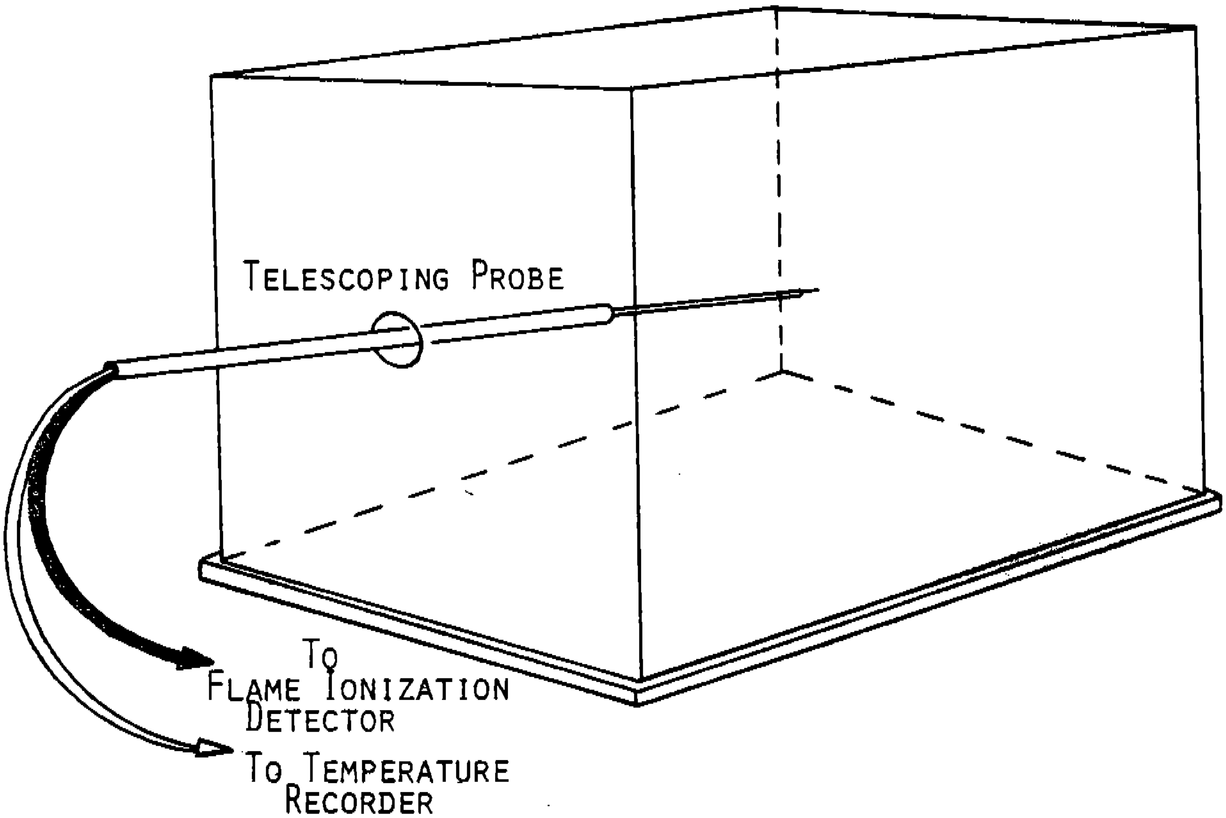

MINI-SHED

FIGURE 3-2 TRAVERSING APPARATUS: TEMPERATURE AND HYDROCARBON CONCENTRATION

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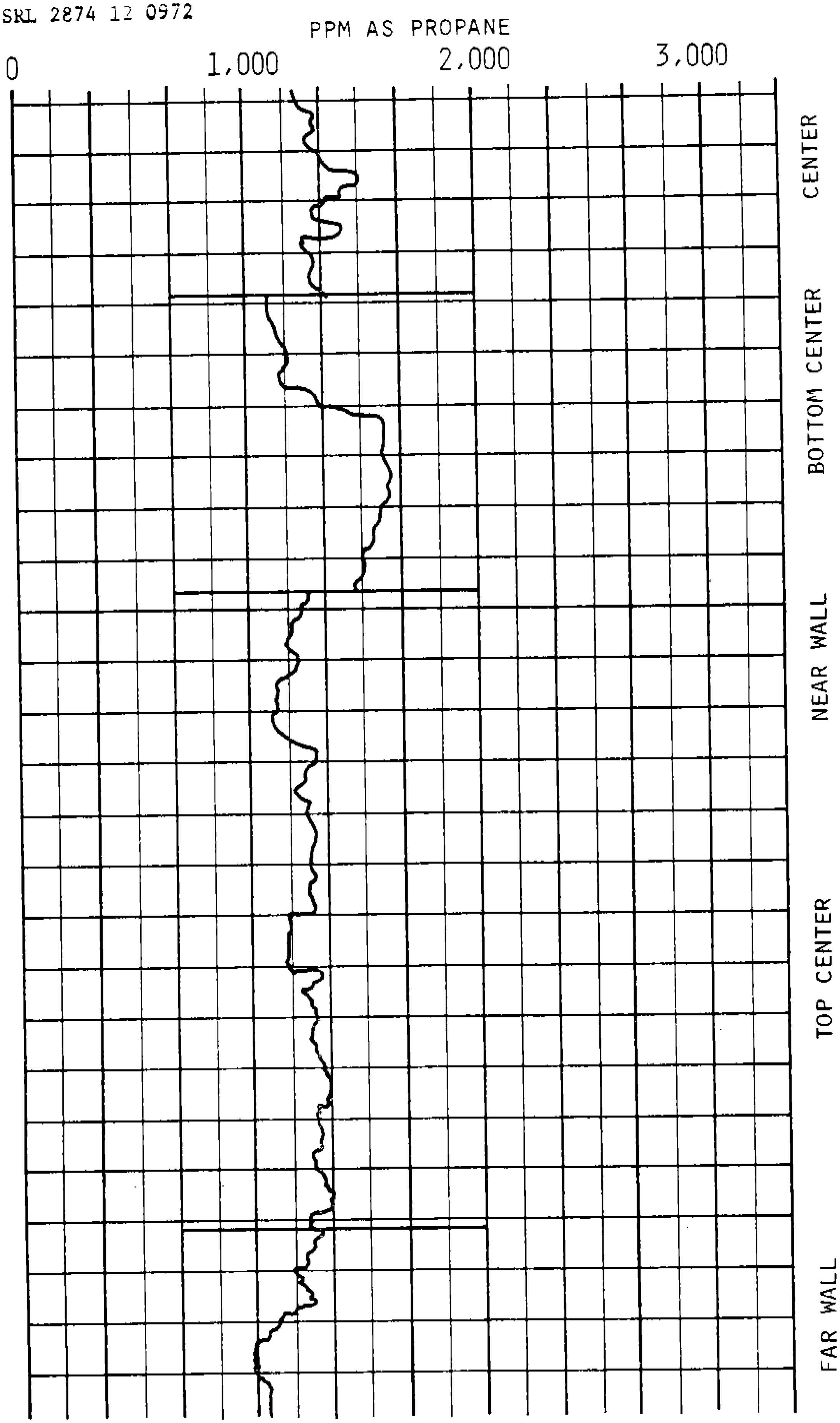

FIGURE 3-3 MINI-SHED VAPOR CONCENTRATION - NO FAN

Homogenization of this mixture was accomplished through operation of the circulation fan. A FID record of a concentration traverse with the fan operating is shown in Figure 3-4. Variation was held within 30 ppm (±2%) of an average measurement found in the center of the enclosure. Operation of this fan was therefore specified in all subsequent SHED tests.

3.2.2 FID Response

SHED measurements, as reported after the first-year investigation, succeeded in accounting for about 75% of the known gasoline losses. Essentially complete accountability of known losses was necessary, of course, if subsequent measurements of losses were to be useful. An experiment was conducted, therefore, whose objective was to identify the procedures required to ensure an adequate accounting of the known losses.

The FID response to known weights of propane injected into the MINI-SHED was first determined and an average accountability rate of 88.1% was obtained. The tests were then repeated using known weights of injected gasoline and the accountability averaged just 83.3%.

At this point attention was directed to the gas blend used to calibrate the FID. The FID had been spanned in each case using a known concentration of propane diluted in nitrogen. In contrast, hydrocarbons captured in the MINI-SHED are diluted by the enclosed air. Since it is generally accepted that oxygen reduces the FID response to hydrocarbons, the final step of the experiment consisted of injecting known weights of gasoline into the MINI-SHED and measuring the vapor concentrations with the FID now calibrated with propane in air. The accountability rate then reached a satisfactory average of 98.4%.

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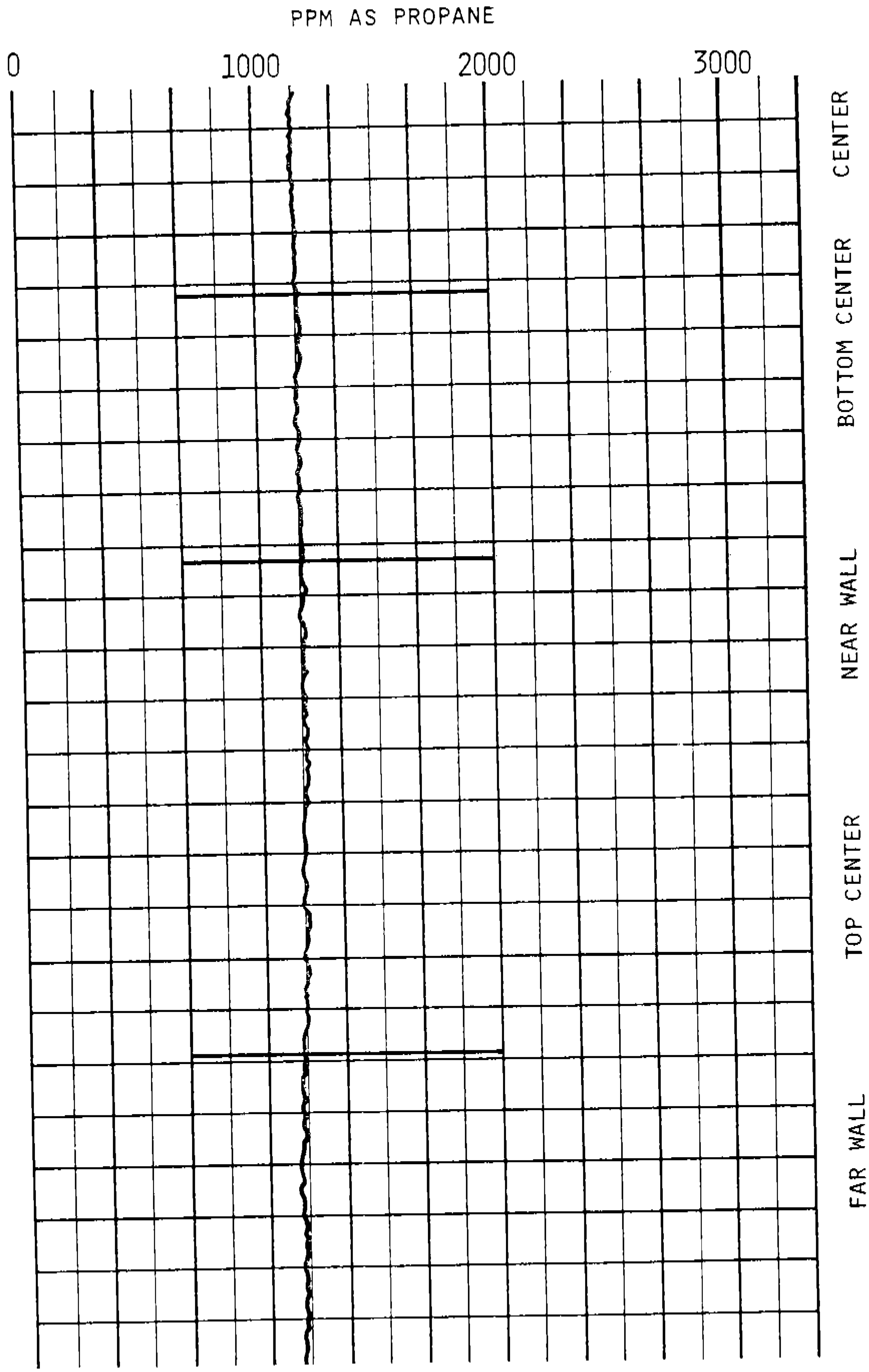

FIGURE 3-4 MINI-SHED VAPOR CONCENTRATION - WITH FAN

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3.3 MEASUREMENT OF ENTRAINED DROPLETS

The existence of entrained droplets in the vapor displaced from fuel tanks during top-fill (or splash-fill) refueling operations is a recognized phenomenon. It was presumed, therefore, that each displaced loss measured in the laboratory was the sum of a displaced vapor loss and a loss due to entrained droplets. To establish indirectly the existence of the entrained droplet loss, and to obtain preliminary estimates of its magnitude, a sample of the top-fill losses measured under controlled conditions of fill rate and temperature was compared with a sample of losses measured under the same conditions but using a bottom-fill technique.

Since entrained droples are generally believed to result from splashing and nozzle edge effects, the generation of droplets was considered to be precluded in the bottom-fill tests by filling the tank from the bottom through a fitting sized to minimize disturbance to the liquid surface inside the tank. It should be noted, however, that the bottom-fill technique may also preclude any excess fuel vaporization which may result from top filling. The test procedures during bottom filling were identical to those for top filling, except for using the bottom fitting rather than a nozzle for the actual delivery of fuel. The rate of delivery through the bottom fitting was controlled by a throttling valve adjusted to maintain the same flow rate as through the nozzle. The flow rate was kept constant throughout this experiment.

Vapor without droplets was displaced and measured under the laboratory conditions shown in the Experimental Plan in the vapor only section. These experiments were designed to duplicate the test conditions shown in the interaction section except for elimination of the nozzle.

Strict control was maintained over the initial temperatures inside the SHED, inside the tank, and of the gasoline to be dispensed during each subsurface fill operation. Gasoline samples were taken from which volatility determinations were made.

The top-fill losses were regressed on dispensed fuel temperature using a first-order exponential fit and the bottom-fill losses were similarly regressed. That is, the natural logarithm of the displaced loss was regressed on a linear function of the temperature $T = T_A = \overline{T}_{DF} = T_{TF}$, where T_A is the ambient temperature, $\overline{T}_{DF}$ is the average dispensed fuel temperature, and T_{TF} is the initial temperature of the fuel in the fuel tank. Each regression equation is thus of the form

$$L_D' = e^{a + bT} \qquad (3\text{-}1)$$

where L_D' is the estimate of displaced loss, in grams per gallon of dispensed gasoline, and a and b are constants.

In all cases the dispensed fuel temperature, tank fuel temperature, and ambient temperature was controlled to be equal. The fill rate was kept constant and the same fuel tank was used throughout this experiment. Since the experiment was conducted over a period of several days, the RVP could not be easily controlled. The regression model for displaced losses was therefore used to correct the RVP in each case to a value of 9.0 psi (see Appendix C). The correction was applied, of course, only to the measurements made during the top-fill/bottom-fill experiment.

The regression curves for the top-fill and bottom-fill losses are shown in Figure 3-5. To determine if the difference in measured losses between the two fill techniques was significant, an analysis of variance

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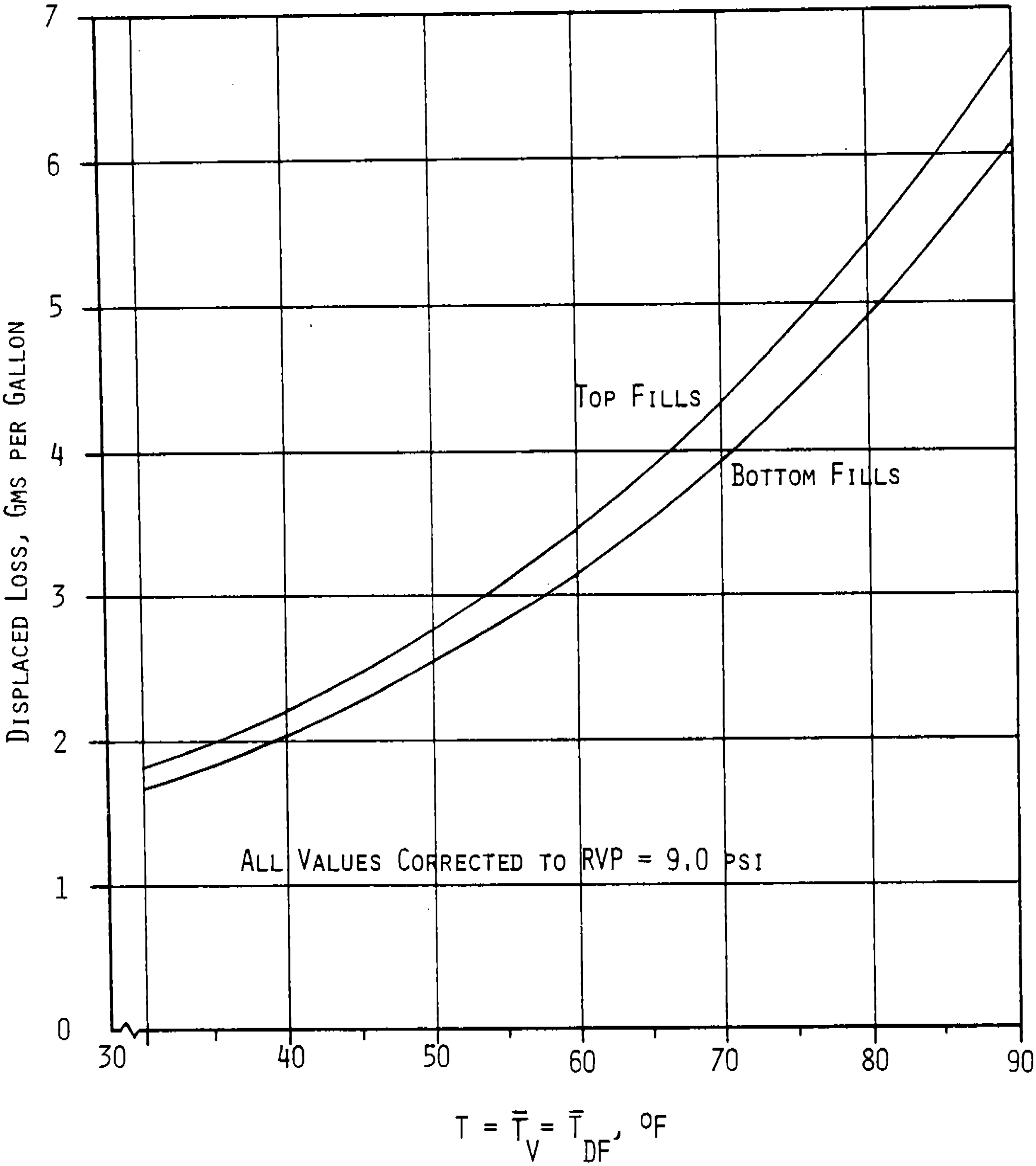

Figure 3-5 COMPARISON OF TOP-FILL AND BOTTOM-FILL DISPLACED LOSSES

(AOV) was performed on the data. As shown in the following AOV table, the two fill techniques yield displaced losses which are significantly different at greater than the 99.5% confidence level.

Summary of Analysis of Variance

Source	df	Sum of Squares	Mean Square	$F_{Comp.}$	$F_{.005}$	$F_{.10}$
A (Fill Type)	1	0.629	0.629	22.46	9.34	
B (Temperature)	2	108.433	54.216	1222.07	6.49	
A x B	2	0.172	0.086	3.07		2.51
Within Cells	27	0.760	0.028			

The finding that the interaction of type of fill and temperature is significant at the 90% confidence level requires that caution must be observed before concluding that the difference between top-fill and bottom-fill losses can be attributed to entrained droplets. That is, if excess fuel vaporization occurs with top fills, and if that phenomenon is temperature dependent, then the difference in displaced loss between fill techniques could be due primarily to excess fuel vaporization. Since the maximum difference is only about 10% at 90°F, and since passenger cars are refueled by top filling, no further investigations were conducted into this question.

3.4 RESULTS OF LABORATORY STUDY

Each of the 15 variables shown in the Experimental Plan, Table 3-1, was analyzed to determine its contribution to the magnitude of the displaced loss measured during controlled refueling operations. The significance of each variable was established with such statistical techniques as regression analysis, analysis of variance, and Student t-tests. Computer analysis of a number of regression models identified three of these variables, two temperatures and RVP, to be adequate to predict displaced losses. A listing of the various measured temperatures, the gasoline RVP, and the measured displaced loss are given in Appendix D for each experiment. The associated fill pipe, fuel tank, and operation data are given in Table 3-1.

3.4.1 Experimental Considerations

In order to maintain control over the variables in the experiment, the refueling operations were conducted in the Scott all-weather room. Consequently, the ambient temperature, the initial temperature of the fuel in the fuel tank, and the initial vapor space temperature were all essentially equal. If one of these temperatures were used as an independent variable in the regression analysis, the results obtained would not differ materially from those using either one of the other two temperatures.

Since the fuel was dispensed from the Scott Fuel Conditioning Cart, the dispensed fuel temperature was essentially constant. In the real world, of course, the dispensed fuel temperature is in the neighborhood of the ambient temperature initially, and then decreases (or increases) toward the temperature of the underground fuel as the fill progresses, the decrease resulting when the ambient temperature is greater than the underground fuel temperature, and conversely. As shown in the first-year program and verified during the present program, the average temperature of the fuel dispensed is the primary variable for estimating the displaced hydrocarbon loss. The temperature of the displaced vapor is similarly related to the ambient and underground fuel temperatures, both in the laboratory and during actual refueling operations at service stations.

Since the volatility of the dispensed fuel is clearly causal in the production of vapor, the RVP of the dispensed fuel was an important input to the analysis. Because of time and cost limitations, however, each batch of fuel was used over several experiments. The varying RVP resulting from the consequent weathering was identified by plotting RVP against date, using measured values of RVP, and then interpolating to determine the RVP for the fuel used in a particular experiment.

It was found during the first-year program that fuel tank shape was not a significant factor in the production of displaced losses. As noted in Table 3-1, this conclusion was verified in the second year of work by conducting some experiments with Tank 2 for comparison with the experiments conducted using Tank 1. Most of the experiments, however, were conducted with Tank 1. Tank 1 is a standard 22-gallon Chevrolet gasoline tank, designed for placement at the rear of the vehicle with the fill pipe terminating behind the centered license plate. A sketch of Tank 1 is shown in Figure 3-6.

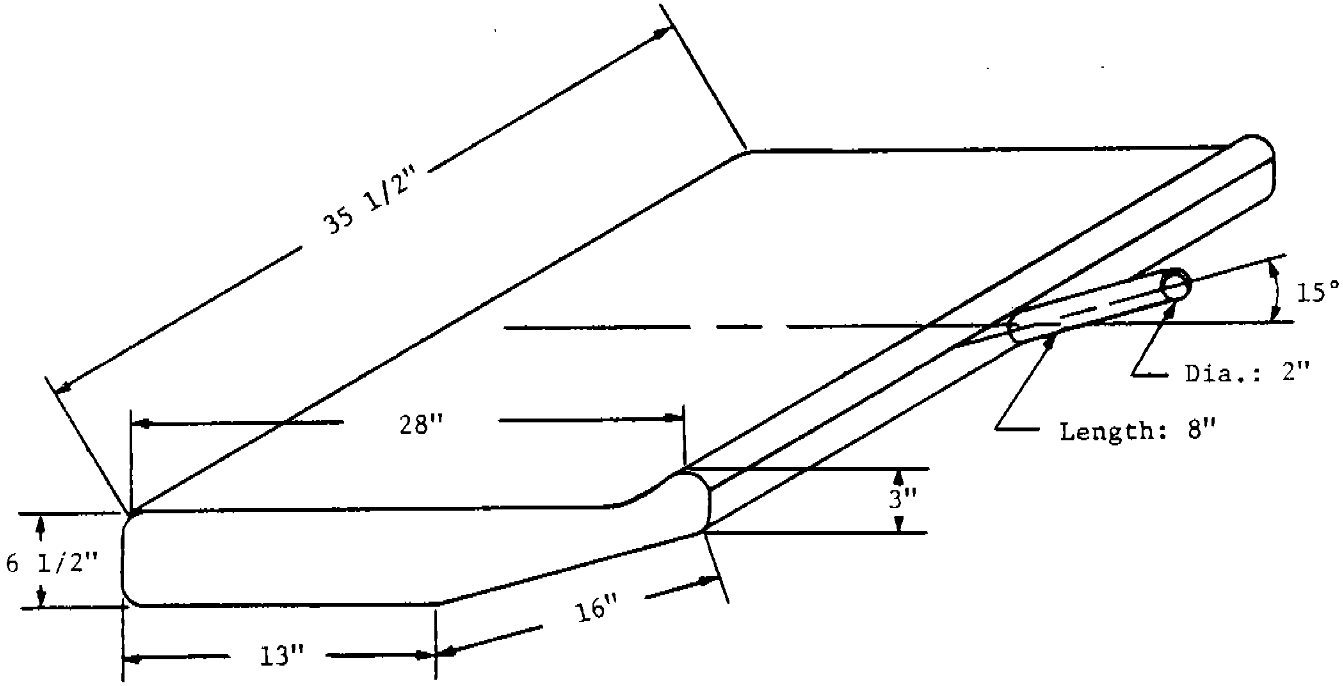

Figure 3-6 Tank Shape 1

3.4.2 Regression Analysis

The number of input variables to a regression analysis increases rapidly as a function of the number of independent experimental variables and the order of the regression. If N_I denotes the number of independent variables, including interaction variables, to be input and analyzed, then

$$N_I = \binom{V + n}{n} - 1, \qquad (3-2)$$

where V = the number of independent experimental variables

n = the order of the regression,

and the parentheses symbolize the number of combinations of V + n things taken n at a time.

Since V = 15 in the present instance, then N_I = 15 for n = 1, N_I = 136 for n = 2, and N_I = 816 for n = 3. For other than linear fits, then, not only is the large number of input variables inconvenient, but more importantly, the size of the sample of experiments is not commensurate with the number of variables. Therefore, various statistical significance tests were used to establish that two of the measured temperatures and the fuel RVP were adequate for the estimation of the displaced loss. (The symbols used from this point on are collected for convenience and defined in Table 3-2.)

Regression analyses could thus be conducted using a much smaller number of input variables. Further efficiency was obtained by using the step-wise regression technique. The first finding was that three-step regressions were adequate, the addition of further steps yielding no useful improvement in the estimates of displaced losses. Further, $\bar{T}_{DF}$ and RVP were always selected by the computer as significant variables. The third variable to be selected, as discussed in 3.4.1 above, could have been T_A, $\bar{T}_V$, T_{VS}, or T_{TF}. Since T_A and $\bar{T}_V$ were both measured during the field survey, the choice was narrowed to those two variables. The standard error of the estimate, s_e (i.e., the standard deviation of the differences between the measured losses and the losses estimated by the regression equation), was slightly smaller using $\bar{T}_V$ than when T_A was used, so $\bar{T}_V$ was chosen. It should be noted, however, that the initial temperature

Table 3-2

Symbol Definitions

RVP = Reid vapor pressure, psi

T = General temperature variable, ^{o}F

T_A = Ambient temperature, ^{o}F

$\overline{T}_{DF}$ = Average dispensed fuel temperature, ^{o}F

T_{TF} = Initial temperature of fuel in vehicle tank, ^{o}F

L'_D = Estimate of displaced loss, grams per gallon

T_{VS} = Initial vapor space temperature, ^{o}F

$\overline{T}_V$ = Average temperature of displaced vapor, ^{o}F

T_{UF} = Temperature of fuel in underground tank, ^{o}F

p_v = Partial pressure of hydrocarbon vapor, ^{o}F

L_v = Displaced vapor loss, grams per gallon of the fuel in the fuel tank would be an excellent choice since it is operationally an independent variable. It is planned to work with that variable, therefore, in the third-year program.

Linear, quadratic, and cubic regressions based on $\overline{T}_{DF}$, $\overline{T}_V$, and RVP were therefore analyzed for goodness of fit and the third-order regression was selected. That regression model for estimating displaced hydrocarbon losses, L_D', is given by

$$L_D' = 2.01570 - 0.02615\ \overline{T}_{DF} - 0.00035\ \overline{T}_V^{\,2} + 0.00013\ \overline{T}_{DF} \times \overline{T}_V \times \text{RVP}. \qquad (3\text{-}3)$$

Equation 3-3 provides a fairly good fit to the experimental data. The multiple correlation coefficient, r, between the measured displaced hydrocarbon loss and the indicated variables has the value $r = 0.947$. The coefficient of determination, r^2, which, in units of percent, gives the percentage of the variance in the data accounted for by the regression relationship, thus has the value 89.6%. Finally, the standard error of the estimate is $s_e = 0.232$ grams/gallon.

Note, however, that when RVP is held constant and $\overline{T}_{DF} = \overline{T}_V = T$, then Equation 3-3 is the quadratic

$$L_D' = a + b \cdot T + c \cdot T^2, \qquad (3\text{-}4)$$

where a, b, and c are constants. Equation 3-4 is, of course, valid under the assumptions stated and within the range of experimental temperatures which did not drop below about 30°F. If Equation 3-4 is analyzed for RVP = 9 the loss decreases to a minimum value at T = 16°F and then starts to increase again with decreasing temperature, an obvious absurdity. Great caution must always be exercised, of course, when extrapolating beyond experimental conditions. In this case, however, the extrapolation reveals that the functional form of the regression is inconsistent with the physical mechanism of displaced loss production.

An exponential form for the regression relationship provides a solution to the difficulty, provided that a good statistical fit is obtained. Therefore, the natural logarithms of the displaced losses were regressed on the variables of interest. The exponential models analyzed were thus of the form

$$L'_D = e^{f(\overline{T}_{DF},\ \overline{T}_V,\ RVP)}, \qquad (3\text{-}5)$$

where the function f was linear, quadratic, or cubic in the independent variables.

3.4.3 Selected Regression Model

Analysis of the regression models based on the functional form of Equation 3-5 revealed the quadratic f to yield better statistics than those for the linear f; the quadratic and cubic functions yielded essentially the same goodness of fit. Since the quadratic f is simpler and more convenient, it was therefore selected for fitting the data.

The regression model selected for estimating displaced hydrocarbon losses is

$$L'_D = \exp\ (a + b \cdot \overline{T}_{DF} + c \cdot \overline{T}_V + d \cdot \overline{T}_V \times RVP), \qquad (3\text{-}6)$$

where $a = -0.02645$

$b = 0.01155$

$c = -0.01226$

$d = 0.00246.$

L'_D is in units of grams/gallon of dispensed fuel, $\overline{T}_{DF}$ and $\overline{T}_V$ are in units of ^oF, and RVP is in units of pounds/square inch.

Equation 3-6 yields a multiple correlation between L'_D and the independent variables of 0.9445, the coefficient of determination is 89.2%, and the standard error of the estimate is 0.236 grams/gallon. The standard errors of the regression coefficients b, c, and d are 0.0011, 0.0018, and 0.0003, respectively. The statistics for the selected model are thus about the same as those for the model given by Equation 3-3. Further, the selected model may be extrapolated to temperatures below those used in the experimental work. While caution is always required when extrapolating from regression relationships, the decrease in the displaced loss with decreased temperature keeps the magnitude of the errors of estimation well bounded.

Conversely, when extrapolating with temperatures greater than 90^oF, the upper limit in the experimental work, the estimating errors became greater as temperatures exceed 90^oF by greater margins. Examination of the data in Appendix D reveals the sample of high-temperature cases to be fairly small. Further, the initial boiling points of the fuels (Appendix A) are in the neighborhood of 90^oF; therefore, the mechanism of vapor formation may be altered at temperatures of 90^oF and higher. Extrapolations beyond 90^oF should thus be avoided until such time as additional laboratory data at higher temperatures become available.

3.4.4 Sensitivity Analysis

After selection of the regression model, a brief sensitivity analysis was conducted. Since L'_D is a function of three variables, the sensitivity analysis might have required a number of two-dimensional slices of the three-dimensional model to be plotted. Fortunately, $\overline{T}_{DF}$ and $\overline{T}_V$ can be expected to correlate well, as indeed was observed during the field survey. Hence, since it would be incorrect to let $\overline{T}_{DF} = \overline{T}_V$ vary independently, and since the correlation between them was quite high ($r = 0.945$), it is sufficient for sensitivity purposes to let $\overline{T}_{DF} = \overline{T}_V = T$. With that assumption then, the regression model can be written for the sensitivity analysis as

$$L_D' = \exp\ (-0.02645 + 0.00071\ T + 0.00246\ T \times RVP). \qquad (3\text{-}7)$$

The sensitivity of the displaced loss to the temperature T is plotted in Figure 3-7 for fixed values of RVP equal to 7 psi, 9 psi, 11 psi, and 13 psi. While the sensitivity of the displaced loss to RVP is indicated in Figure 3-7 it may be seen more clearly in Figure 3-8 where the displaced loss is plotted as a function of RVP for fixed values of T equal to 30°F, 45°F, 60°F, 75°F, and 90°F.

It must be noted at this point, however, that refineries blend fuels with volatilities which are appropriate for the seasonal temperatures to be encountered. A fuel with an RVP of 11 or 13, for example, would never be encountered during hot weather. Conversely, during cold weather one will not encounter fuels with low RVP values. Consequently, in practice none of the curves in Figures 3-7 and 3-8 is applicable over the total range shown.

The curves in Figures 3-7 and 3-8 are given only to illustrate the sensitivity of the displaced loss to temperature and fuel volatility. The regression model, Equation 3-6, should be used to determine estimates of the loss for given values of the three input variables.

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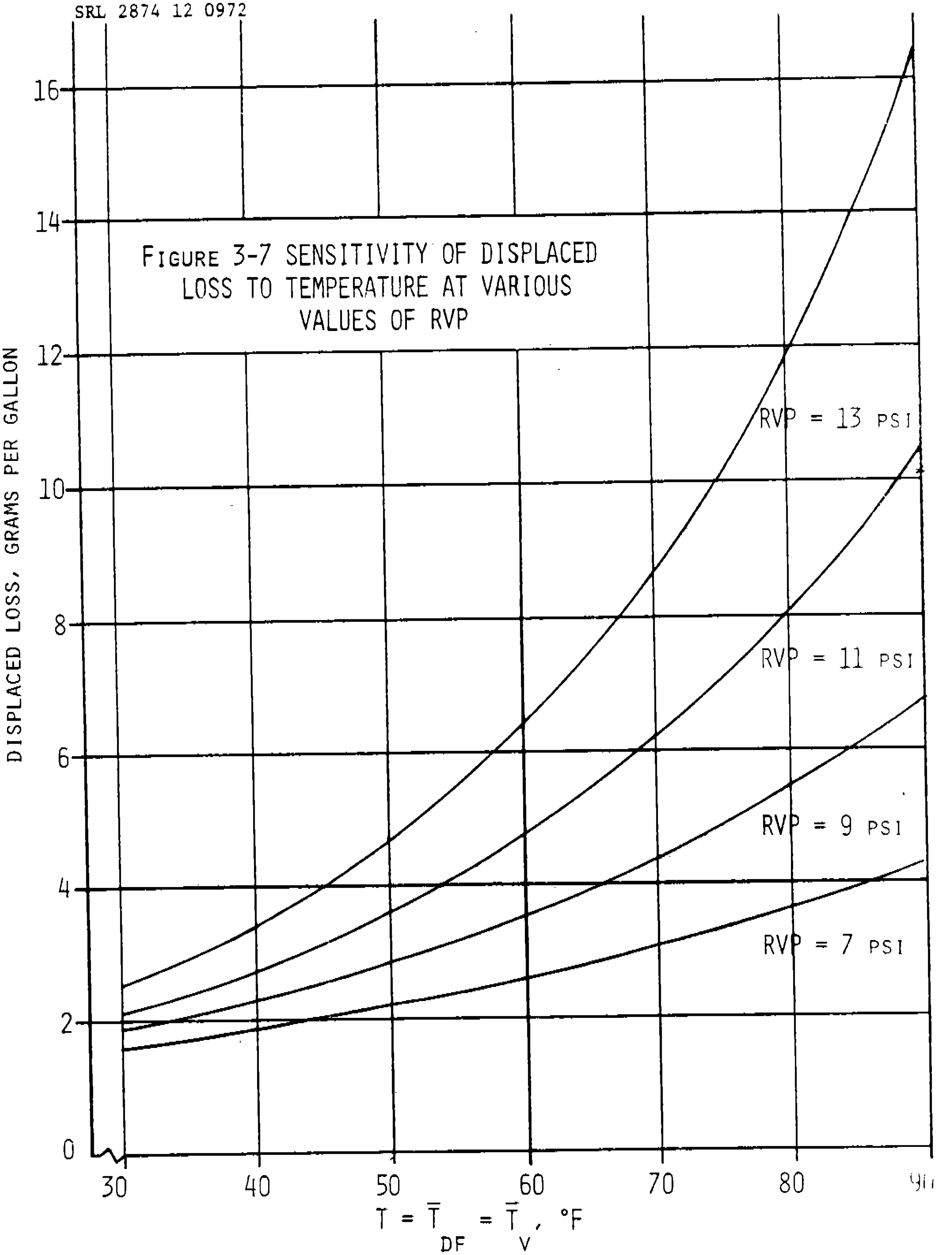

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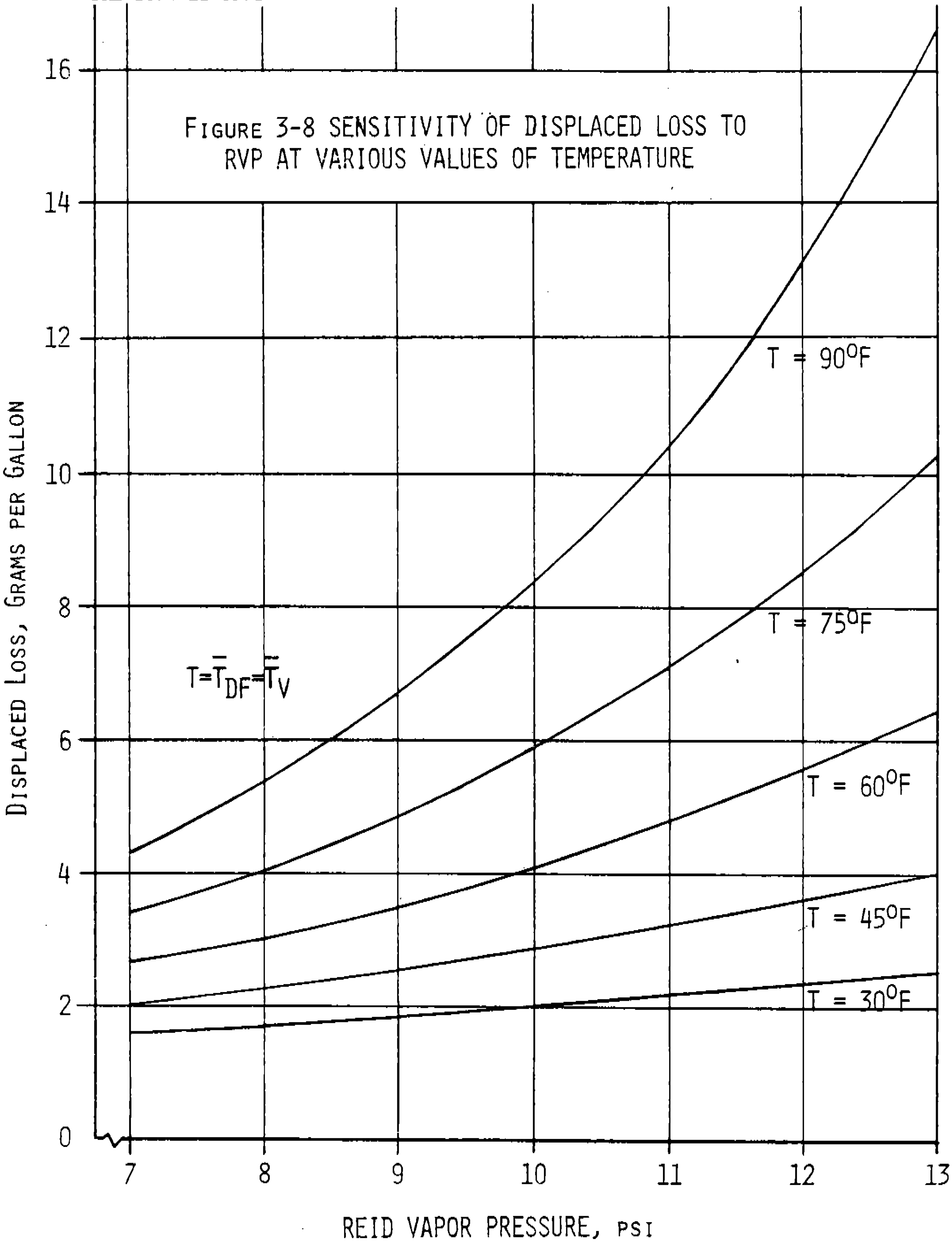

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3.4.5 Comparison of Scott Regression Model with Ideal Gas Model

The ideal gas model derived in Appendix E has the form

$$L_v = \frac{5.6515\ p_v\ (62 + 0.059\ \Delta T)}{T + 459.7}, \tag{3-8}$$

where L_v = displaced vapor loss, gms/gal

p_v = partial pressure of hydrocarbon vapor, psi

T = Vapor temperature, ^oF

$\Delta T = T - 60.$

In order to compare the loss estimated by the Scott regression model with the loss computed from the ideal gas model, again assume that $\overline{T}_{DF} = \overline{T}_V = T$ and let RVP have the nominal value 9.0 psi. Substituting that value of RVP into Equation 3-7, the Scott regression model under these assumptions is of the form

$$L_D' = \exp\ (-0.02645 + 0.02143T). \tag{3-9}$$

Plots of Equations 3-8 and 3-9 are shown in Figure 3-9. It should be observed that the ideal gas model estimates evaporative vapor loss only, while the Scott regression model estimates displaced loss during the complex, dynamic refueling operation.

The ideal gas model was also put into the exponential form of Equation 3-9 by regressing the natural logarithms of the calculated values of L_v on T. For RVP = 9.0, then, the correlation coefficient between the variables is 0.9986 and the ideal gas model can be written in the alternate form

$$L_v = \exp\ (-0.05783 + 0.01976\ T). \qquad (3\text{-}10)$$

It should be noted that while Equation 3-10 will not exactly reproduce the ideal gas plot in Figure 3-9, the fit will be found to be quite good.

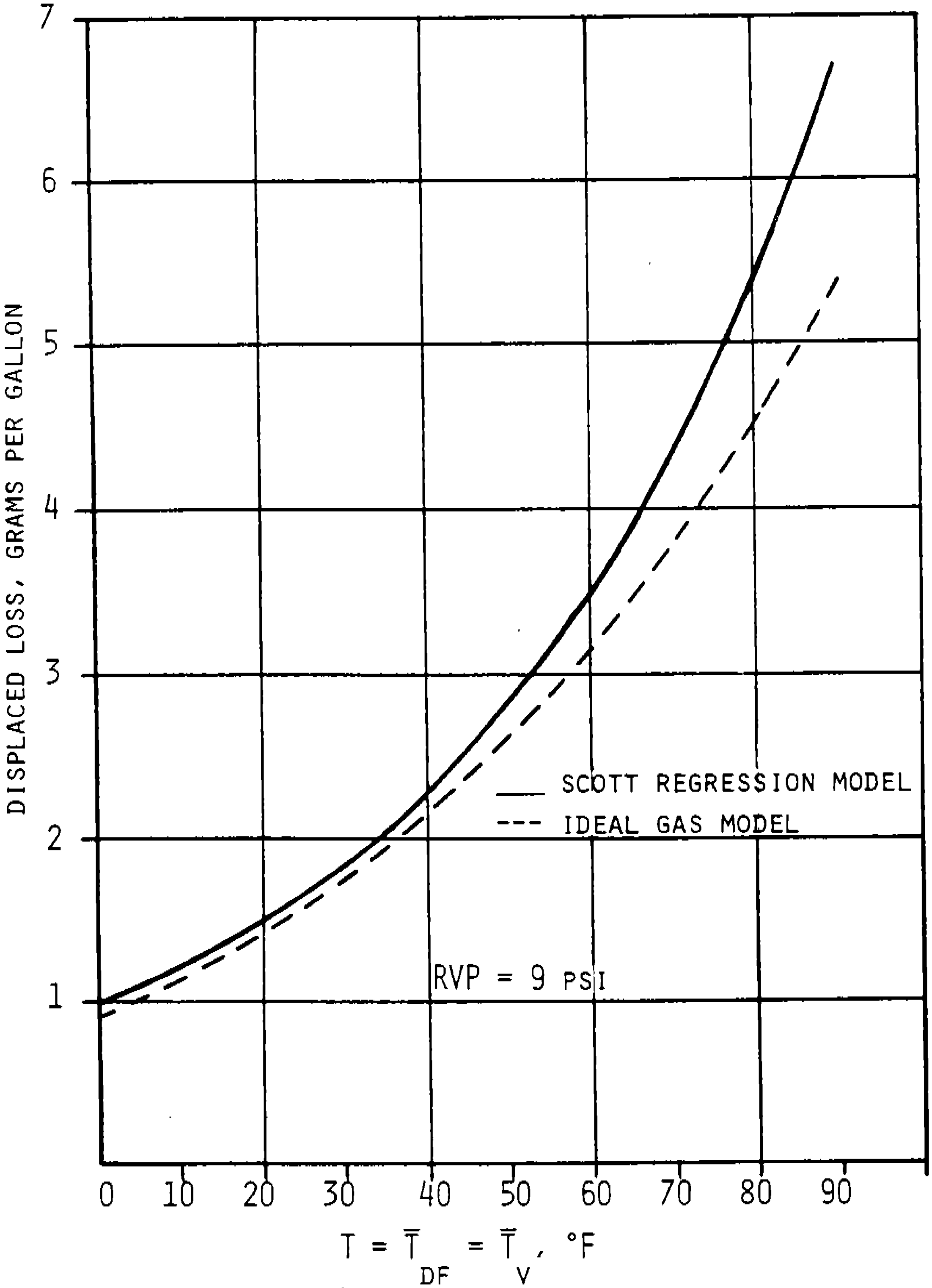

FIGURE 3-9 COMPARISON OF REGRESSION MODEL WITH IDEAL GAS MODEL

4.0 FIELD SURVEY

A brief survey of the occurrence of spill losses during refueling operations in the field was conducted during the first-year program. The major effort in the second year of the program was directed toward obtaining a large sample of refueling observations in the field to determine the magnitudes and frequencies of the various types of spill losses. In addition, an instrumented nozzle was used to record dispensed fuel temperature and displaced vapor temperature during a total of 732 refueling operations. These data were supplemented with measurements of ambient temperature and, when feasible, underground tank fuel temperature. Data were collected in five cities (chosen by the CAPE-9 Project Group) during each of the four seasons, as shown in Figure 4-1. A catalog of fuel tank and filler pipe dimensions was compiled for domestic passenger cars and coded on punched cards for the purpose of correlating those data with spill occurrence.

4.1 CATALOG OF FUEL TANK CONFIGURATIONS

Data for the fuel tank catalog were obtained from information provided by the major automobile manufacturers and from measurements of fuel tank dimensions. The latter was accomplished by dispatching a team of two technicians to a number of used car lots where tank shape, anti-spill provisions, and existence of an independent tank vent were determined by make, year, and model of vehicle. The length of the fill pipe, the inside diameter of the fill pipe, and the angle from the horizontal of the fill pipe were measured.

	1970						1971					
	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN
LOS ANGELES		X					X X			X		
HOUSTON			X			X		X		X		
ATLANTA			X			X		X		X		
NEW YORK			X			X		X			X	
CHICAGO			X			X		X			X	

FIGURE 4-1 FIELD SURVEY SCHEDULE

The vehicles included in this survey were most of the popular models among domestic makes manufactured between 1965 and 1971. A make/model code number was assigned which, when prefixed with the year of manufacture, yielded a five-digit code number which was used on the computer to correlate configuration with spill occurrence. That is, the code number was used to retrieve the dimensions data associated with that code number. During the five-city survey, therefore, it was only necessary for the surveyors to note make, year, and model of the vehicle being refueled.

4.2 SURVEYOR TRAINING

Collection of spillage data in the field required the development of a technique to permit rapid and reasonably accurate estimates of the magnitudes of the various spill types. Preliminary experimentation indicated that the magnitude of the spill, in grams, could be estimated from the spill diameter, in inches. Known weights of gasoline were therefore spilled on a concrete apron and average or equivalent wetted diameters were measured. The apron was a well-mopped smooth concrete surface typical of those found at all the service stations surveyed. The spill diameter data were then regressed on the weight data; the relationship is shown in Figure 4-2.

Two technicians were trained to estimate equivalent spill diameters with acceptable repeatability and accuracy and to recognize variations in the wetted areas as they related to equivalent diameters. To ensure consistency in estimating, the technicians were re-tested before and after each seasonal survey. As will be discussed below, the spill loss

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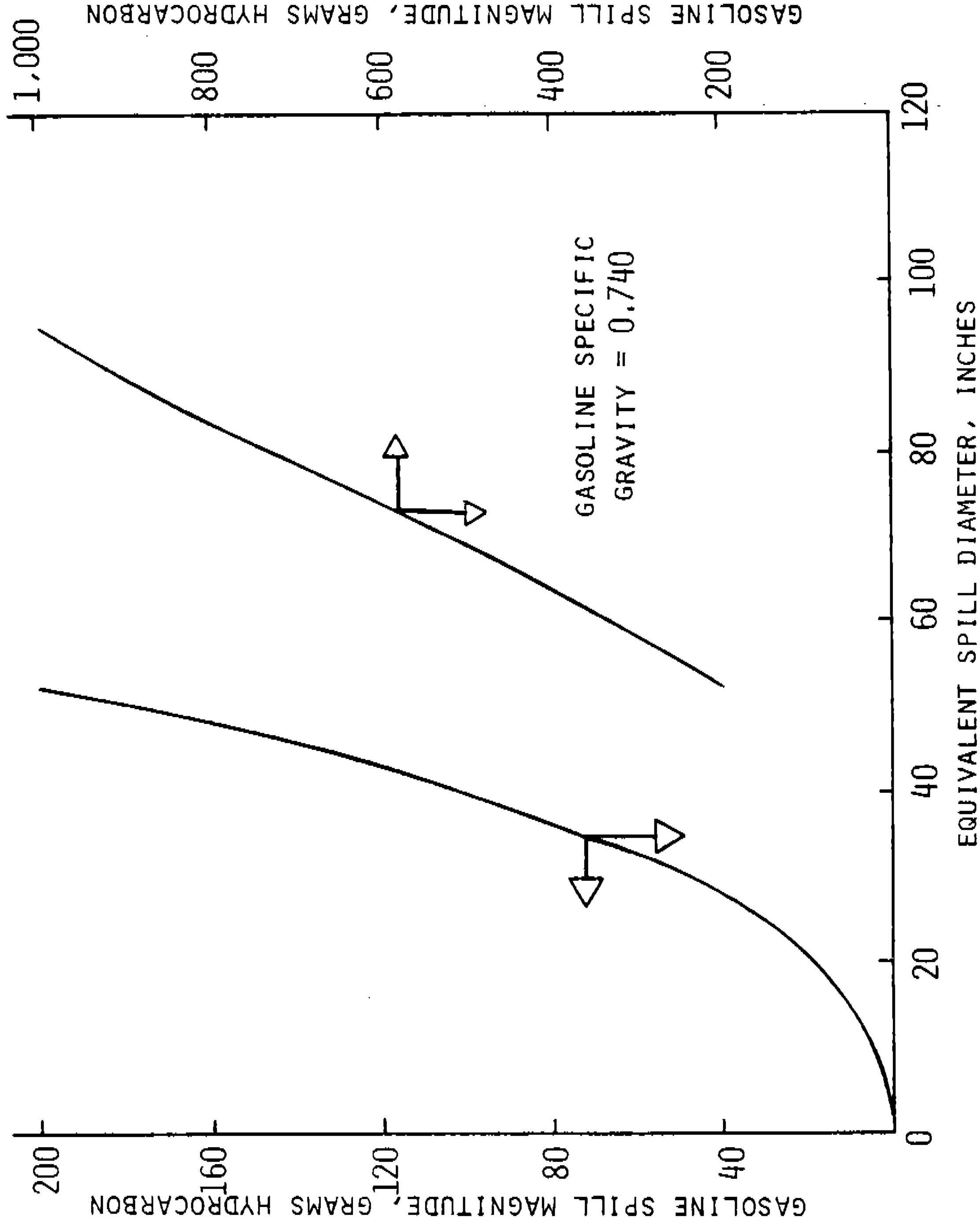

FIGURE 4-2 GASOLINE SPILL MAGNITUDE vs. EQUIVALENT SPILL DIAMETER FOR TYPICAL GASOLINE

is only about 6% of the total loss. Precise estimates are therefore not required. The achieved estimating accuracies impact the total loss by less than about 1% in each case. Further, no systematic bias in estimating accuracy was detected, so the errors tend to average out in composite computations.

4.3 SPILL OBSERVATION PROCEDURES

Two trained technicians were dispatched to five cities during each of the four seasons in accordance with the schedule in Figure 4-1. Observations and measurements were made at neighborhood service stations and at freeway-associated stations. Operations were scheduled throughout the working day.

Local oil distributors were contacted in each of the five cities to be surveyed. They were informed of the intent of the survey and were asked to cooperate in securing representative service stations where survey operations could be conducted. The station managers and attendants were told only that a consumer survey of replacement auto parts was to be performed. In order to exclude possible bias in the spill data, no mention was made of the true intention to observe the refueling techniques since that knowledge might have precipitated extraordinary care in handling. The effect of the presence of the Scott observers, if any, is unknown. It is thus prudent to consider that the results obtained may reflect spill losses closer to a minimum than to an average.

Upon arrival at the station, and with the manager's permission, the surveyor selected an observation position convenient for the observation of the refueling operation. In order to conceal the intent of the survey, the observed data were collected on a form with disguised column headings for the section in which losses and associated data were recorded. As noted above, the magnitude of the hydrocarbon loss due to spillage was recorded in the form of a spill diameter which subsequent data processing on the computer converted to grams.

At the start of each session, the surveyor recorded the date, city, season, freeway proximity, and sales volume category of the station. Immediately before each operation he noted the time, vehicle year and make/model code, and the grade of gasoline to be dispensed. The intensity of vehicular traffic through the refueling area of the service station and its impact on the attendant's apparent work load were also noted.

The observer identified each spill loss as a prefill drip, spit-back loss, overfill loss, or postfill drip. In the event that part of the spill fell on the vehicle surface, thus not contributing to the wet diameter on the ground, an estimate was made of that part of the loss and noted on the data collection form.

During each refueling operation the surveyor also noted the tooth in which the nozzle trigger was latched, the depth and angle of nozzle insertion, and whether any stretching of the hose made careful handling of the nozzle difficult.

At the conclusion of the operation, the surveyor noted whether the fill was partial or complete and recorded the total number of gallons dispensed. The attendant was then scored on the care with which he performed the refueling. This score was supplemented with an observation of whether discomfort, resulting in less care taken, could be due to wind, rain, or cold. Finally, the ambient temperature was recorded throughout the day at regular intervals.

4.4 COLLECTION OF TEMPERATURE DATA

The temperatures of the dispensed gasoline and the displaced vapor were measured with a nozzle instrumented with two thermocouples. Continuous recordings of these temperatures during the refueling operation were made with a strip-chart recorder.

The displaced vapor temperature was measured with a thermocouple attached to the top and end of a standard dispensing nozzle which, when the nozzle was inserted, was located in the annular space between the nozzle discharge tube and the fuel tank fill pipe inside wall. The hot junction was protected by a tubular shield which permitted the out-flowing vapor to impinge on the thermocouple. Dispensed gasoline temperature was measured by another thermocouple which was located inside the discharge tube of the nozzle such that the hot junction was washed by the flowing gasoline. Up to four nozzles at the service station could be instrumented in this manner. Instrumented nozzles were not used, however, at those stations where spills were being observed.

Thermocouple extension cables were routed from the service station island across the apron to a selector switch and a dual-pen strip-chart recorder. One channel recorded vapor temperature and the other recorded gasoline temperature. The switch was used to select the thermocouple pair being employed.

This apparatus suffered several design deficiencies during the early program. Initially only one nozzle, provided by Scott, was instrumented for the two temperatures of interest. Before each survey session could begin, an existing nozzle had to be removed in order to install the instrumented assembly. Consequently, only one dispenser on the island could be monitored. Leakage had to be checked and corrected after each installation and removal. Further inconvenience resulted since the two temperature potentials were charted on two independent recorders which thus had to be individually calibrated, spanned, and synchronized with the operation. Rain and cleaning water shorted out the extension wire used initially. Abrasion resulting from service station traffic caused open circuits.

Subsequent improvements in the instrumentation system produced reliable temperature measurements. The two single-channel recorders used in the summer survey were replaced by a dual-channel unit which provided synchronization of the two traces. An easily-installed dual-thermocouple probe was designed to facilitate quick attachment to existing nozzles. Four of these probes, plus a selector switch, were fabricated so that up to four dispensers on an island could be monitored. The extension cable insulation was modified and made waterproof and a plastic hose was placed around the cable bundle to protect it from vehicular abrasion.

The thermocouple probes were secured to as many as four nozzles on one island. All grades of product were instrumented. If only three grades of gasoline were being pumped, then the fourth probe was attached to another nozzle dispensing the most popular grade.

The extension cables were routed so as to cause the least interference with the operation. The cable bundle was laid across the apron to a convenient location for the recorder and selector switch. A safe zone was sought which presented the least impediment to normal service station traffic while still reserving a good vantage point for the surveyor to identify vehicles being filled.

At the start of each session the surveyor recorded the date, city, season, freeway proximity, sales volume category, and moisture content in the ambient air. Just before each operation, the surveyor selected the thermocouple probe attached to the nozzle to be used, turned on the recorder, and noted the time, vehicle year and make/model code, grade of gasoline to be dispensed, and the ambient temperature.

During each operation the surveyor noted the tooth in which the nozzle trigger was latched, the depth and angle of nozzle insertion, and the incidence of solar radiation on the hose. Vapor and gasoline temperatures were recorded throughout the fill operation. After conclusion of the fill, the surveyor turned off the recorder and noted whether a complete or partial fill had been performed, the total gallons of gasoline dispensed, and the elapsed time since the nozzle had last been used.

An example of one of these records is shown in Figure 4-3. The temperature of the gasoline originally in the nozzle is raised above ambient temperature by solar radiation, as evidenced at the beginning of the trace. As colder gasoline issues from the nozzle, the temperature falls toward the underground temperature. The displaced vapor temperature decreases from above

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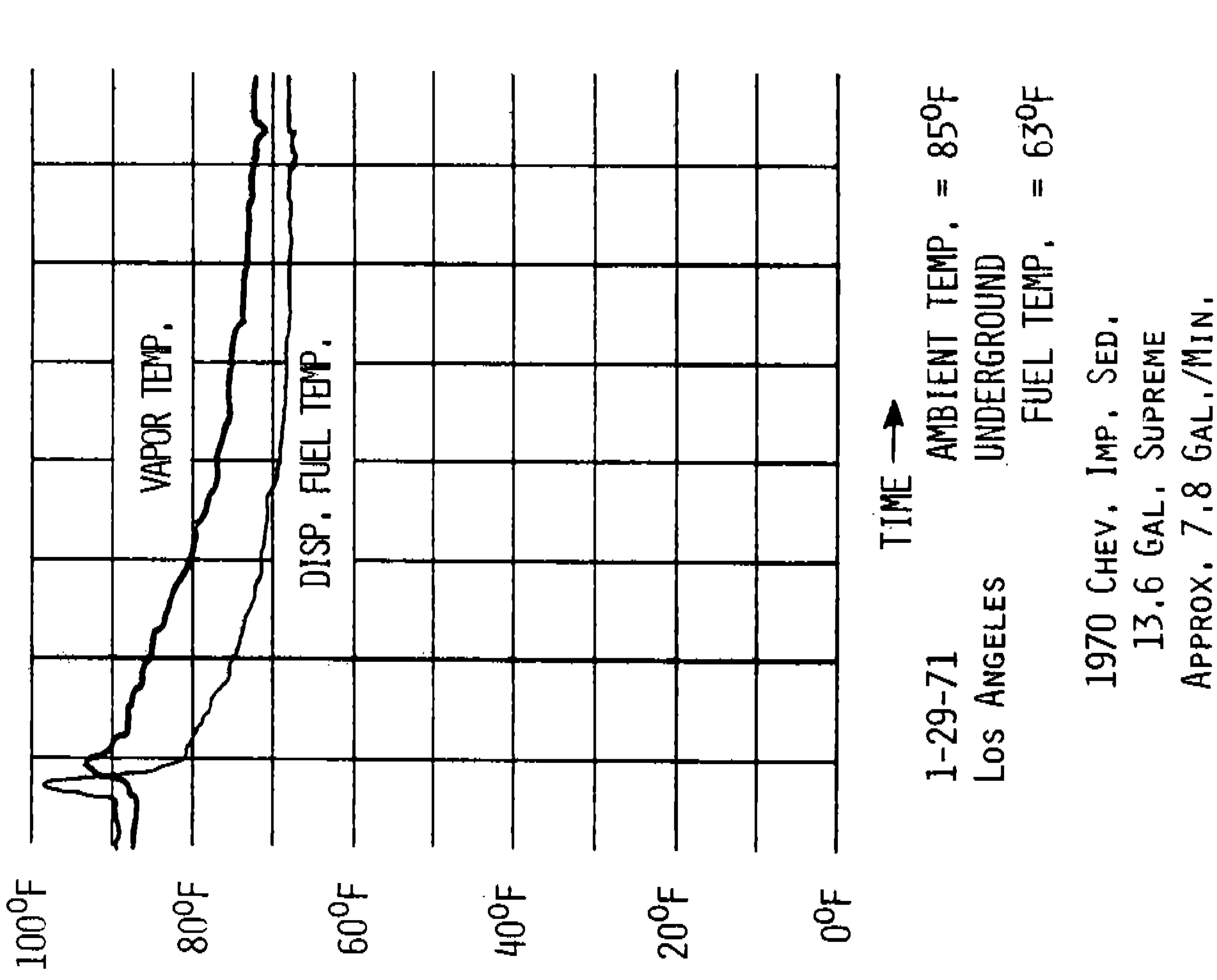

Figure 4-3 TYPICAL FIELD SURVEY TEMPERATURE RECORD

ambient to within 5° of the dispensed fuel temperature, indicating the influence of the temperature of the dispensed gasoline.

An attempt was made each day to measure the underground gasoline storage temperature in each grade of product. If a drop (delivery of truck-transported gasoline) were anticipated, the underground temperatures were measured just before and after the delivery. At several stations these measurements were unobtainable because the storage tank caps were sealed by the distributor. The collected data were transcribed to a convenient format for punching cards and computer processing. Average observed underground gasoline storage temperatures, the associated sample sizes, and the range are given in Table 4-1 for the three grades of gasoline dispensed. Data for the ambient temperatures measured at the same time as the dispensed fuel and displaced vapor measurements are summarized in Table 4-2. The average observed dispensed gasoline temperatures and the average observed displaced vapor temperatures for each city/season, together with sample sizes and ranges, are shown in Table 4-3. Table 4-4 lists the average Reid vapor pressures reported by the Ethyl Corporation for the cities of interest during the months surveyed (References 7 through 11). Computer printouts of the field survey temperature data are given in Appendix F.

Table 4-1

Underground Gasoline Temperatures

City	Season	UNLEADED Sample Size	UNLEADED Avge. Temp, Deg.F	UNLEADED Range, Deg.F	REGULAR Sample Size	REGULAR Avge. Temp, Deg.F	REGULAR Range, Deg.F	SUPER Sample Size	SUPER Avge. Temp, Deg.F	SUPER Range, Deg.F
Los Angeles	Winter	3	66	65-66	3	64	63-65	3	64	63-66*
	Spring	1	70	70-70	1	69	69-69	1	68	68-68
	Summer	-	--	--	-	--	--	-	--	--
	Fall	4	66	64-68*	4	62	60-65*	4	60	57-64*
Houston	Winter	1	65	65-65	1	67	67-67	1	67	67-67
	Spring	7	75	74-75	7	73	73-73	7	75	74-75
	Summer	-	--	--	-	--	--	-	--	--
	Fall	-	--	--	-	--	--	-	--	--
Chicago	Winter	1	45	45-45	1	36	36-36	1	36	36-36
	Spring	2	52	52-52	2	50	50-50	2	51	51-51
	Summer	-	--	--	-	--	--	-	--	--
	Fall	3	50	49-50	3	41	41-41	4	42	42-42
New York	Winter	1	41	41-41	1	39	39-39	1	40	40-40
	Spring	4	51	51-51	4	51	51-51	4	51	51-52
	Summer	-	--	--	-	--	--	-	--	--
	Fall	3	50	48-52*	3	51	50-52*	3	50	49-52*
Atlanta	Winter	2	42	33-51*	2	42	32-53*	2	29	27-31*
	Spring	7	62	62-62	7	63	63-63	7	64	64-64
	Summer	-	--	--	-	--	--	-	--	--
	Fall	1	60	60-60	1	56	56-56	1	58	58-58

Note: A dash indicates no data were collected.
*Includes measurements made before and after a fuel drop.

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Table 4-2

Summary of Observed Ambient Temperatures

City	Season	AMBIENT TEMPERATURE Sample Size	Avge., Deg F	Range, Deg F
Los Angeles	Winter	51	73	58 - 90
	Spring	49	75	69 - 80
	Summer	4	88	88 - 88
	Fall	44	52	33 - 57
Houston	Winter	52	61	45 - 77
	Spring	56	75	63 - 85
	Summer	33	90	83 - 98
	Fall	--	--	--
Chicago	Winter	41	40	33 - 50
	Spring	52	68	58 - 72
	Summer	23	76	72 - 82
	Fall	55	40	31 - 48
New York	Winter	35	41	30 - 55
	Spring	49	63	39 - 72
	Summer	15	75	59 - 93
	Fall	29	54	45 - 65
Atlanta	Winter	53	29	22 - 41
	Spring	54	67	56 - 73
	Summer	15	85	79 - 90
	Fall	22	47	42 - 52

Note: A dash indicates no data were collected.

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Table 4-3

Summary of Observed Fuel and Vapor Temperatures

		AVERAGE DISPENSED FUEL TEMPERATURE			AVERAGE DISPLACED VAPOR TEMPERATURE		
City	Season	Sample Size	Avge, Deg.F	Range, Deg.F	Sample Size	Avge, Deg.F	Range, Deg.F
Los Angeles	Winter	51	68	62 - 77	51	72	62 - 85
	Spring	49	74	71 - 79	49	77	70 - 83
	Summer	4	87	85 - 89	4	90	85 - 92
	Fall	44	60	46 - 64	44	60	42 - 70
Houston	Winter	52	69	56 - 75	52	67	53 - 82
	Spring	56	75	67 - 80	56	77	65 - 86
	Summer	33	91	88 - 97	33	93	87 -101
	Fall	--	--	--	--	--	--
Chicago	Winter	41	38	36 - 44	41	44	34 - 62
	Spring	52	56	52 - 63	52	66	57 - 79
	Summer	23	78	76 - 86	23	79	68 - 89
	Fall	55	44	40 - 47	55	44	35 - 50
New York	Winter	35	40	37 - 51	35	42	37 - 53
	Spring	49	57	54 - 62	49	63	55 - 75
	Summer	15	69	49 - 82	15	72	52 - 93
	Fall	29	52	45 - 60	29	54	46 - 66
Atlanta	Winter	53	46	40 - 49	53	45	30 - 60
	Spring	54	66	64 - 69	54	69	61 - 75
	Summer	15	85	82 - 88	15	90	83 - 97
	Fall	22	55	46 - 67	22	52	43 - 58

Note: A dash indicates no data were collected.

Table 4-4

AVERAGE PUBLISHED GASOLINE VOLATILITY
(Reid Vapor Pressure, psi)

CITY	SEASON			
	WINTER	SPRING	SUMMER	FALL
LOS ANGELES	11.1	9.7	8.4	9.8
HOUSTON	11.7	10.0	8.8	9.8
ATLANTA	12.0	10.6	9.0	10.1
NEW YORK	13.2	11.2	9.0	11.1
CHICAGO	12.7	11.4	9.2	10.5

4.5 RESULTS OF SPILL LOSS SURVEY

After completion of the survey for each season, the data relevant to spills were transcribed to a coding form and then punched on cards for computer compilation and analysis. Spill-data summaries for the four seasons are given in Tables 4-5 through 4-8, the four season composite data by type of spill are given in Table 4-9, and the composite data summary for all seasons and all spills is given in Table 4-10.

In each of the summary data tables the total number of losses is less than the sum of the number of losses for the four spill types. The reason for this result is the occurrence of refueling operations where more that one spill type occurs during the refueling event. Since the desired loss measure is in units of grams per observation, or refueling event, the total number of losses must be the total number of refueling events where at least one spill occurred.

In each sub-section of the data tables corresponding to each type of loss, the number of losses is the number of spills of that type. The average loss is then the total loss for that spill type divided by the number of spills of that type. The probability of that type of loss is simply the number of losses of that type divided by the total number of observations, or refueling events. In the subsection for the totals, the probability of a spill loss is the number of refueling operations in which at least one spill occurred divided by the total number of refueling events.

Table 4-5

REFUELING SPILL LOSS SUMMARY

Summer Survey

City	N	Spit-back Loss		Overfill Loss		Nozzle Loss (Prefill)		Nozzle Loss (Postfill)	
		Average Loss, Grams	Loss Prob	Average Loss, Grams	Loss Prob	Average Loss, Grams	Loss Prob	Average Loss, Grams	Loss Prob
Los Angeles	124	2.4	0.032	2.3	0.065	6.0	0.008	0.4	0.024
Houston	205	261.7	0.054	10.6	0.239	1.2	0.059	4.6	0.132
Chicago	317	4.5	0.066	18.7	0.063	2.5	0.019	2.1	0.022
New York	512	3.4	0.063	34.2	0.070	7.5	0.008	1.6	0.035
Atlanta	340	5.1	0.038	3.7	0.044	3.6	0.015	4.1	0.021
Composite	1498	39.0	0.054	17.2	0.085	3.0	0.019	3.2	0.041

TABLE 4-6

REFUELING SPILL LOSS SUMMARY

FALL SURVEY

		Spit-back Loss		Overfill Loss		Nozzle Loss (Prefill)		Nozzle Loss (Postfill)	
City	N	Average Loss, Grams	Loss Prob	Average Loss, Grams	Loss Prob	Average Loss, Grams	Loss Prob	Average Loss, Grams	Loss Prob
Los Angeles	308	11.1	0.153	7.8	0.211	10.5	0.042	2.0	0.214
Houston	351	12.6	0.095	10.8	0.074	6.5	0.031	5.5	0.034
Chicago	330	22.3	0.064	78.4	0.033	13.7	0.021	5.8	0.030
New York	405	14.0	0.165	9.0	0.106	14.7	0.057	5.9	0.111
Atlanta	344	9.3	0.035	11.3	0.029	6.4	0.035	5.5	0.017
Composite	1738	13.6	0.102	15.4	0.089	10.9	0.038	4.0	0.080

TABLE 4-7

REFUELING SPILL LOSS SUMMARY

WINTER SURVEY

		Spit-back Loss		Overfill Loss		Nozzle Loss (Prefill)		Nozzle Loss (Postfill)	
City	N	Average Loss, Grams	Loss Prob	Average Loss, Grams	Loss Prob	Average Loss, Grams	Loss Prob	Average Loss, Grams	Loss Prob
Los Angeles	268	9.8	0.187	5.3	0.243	5.0	0.060	3.0	0.209
Houston	326	7.8	0.227	7.4	0.230	5.0	0.049	2.8	0.172
Chicago	230	10.6	0.157	2.4	0.135	2.6	0.087	1.6	0.283
New York	249	5.7	0.145	3.1	0.185	5.2	0.088	1.3	0.498
Atlanta	317	10.4	0.221	5.3	0.240	2.3	0.047	1.1	0.319
Composite	1390	9.0	0.191	5.2	0.211	4.0	0.064	1.7	0.289

TABLE 4-8

REFUELING SPILL LOSS SUMMARY

SPRING SURVEY

City	N	Spit-Back Loss		Overfill Loss		Nozzle Loss (Prefill)		Nozzle Loss (Postfill)	
		Average Loss, Grams	Loss Prob	Average Loss, Grams	Loss Prob	Average Loss, Grams	Loss Prob	Average Loss, Grams	Loss Prob
Los Angeles	305	11.4	0.177	2.8	0.131	10.5	0.043	1.1	0.269
Houston	405	19.1	0.193	6.6	0.212	3.2	0.025	1.4	0.272
Chicago	357	3.8	0.137	4.4	0.174	1.9	0.031	1.2	0.193
New York	349	8.6	0.195	5.6	0.261	0.4	0.009	0.9	0.341
Atlanta	377	8.5	0.133	4.1	0.127	0.9	0.029	0.9	0.268
Composite	1793	11.0	0.167	5.1	0.182	4.2	0.027	1.1	0.268

TABLE 4-9

REFUELING SPILL LOSS SUMMARY

FOUR-SEASON COMPOSITE

		Spit-back Loss		Overfill Loss		Nozzle Loss (Prefill)		Nozzle Loss (Postfill)	
City	N	Average Loss, Grams	Loss Prob	Average Loss, Grams	Loss Prob	Average Loss, Grams	Loss Prob	Average Loss, Grams	Loss Prob
Los Angeles	1005	10.6	0.154	5.5	0.177	8.3	0.043	1.9	0.206
Houston	1287	27.6	0.150	9.1	0.183	4.1	0.038	2.4	0.159
Chicago	1234	8.9	0.103	12.7	0.100	4.2	0.036	1.7	0.122
New York	1515	9.0	0.134	10.5	0.143	9.3	0.034	1.9	0.202
Atlanta	1378	9.2	0.105	5.2	0.108	3.2	0.031	1.2	0.156
Composite	6419	13.7	0.128	8.6	0.141	5.9	0.036	1.8	0.169

TABLE 4-10

TOTAL SPILL LOSS SUMMARY

FOUR-SEASON COMPOSITE

CITY	N	AVERAGE REFILL, GALLONS	NO. OF REF. OPERATIONS WITH SPILLS	AVERAGE SPILL LOSS, GRAMS	SPILL LOSS FREQ., %	AVERAGE SPILL LOSS, GMS/REFILL
LOS ANGELES	1005	11.8	392	8.6	39.0	3.3
HOUSTON	1287	12.8	480	17.0	37.3	6.3
CHICAGO	1234	11.7	321	9.8	26.0	2.6
NEW YORK	1515	10.0	546	9.5	36.0	3.4
ATLANTA	1378	11.5	372	6.7	27.0	1.8
COMPOSITE	6419	11.5	2111	10.6	32.9	3.5

The result of primary interest, of course, is that the combined spill losses from all sources, averaged over all refueling operations, amount to just 3.5 grams per refueling event. Using a national average fuel consumption estimate of 13.4 miles per gallon, published in the 1971 National Petroleum News statistical issue, and using the composite average fill datum of 11.5 gallons, the spill loss thus averages out to just 0.023 grams per mile.

4.6 ANALYSIS OF SPILL DATA

The liquid spill data obtained during the first-year refueling loss field survey indicated that these spills may be related to various parameters that can be measured and recorded during each observed refueling operation. These refueling parameters include items of service station information, automobile fuel tank configuration, operator technique, and operator discomfort indices.

Since the spring survey data were the most complete with respect to these refueling parameters, a sub-sample of the spring data, consisting of 1063 refueling operations for which complete data were available, was subjected to analysis. Each type of spill was analyzed with the step-wise multiple linear regression technique in two ways. The magnitude of the spill for each type was regressed on the refueling parameters for just those cases where a spill had occurred. The occurrence of each type of spill, on a go/no-go basis, was regressed on the appropriate parameters for all 1063 data points. A subset of all the refueling parameters was input to the analyses of each spill type, since some refueling parameters are clearly independent of any given type of fill; e.g., fill pipe length does not affect prefill or postfill nozzle losses.

The results of the regression analyses are presented in Tables 4-11 through 4-19. The parameters found to be significant are listed in their computer-selected order of effect on the dependent variable (the spill). The number of data points, the multiple correlation coefficient, r, and the coefficient of determination, r^2, are given for each case. A description of the effect and a listing of the non-significant input parameters are also included in the tables.

Each step-wise multiple linear regression analysis was terminated when the addition of a new refueling parameter into the regression did not significantly reduce the error sum of squares, as tested with the Fisher F. Significant parameters were determined in all but one of the analyses; however, the standard error for each equation is relatively large and the coefficients of determination are quite small, so that the spill loss measures are not predictable with the regression equations.

Tables 4-11 and 4-12 show the regression results for magnitude and probability of prefill nozzle losses. The low number of observed spills is due to the fact that frequently no gasoline was in the nozzle so that none could be spilled, even when the nozzle was held in a position that would otherwise cause a spill. Evaporation of gasoline from the nozzle between fills, the existence of postfill nozzle losses, and emptying of nozzle are primary causes of no gasoline in the nozzle at the beginning of each fill.

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Table 4-11

Regression of Magnitude of Prefill Nozzle Loss on Refueling Parameters

Parameters	Number of Data Points	r	r^2	Description of Parameter Effect
Significant:				
Operator technique	25	0.528	0.279	Spill larger with poor technique
Non-Significant:				
Operator work load				
Station location				
Station monthly volume				
Current station work load				
Uncomfortable temperature				
Uncomfortable wind				
Uncomfortable rain				
Hose extension required for fill				
Deviation of nozzle insertion from vertical				
Fuel tank fill pipe angle from horizontal				

Table 4-12

Regression of Probability of Prefill Nozzle Loss on Refueling Parameters

Parameters	Number of Data Points	r	r^2	Description of Parameter Effect
Significant:				
Deviation of nozzle insertion from vertical	1063	0.062	0.004	Higher probability with more horizontal nozzle orientation
Non-Significant:				
Operator technique				
Operator work load				
Station location				
Station monthly volume				
Current station work load				
Uncomfortable temperature				
Uncomfortable wind				
Uncomfortable rain				
Hose extension required for fill				
Fuel fill pipe angle from horizontal				

Operator technique is the only significant parameter affecting prefill nozzle loss magnitude. The deviation of nozzle insertion from the vertical affects the probability of a prefill nozzle loss because, as the nozzle is rotated to the left or right (more horizontal), the more readily that gasoline can drip from the nozzle.

No significant variables were found in the analysis of the magnitude of spit-back losses (Table 4-13). Four parameters, however, were found to affect significantly the probability of a spit-back loss (Table 4-14). The probability of a spit-back is greater for complete fills, since pressure build-up in the tank is more likely when the tank is nearly full. The higher probability of spit-back for the flat, horizontal type of tanks may be due to the fact that many of these tanks have fill pipes which are more horizontal than are those for the vertical fender type. A faster filling rate is likely to cause a more rapid and severe pressure build-up in the fuel tank, resulting in a higher probability of spit-back loss. Shallow nozzle insertion during refueling allows gasoline to leave the nozzle and enter the fuel tank fill pipe near the cap end where a pressure build-up in the tank can force the gasoline out more easily than when the nozzle is fully inserted into the fill pipe.

Refueling parameters depicting service station characteristics appear to affect the magnitude of overfills most significantly (Table 4-15). Non-freeway stations and low-volume stations tended to have larger overfills than did freeway and high-volume stations. This may be due to the fact that these stations normally do not have full-time people just to pump gasoline. The attendent, therefore, may be more rushed or he may tend to put as much gasoline into the tank as possible,

Table 4-13

Regression of Magnitude of Spit-back Loss on Refueling Parameters

Parameters	Number of Data Points	r	r^2	Description of Parameter Effect
Significant:				
None	182			None
Non-Significant:				
Fuel tank fill pipe diameter				
Fuel tank fill pipe length				
Fuel tank fill pipe angle from horizontal				
Fuel tank shape				
Fuel tank vented				
Anti-spill device in fuel tank				
Filling rate				
Depth of nozzle insertion				
Deviation of nozzle insertion from vertical				
Fill completion				

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Table 4-14

Regression of Probability of Spit-back Loss on Refueling Parameters

Parameters	Number of Data Points	r	r^2	Description of Parameter Effect
Significant:				
Fill completion	1063	0.226	0.051	Higher probability for complete fill
Fuel tank shape	1063	0.325	0.106	Higher probability for flat tank than vertical fender type
Filling rate	1063	0.339	0.115	Higher probability for faster rate
Depth of nozzle insertion	1063	0.354	0.125	Higher probability for shallow insertion
Non-Significant:				
Station location				
Station monthly volume				
Fuel tank fill pipe diameter				
Fuel tank fill pipe length				
Fuel tank fill pipe angle from horizontal				
Fuel tank vented				
Anti-spill device in fuel tank				
Deviation of nozzle insertion from vertical				

Table 4-15

Regression of Magnitude of Overfill
Loss on Refueling Parameters

Parameters	Number of Data Points	r	r^2	Description of Parameter Effect
Significant:				
Station location	194	0.213	0.045	Larger spills for non-freeway locations
Uncomfortable wind	194	0.284	0.081	Larger spills during uncomfortable wind
Operator technique	194	0.319	0.102	Larger spills for poor technique
Station monthly volume	194	0.354	0.125	Larger spills for lower volume stations

Non-Significant:

Fuel tank fill pipe diameter

Fuel tank fill pipe length

Fuel tank fill pipe angle from horizontal

Anti-spill device in fuel tank

Fuel tank vented

Fuel tank shape

Filling rate

Fill completion

Depth of nozzle insertion

Deviation of nozzle insertion from vertical

Current station work load

Operator work load

Hose extension required for fill

Uncomfortable rain

Uncomfortable temperature

thus causing an overfill. Uncomfortable wind conditions and poor operator technique caused larger overfill losses. Poor operator technique, a complete fill, and a flat, horizontal fuel tank all combine to increase the probability of overfill loss (Table 4-16).

The magnitude of postfill nozzle losses is most strongly influenced by operator technique (Table 4-17). Non-freeway stations again tend to have larger postfill nozzle losses than do those at freeway locations. Operator technique was also most significant with respect to the probability of a postfill nozzle loss. Abnormally long hose extensions, when required for a fill, also increased the probability of a postfill nozzle loss. This may have forced the attendant to insert the nozzle into the fill pipe at an odd angle, resulting in a higher probability of spill when the nozzle was removed (Table 4-18). The results of the analysis of the spill losses have been summarized for convenience in Table 4-19.

Refueling operations were observed on passenger cars whose fuel tanks had one of five types of anti-spill device or no device at all. For each of these six data classes, Table 4-20 shows the number of complete-fill refueling operations observed, the number of spit-back losses, the probability of a spit-back, and the average and standard deviation of the spit-back magnitude when such a loss occurred. A statistical analysis of these data was not attempted for two reasons: 1) except for the cascade baffle type of device, the sample sizes are too small; 2) more importantly, the no-device category consists of some unknown number of sub-categories. That is, some fuel tanks with no device rarely spit-back, some occasionally spit back, and others will invariably spit back.

Table 4-16

Regression of Probability of Overfill Loss on Refueling Parameters

Parameters	Number of Data Points	r	r^2	Description of Parameter Effect
Significant:				
Operator technique	1063	0.333	0.111	Higher probability with poor technique
Fill completion	1063	0.395	0.156	Higher probability with complete fill
Fuel tank shape	1063	0.418	0.175	Higher probability with flat horizontal tank than vertical fender type

Non-Significant:

Station location

Station monthly volume

Fuel tank fill pipe diameter

Fuel tank fill pipe length

Fuel tank fill pipe angle from horizontal

Anti-spill device in fuel tank

Fuel tank vented

Filling rate

Depth of nozzle insertion

Deviation of nozzle insertion from vertical

Current station work load

Operator work load

Hose extension required for fill

Uncomfortable wind

Uncomfortable rain

Uncomfortable temperature

Table 4-17

Regression of Magnitude of Postfill Nozzle Loss on Refueling Parameters

Parameters	Number of Data Points	r	r^2	Description of Parameter Effect
Significant:				
Operator technique	286	0.221	0.049	Larger spill for poor technique
Station location	286	0.287	0.082	Larger spill for non-freeway stations
Non-Significant:				
Station monthly volume				
Current station work load				
Operator work load				
Fuel tank fill pipe angle				
Deviation of nozzle insertion from vertical				
Hose extension required for fill				
Uncomfortable wind				
Uncomfortable rain				
Uncomfortable temperature				

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Table 4-18

Regression of Probability of Postfill Nozzle Loss on Refueling Parameters

Parameters	Number of Data Points	r	r^2	Description of Parameter Effect
Significant:				
Operator technique	1063	0.450	0.202	Higher probability with poor technique
Hose extension required for fill	1063	0.454	0.206	Higher probability with abnormally high extension
Fill pipe angle from horizontal	1063	0.458	0.210	Higher probability for fill pipes nearly horizontal
Non-Significant:				
Station monthly volume				
Station location				
Deviation of nozzle insertion from vertical				
Current station work load				
Operator work load				
Uncomfortable wind				
Uncomfortable rain				
Uncomfortable temperature				

Table 4-19

RESULTS OF REGRESSION ANALYSIS TO IDENTIFY FACTORS SIGNIFICANT TO PRODUCTION OF SPILL LOSSES

	Significant Factors	
Type of Spill	Loss Magnitude	Loss Probability
Prefill Nozzle	Operator Technique	Nozzle Insertion Angle
Spit-Back	None	Fill Completion Fuel Tank Shape Fill Rate Nozzle Insertion Depth
Overfill	Station Location Uncomfortable Wind Operator Technique Station Volume	Operator Technique Fill Completion Fuel Tank Shape
Postfill Nozzle	Operator Technique Station Location	Operator Technique Hose Extension Required Fill Pipe Angle

Table 4-20

Summary of Spit-Back Refueling Losses For Various Fuel Tank Anti-Spill Devices

Anti-Spill Device Type	No. Of Complete Refueling Operations Observed	No. Of Spit-Back Losses	Prob. Of a Spit-Back	Average Spit-Back Loss, grams	Standard Deviation Of The Spit-Back Losses, grams
Slotted Baffle	6	3	0.500	18.13	18.07
Cascade Baffle	198	40	0.202	5.28	9.59
External Vent Tube	12	5	0.417	13.60	21.33
Perforated Baffle	4	0	0.0	0.0	0.0
Integral Vent Tube	22	8	0.364	7.84	12.77
Total For All Devices	242	56	0.231	7.08	11.99
No Anti-Spill Device	536	116	0.216	9.19	12.17
Total	778	172	0.221	8.50	12.12

5.0 TOTAL REFUELING LOSS MODEL

A regression model for estimating the displaced hydrocarbon loss during a single refueling operation was discussed in Section 3 and the average magnitudes and probabilities of spill losses were presented in Section 4. The next step, the development of a total refueling loss model, will be a primary objective of the third-year program. The functional form of two types of total refueling loss model will, however, be discussed in this section: (1) total refueling loss per operation, and (2) total refueling loss for a given region over a specified period of time. The latter model would provide planners with a needed estimating tool, and the former is developed for purposes of the present report.

5.1 TOTAL REFUELING LOSS PER OPERATION

The total refueling loss for a single refueling operation is simply the sum of the displaced and spill losses. To this point the displaced loss has been estimated in units of grams per gallon of gasoline dispensed and spill losses have been estimated in grams per refueling operation. Therefore, the total estimated refueling loss, in units of grams per refueling operation, is given simply by

$$L' = L'_D + \frac{1}{G} (L'_{NB} + L'_{NA} + L'_{SB} + L'_{OF}), \qquad (5\text{-}1)$$

where

L' = Estimated total hydrocarbon refueling loss, grams per gallon of gasoline dispensed

L'_D = Estimated displaced hydrocarbon loss, grams per gallon of gasoline dispensed

G = Quantity of gasoline dispensed, gallons

L'_{NB} = Estimated prefill nozzle loss, grams per refueling operation

L'_{NA} = Estimated postfill nozzle loss, grams per refueling operation

L'_{SB} = Estimated spit-back loss, grams per refueling operation

L'_{OF} = Estimated overfill loss, grams per refueling operation.

The best available estimate of L'_D is that given by Equation 3-6 of Section 3; i.e., the Scott regression model. The best available estimates for the various spill losses are the composite averages obtained from the field survey and reported in Section 4. Thus, observing that a total spill-loss estimate is equivalent to the properly-weighted sum of the four spill-type estimates, if L'_S denotes the estimated total spill loss per refueling operation, then Equation 5-1 may be written simply as

$$L' = \frac{L'_S}{G} + L'_D. \qquad (5\text{-}2)$$

Using as best estimates for L'_D and L'_S the relationships and average data values developed during the second year of the refueling losses program, and letting $G = \bar{G}$ = the average number of gallons of gasoline dispensed, as observed during the field survey, Equation 5-2 can be written explicitly as

$$\begin{aligned} L' &= \frac{\bar{L}_S}{\bar{G}} + L'_D = \frac{3.5}{11.5} + L'_D \\ &= 0.304 + \exp\,(-0.02645 + 0.01155\,\bar{T}_{DF} \\ &\qquad - 0.01226\,\bar{T}_V + 0.00246\,\bar{T}_V \times RVP), \end{aligned} \qquad (5\text{-}3)$$

where L' is in units of grams of hydrocarbons per gallon of dispensed gasoline, RVP is in units of pounds per square inch, and the average fuel and vapor temperatures ($\overline{T}_{DF}$ and $\overline{T}_V$, respectively) are in ^oF.

It must be noted at this point that one cannot use Equation 5-3 to estimate losses over a region by inserting average values for $\overline{T}_{DF}$, $\overline{T}_V$, and RVP and then multiplying by the total number of gallons of gasoline dispensed. If the relationship between L' and the other variables were linear, an average value for L' could be so computed. The relationship is non-linear, of course, as evidenced by Figures 3-7 and 3-8, so the total refueling loss model for application over a region must be somewhat more complex, as discussed in 5.3 below.

5.2 ESTIMATION OF DISPLACED LOSSES FROM FIELD SURVEY DATA

In the course of the field survey data collection effort, 732 measurements of each of $\overline{T}_{DF}$ and $\overline{T}_V$ were obtained. These temperature measurements, together with the published values of RVP for each city and season (Table 4-4), were used as inputs to the regression model (Equation 3-6) and the associated displaced hydrocarbon losses estimated. These estimates are given in Tables 5-1 and 5-2 by city and season. The average temperatures and their ranges have already been reported in Table 4-2.

It must be emphasized that caution must be observed in interpreting the data in those tables. Although the total sample size is large (N=732), it is comprised of much smaller sub-samples. For example, the average displaced loss reported for Los Angeles during the summer season is based on just four observations and no observations were obtained in Houston during the fall season. Under these conditions, then, the sample cannot be considered to be representative with respect to time of year.

Note also that the temperature measurements were made just during the hours of about 0800 - 1700. Service stations are typically open during the hours of about 0600 - 2200. The sample cannot, therefore, be considered to be representative with respect to time of day. Similarly, since the quantity of fuel dispensed per unit of time varies with time of day, the field survey temperature data cannot be considered to be properly weighted.

It is nonetheless useful to examine the estimated displaced hydrocarbon losses given in Tables 5-1 and 5-2. The sample was randomly drawn, of course, and hence is representative of the time span within which it was drawn, since the sample size is fairly respectable for most of the city-season combinations. The data thus provide a basis for estimating the magnitude of the problem.

Based on the total sample, the composite average displaced hydrocarbon loss is 5.0 grams per gallon. When the average spill loss of 0.3 grams per gallon is added, the total refueling loss is 5.3 grams of hydrocarbons per gallon of dispensed gasoline, or about 0.40 grams per mile, averaged over five cities and four seasons, and subject to the limitations discussed above.

The observational and measured data obtained in the course of this investigation thus indicate clearly that displaced losses are the primary constituents of the total refueling loss. Approximately 94% of the

Table 5-1

DISPLACED LOSS SUMMARY

Summer Survey

City	Sample Size	Av. Disp. Loss, grams/fill	Av. Disp. Loss, grams/gallon
Los Angeles	4	63.1	5.6
Houston	33	91.2	6.6
Chicago	23	57.1	5.4
New York	15	65.0	4.5
Atlanta	15	100.2	6.2
Composite	90	78.4	5.9
Fall Survey			
Los Angeles	44	45.9	3.9
Houston	0	--	--
Chicago	55	35.6	2.9
New York	29	44.0	4.0
Atlanta	22	35.3	3.5
Composite	150	40.2	3.6

Table 5-2

DISPLACED LOSS SUMMARY

City	Sample Size	Av. Disp. Loss, grams/fill	Av. Disp. Loss, grams/gallon
Winter Survey			
Los Angeles	51	65.0	6.4
Houston	52	78.3	6.6
Chicago	41	38.8	3.5
New York	35	42.8	3.6
Atlanta	53	36.6	3.6
Composite	232	53.5	4.9
Spring Survey			
Los Angeles	49	61.8	5.5
Houston	56	77.3	6.0
Chicago	52	63.4	5.3
New York	49	52.1	4.9
Atlanta	54	61.2	5.4
Composite	260	63.5	5.5

total loss, computed from the field survey data sample, is due to the displaced loss which occurs, of course, during every refueling operation. Spill losses were observed to occur overall in about one-third of the refueling operations and contributed the remaining 6% of the total loss. The loss data already given in detail are summarized in Table 5-3 by source of loss and in descending order of contribution to the total loss. (Note that the spill probabilities in Table 5-3 do not sum to one-third because more than one spill type may occur for any given refueling operation.)

The field survey of refueling operations included the collection of data on whether a partial fill or complete fill was ordered. These data are summarized in Table 5-4 by city and season. Overall, 65.6% of the refueling operations observed were fill-ups, and that statistic ranged over all cities and seasons from 43.0% to 78.5%.

Figure 5-1 contrasts the average refueling loss of 0.396 grams per mile (assuming 13.4 miles per gallon) with the Federal exhaust emission control requirement for hydrocarbons by calendar year, also in units of grams per mile. As a percentage of the Federal requirement on unburned hydrocarbons from exhaust emissions, the refueling loss in hydrocarbons ranges from 11.6% in 1972 to 96.6% in 1975 and 1976. As a percentage of the average unburned hydrocarbon emissions from uncontrolled vehicles, the refueling loss is about 4%.

The various factors which must be considered to obtain representative estimates of the refueling losses are identified in the following development of a total refueling loss model.

TABLE 5-3

TOTAL REFUELING LOSS BY SOURCE

	AVERAGE MAGNITUDE GMS/LOSS	PROBABILITY OF LOSS	AVERAGE MAGNITUDE, GMS/OPERATION	CONTRIBUTION TO TOTAL, %
DISPLACED LOSS	57.4	1.0	57.4	94.3
SPIT-BACK	13.7	0.128	1.8	3.0
OVERFILL	8.6	0.141	1.2	2.0
PRE-FILL DRIP	5.9	0.036	0.2	0.3
POST-FILL DRIP	1.8	0.169	0.3	0.5
TOTAL REFUELING LOSS			60.9	

TABLE 5-4

PERCENT OF COMPLETE FILLS

	WINTER	SPRING	SUMMER	FALL	FOUR-SEASON COMPOSITE
LOS ANGELES	69.3	69.2	57.8	70.2	68.3
HOUSTON	73.0	78.5	77.7	70.9	75.1
CHICAGO	61.6	65.5	60.9	68.6	64.5
NEW YORK	43.0	71.4	58.0	59.7	59.1
ATLANTA	63.0	64.5	65.7	58.2	62.9
FIVE-CITY COMPOSITE	62.8	70.0	63.3	65.3	65.6

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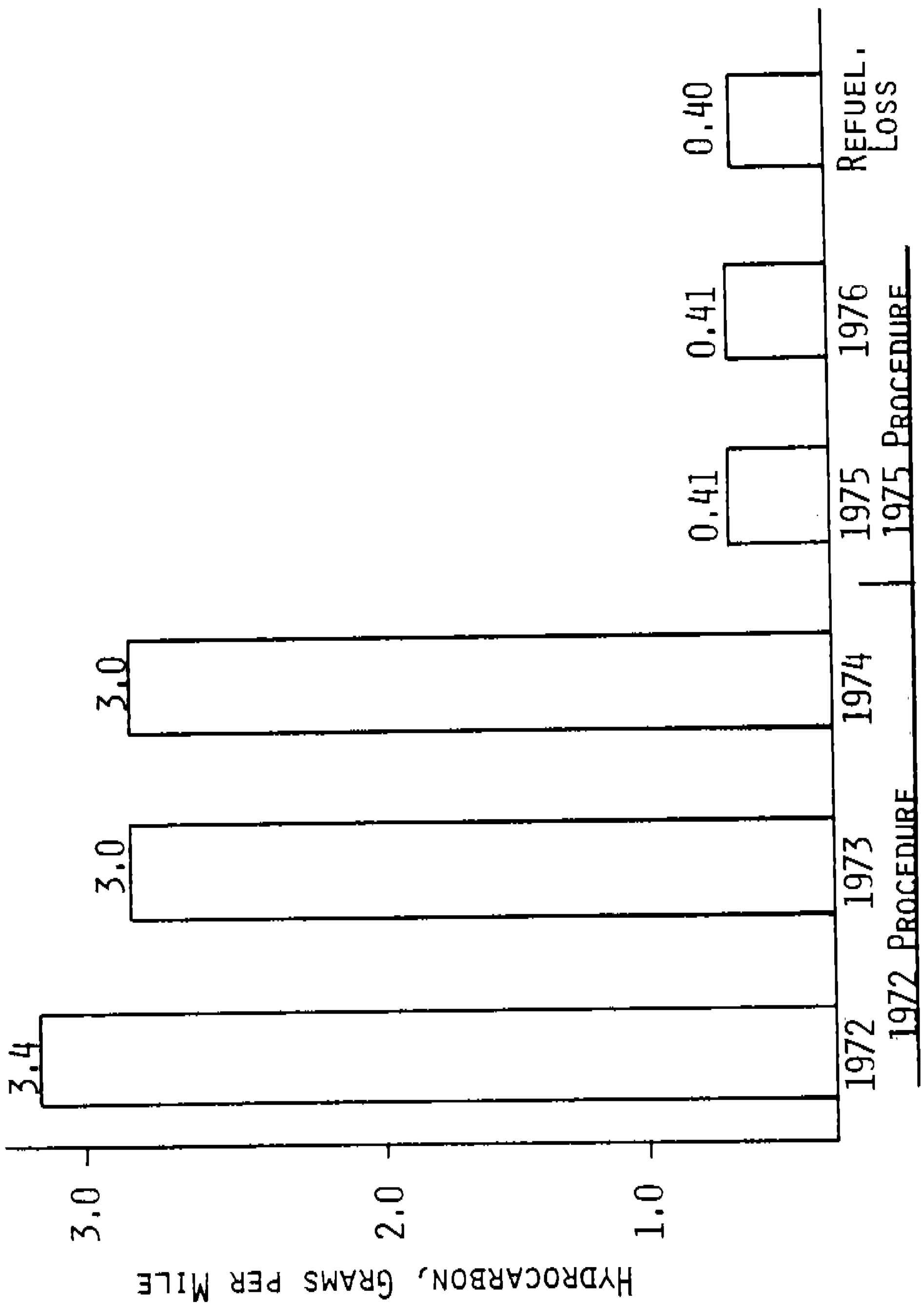

FIGURE 5-1 COMPARISON OF OBSERVED REFUELING LOSS WITH FEDERAL STANDARDS ON EXHAUST EMISSIONS

5.3 TOTAL REFUELING LOSS MODELS

As discussed above, the model developed to this point yields the estimated total refueling loss for a single refueling operation. To obtain an estimate of the total loss for a given region over some unit of time, it is necessary to determine the average number of gallons of gasoline dispensed per refueling operation, the number of refueling operations as a function of time of day, the variation of $\overline{T}_{DF}$ and $\overline{T}_V$ with time of day and day of year, and the variation of RVP with time of year. A number of approaches to the development of such a total refueling loss model may be identified, some of which will be addressed in the following discussion.

Suppose one wishes to estimate the total refueling loss in a given city over some 24-hour period selected from the months May through October. In order to compute displaced hydrocarbon losses, functions T_V and T_{DF} are needed to express the vapor and dispensed fuel temperatures as a function of time of day. That is, we require functional relationships

$$\overline{T}_V = T_V(t)$$

$$\overline{T}_{DF} = T_{DF}(t),$$

where t is time of day. Although the form of the functions T_V and T_{DF} is not known at this time, regression analyses conducted on the field survey temperature data indicate that the vapor and dispensed fuel temperatures during a refueling operation vary as functions of the ambient temperature, T_A, the underground fuel temperature, T_{UF}, and the initial temperature of the fuel in the vehicle fuel tank. The dispensed fuel and displaced vapor temperatures are thus not independent variables. As noted earlier, the correlation coefficient between these variables was 0.945 in the field survey sample.

An example of an underground fuel temperature annual record, provided by the American Petroleum Institute, is shown in Figure 5-2. Unfortunately, the ambient temperature record is not available for comparison. A typical diurnal variation in ambient temperature during the months of May through October is shown in Figure 5-3 at the indicated percentile levels. Data relating the initial temperature of the fuel in the vehicle fuel tank to the ambient temperature and the vehicle's operating pattern are available from the CRC-APRAC-CAPE-5 program. It is considered that T_V and T_{DF} will be functions similar to those shown in Figure 5-3.

Since an estimate of the average number of gallons dispensed during a refueling operation is provided by the field survey data in Section 4, all that is required now is a function, say R(t), which gives the number of refueling operations over the area of interest as a function of time of day. An example of how R(t) might look is shown in Figure 5-4. (The function shown is for illustration only and is not based on actual data.) Note that R(t) need not be a single closed form function. I.e., one might define $R(t) = R_1(t) + R_2(t) + \ldots + R_n(t)$, where each $R_i(t)$ is defined over a separate portion of R(t).

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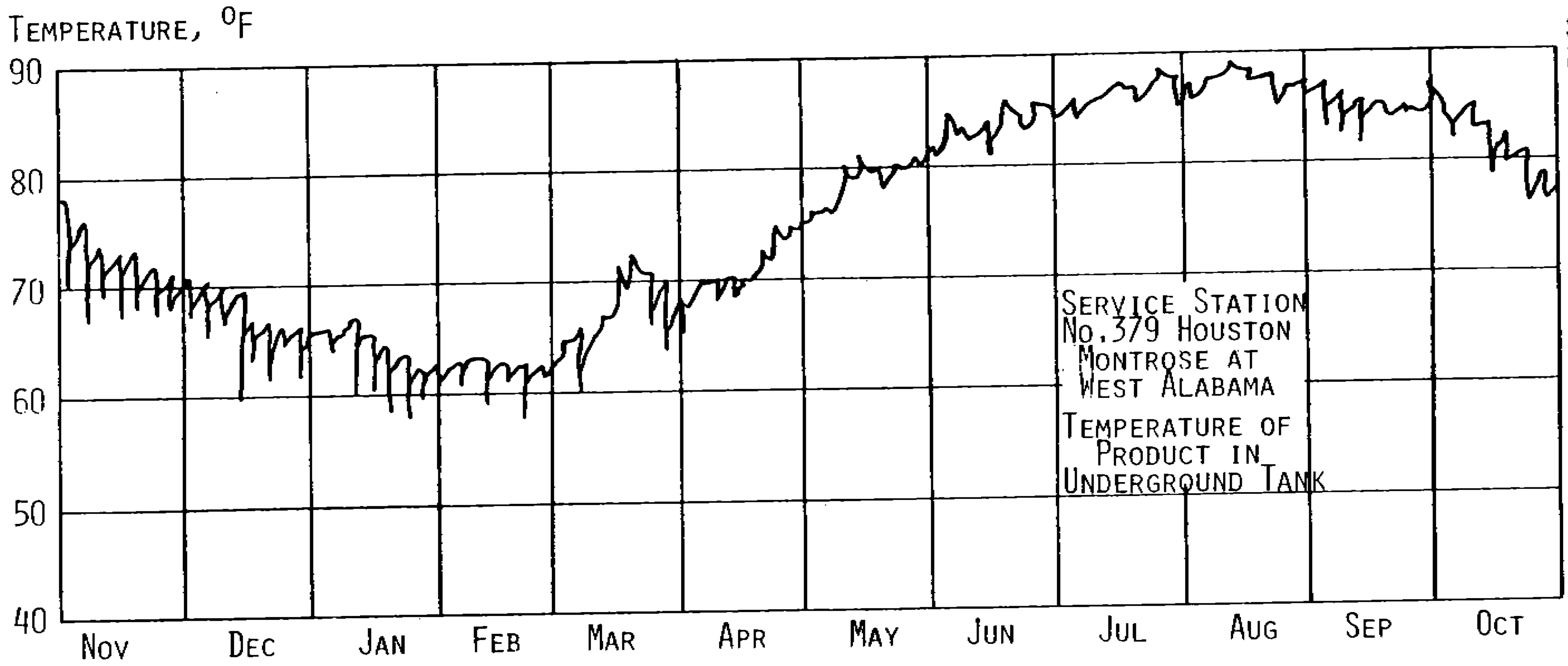

FIGURE 5-2 EXAMPLE OF ANNUAL VARIATION IN UNDERGROUND FUEL TEMPERATURE (1954-55)

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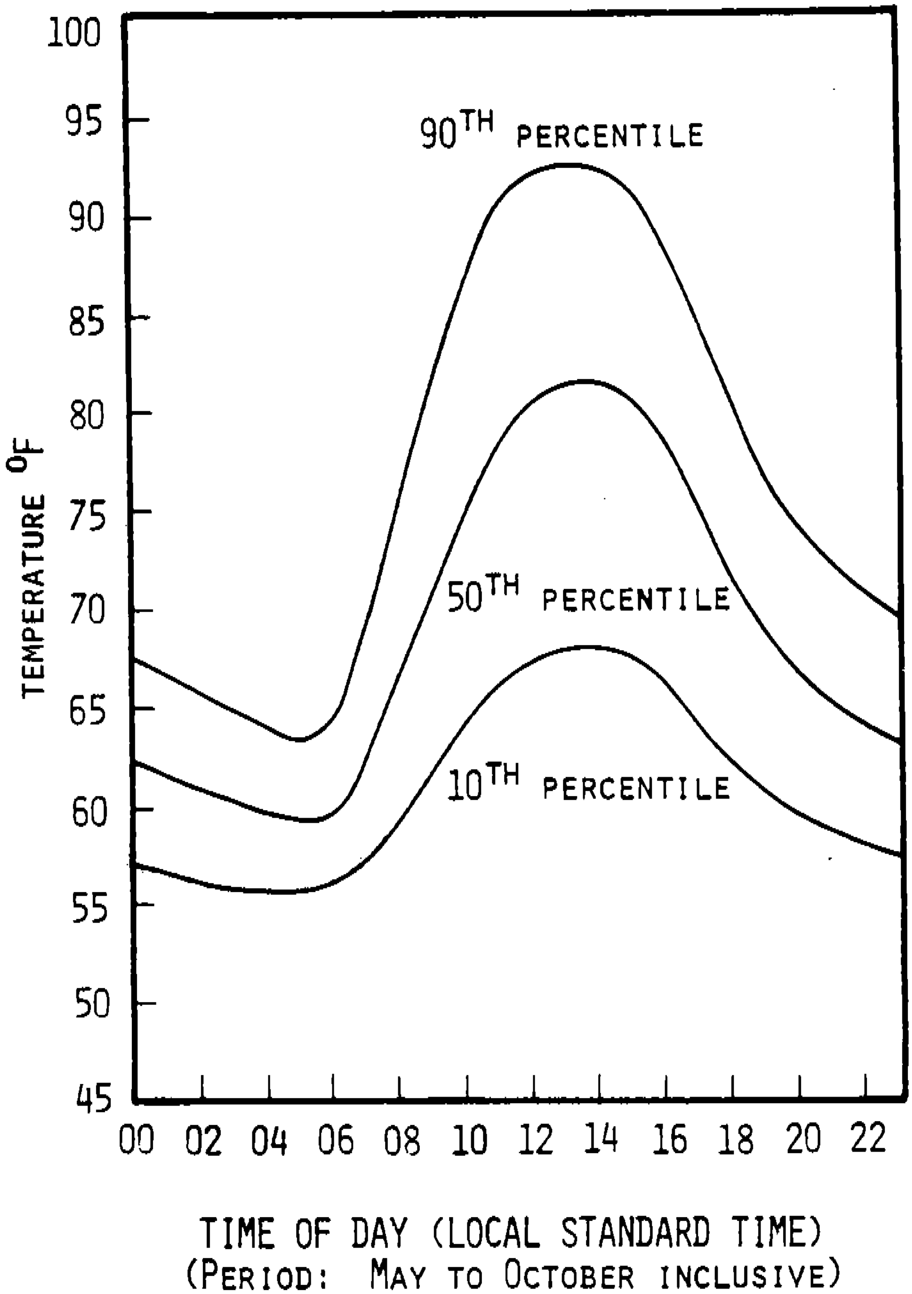

FIGURE B-2

FIGURE 5-3 TYPICAL DIURNAL TEMPERATURE PATTERNS

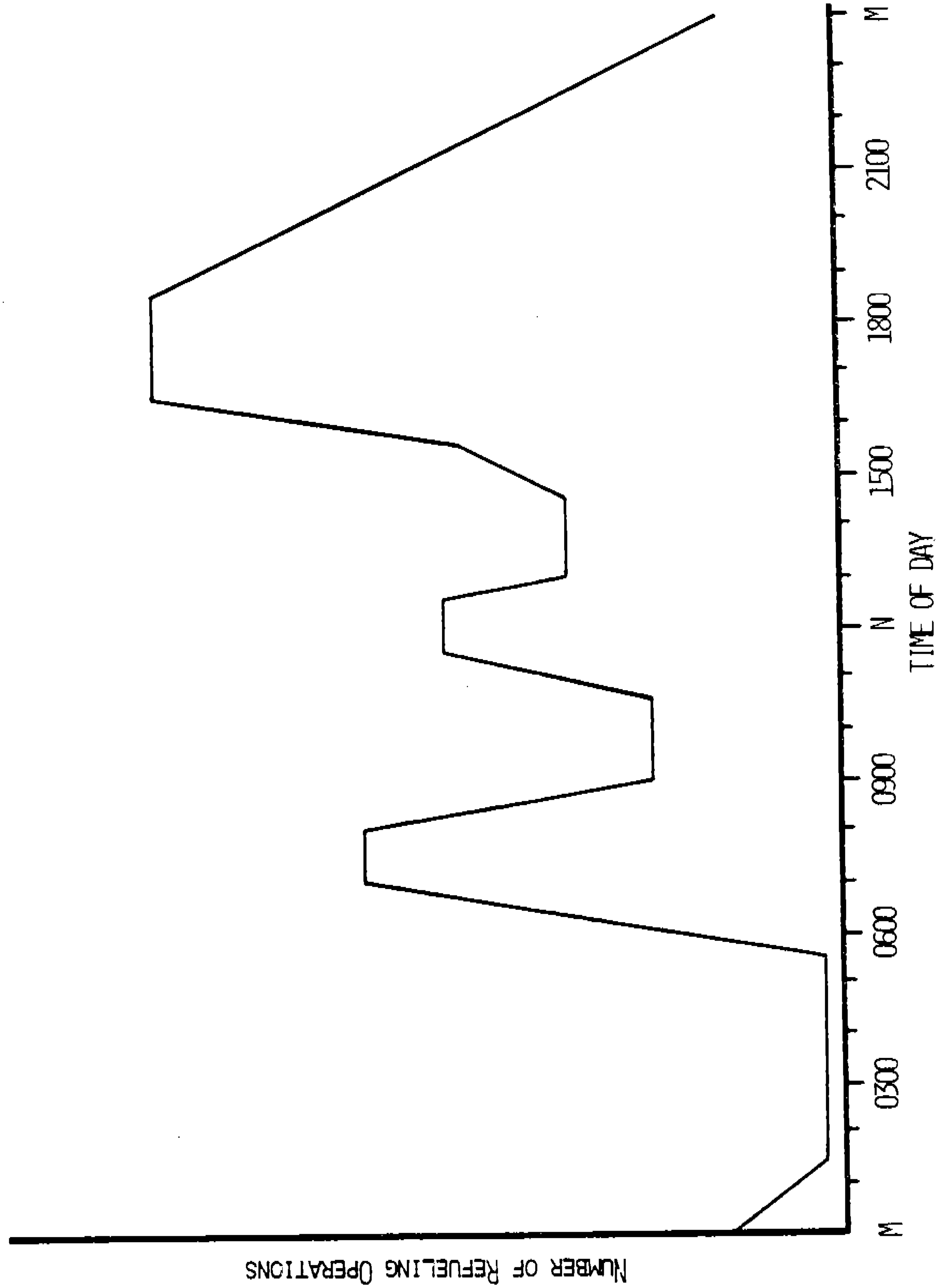

FIGURE 5-4 EXAMPLE OF FUNCTION RELATING REFUELING OPERATIONS TO TIME OF DAY

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Therefore, the total refueling loss model for estimating losses in a 24-hour period for a single city is of the form

$$L'_R = G \int_0^{24} L'[T_V(t), T_{DF}(t), RVP]\ R(t)\ dt, \tag{5-4}$$

where

L'_R = total refueling loss in a 24-hour period, grams

G = average volume of gasoline dispensed per refueling operation, gallons

L'[] = total hydrocarbon loss per refueling operation, grams per gallon of dispensed gasoline (Equation 5-3)

t = time of day on 24-hour clock, hours

$T_V(t)$ = average vapor temperature during refueling as a function of time of day, °F

$T_{DF}(t)$ = average dispensed fuel temperature during refueling as a function of time of day, °F

RVP = Reid vapor pressure, psi (assumed to be constant over a 24-hour period)

R(t) = the total number of refueling operations conducted as a a function of time of day.

Since the functions $T_V(t)$, $T_{DF}(t)$, and R(t) will undoubtedly be obtained by statistical curve fitting, and since better fits can usually be obtained by fitting the data curves section-by-section, it is likely that each of those functions will be represented by a sum of functions. In that event, assuming corresponding sub-functions to be defined over the same time intervals (a simplifying but not necessary assumption), then the model takes the form

$$L'_R = G \sum_{i=1}^{n} \int_{t_{i-1}}^{t_i} L'[T_{V_i}(t), T_{DF_i}(t), RVP]\ R_i(t)\ dt, \tag{5-5}$$

where now

$$T_V(t) = T_{V_1}(t) + T_{V_2}(t) + \ldots + T_{V_n}(t)$$

$$T_{DF}(t) = T_{DF_1}(t) + T_{DF_2}(t) + \ldots + T_{DF_n}(t)$$

$$R(t) = R_1(t) + R_2(t) + \ldots + R_n(t),$$

the i-th interval is (t_{i-1}, t_i), and $t_o = 0$.

Finally, an approach likely to be taken by regional planners because of its simplicity (curves need not be fit to data), consists of first dividing the 24-hour day into n time intervals (not necessarily of equal duration) which are small enough that the functions are approximately linear. Within each time interval an average value is then identified for each function; i.e., for each interval i, define the constant values $\overline{T}_V(t_i)$, $\overline{T}_{DF}(t_i)$, and $\overline{R}(t_i)$. The model now has the form

$$L'_R = \overline{G} \sum_{i=1}^{n} L'[\overline{T}_V(t_i), \overline{T}_{DF}(t_i), RVP]\, \overline{R}(t_i). \quad (5\text{-}6)$$

The procedures for the generalization of the model approaches described above for application to other cases of interest are straightforward extensions of the techniques already discussed.

REFERENCES

1. "Tentative Methods of Measuring Evaporation Loss From Petroleum Tanks and Transportation Equipment;" API Bulletin 2512; July 1957.

2. "Evaporation Loss in the Petroleum Industry - Causes and Control;" API Bulletin 2513; February 1959.

3. "Evaporation Loss From Tank Cars, Tank Trucks, and Marine Vessels;" API Bulletin 2514; November 1959.

4. "Comparative Methods for Evaluation Conservation Mechanisms for Evaporation Loss;" API Bulletin 2522.

5. "Investigation of Passenger Car Refueling Losses;" Scott Research Laboratories, Inc., March 6, 1970.

6. "Measurement of Total Vehicle Evaporative Emissions." Paper 680125 presented at the SAE Annual Meeting, Detroit, Michigan, January, 1968, S. W. Martens and K. W. Thurston, General Motors Corporation.

7. "Volatility Data on Individual Gasoline Samples", August 1970, Ethyl Corporation, Baton Rouge, La.

8. "Volatility Data on Individual Gasoline Samples", November 1970, Ethyl Corporation.

9. "Volatility Data on Individual Gasoline Samples", January 1971, Ethyl Corporation.

10. "Volatility Data on Individual Gasoline Samples", February 1971, Ethyl Corporation.

11. "Volatility Data on Individual Gasoline Samples", April 1971, Ethyl Corporation.

APPENDIX A

FUEL INSPECTION DATA

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Table A-1

Fuel Inspection Data

(Measurements Made by the Ethyl Corporation, Long Beach, California)

	Sample 321-1	Sample 329-1	Sample 333-1
RVP, psi	10.3	7.5	10.6
FIA, % Aromatics	19.0	22.6	18.9
% Olefins	7.7	7.0	7.3
% Saturates	73.3	70.4	73.8
Distillation, °F			
Initial Boiling Point, °F	90	96	89
5% Evaporated, °F	106	126	110
10% Evaporated, °F	119	137	121
15% Evaporated, °F	126	145	130
20% Evaporated, °F	138	151	139
30% Evaporated, °F	156	166	160
40% Evaporated, °F	176	183	179
50% Evaporated, °F	197	200	199
60% Evaporated, °F	216	220	218
70% Evaporated, °F	243	241	241
80% Evaporated, °F	273	271	271
90% Evaporated, °F	320	319	320
95% Evaporated, °F	350	355	356
Final Boiling Point, °F	404	410	401
Recovery, percent	97.0	99.0	98.0
Residue, percent	1.0	1.0	1.0
Loss, percent	2.0	0.0	1.0

APPENDIX B

VOLATILITY DATA

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Table B-1

Volatility Data

(Duplicate Measurements Made by the Ethyl Corporation, Long Beach, California)

Sample Number	Average Measured RVP, psi
301-7	8.6
305-1	7.9
309-1	7.9
314-2	8.2
319-3	8.4
320-2	8.9
323-1	8.5
325-2	7.9
330-3	7.4
331-0	11.4
333-5	10.0
335-8	8.5
336-3	8.1

APPENDIX C

CONVERSION OF RVP TO A STANDARD VALUE

CONVERSION OF RVP TO A STANDARD VALUE

Because of the weathering phenomenon, the RVP of a given fuel varied between the first and last experiment in a series. Thus, if one wishes a series of measurements normalized to a constant value of RVP, as in the top-fill/bottom-fill experiment, a correction factor is required. A correction provided by the displaced loss regression model given by Equation 3-3 is more convenient for this purpose than one based on the exponential regression. (For definitions of the symbols, see Table 3-2).

The form of the model given by Equation 3-3 is

$$L'_D = 2.01570 - 0.02615\ \overline{T}_{DF} - 0.00035\ \overline{T}_V^2 + 0.00013\ \overline{T}_{DF} \times \overline{T}_V \times \text{RVP}. \qquad \text{(C-1)}$$

If the desired constant value of RVP is 9.0 psi, then

$$L'_D\ (\text{RVP} = 9) = 2.01570 - 0.02615\ \overline{T}_{DF} - 0.00035\ \overline{T}_V^2 + 0.00013\ \overline{T}_{DF} \times \overline{T}_V \times 9.0 \qquad \text{(C-2)}$$

The desired correction factor is then obtained by subtracting (C-1) from (C-2); i.e., the required correction to the measured loss is

$$\Delta L_M = 0.00013\ \overline{T}_{DF} \times \overline{T}_V\ (9.0 - \text{RVP}). \qquad \text{(C-3)}$$

To illustrate, if the measured loss at an RVP = 8.0 is L_M, then one estimates the loss at an RVP = 9.0, for $\overline{T}_{DF} = \overline{T}_V = 60^{\circ}F$, to be

$$L_M + \Delta L_M = L_M + 0.00013 \times 60 \times 60 \times (9.0 - 8.0)$$
$$= L_M + 0.47.$$

APPENDIX D

LABORATORY DATA

TABLE D - 1. LABORATORY DATA

EXPER NUMBER	FILL TYPE	* * * * * * * TEMPERATURE - DEG F * * * * * *					RVP (PSI)	DISPLACED LOSS (GMS/GAL)
		AMBIENT	AVERAGE DISP FUEL	AVERAGE VAPOR	INITIAL TANK FUEL	INITIAL VAPOR SPACE		
331-3	T	29	33	35	28	28	10.9	2.2
331-4	T	24	48	31	33	24	10.8	2.7
331-5	T	33	53	35	35	33	10.7	2.9
331-6	T	30	52	33	35	29	10.6	2.9
333-1	T	30	44	37	35	33	10.6	2.7
333-2	T	32	36	33	35	31	10.5	2.4
333-3	T	32	34	32	35	32	10.4	2.3
333-4	T	34	35	34	35	34	10.3	2.3
332-1	B	34	51	33	33	33	10.3	2.6
332-2	B	32	50	31	34	33	10.2	1.9
332-3	B	34	51	32	35	34	10.2	2.1
332-4	B	36	51	33	39	37	10.1	2.2
321-1	T	34	54	37	39	36	10.3	2.8
321-2	T	33	54	37	37	34	10.1	2.7
321-3	T	35	54	39	39	36	9.9	2.7
321-4	T	36	57	41	40	39	9.8	2.8
322-1	T	34	36	34	35	34	9.7	2.1
322-2	T	34	35	35	36	35	9.6	2.1
322-3	T	36	33	35	36	36	9.5	2.1
322-04	T	35	35	35	35	34	9.4	2.0
301-1	T	58	56	57	59	59	9.3	3.3
301-2	T	59	57	58	59	59	9.3	3.3
301-3	T	60	59	59	60	60	9.2	3.5
301-4	T	60	60	60	60	60	9.1	3.4
320-1	B	60	60	60	60	60	9.1	2.8
320-2	B	60	60	60	60	60	9.1	3.1
320-3	B	60	60	57	60	59	9.0	3.2
320-4	B	58	60	57	60	57	8.9	2.8
320-5	B	57	59	57	59	57	8.9	2.7
317-1	T	61	60	60	60	60	8.8	3.4
317-2	T	61	60	60	61	61	8.8	3.4
317-3	T	62	60	60	61	62	8.8	3.3

TABLE D - 1. (CONTINUED) LABORATORY DATA

EXPER NUMBER	FILL TYPE	* * * * * * * TEMPERATURE - DEG F * * * * * * AMBIENT	AVERAGE DISP FUEL	AVERAGE VAPOR	INITIAL TANK FUEL	INITIAL VAPOR SPACE	RVP (PSI)	DISPLACED LOSS (GMS/GAL)
317-4	T	60	59	59	60	60	8.7	3.3
318-1	T	60	60	59	60	60	8.7	3.3
318-2	T	58	60	58	59	59	8.7	3.3
318-3	T	59	59	60	59	60	8.6	3.3
318-6	T	61	59	60	60	61	8.5	3.4
319-1	T	59	58	58	62	59	8.5	3.5
319-2	T	59	59	59	61	60	8.5	3.6
319-3	T	60	60	59	60	60	8.5	3.6
315-01	T	60	61	61	60	60	8.4	3.1
315-02	T	61	62	61	61	60	8.4	3.4
316-01	T	59	61	60	61	60	8.4	3.2
316-02	T	60	60	60	61	59	8.3	3.1
323-01	T	60	36	56	60	60	8.3	2.3
323-02	T	60	36	54	58	59	8.3	2.4
323-03	T	62	39	58	61	61	8.3	2.5
323-0420	T	62	38	50	59	62	8.2	2.4
323-0520	T	61	35	47	50	58	8.2	2.1
312-01	T	61	57	60	61	61	8.2	3.3
312-02	T	60	60	59	59	59	8.2	3.1
312-03	T	61	60	60	59	60	8.1	3.1
313-01	T	61	61	61	60	61	8.1	3.2
313-02	T	62	61	62	60	62	8.1	3.2
314-01	T	61	61	61	60	60	8.1	3.2
314-02	T	60	61	60	60	60	8.1	3.2
324-01	T	91	64	85	85	90	8.1	4.0
324-02	T	92	64	84	84	92	8.1	3.8
325-01	B	91	56	89	83	90	8.1	4.5
325-02	B	89	60	89	84	90	8.1	4.6
326-01	T	91	89	91	90	92	8.0	5.8
326-02	T	92	92	92	90	92	8.0	5.8
336-01	B	92	92	92	91	92	8.0	5.5
336-02	B	91	92	92	90	92	8.0	5.4

TABLE D - 1. (CONTINUED) LABORATORY DATA

EXPER NUMBER	FILL TYPE	* * * * * * * TEMPERATURE - DEG F: AMBIENT	AVERAGE DISP FUEL	AVERAGE VAPOR	INITIAL TANK FUEL	INITIAL VAPOR SPACE * * * * * *	RVP (PSI)	DISPLACED LOSS (GMS/GAL)
326-03	T	91	90	91	90	92	7.9	5.5
336-03	B	91	92	91	88	91	7.9	5.2
327-01	T	62	68	65	62	62	7.5	3.0
327-02	T	63	62	62	63	62	7.5	2.9
327-03	T	61	62	63	63	61	7.5	2.9
327-04	T	62	62	62	62	61	7.5	2.8
328-01	T	60	44	56	61	59	7.5	2.2
328-02	T	60	42	55	60	59	7.5	2.2
329-01	T	90	68	87	80	93	7.5	3.5
329-02	T	91	66	86	80	92	7.5	3.2
329-03	T	91	65	82	80	88	7.5	3.1
329-04	T	90	69	84	80	91	7.4	3.2
330-01	T	92	87	89	85	92	7.4	4.3
330-02	T	91	89	90	86	91	7.4	4.5
330-03	T	91	90	90	88	90	7.4	4.6
309-01	T	62	62	62	61	61	7.9	3.0
309-02	T	64	62	63	62	63	7.9	3.7
309-03	T	60	61	62	60	60	7.9	3.1
310-01	T	63	62	62	61	62	7.9	3.5
310-02	T	59	61	61	61	60	7.9	3.7
309-04	T	60	61	60	60	59	7.9	3.6
309-05	T	60	61	61	60	60	7.9	3.8
308-01	T	61	61	61	60	60	7.9	3.4
308-02	T	60	61	61	60	59	7.9	3.5
308-03	T	61	62	61	60	60	7.9	3.6
337-01	T	61	62	59	61	60	7.9	3.3
337-02	T	62	63	61	62	61	7.9	2.6
311-01	T	61	62	62	60	59	7.9	2.9
311-02	T	61	63	63	59	59	7.9	2.9
304-01	T	61	62	62	61	61	7.9	2.8
304-02	T	59	62	61	61	61	7.9	2.8
303-01	T	61	62	60	60	59	7.9	2.7

TABLE D - 1. (CONTINUED) LABORATORY DATA

EXPER NUMBER	FILL TYPE	* * * * * * * TEMPERATURE - DEG F AMBIENT	AVERAGE DISP FUEL	AVERAGE VAPOR	INITIAL TANK FUEL	INITIAL VAPOR SPACE * * * * * *	RVP (PSI)	DISPLACED LOSS (GMS/GAL)
303-02	T	60	62	59	60	59	7.9	2.8
306-01	T	62	62	62	62	62	7.9	3.0
306-02	T	61	62	62	61	61	7.9	3.1
305-01	T	60	61	60	60	60	7.9	2.9
305-02	T	59	61	61	60	59	7.9	2.8
302-01	T	60	61	60	60	60	7.9	2.9
302-02	T	60	61	61	60	60	7.9	3.0
302-03	T	60	61	60	60	60	7.9	3.3
307-01	T	60	61	61	60	60	7.9	3.0
307-02	T	62	61	61	61	61	7.9	2.8
301-05	T	60	61	59	62	60	7.9	2.9
301-06	T	60	62	60	61	60	7.9	2.9
301-07	T	62	63	61	64	62	8.6	3.5
301-08	T	61	62	62	61	60	8.6	3.4
301-09	T	59	62	61	61	59	8.6	3.4
322-05	T	40	35	37	42	40	8.6	2.2
322-06	T	37	35	35	38	37	8.6	2.0
322-07	T	37	35	35	37	37	8.5	1.9
335-01	B	34	35	33	35	34	8.5	1.7
335-04	B	37	35	34	35	35	8.5	1.9
335-05	B	35	35	35	35	35	8.5	1.6
335-06	B	38	37	35	37	37	8.5	2.2
335-07	B	35	36	34	36	35	8.5	1.8
335-08	B	35	35	33	35	34	8.5	1.9
333-05	T	36	35	33	36	35	10.0	2.1
333-06	T	37	35	34	35	35	10.0	2.2
334-01	B	37	35	36	35	36	10.0	2.3
334-02	B	38	35	35	35	37	9.9	2.2
333-07	T	37	36	35	35	37	9.8	2.3

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APPENDIX E

DISPLACED VAPOR LOSS BY IDEAL GAS MODEL

DISPLACED VAPOR LOSS BY IDEAL GAS MODEL

Suppose a mixture of hydrocarbon vapor and air has the properties of an ideal gas. The equation of state for the hydrocarbon vapor is

$$p_v V = \frac{m_v R_u T}{M_v}, \tag{1}$$

where

p_v = the partial pressure of the hydrocarbon vapor at saturation, psia

V = volume of mixture, cu. ft.

m_v = mass of the hydrocarbon vapor, lbm

R_u = universal gas constant = 1545 lb-ft/mol ^oR

T = temperature of mixture, ^oR

M_v = molecular weight of hydrocarbon vapor

Assume the volume of vapor displaced, V, equals the volume of liquid dispensed. Then, letting V in (1) be the number of gallons of fuel dispensed and making the appropriate units conversions, one may solve for the vapor loss in grams as follows:

$$m_v = \frac{p_v V M_v}{R_u T}$$

$$= \frac{p_v\left(\frac{lbs}{in^2}\right)\left(453.59 \frac{gms}{lb}\right)\left(144 \frac{in^2}{ft^2}\right) V(gal) \left(0.13368 \frac{ft^3}{gal}\right) M_v \left(\frac{lbs}{mol}\right)}{R_u\left(\frac{lb - ft}{mol\ ^oR}\right) T \left(^oR\right)}$$

$$= \frac{(453.59)\ (144)\ (0.13368)\ p_v V M_v}{1545\ T}, \text{ gms}$$

$$= \frac{5.6515\ p_v V M_v}{T + 459.7} \text{ gms}, \tag{2}$$

where T is now in units of ^{o}F.

The molecular weight of the hydrocarbon vapor, as discussed in Appendix II of Reference 2, is a function of temperature and the 10%-point slope on the distillation curve. Assuming RVP = 9.0, then $M_V = 62$ at $60^{o}F$. The average value of the 10%-point slope for motor gasoline is usually taken as s = 3. For that value of s = 3, the molecular weight increases or decreases in increments of 0.059 per degree of temperature increase or decrease, respectively. Thus, if $\Delta T = T - 60$, T in ^{o}F, M_V may be replaced in (2) by $M_V = 62 + 0.059 \Delta T$.

Finally, letting V = 1 gal, the displaced vapor loss in units of grams per gallon is given by

$$m_v = \frac{5.6515\ p_V\ (62 + 0.059\ \Delta T)}{T + 459.7}. \qquad (3)$$

Values of p_V may be computed with the aid of the nomographs, based on NBS data, in Appendix V of Reference 2 which give P_V as a function of RVP, T, and s. For RVP = 9.0 and s = 3, vapor losses, denoted by L_V, are given in the following table for the indicated temperatures.

$T(^{o}F)$	p_V (psia)	L_V (gms/gal)
0	1.25	0.90
20	2.02	1.42
35	2.80	1.94
50	3.85	2.62
60	4.67	3.15
75	6.20	4.12
90	8.20	5.38

APPENDIX F

FIELD SURVEY TEMPERATURE DATA

TABLE F - 1. FIELD SURVEY TEMPERATURE DATA

CITY	SEASON	**** DATE *** MO	DY	YR	HOUR	SERVICE STATION LOC	VOL	** REFUELING OPERATION *** FILL	GAL DISP	FUEL GRADE	DISP RATE	SOLAR RAD	TEMP. - DEG F AMB	DISP FUEL	DISPL VAPOR	TIME BETWN FILLS, MIN
L.A.	WINTER	1	25	71	1210	FRWY	HI	FULL	12.6	PREM	MED	SUN	58	63	70	***
L.A.	WINTER	1	25	71	1230	FRWY	HI	FULL	17.4	PREM	MED	SHADE	58	63	63	20
L.A.	WINTER	1	25	71	1248	FRWY	HI	FULL	10.7	PREM	LO	SUN	59	66	67	***
L.A.	WINTER	1	25	71	1255	FRWY	HI	FULL	18.6	REG	MED	SUN	60	65	68	7
L.A.	WINTER	1	25	71	1300	FRWY	HI	PART	10.0	PREM	HI	SUN	62	66	65	5
L.A.	WINTER	1	25	71	1310	FRWY	HI	PART	7.7	PREM	HI	SUN	63	66	67	10
L.A.	WINTER	1	25	71	1327	FRWY	HI	FULL	9.3	REG	MED	SHADE	64	62	68	***
L.A.	WINTER	1	25	71	1341	FRWY	HI	FULL	19.6	PREM	MED	SHADE	65	63	63	71
L.A.	WINTER	1	25	71	1350	FRWY	HI	FULL	15.6	PREM	LO	SUN	66	66	65	40
L.A.	WINTER	1	25	71	1426	FRWY	HI	PART	5.2	PREM	HI	SUN	67	68	72	36
L.A.	WINTER	1	25	71	1525	FRWY	HI	FULL	8.5	PREM	LO	SHADE	67	64	69	104
L.A.	WINTER	1	25	71	1621	FRWY	HI	PART	12.9	PREM	MED	SUN	67	65	71	563
L.A.	WINTER	1	26	71	1200	FRWY	HI	FULL	6.5	REG	MED	SUN	76	72	78	***
L.A.	WINTER	1	26	71	1205	FRWY	HI	PART	6.5	PREM	HI	SUN	76	69	30	***
L.A.	WINTER	1	26	71	1210	FRWY	HI	FULL	8.9	PREM	MED	SUN	76	67	78	5
L.A.	WINTER	1	26	71	1240	FRWY	HI	FULL	15.1	PREM	HI	SUN	78	69	74	30
L.A.	WINTER	1	26	71	1243	FRWY	HI	PART	2.7	PREM	HI	SUN	78	67	68	3
L.A.	WINTER	1	26	71	1900	FRWY	HI	FULL	15.2	PREM	MED	SHADE	62	66	70	***
L.A.	WINTER	1	26	71	1910	FRWY	HI	PART	2.7	PREM	HI	SHADE	62	64	64	10
L.A.	WINTER	1	26	71	1955	FRWY	HI	FULL	19.8	PREM	HI	NIGHT	62	66	68	45
L.A.	WINTER	1	26	71	2000	FRWY	HI	FULL	7.2	REG	MED	NIGHT	62	65	65	***
L.A.	WINTER	1	26	71	2015	FRWY	HI	FULL	7.2	PREM	HI	NIGHT	62	66	66	15
L.A.	WINTER	1	26	71	2050	FRWY	HI	FULL	6.9	REG	HI	NIGHT	62	64	64	50
L.A.	WINTER	1	26	71	2055	FRWY	HI	FULL	10.3	PREM	MED	NIGHT	62	64	66	40
L.A.	WINTER	1	26	71	2057	FRWY	HI	FULL	8.1	REG	HI	NIGHT	62	64	63	7
L.A.	WINTER	1	26	71	2100	FRWY	HI	FULL	8.3	REG	MED	NIGHT	62	65	65	3
L.A.	WINTER	1	26	71	2120	FRWY	HI	FULL	13.3	PREM	LO	NIGHT	62	65	66	25
L.A.	WINTER	1	26	71	2145	FRWY	HI	FULL	8.3	REG	MED	NIGHT	61	63	62	45
L.A.	WINTER	1	26	71	2147	FRWY	HI	PART	5.4	PREM	HI	NIGHT	61	62	62	***
L.A.	WINTER	1	27	71	1045	FRWY	HI	FULL	8.3	REG	MED	SUN	82	71	73	***
L.A.	WINTER	1	27	71	1130	FRWY	HI	FULL	14.0	PREM	MED	SUN	82	70	76	***
L.A.	WINTER	1	27	71	1215	FRWY	HI	FULL	7.3	PREM	HI	SUN	82	70	74	45

NOTE, '****' MEANS NO DATA

TABLE F - 1. (CONTINUED) FIELD SURVEY TEMPERATURE DATA

CITY	SEASON	**** DATE *** MO	DY	YR	HOUR	SERVICE STATION LOC	VOL	** REFUELING OPERATION *** FILL	GAL DISP	FUEL GRADE	DISP RATE	SOLAR RAD	TEMP. - DEG F AMB	DISP FUEL	DISPL VAPOR	TIME BETWN FILLS, MIN
L.A.	WINTER	1	27	71	1505	FRWY	HI	FULL	16.3	PREM	MED	SUN	88	71	76	25
L.A.	WINTER	1	27	71	1539	FRWY	HI	PART	5.4	PREM	HI	SUN	86	75	78	34
L.A.	WINTER	1	27	71	1632	FRWY	HI	PART	6.1	REG	MED	SUN	76	76	78	***
L.A.	WINTER	1	27	71	1640	FRWY	HI	FULL	18.0	PREM	HI	SUN	75	73	79	***
L.A.	WINTER	1	29	71	1115	FRWY	HI	FULL	6.8	PREM	MED	SUN	72	72	75	***
L.A.	WINTER	1	29	71	1135	FRWY	HI	PART	5.5	PREM	MED	SUN	73	71	91	20
L.A.	WINTER	1	29	71	1155	FRWY	HI	PART	5.4	PREM	HI	SUN	76	72	79	20
L.A.	WINTER	1	29	71	1213	FRWY	HI	FULL	8.2	PREM	HI	SUN	77	71	80	***
L.A.	WINTER	1	29	71	1230	FRWY	HI	FULL	12.2	REG	LO	SUN	82	71	80	***
L.A.	WINTER	1	29	71	1251	FRWY	HI	PART	6.1	REG	MED	SUN	84	71	76	21
L.A.	WINTER	1	29	71	1321	FRWY	HI	FULL	13.6	PREM	MED	SUN	85	72	79	81
L.A.	WINTER	1	29	71	1324	FRWY	HI	FULL	14.9	PREM	MED	SUN	88	67	77	3
L.A.	WINTER	1	29	71	1357	FRWY	HI	FULL	8.2	REG	MED	SUN	88	74	80	66
L.A.	WINTER	1	29	71	1446	FRWY	HI	PART	6.2	REG	HI	SUN	90	76	85	49
L.A.	WINTER	1	29	71	1455	FRWY	HI	FULL	16.6	PREM	MED	SUN	90	73	73	91
L.A.	WINTER	1	29	71	1517	FRWY	HI	PART	8.2	PREM	HI	SUN	89	72	75	22
L.A.	WINTER	1	29	71	1522	FRWY	HI	PART	6.1	REG	MED	SUN	89	77	84	36
L.A.	WINTER	1	29	71	1541	FRWY	HI	FULL	9.8	PREM	MED	SUN	88	73	78	24
L.A.	WINTER	1	29	71	1616	FRWY	HI	FULL	18.0	PREM	MED	SUN	86	72	77	243
HOUS	WINTER	2	2	71	1045	FRWY	HI	FULL	16.7	REG	HI	SHADE	46	67	61	***
HOUS	WINTER	2	2	71	1115	FRWY	HI	FULL	20.1	UNLD	HI	SHADE	46	65	59	***
HOUS	WINTER	2	2	71	1120	FRWY	HI	FULL	12.7	REG	HI	SHADE	45	67	53	35
HOUS	WINTER	2	2	71	1140	FRWY	HI	FULL	8.4	UNLD	HI	SHADE	45	69	61	25
HOUS	WINTER	2	2	71	1235	FRWY	HI	FULL	7.2	REG	MED	SHADE	46	62	54	75
HOUS	WINTER	2	2	71	1250	FRWY	HI	FULL	14.6	PREM	HI	SHADE	46	63	59	***
HOUS	WINTER	2	2	71	1410	FRWY	HI	PART	10.5	UNLD	MED	SHADE	47	61	57	***
HOUS	WINTER	2	2	71	1450	FRWY	HI	FULL	18.0	UNLD	MED	SHADE	49	68	58	40
HOUS	WINTER	2	2	71	1520	FRWY	HI	PART	12.6	REG	HI	SHADE	49	66	64	***
HOUS	WINTER	2	2	71	1557	FRWY	HI	FULL	14.5	PREM	MED	SHADE	49	63	56	***
HOUS	WINTER	2	2	71	1601	FRWY	HI	FULL	16.5	PREM	HI	SHADE	49	69	60	4
HOUS	WINTER	2	2	71	1627	FRWY	HI	FULL	24.1	PREM	HI	SHADE	46	69	63	26
HOUS	WINTER	2	2	71	1637	FRWY	HI	FULL	20.8	REG	HI	SHADE	48	68	63	77

NOTE, '****' MEANS NO DATA

TABLE F - 1. (CONTINUED) FIELD SURVEY TEMPERATURE DATA

CITY	SEASON	DATE MO	DATE DY	DATE YR	DATE HOUR	SERVICE STATION LOC	SERVICE STATION VOL	REFUELING OPERATION FILL	GAL DISP	FUEL GRADE	DISP RATE	SOLAR RAD	TEMP. - DEG F AMB	DISP FUEL	DISPL VAPOR	TIME BETWN FILLS, MIN
HOUS	WINTER	2	2	71	1652	FRWY	HI	PART	5.3	PREM	HI	SHADE	48	64	55	25
HOUS	WINTER	2	2	71	1653	FRWY	HI	FULL	16.7	PREM	HI	SHADE	48	68	60	1
HOUS	WINTER	2	2	71	1700	FRWY	HI	FULL	15.6	PREM	HI	SHADE	48	69	65	7
HOUS	WINTER	2	2	71	1705	FRWY	HI	FULL	11.0	PREM	HI	SHADE	47	69	61	5
HOUS	WINTER	2	2	71	1715	FRWY	HI	PART	3.0	REG	HI	SHADE	47	56	61	38
HOUS	WINTER	2	2	71	1720	FRWY	HI	FULL	12.8	UNLD	MED	SHADE	47	65	62	150
HOUS	WINTER	2	2	71	1723	FRWY	HI	PART	5.4	UNLD	HI	SHADE	47	69	65	3
HOUS	WINTER	2	2	71	1727	FRWY	HI	FULL	16.7	PREM	HI	SHADE	47	68	60	22
HOUS	WINTER	2	2	71	1729	FRWY	HI	PART	13.2	PREM	HI	SHADE	48	69	65	2
HOUS	WINTER	2	2	71	1735	FRWY	HI	FULL	8.6	REG	HI	SHADE	48	65	57	20
HOUS	WINTER	2	2	71	1745	FRWY	HI	PART	7.4	PREM	HI	SHADE	48	65	57	16
HOUS	WINTER	2	2	71	1750	FRWY	HI	FULL	16.3	UNLD	HI	SHADE	48	68	58	27
HOUS	WINTER	2	3	71	1215	FRWY	HI	FULL	3.3	REG	MED	SUN	74	72	70	***
HOUS	WINTER	2	3	71	1216	FRWY	HI	PART	3.0	REG	HI	SUN	74	71	71	1
HOUS	WINTER	2	3	71	1218	FRWY	HI	FULL	16.0	PREM	MED	SUN	74	72	70	***
HOUS	WINTER	2	3	71	1239	FRWY	HI	FULL	13.2	PREM	MED	SUN	75	71	77	21
HOUS	WINTER	2	3	71	1258	FRWY	HI	FULL	12.9	PREM	MED	SUN	75	71	73	19
HOUS	WINTER	2	3	71	1301	FRWY	HI	FULL	12.3	PREM	MED	SHADE	75	70	73	3
HOUS	WINTER	2	3	71	1324	FRWY	HI	FULL	8.3	REG	MED	SHADE	74	73	72	68
HOUS	WINTER	2	3	71	1328	FRWY	HI	FULL	22.7	REG	MED	SUN	75	71	71	4
HOUS	WINTER	2	3	71	1335	FRWY	HI	PART	7.9	PREM	MED	SUN	75	72	76	34
HOUS	WINTER	2	3	71	1356	FRWY	HI	FULL	17.7	PREM	MED	SUN	76	71	76	21
HOUS	WINTER	2	3	71	1406	FRWY	HI	FULL	13.8	UNLD	MED	SUN	76	72	72	***
HOUS	WINTER	2	3	71	1436	FRWY	HI	PART	7.9	PREM	HI	SUN	76	73	75	40
HOUS	WINTER	2	3	71	1446	FRWY	HI	FULL	10.3	REG	LO	SHADE	76	73	73	78
HOUS	WINTER	2	3	71	1450	FRWY	HI	PART	5.3	PREM	MED	SHADE	77	72	76	14
HOUS	WINTER	2	3	71	1525	FRWY	HI	FULL	7.8	PREM	MED	SUN	76	73	82	35
HOUS	WINTER	2	3	71	1550	FRWY	HI	PART	2.6	PREM	HI	SHADE	75	75	78	25
HOUS	WINTER	2	3	71	1555	FRWY	HI	FULL	15.9	REG	MED	SHADE	75	73	74	69
HOUS	WINTER	2	3	71	1600	FRWY	HI	FULL	12.5	REG	MED	SHADE	75	71	71	5
HOUS	WINTER	2	3	71	1607	FRWY	HI	FULL	16.3	UNLD	MED	SHADE	75	72	73	121
HOUS	WINTER	2	3	71	1620	FRWY	HI	FULL	17.0	PREM	MED	SHADE	74	72	72	20

NOTE. '****' MEANS NO DATA

TABLE F - 1. (CONTINUED) FIELD SURVEY TEMPERATURE DATA

		**** DATE ***				SERVICE STATION		** REFUELING OPERATION ***					TEMP. - DEG F			TIME BETWN FILLS,
CITY	SEASON	MO	DY	YR	HOUR	LOC	VOL	FILL	GAL DISP	FUEL GRADE	DISP RATE	SOLAR RAD	AMB	DISP FUEL	DISPL VAPOR	MIN
HOUS	WINTER	2	3	71	1625	FRWY	HI	PART	5.4	UNLD	MED	SHADE	74	72	73	18
HOUS	WINTER	2	3	71	1650	FRWY	HI	FULL	12.7	UNLD	MED	SHADE	74	71	73	25
HOUS	WINTER	2	3	71	1700	FRWY	HI	PART	3.0	REG	HI	SHADE	74	75	75	40
HOUS	WINTER	2	3	71	1710	FRWY	HI	PART	10.0	REG	MED	SHADE	73	72	75	10
HOUS	WINTER	2	3	71	1715	FRWY	HI	FULL	9.9	UNLD	MED	SHADE	73	71	71	25
HOUS	WINTER	2	3	71	1735	FRWY	HI	FULL	13.6	REG	MED	SHADE	72	72	71	25
HOUS	WINTER	2	3	71	1800	FRWY	HI	FULL	13.7	REG	MED	SHADE	70	72	70	25
CHI	WINTER	2	24	71	0953	NBHD	HI	FULL	14.9	REG	MED	SHADE	33	36	38	***
CHI	WINTER	2	24	71	1037	NBHD	HI	FULL	19.4	REG	MED	SHADE	33	36	39	44
CHI	WINTER	2	24	71	1056	NBHD	HI	FULL	8.1	REG	MED	SHADE	33	36	37	19
CHI	WINTER	2	24	71	1059	NBHD	HI	FULL	12.9	REG	MED	SHADE	34	36	38	3
CHI	WINTER	2	24	71	1116	NBHD	HI	PART	2.4	REG	HI	SHADE	34	36	34	17
CHI	WINTER	2	24	71	1119	NBHD	HI	PART	6.7	PREM	LO	SHADE	34	37	38	***
CHI	WINTER	2	24	71	1154	NBHD	HI	FULL	8.5	PREM	MED	SHADE	35	38	40	35
CHI	WINTER	2	24	71	1229	NBHD	HI	FULL	10.4	REG	MED	SHADE	35	37	40	73
CHI	WINTER	2	24	71	1243	NBHD	HI	FULL	15.9	PREM	MED	SHADE	35	37	37	49
CHI	WINTER	2	24	71	1334	NBHD	HI	PART	4.9	REG	HI	SHADE	35	38	44	65
CHI	WINTER	2	24	71	1355	NBHD	HI	FULL	11.9	REG	MED	SUN	35	38	46	21
CHI	WINTER	2	24	71	1428	NBHD	HI	PART	10.0	PREM	MED	SHADE	35	39	40	105
CHI	WINTER	2	24	71	1447	NBHD	HI	PART	9.8	REG	LO	SHADE	35	40	47	52
CHI	WINTER	2	24	71	1503	NBHD	HI	FULL	22.1	PREM	MED	SUN	35	37	36	35
CHI	WINTER	2	24	71	1526	NBHD	HI	PART	11.6	PREM	HI	SHADE	37	37	38	23
CHI	WINTER	2	24	71	1530	NBHD	HI	FULL	10.0	PREM	MED	SHADE	37	37	37	4
CHI	WINTER	2	24	71	1536	NBHD	HI	PART	2.4	REG	MED	SHADE	37	40	46	49
CHI	WINTER	2	24	71	1547	NBHD	HI	PART	10.1	PREM	MED	SHADE	37	37	36	17
CHI	WINTER	2	24	71	1556	NBHD	HI	FULL	17.8	PREM	HI	SHADE	38	36	36	9
CHI	WINTER	2	24	71	1604	NBHD	HI	FULL	21.6	PREM	HI	SHADE	38	37	37	8
CHI	WINTER	2	24	71	1619	NBHD	HI	PART	10.0	REG	LO	SHADE	38	37	39	53
CHI	WINTER	2	25	71	1055	NBHD	HI	FULL	18.6	REG	HI	SUN	40	37	42	***
CHI	WINTER	2	25	71	1100	NBHD	HI	PART	5.0	PREM	MED	SUN	40	42	51	***
CHI	WINTER	2	25	71	1120	NBHD	HI	FULL	12.8	REG	LO	SUN	40	37	39	25
CHI	WINTER	2	25	71	1130	NBHD	HI	FULL	9.6	REG	HI	SUN	40	37	44	10

NOTE, '***' MEANS NO DATA

TABLE F - 1. (CONTINUED) FIELD SURVEY TEMPERATURE DATA

CITY	SEASON	DATE MO.	DATE DY	DATE YR	DATE HOUR	SERVICE STATION LOC	SERVICE STATION VOL	REFUELING OPERATION FILL	GAL DISP	FUEL GRADE	DISP RATE	SOLAR RAD	TEMP. - DEG F AMB	DISP FUEL	DISPL VAPOR	TIME BETWN FILLS, MIN
CHI	WINTER	2	25	71	1148	NBHD	HI	FULL	19.5	REG	MED	SUN	40	37	39	18
CHI	WINTER	2	25	71	1150	NBHD	HI	FULL	12.2	REG	HI	SUN	40	37	47	2
CHI	WINTER	2	25	71	1158	NBHD	HI	FULL	16.4	PREM	HI	SUN	40	40	51	58
CHI	WINTER	2	25	71	1202	NBHD	HI	FULL	9.4	REG	HI	SUN	42	37	45	12
CHI	WINTER	2	25	71	1213	NBHD	HI	FULL	6.4	REG	LO	SUN	44	39	45	11
CHI	WINTER	2	25	71	1215	NBHD	HI	FULL	4.9	REG	MED	SUN	44	37	41	2
CHI	WINTER	2	25	71	1225	NBHD	HI	FULL	13.7	REG	HI	SUN	46	37	41	10
CHI	WINTER	2	25	71	1235	NBHD	HI	FULL	16.3	REG	HI	SUN	46	37	46	10
CHI	WINTER	2	25	71	1307	NBHD	HI	PART	6.7	PREM	HI	SUN	50	44	60	69
CHI	WINTER	2	25	71	3156	NBHD	HI	FULL	10.7	REG	LO	SUN	50	40	50	40
CHI	WINTER	2	25	71	1320	NBHD	HI	PART	4.5	PREM	HI	SUN	47	44	58	13
CHI	WINTER	2	25	71	1330	NBHD	HI	PART	7.3	REG	HI	SUN	45	41	52	15
CHI	WINTER	2	25	71	1340	NBHD	HI	FULL	17.9	PREM	MED	SUN	45	39	43	20
CHI	WINTER	2	25	71	1350	NBHD	HI	FULL	12.3	PREM	MED	SUN	46	39	55	10
CHI	WINTER	2	25	71	1400	NBHD	HI	PART	8.0	PREM	HI	SUN	46	38	62	10
CHI	WINTER	2	25	71	1402	NBHD	HI	FULL	12.1	REG	HI	SUN	46	38	56	32
NYC	WINTER	2	16	71	0938	NBHD	LO	FULL	8.3	REG	MED	SUN	35	40	40	***
NYC	WINTER	2	16	71	1016	NBHD	LO	PART	7.4	UNLD	MED	SUN	35	43	43	***
NYC	WINTER	2	16	71	1107	NBHD	LO	FULL	22.7	PREM	HI	SUN	35	40	44	***
NYC	WINTER	2	16	71	1158	NBHD	LO	PART	7.0	PREM	HI	SUN	37	42	47	51
NYC	WINTER	2	16	71	1220	NBHD	LO	PART	7.0	PREM	HI	SUN	35	40	45	22
NYC	WINTER	2	16	71	1330	NBHD	LO	FULL	14.3	REG	HI	SUN	35	40	40	232
NYC	WINTER	2	16	71	1445	NBHD	LO	FULL	15.8	REG	HI	SUN	34	39	39	75
NYC	WINTER	2	16	71	1457	NBHD	LO	PART	7.0	PREM	HI	SUN	34	39	40	157
NYC	WINTER	2	17	71	1020	NBHD	HI	FULL	7.7	REG	LO	SHADE	34	38	38	***
NYC	WINTER	2	17	71	1025	NBHD	HI	PART	7.2	UNLD	MED	SHADE	34	37	37	***
NYC	WINTER	2	17	71	1145	NBHD	HI	FULL	21.4	REG	HI	SHADE	34	38	37	85
NYC	WINTER	2	17	71	1207	NBHD	HI	PART	3.3	PREM	HI	SHADE	34	38	40	***
NYC	WINTER	2	17	71	1215	NBHD	HI	FULL	19.3	PREM	HI	SHADE	33	38	38	8
NYC	WINTER	2	17	71	1230	NBHD	HI	FULL	13.4	UNLD	HI	SHADE	33	37	38	125
NYC	WINTER	2	17	71	1320	NBHD	HI	PART	7.2	UNLD	HI	SHADE	32	40	38	50
NYC	WINTER	2	17	71	1337	NBHD	HI	PART	3.4	REG	HI	SHADE	33	38	37	112

NOTE, ***** MEANS NO DATA

TABLE F - 1. (CONTINUED) FIELD SURVEY TEMPERATURE DATA

		**** DATE ***				SERVICE STATION		** REFUELING OPERATION ***					TEMP. - DEG F			TIME BETWN FILLS,
CITY	SEASON	MO	DY	YR	HOUR	LOC	VOL	FILL	GAL DISP	FUEL GRADE	DISP RATE	SOLAR RAD	AMB	DISP FUEL	DISPL VAPOR	MIN
NYC	WINTER	2	17	71	1445	NBHD	HI	FULL	13.2	REG	HI	SHADE	33	38	37	68
NYC	WINTER	2	17	71	1455	NBHD	HI	PART	2.3	PREM	HI	SHADE	33	38	34	160
NYC	WINTER	2	17	71	1535	NBHD	HI	PART	7.6	REG	HI	SHADE	30	38	37	***
NYC	WINTER	2	17	71	1600	NBHD	HI	FULL	15.7	PREM	HI	SHADE	30	37	38	65
NYC	WINTER	2	17	71	1602	NBHD	HI	FULL	15.4	UNLD	HI	SHADE	30	37	37	162
NYC	WINTER	2	17	71	1642	NBHD	HI	FULL	15.4	REG	HI	SHADE	30	38	37	117
NYC	WINTER	2	18	71	1002	NBHD	HI	FULL	19.6	PREM	HI	SUN	55	41	49	***
NYC	WINTER	2	18	71	1017	NBHD	HI	FULL	15.1	UNLD	HI	SUN	53	45	50	***
NYC	WINTER	2	18	71	1047	NBHD	HI	FULL	16.3	PREM	HI	SUN	53	41	53	45
NYC	WINTER	2	18	71	1110	NBHD	HI	PART	2.6	REG	HI	SUN	53	51	52	***
NYC	WINTER	2	18	71	1114	NBHD	HI	FULL	15.3	REG	LO	SUN	54	42	44	4
NYC	WINTER	2	18	71	1131	NBHD	HI	FULL	19.4	REG	LO	SUN	54	42	45	17
NYC	WINTER	2	18	71	1145	NBHD	HI	FULL	8.9	UNLD	HI	SUN	54	46	53	88
NYC	WINTER	2	18	71	1210	NBHD	HI	FULL	16.3	REG	HI	SUN	54	42	43	39
NYC	WINTER	2	18	71	1232	NBHD	HI	PART	4.7	PREM	HI	SHADE	54	41	47	105
NYC	WINTER	2	18	71	1335	NBHD	HI	FULL	18.0	REG	HI	SHADE	54	41	41	85
NYC	WINTER	2	18	71	1346	NBHD	HI	FULL	14.4	UNLD	LO	SHADE	54	42	47	121
NYC	WINTER	2	18	71	1353	NBHD	HI	PART	4.8	UNLD	HI	SHADE	54	40	46	7
NYC	WINTER	2	18	71	1403	NBHD	HI	FULL	12.3	REG	LO	SHADE	55	41	42	113
ATL	WINTER	2	9	71	1230	FRWY	LO	FULL	10.3	PREM	HI	SHADE	24	44	42	***
ATL	WINTER	2	9	71	1240	FRWY	LO	FULL	14.8	PREM	HI	SHADE	24	46	45	***
ATL	WINTER	2	9	71	1250	FRWY	LO	PART	2.8	REG	HI	SHADE	24	41	34	***
ATL	WINTER	2	9	71	1325	FRWY	LO	FULL	15.4	PREM	HI	SHADE	24	45	45	45
ATL	WINTER	2	9	71	1345	FRWY	LO	FULL	13.9	REG	MED	SHADE	24	46	44	55
ATL	WINTER	2	9	71	1350	FRWY	LO	PART	5.8	REG	HI	SHADE	24	48	37	5
ATL	WINTER	2	9	71	1410	FRWY	LO	PART	5.2	PREM	HI	SHADE	24	41	39	20
ATL	WINTER	2	9	71	1415	FRWY	LO	FULL	12.6	PREM	HI	SHADE	24	47	46	105
ATL	WINTER	2	9	71	1417	FRWY	LO	PART	7.4	PREM	HI	SHADE	24	48	46	2
ATL	WINTER	2	9	71	1430	FRWY	LO	FULL	16.8	PREM	HI	SHADE	24	48	47	13
ATL	WINTER	2	9	71	1510	FRWY	LO	PART	2.6	PREM	HI	SHADE	24	46	43	105
ATL	WINTER	2	9	71	1540	FRWY	LO	FULL	14.3	PREM	HI	SHADE	24	47	47	30
ATL	WINTER	2	9	71	1615	FRWY	LO	FULL	10.6	PREM	HI	SHADE	24	46	44	35

NOTE. '****' MEANS NO DATA

TABLE F - 1. (CONTINUED) FIELD SURVEY TEMPERATURE DATA

		**** DATE ***				SERVICE STATION		** REFUELING OPERATION ***					TEMP. - DEG F			TIME BETWN FILLS, MIN
CITY	SEASON	MO	DY	YR	HOUR	LOC	VOL	FILL	GAL. DISP	FUEL GRADE	DISP RATE	SOLAR RAD	AMB	DISP FUEL	DISPL VAPOR	
ATL	WINTER	2	9	71	1655	FRWY	LO	PART	2.7	PREM	HI	***	24	42	38	145
ATL	WINTER	2	9	71	1705	FRWY	LO	FULL	15.7	PREM	HI	SHADE	23	46	45	50
ATL	WINTER	2	9	71	1720	FRWY	LO	PART	9.0	PREM	HI	SHADE	23	44	41	190
ATL	WINTER	2	9	71	1730	FRWY	LO	PART	2.9	REG	HI	SHADE	22	45	36	10
ATL	WINTER	2	9	71	1734	FRWY	LO	FULL	20.3	PREM	HI	SHADE	22	46	45	39
ATL	WINTER	2	9	71	1737	FRWY	LO	FULL	15.2	PREM	HI	SHADE	22	47	46	32
ATL	WINTER	2	9	71	1745	FRWY	LO	FULL	15.8	REG	HI	SHADE	22	46	38	15
ATL	WINTER	2	10	71	1105	FRWY	LO	FULL	15.0	REG	HI	SUN	24	46	47	***
ATL	WINTER	2	10	71	1115	FRWY	LO	PART	8.6	REG	HI	SUN	24	47	46	10
ATL	WINTER	2	10	71	1235	FRWY	LO	PART	5.4	PREM	HI	SHADE	24	41	40	***
ATL	WINTER	2	10	71	1311	FRWY	LO	PART	2.9	REG	HI	SHADE	24	42	40	116
ATL	WINTER	2	10	71	1313	FRWY	LO	FULL	2.9	REG	HI	SHADE	24	45	30	3
ATL	WINTER	2	10	71	1315	FRWY	LO	FULL	3.0	PREM	HI	SHADE	24	40	37	40
ATL	WINTER	2	10	71	1345	FRWY	LO	FULL	12.8	REG	HI	SHADE	24	46	46	30
ATL	WINTER	2	10	71	1402	FRWY	LO	PART	12.9	PREM	HI	SHADE	25	44	42	47
ATL	WINTER	2	10	71	1405	FRWY	LO	FULL	8.4	PREM	HI	SHADE	25	44	43	***
ATL	WINTER	2	10	71	1408	FRWY	LO	PART	2.9	REG	MED	SHADE	25	45	45	23
ATL	WINTER	2	10	71	1413	FRWY	LO	FULL	19.8	PREM	HI	SHADE	25	47	47	8
ATL	WINTER	2	10	71	1440	FRWY	LO	PART	5.7	REG	HI	SHADE	25	45	38	32
ATL	WINTER	2	10	71	1451	FRWY	LO	PART	10.3	PREM	HI	SHADE	25	45	46	49
ATL	WINTER	2	10	71	1630	FRWY	LO	FULL	14.9	REG	HI	SHADE	25	46	45	110
ATL	WINTER	2	10	71	1650	FRWY	LO	FULL	16.9	REG	HI	SHADE	33	47	47	20
ATL	WINTER	2	10	71	1655	FRWY	LO	FULL	14.4	PREM	MED	SHADE	33	44	44	124
ATL	WINTER	2	10	71	1705	FRWY	LO	FULL	11.4	REG	HI	SHADE	33	47	47	15
ATL	WINTER	2	10	71	1721	FRWY	LO	FULL	15.8	REG	HI	SHADE	33	47	47	16
ATL	WINTER	2	10	71	1730	FRWY	LO	FULL	11.0	REG	HI	SHADE	33	47	47	9
ATL	WINTER	2	10	71	1735	FRWY	LO	PART	7.7	PREM	HI	SHADE	33	44	43	40
ATL	WINTER	2	11	71	1135	FRWY	LO	FULL	15.0	REG	MED	SUN	38	47	51	***
ATL	WINTER	2	11	71	1222	FRWY	LO	PART	5.7	REG	HI	SHADE	38	48	51	47
ATL	WINTER	2	11	71	1226	FRWY	LO	PART	5.8	REG	MED	SHADE	39	48	53	4
ATL	WINTER	2	11	71	1300	FRWY	LO	FULL	8.9	REG	HI	SHADE	39	48	49	34
ATL	WINTER	2	11	71	1315	FRWY	LO	PART	2.9	REG	HI	SHADE	39	49	53	15

NOTE, '****' MEANS NO DATA

TABLE F - 1. (CONTINUED) FIFLD SURVEY TEMPERATURE DATA

CITY	SEASON	**** DATE *** ************ MO	DY	YR	HOUR	SERVICE STATION ******* LOC	VOL	** REFUELING OPERATION *** ************************ FILL	GAL DISP	FUEL GRADE	DISP RATE	SOLAR RAD	TEMP. - DEG F ************* AMB	DISP FUEL	DISPL VAPOR	TIME BETWN FILLS, MIN
ATL	WINTER	2	11	71	1329	FRWY	LO	PART	2.9	REG	HI	SHADE	39	49	53	14
ATL	WINTER	2	11	71	1337	FRWY	LO	FULL	14.0	REG	MED	SHADE	39	48	50	8
ATL	WINTER	2	11	71	1355	FRWY	LO	FULL	21.0	PREM	HI	SHADE	39	46	46	***
ATL	WINTER	2	11	71	1430	FRWY	LO	FULL	11.6	PREM	HI	SHADE	39	46	48	***
ATL	WINTER	2	11	71	1445	FRWY	LO	FULL	12.8	PREM	HI	SHADE	39	47	48	50
ATL	WINTER	2	11	71	1615	FRWY	LO	PART	5.2	PREM	HI	SHADE	41	46	50	105
ATL	WINTER	2	11	71	1630	FRWY	LO	PART	2.9	REG	HI	SHADE	41	49	60	173
ATL	WINTER	2	11	71	1637	FRWY	LO	PART	7.7	PREM	HI	SHADE	41	47	49	107
L.A.	SPRING	4	12	71	1113	FRWY	HI	FULL	15.0	PREM	HI	SHADE	74	74	78	***
L.A.	SPRING	4	12	71	1130	FRWY	HI	PART	6.9	REG	HI	SUN	76	76	79	***
L.A.	SPRING	4	12	71	1250	FRWY	HI	PART	3.2	PREM	MED	SUN	78	79	80	97
L.A.	SPRING	4	12	71	1255	FRWY	HI	FULL	5.3	PREM	MED	SHADE	78	74	78	55
L.A.	SPRING	4	12	71	1305	FRWY	HI	FULL	7.4	REG	HI	SHADE	78	73	75	95
L.A.	SPRING	4	12	71	1308	FRWY	HI	FULL	14.9	PREM	MED	SHADE	78	73	80	13
L.A.	SPRING	4	12	71	1313	FRWY	HI	FULL	13.8	REG	MED	SHADE	79	77	83	***
L.A.	SPRING	4	12	71	1325	FRWY	HI	PART	15.2	PREM	HI	SHADE	79	73	81	17
L.A.	SPRING	4	12	71	1335	FRWY	HI	FULL	15.1	PREM	LO	SHADE	79	72	76	***
L.A.	SPRING	4	12	71	1345	FRWY	HI	FULL	10.7	REG	MED	SHADE	79	77	79	32
L.A.	SPRING	4	12	71	1410	FRWY	HI	FULL	3.4	REG	MED	SHADE	79	77	82	25
L.A.	SPRING	4	12	71	1410	FRWY	HI	FULL	6.9	REG	LO	SHADE	79	73	79	55
L.A.	SPRING	4	12	71	1420	FRWY	HI	PART	6.9	REG	HI	SHADE	79	78	80	10
L.A.	SPRING	4	12	71	1504	FRWY	HI	FULL	8.4	REG	HI	SHADE	79	74	79	44
L.A.	SPRING	4	12	71	1515	FRWY	HI	FULL	21.1	PREM	LO	SHADE	79	73	76	100
L.A.	SPRING	4	12	71	1529	FRWY	HI	FULL	9.8	REG	MED	SHADE	79	79	82	25
L.A.	SPRING	4	12	71	1620	FRWY	HI	FULL	15.9	PREM	HI	SHADE	73	75	79	175
L.A.	SPRING	4	12	71	1640	FRWY	HI	FULL	14.2	REG	MED	SHADE	71	74	81	71
L.A.	SPRING	4	12	71	1645	FRWY	HI	FULL	17.0	PREM	HI	SUN	71	74	80	25
L.A.	SPRING	4	13	71	1032	FRWY	HI	FULL	14.2	REG	MED	SHADE	74	72	75	***
L.A.	SPRING	4	13	71	1035	FRWY	HI	FULL	9.0	REG	MED	SHADE	74	74	79	***
L.A.	SPRING	4	13	71	1117	FRWY	HI	FULL	11.3	PREM	HI	SHADE	75	73	75	2
L.A.	SPRING	4	13	71	1120	FRWY	HI	PART	9.1	PREM	HI	SHADE	75	72	77	3
L.A.	SPRING	4	13	71	1200	FRWY	HI	FULL	10.7	REG	HI	SHADE	76	74	81	85

NOTE, '****' MEANS NO DATA

TABLE F - 1. (CONTINUED) FIELD SURVEY TEMPERATURE DATA

		**** DATE ***				SERVICE STATION		** REFUELING OPERATION ***					TEMP. - DEG F			TIME BETWN FILLS,
CITY	SEASON	MO	DY	YR	HOUR	LOC	VOL	FILL	GAL DISP	FUEL GRADE	DISP RATE	SOLAR RAD	AMB	DISP FUEL	DISPL VAPOR	MIN
L.A.	SPRING	4	13	71	1205	FRWY	HI	FULL	15.5	PREM	HI	SUN	76	73	77	45
L.A.	SPRING	4	13	71	1208	FRWY	HI	FULL	9.9	REG	LO	SHADE	76	73	80	8
L.A.	SPRING	4	13	71	1215	FRWY	HI	FULL	5.4	PREM	HI	SHADE	77	74	75	90
L.A.	SPRING	4	13	71	1217	FRWY	HI	PART	3.4	PREM	HI	SHADE	78	73	78	9
L.A.	SPRING	4	13	71	1220	FRWY	HI	FULL	10.4	PREM	HI	SHADE	78	71	75	15
L.A.	SPRING	4	13	71	1225	FRWY	HI	FULL	11.1	REG	MED	SHADE	79	73	78	8
L.A.	SPRING	4	13	71	1258	FRWY	HI	FULL	20.0	PREM	LO	SHADE	80	73	76	43
L.A.	SPRING	4	13	71	1315	FRWY	HI	PART	6.1	PREM	HI	SUN	78	75	83	55
L.A.	SPRING	4	13	71	1355	FRWY	HI	PART	6.1	PREM	HI	SHADE	78	75	80	40
L.A.	SPRING	4	13	71	1415	FRWY	HI	PART	6.8	REG	MED	SHADE	76	73	78	223
L.A.	SPRING	4	13	71	1430	FRWY	HI	FULL	12.5	REG	LO	SHADE	75	72	77	125
L.A.	SPRING	4	13	71	1450	FRWY	HI	FULL	17.1	PREM	MED	SHADE	74	73	77	55
L.A.	SPRING	4	13	71	1500	FRWY	HI	FULL	12.2	PREM	MED	SHADE	73	72	74	10
L.A.	SPRING	4	13	71	1504	FRWY	HI	FULL	8.7	PREM	MED	SHADE	72	73	78	126
L.A.	SPRING	4	13	71	1525	FRWY	HI	PART	6.1	PREM	MED	SHADE	71	73	75	25
L.A.	SPRING	4	13	71	1540	FRWY	HI	FULL	14.1	REG	MED	SHADE	69	72	73	85
L.A.	SPRING	4	13	71	1545	FRWY	HI	FULL	15.8	PREM	MED	SHADE	69	72	74	41
L.A.	SPRING	4	13	71	1615	FRWY	HI	FULL	7.5	REG	MED	SHADE	69	72	74	95
L.A.	SPRING	4	13	71	1635	FRWY	HI	FULL	9.7	REG	MED	SHADE	69	72	71	20
L.A.	SPRING	4	13	71	1645	FRWY	HI	FULL	15.6	REG	MED	SHADE	69	72	72	10
L.A.	SPRING	4	13	71	1650	FRWY	HI	FULL	12.2	PREM	HI	SHADE	69	72	73	85
L.A.	SPRING	4	13	71	1704	FRWY	HI	FULL	13.9	PREM	MED	SHADE	69	72	72	14
L.A.	SPRING	4	13	71	1719	FRWY	HI	FULL	11.7	PREM	MED	SHADE	69	72	73	15
L.A.	SPRING	4	13	71	1725	FRWY	HI	FULL	20.2	PREM	MED	SHADE	69	72	72	6
L.A.	SPRING	4	13	71	1730	FRWY	HI	FULL	9.4	PREM	LO	SHADE	69	71	70	5
HOUS	SPRING	4	19	71	1200	NBHD	HI	FULL	8.9	PREM	HI	SHADE	85	80	86	***
HOUS	SPRING	4	19	71	1230	NBHD	HI	FULL	17.1	PREM	MED	SHADE	85	76	83	30
HOUS	SPRING	4	19	71	1300	NBHD	HI	FULL	7.7	UNLD	MED	SHADE	85	79	83	***
HOUS	SPRING	4	19	71	1330	NBHD	HI	FULL	11.8	UNLD	MED	SHADE	85	77	81	30
HOUS	SPRING	4	19	71	1351	NBHD	HI	FULL	16.7	UNLD	HI	SHADE	85	77	91	21
HOUS	SPRING	4	19	71	1407	NBHD	HI	FULL	15.2	UNLD	HI	SHADE	84	76	81	16
HOUS	SPRING	4	19	71	1440	NBHD	HI	FULL	12.4	REG	HI	SHADE	84	77	73	***

NOTE, '***' MEANS NO DATA

TABLE F - 1. (CONTINUED) FIELD SURVEY TEMPERATURE DATA

CITY	SEASON	**** DATE *** MO	DY	YR	HOUR	SERVICE STATION LOC	VOL	** REFUELING OPERATION *** FILL	GAL DISP	FUEL GRADE	DISP RATE	SOLAR RAD	TEMP. - DEG F AMB	DISP FUEL	DISPL VAPOR	TIME BETWN FILLS, MIN
HOUS	SPRING	4	19	71	1200	NBHD	HI	FULL	8.9	PREM	HI	SHADE	85	80	86	***
HOUS	SPRING	4	19	71	1230	NBHD	HI	FULL	17.1	PREM	MED	SHADE	85	76	83	30
HOUS	SPRING	4	19	71	1300	NBHD	HI	FULL	7.7	UNLD	MED	SHADE	85	79	83	***
HOUS	SPRING	4	19	71	1330	NBHD	HI	FULL	11.8	UNLD	MED	SHADE	85	77	81	30
HOUS	SPRING	4	19	71	1351	NBHD	HI	FULL	16.7	UNLD	HI	SHADE	85	77	81	21
HOUS	SPRING	4	19	71	1407	NBHD	HI	FULL	15.2	UNLD	HI	SHADE	84	76	81	16
HOUS	SPRING	4	19	71	1440	NBHD	HI	FULL	12.4	REG	HI	SHADE	84	77	79	***
HOUS	SPRING	4	19	71	1455	NBHD	HI	FULL	4.8	UNLD	MED	SHADE	84	79	81	48
HOUS	SPRING	4	19	71	1506	NBHD	HI	PART	6.1	UNLD	HI	SHADE	84	77	83	11
HOUS	SPRING	4	19	71	1508	NBHD	HI	FULL	14.7	PREM	HI	SHADE	84	77	90	158
HOUS	SPRING	4	19	71	1512	NBHD	HI	FULL	18.8	UNLD	HI	SHADE	84	76	78	6
HOUS	SPRING	4	19	71	1517	NBHD	HI	PART	5.9	PREM	HI	SHADE	84	77	85	9
HOUS	SPRING	4	19	71	1525	NBHD	HI	FULL	8.9	REG	MED	SHADE	84	77	82	45
HOUS	SPRING	4	19	71	1545	NBHD	HI	FULL	15.5	PREM	HI	SHADE	84	77	81	28
HOUS	SPRING	4	19	71	1550	NBHD	HI	FULL	20.1	PREM	HI	SHADE	84	75	79	5
HOUS	SPRING	4	19	71	1552	NBHD	HI	FULL	7.2	REG	MED	SHADE	84	79	82	27
HOUS	SPRING	4	19	71	1555	NBHD	HI	FULL	13.8	PREM	MED	SHADE	84	76	80	5
HOUS	SPRING	4	19	71	1558	NBHD	HI	FULL	16.4	PREM	HI	SHADE	84	75	78	3
HOUS	SPRING	4	19	71	1605	NBHD	HI	FULL	15.1	UNLD	HI	SHADE	84	78	80	53
HOUS	SPRING	4	20	71	0915	NBHD	HI	PART	8.9	PREM	HI	SHADE	63	73	70	***
HOUS	SPRING	4	20	71	0916	NBHD	HI	FULL	9.2	REG	MED	SHADE	63	72	69	***
HOUS	SPRING	4	20	71	0928	NBHD	HI	FULL	19.5	UNLD	HI	SHADE	63	74	71	***
HOUS	SPRING	4	20	71	0940	NBHD	HI	FULL	23.1	PREM	HI	SHADE	63	74	73	25
HOUS	SPRING	4	20	71	0947	NBHD	HI	PART	3.3	REG	HI	SHADE	63	70	65	31
HOUS	SPRING	4	20	71	0955	NBHD	HI	FULL	9.3	PREM	HI	SHADE	64	74	72	15
HOUS	SPRING	4	20	71	1020	NBHD	HI	FULL	8.5	PREM	HI	SHADE	64	73	69	25
HOUS	SPRING	4	20	71	1030	NBHD	HI	FULL	13.7	PREM	HI	SHADE	64	75	69	10
HOUS	SPRING	4	20	71	1040	NBHD	HI	FULL	20.1	REG	HI	SHADE	64	74	73	53
HOUS	SPRING	4	20	71	1112	NBHD	HI	FULL	11.6	REG	HI	SHADE	64	72	72	32
HOUS	SPRING	4	20	71	1405	NBHD	HI	FULL	20.5	PREM	HI	SHADE	64	74	76	***
HOUS	SPRING	4	20	71	1413	NBHD	HI	PART	3.3	REG	HI	SHADE	64	69	68	***
HOUS	SPRING	4	20	71	1425	NBHD	HI	FULL	17.0	PREM	HI	SHADE	64	74	74	20

NOTE, '****' MEANS NO DATA

TABLE F - 1. (CONTINUED) FIELD SURVEY TEMPERATURE DATA

CITY	SEASON	MO.	DY	YR	HOUR	SERVICE STATION LOC	SERVICE STATION VOL	FILL	GAL DISP	FUEL GRADE	DISP RATE	SOLAR RAD	TEMP. AMB (DEG F)	TEMP. DISP FUEL (DEG F)	TEMP. DISPL VAPOR (DEG F)	TIME BETWN FILLS, MIN
HOUS	SPRING	4	20	71	1437	NBHD	HI	FULL	7.4	PREM	HI	SHADE	64	75	71	12
HOUS	SPRING	4	20	71	1440	NBHD	HI	FULL	19.6	PREM	HI	SHADE	64	75	75	3
HOUS	SPRING	4	20	71	1525	NBHD	HI	FULL	11.3	PREM	HI	SHADE	64	74	74	45
HOUS	SPRING	4	20	71	1530	NBHD	HI	FULL	11.7	REG	HI	SHADE	64	73	71	77
HOUS	SPRING	4	20	71	1630	NBHD	HI	FULL	14.3	PREM	HI	SHADE	64	74	69	65
HOUS	SPRING	4	20	71	1650	NBHD	HI	FULL	16.5	PREM	HI	SHADE	64	74	73	20
HOUS	SPRING	4	20	71	1702	NBHD	HI	FULL	17.4	PREM	HI	SHADE	64	74	73	12
HOUS	SPRING	4	20	71	1715	NBHD	HI	FULL	22.9	UNLD	HI	SHADE	64	67	76	75
HOUS	SPRING	4	21	71	0915	NBHD	HI	FULL	14.7	REG	HI	SHADE	73	74	72	***
HOUS	SPRING	4	21	71	0920	NBHD	HI	FULL	15.1	REG	HI	SHADE	73	74	76	5
HOUS	SPRING	4	21	71	0930	NBHD	HI	FULL	15.5	PREM	HI	SHADE	74	75	77	***
HOUS	SPRING	4	21	71	0945	NBHD	HI	PART	11.8	PREM	HI	SHADE	74	75	74	15
HOUS	SPRING	4	21	71	0950	NBHD	HI	FULL	8.7	REG	HI	SHADE	74	73	73	30
HOUS	SPRING	4	21	71	1005	NBHD	HI	FULL	18.2	PREM	HI	SHADE	75	74	76	20
HOUS	SPRING	4	21	71	1040	NBHD	HI	PART	6.1	UNLD	MED	SHADE	76	75	76	***
HOUS	SPRING	4	21	71	1045	NBHD	HI	PART	8.9	PREM	HI	SUN	76	77	81	40
HOUS	SPRING	4	21	71	1100	NBHD	HI	FULL	7.1	PREM	HI	SUN	76	75	76	15
CHI	SPRING	5	10	71	0955	NBHD	HI	PART	12.2	REG	MED	SUN	67	55	62	***
CHI	SPRING	5	10	71	1020	NBHD	HI	PART	11.1	PREM	HI	SHADE	68	55	57	***
CHI	SPRING	5	10	71	1048	NBHD	HI	PART	8.0	REG	LO	SHADE	68	57	67	53
CHI	SPRING	5	10	71	1105	NBHD	HI	FULL	15.9	REG	MED	SHADE	69	55	59	17
CHI	SPRING	5	10	71	1115	NBHD	HI	PART	8.0	REG	LO	SUN	70	60	69	10
CHI	SPRING	5	10	71	1125	NBHD	HI	FULL	15.8	PREM	MED	SUN	70	60	71	65
CHI	SPRING	5	10	71	1152	NBHD	HI	PART	7.3	REG	MED	SUN	71	60	73	37
CHI	SPRING	5	10	71	1202	NBHD	HI	PART	8.9	PREM	MED	SHADE	71	58	68	37
CHI	SPRING	5	10	71	1215	NBHD	HI	FULL	21.2	REG	MED	SHADE	71	56	64	23
CHI	SPRING	5	10	71	1225	NBHD	HI	FULL	13.3	REG	LO	SHADE	71	55	63	10
CHI	SPRING	5	10	71	1235	NBHD	HI	FULL	22.3	REG	MED	SHADE	72	55	61	10
CHI	SPRING	5	10	71	1245	NBHD	HI	FULL	14.2	PREM	MED	SUN	72	57	69	43
CHI	SPRING	5	10	71	1247	NBHD	HI	FULL	20.4	PREM	MED	SHADE	72	54	60	2
CHI	SPRING	5	10	71	1409	NBHD	HI	PART	2.4	REG	HI	SUN	72	57	79	***
CHI	SPRING	5	10	71	1415	NBHD	HI	FULL	20.8	REG	HI	SHADE	72	52	62	6

NOTE, '****' MEANS NO DATA

TABLE F - 1. (CONTINUED) FIELD SURVEY TEMPERATURE DATA

CITY	SEASON	**** DATE *** MO	DY	YR	HOUR	SERVICE STATION LOC	VOL	** REFUELING OPERATION *** FILL	GAL DISP	FUEL GRADE	DISP RATE	SOLAR RAD	TEMP. - DEG F AMB	DISP FUEL	DISPL VAPOR	TIME BETWN FILLS, MIN
CHI	SPRING	5	10	71	1440	NBHD	HI	PART	11.1	PREM	MED	SUN	72	61	77	***
CHI	SPRING	5	10	71	1510	NBHD	HI	FULL	15.9	REG	MED	SHADE	72	58	70	55
CHI	SPRING	5	10	71	1515	NBHD	HI	PART	12.2	REG	MED	SUN	72	54	62	5
CHI	SPRING	5	10	71	1528	NBHD	HI	FULL	15.6	REG	MED	SUN	72	56	65	13
CHI	SPRING	5	10	71	1532	NBHD	HI	FULL	6.6	REG	MED	SUN	72	55	67	4
CHI	SPRING	5	10	71	1537	NBHD	HI	FULL	16.7	REG	LO	SUN	72	56	72	5
CHI	SPRING	5	10	71	1545	NBHD	HI	PART	9.3	REG	HI	SHADE	70	55	71	8
CHI	SPRING	5	10	71	1548	NBHD	HI	PART	6.7	PREM	HI	SHADE	70	63	78	68
CHI	SPRING	5	10	71	1555	NBHD	HI	FULL	15.9	REG	MED	SUN	70	56	69	10
CHI	SPRING	5	10	71	1610	NBHD	HI	FULL	14.8	REG	LO	SHADE	70	56	73	15
CHI	SPRING	5	10	71	1622	NBHD	HI	FULL	12.2	REG	MED	SUN	70	56	58	12
CHI	SPRING	5	10	71	1626	NBHD	HI	FULL	8.0	PREM	MED	SUN	70	56	67	38
CHI	SPRING	5	10	71	1755	NBHD	HI	FULL	13.2	PREM	HI	SUN	70	55	68	89
CHI	SPRING	5	10	71	1755	NBHD	HI	FULL	21.7	PREM	HI	SUN	71	54	66	***
CHI	SPRING	5	10	71	1758	NBHD	HI	FULL	4.6	REG	HI	SUN	71	59	75	96
CHI	SPRING	5	10	71	1800	NBHD	HI	FULL	10.6	REG	HI	SUN	71	55	65	2
CHI	SPRING	5	10	71	1810	NBHD	HI	FULL	14.6	REG	MED	SHADE	71	55	66	10
CHI	SPRING	5	10	71	1815	NBHD	HI	FULL	13.6	REG	HI	SHADE	71	55	65	5
CHI	SPRING	5	10	71	1845	NBHD	HI	FULL	8.1	REG	HI	SHADE	71	59	69	30
CHI	SPRING	5	10	71	1850	NBHD	HI	PART	6.7	PREM	MED	SHADE	71	60	68	55
CHI	SPRING	5	10	71	1855	NBHD	HI	FULL	14.0	REG	MED	SHADE	68	56	63	10
CHI	SPRING	5	10	71	1856	NBHD	HI	FULL	14.3	REG	MED	SHADE	68	54	66	1
CHI	SPRING	5	10	71	1900	NBHD	HI	FULL	11.1	PREM	MED	SHADE	68	57	68	10
CHI	SPRING	5	10	71	1903	NBHD	HI	FULL	12.3	UNLD	HI	SHADE	68	62	69	***
CHI	SPRING	5	10	71	1907	NBHD	HI	FULL	7.4	REG	LO	SHADE	68	55	71	11
CHI	SPRING	5	10	71	1910	NBHD	HI	FULL	17.4	REG	HI	SHADE	68	53	61	3
CHI	SPRING	5	10	71	1928	NBHD	HI	FULL	21.5	REG	HI	SHADE	68	54	63	18
CHI	SPRING	5	10	71	1932	NBHD	HI	PART	12.2	REG	LO	SHADE	65	53	59	4
CHI	SPRING	5	10	71	1933	NBHD	HI	FULL	12.7	REG	HI	SHADE	65	53	60	1
CHI	SPRING	5	10	71	2004	NBHD	HI	FULL	10.0	PREM	LO	SHADE	61	60	68	64
CHI	SPRING	5	10	71	2010	NBHD	HI	FULL	13.7	REG	MED	SHADE	61	56	66	37
CHI	SPRING	5	10	71	2035	NBHD	HI	PART	4.8	REG	MED	SHADE	61	57	63	25

NOTE, '****' MEANS NO DATA

TABLE F - 1. (CONTINUED) FIELD SURVEY TEMPERATURE DATA

		**** DATE ***				SERVICE STATION *******		** REFUELING OPERATION ***					TEMP. - DEG F *************			TIME BETWN FILLS,
CITY	SEASON	MO	DY	YR	HOUR	LOC	VOL	FILL	GAL DISP	FUEL GRADE	DISP RATE	SOLAR RAD	AMB	DISP FUEL	DISPL VAPOR	MIN
CHI	SPRING	5	10	71	2040	NBHD	HI	FULL	5.9	REG	HI	SHADE	61	54	59	5
CHI	SPRING	5	10	71	2045	NBHD	HI	FULL	12.3	REG	HI	SHADE	61	54	61	5
CHI	SPRING	5	10	71	2050	NBHD	HI	PART	5.0	PREM	MED	SHADE	58	54	60	46
CHI	SPRING	5	10	71	2055	NBHD	HI	PART	11.1	PREM	HI	SHADE	58	56	61	5
CHI	SPRING	5	10	71	2100	NBHD	HI	FULL	4.8	REG	HI	SHADE	58	54	64	15
NYC	SPRING	5	4	71	1230	NBHD	LO	PART	7.0	PREM	MED	SHADE	54	54	55	15
NYC	SPRING	5	4	71	1300	NBHD	LO	FULL	13.8	REG	MED	SHADE	54	54	57	***
NYC	SPRING	5	4	71	1325	NBHD	LO	FULL	16.3	REG	MED	SHADE	56	54	56	25
NYC	SPRING	5	4	71	1355	NBHD	LO	PART	7.0	PREM	HI	SHADE	58	54	59	85
NYC	SPRING	5	4	71	1410	NBHD	LO	FULL	11.9	UNLD	HI	SHADE	59	58	60	***
NYC	SPRING	5	4	71	1420	NBHD	LO	PART	7.0	PREM	HI	SHADE	58	55	57	25
NYC	SPRING	5	4	71	1435	NBHD	LO	FULL	14.4	PREM	HI	SHADE	58	55	59	15
NYC	SPRING	5	4	71	1445	NBHD	LO	FULL	18.6	REG	HI	SHADE	39	55	60	80
NYC	SPRING	5	4	71	1450	NBHD	LO	PART	7.0	PREM	HI	SHADE	59	55	63	15
NYC	SPRING	5	4	71	1455	NBHD	LO	PART	14.0	PREM	HI	SHADE	59	54	59	5
NYC	SPRING	5	4	71	1500	NBHD	LO	PART	5.8	PREM	HI	SHADE	59	54	62	5
NYC	SPRING	5	4	71	1515	NBHD	LO	PART	5.8	UNLD	HI	SHADE	59	58	60	65
NYC	SPRING	5	4	71	1517	NBHD	LO	PART	9.3	PREM	HI	SHADE	59	55	59	17
NYC	SPRING	5	4	71	1532	NBHD	LO	FULL	6.8	UNLD	HI	SHADE	58	56	61	17
NYC	SPRING	5	4	71	1545	NBHD	LO	FULL	8.7	UNLD	HI	SHADE	58	55	61	12
NYC	SPRING	5	4	71	1550	NBHD	LO	FULL	7.9	PREM	HI	SHADE	58	57	61	33
NYC	SPRING	5	4	71	1615	NBHD	LO	FULL	18.7	PREM	HI	SHADE	58	55	68	20
NYC	SPRING	5	5	71	1115	NBHD	LO	FULL	12.0	UNLD	HI	SHADE	68	57	64	***
NYC	SPRING	5	5	71	1120	NBHD	LO	PART	12.0	UNLD	HI	SHADE	68	56	61	5
NYC	SPRING	5	5	71	1130	NBHD	LO	FULL	8.7	PREM	HI	SHADE	68	55	64	***
NYC	SPRING	5	5	71	1200	NBHD	LO	PART	11.7	PREM	HI	SHADE	70	57	67	30
NYC	SPRING	5	5	71	1210	NBHD	LO	FULL	10.0	PREM	HI	SHADE	70	56	63	10
NYC	SPRING	5	5	71	1220	NBHD	LO	PART	9.3	PREM	MED	SUN	70	57	64	10
NYC	SPRING	5	5	71	1256	NBHD	LO	FULL	9.4	REG	MED	SUN	70	58	63	***
NYC	SPRING	5	5	71	1503	NBHD	LO	FULL	7.7	PREM	MED	SUN	72	59	70	3
NYC	SPRING	5	5	71	1500	NBHD	LO	PART	9.3	PREM	HI	SHADE	72	62	65	***
NYC	SPRING	5	5	71	1505	NBHD	LO	FULL	9.6	REG	MED	SHADE	72	60	71	***

NOTE, '****' MEANS NO DATA

TABLE F - 1. (CONTINUED) FIELD SURVEY TEMPERATURE DATA

		**** DATE ***				SERVICE STATION		** REFUELING OPERATION ***					TEMP. - DEG F			TIME BETWN FILLS,
CITY	SEASON	MO	DY	YR	HOUR	LOC	VOL	FILL	GAL DISP	FUEL GRADE	DISP RATE	SOLAR RAD	AMB	DISP FUEL	DISPL VAPOR	MIN
NYC	SPRING	5	5	71	1512	NBHD	LO	FULL	13.0	PREM	HI	SHADE	71	58	68	9
NYC	SPRING	5	5	71	1540	NBHD	LO	PART	11.7	PREM	MED	SUN	71	60	65	28
NYC	SPRING	5	5	71	1550	NBHD	LO	FULL	12.9	REG	HI	SHADE	71	59	68	45
NYC	SPRING	5	5	71	1552	NBHD	LO	FULL	12.1	PREM	HI	SHADE	71	57	75	12
NYC	SPRING	5	5	71	1602	NBHD	HI	FULL	21.0	PREM	HI	SUN	70	56	66	10
NYC	SPRING	5	5	71	1607	NBHD	HI	FULL	14.4	REG	HI	SHADE	70	57	62	17
NYC	SPRING	5	5	71	1609	NBHD	HI	FULL	7.9	PREM	HI	SHADE	70	58	75	7
NYC	SPRING	5	5	71	1614	NBHD	HI	FULL	3.9	REG	HI	SHADE	70	59	69	7
NYC	SPRING	5	5	71	1625	NBHD	HI	PART	2.6	REG	HI	SHADE	70	61	71	11
NYC	SPRING	5	5	71	1635	NBHD	HI	PART	4.7	PREM	HI	SHADE	70	61	72	26
NYC	SPRING	5	5	71	1637	NBHD	HI	FULL	16.0	PREM	HI	SHADE	70	57	68	2
NYC	SPRING	5	6	71	1000	NBHD	LO	FULL	8.4	REG	HI	SHADE	61	59	60	***
NYC	SPRING	5	6	71	1540	NBHD	LO	FULL	6.1	REG	HI	SHADE	60	59	61	***
NYC	SPRING	5	6	71	1605	NBHD	LO	FULL	9.7	REG	HI	SHADE	60	57	60	10
NYC	SPRING	5	6	71	1615	NBHD	LO	FULL	13.7	PREM	HI	SHADE	60	59	65	***
NYC	SPRING	5	6	71	1635	NBHD	LO	FULL	17.0	PREM	HI	SHADE	60	57	59	17
NYC	SPRING	5	6	71	1650	NBHD	LO	PART	9.5	PREM	HI	SHADE	60	57	64	15
NYC	SPRING	5	6	71	1730	NBHD	LO	PART	7.6	REG	HI	SHADE	60	58	60	85
NYC	SPRING	5	6	71	1735	NBHD	LO	FULL	12.1	REG	HI	SHADE	60	57	62	5
NYC	SPRING	5	6	71	1740	NBHD	LO	PART	7.0	PREM	HI	SHADE	60	59	62	50
NYC	SPRING	5	6	71	1800	NBHD	LO	FULL	10.7	UNLD	HI	SHADE	60	57	60	***
NYC	SPRING	5	6	71	1805	NBHD	LO	FULL	15.0	REG	LO	SHADE	60	58	59	30
ATL	SPRING	4	29	71	0959	FRWY	HI	FULL	10.4	REG	LO	SHADE	70	67	66	***
ATL	SPRING	4	29	71	1030	FRWY	HI	PART	10.0	REG	LO	SHADE	70	67	68	31
ATL	SPRING	4	29	71	1044	FRWY	HI	PART	13.9	PREM	MED	SHADE	70	68	69	***
ATL	SPRING	4	29	71	1047	FRWY	HI	FULL	11.5	PREM	HI	SHADE	71	68	69	3
ATL	SPRING	4	29	71	1115	FRWY	HI	PART	10.0	PREM	LO	SHADE	71	68	73	28
ATL	SPRING	4	29	71	1138	FRWY	HI	FULL	20.2	PREM	MED	SHADE	71	68	69	23
ATL	SPRING	4	29	71	1145	FRWY	HI	PART	9.4	REG	LO	SUN	72	69	74	7
ATL	SPRING	4	29	71	1220	FRWY	HI	FULL	20.3	PREM	LO	SHADE	72	67	72	42
ATL	SPRING	4	29	71	1256	FRWY	HI	PART	11.2	PREM	HI	SHADE	72	67	73	36
ATL	SPRING	4	29	71	1315	FRWY	HI	FULL	9.5	PREM	MED	SHADE	72	67	73	***

NOTE, '****' MEANS NO DATA

TABLE F - 1. (CONTINUED) FIELD SURVEY TEMPERATURE DATA

CITY	SEASON	**** DATE *** MO	DY	YR	HOUR	SERVICE STATION LOC	VOL	** REFUELING OPERATION *** FILL	GAL DISP	FUEL GRADE	DISP RATE	SOLAR RAD	TEMP. - DEG F AMB	DISP FUEL	DISPL VAPOR	TIME BETWN FILLS, MIN
ATL	SPRING	4	29	71	1520	FRWY	HI	FULL	9.6	PREM	HI	SHADE	72	67	70	67
ATL	SPRING	4	29	71	1345	FRWY	HI	FULL	16.6	REG	MED	SHADE	72	68	73	120
ATL	SPRING	4	29	71	1406	FRWY	HI	PART	11.1	PREM	MED	SHADE	73	67	71	51
ATL	SPRING	4	29	71	1413	FRWY	HI	FULL	13.9	PREM	HI	SHADE	73	67	72	7
ATL	SPRING	4	29	71	1440	FRWY	HI	PART	5.6	PREM	MED	SHADE	73	67	75	104
ATL	SPRING	4	29	71	1459	FRWY	HI	FULL	16.1	PREM	MED	SHADE	73	66	74	19
ATL	SPRING	4	29	71	1541	FRWY	HI	PART	3.1	REG	HI	SHADE	72	68	70	116
ATL	SPRING	4	29	71	1613	FRWY	HI	FULL	15.4	PREM	HI	SHADE	71	67	69	53
ATL	SPRING	4	29	71	1626	FRWY	HI	FULL	17.2	PREM	MED	SHADE	70	65	69	13
ATL	SPRING	4	29	71	1635	FRWY	HI	PART	6.4	PREM	MED	SHADE	69	69	71	9
ATL	SPRING	4	29	71	1730	FRWY	HI	FULL	9.4	PREM	HI	SHADE	69	65	68	55
ATL	SPRING	4	29	71	1738	FRWY	HI	PART	9.4	REG	HI	SHADE	69	67	71	117
ATL	SPRING	4	29	71	1750	FRWY	HI	FULL	7.9	REG	HI	SHADE	68	66	72	12
ATL	SPRING	4	29	71	1756	FRWY	HI	PART	6.3	REG	HI	SHADE	68	67	75	6
ATL	SPRING	4	29	71	1815	FRWY	HI	FULL	13.0	REG	HI	SHADE	67	66	69	19
ATL	SPRING	4	29	71	1845	FRWY	HI	PART	5.6	PREM	HI	SHADE	67	67	69	134
ATL	SPRING	4	29	71	1907	FRWY	HI	FULL	14.5	REG	HI	SHADE	67	65	68	52
ATL	SPRING	4	29	71	1930	FRWY	HI	FULL	13.0	PREM	LO	SHADE	67	67	72	120
ATL	SPRING	4	29	71	1936	FRWY	HI	FULL	14.4	PREM	HI	SHADE	67	66	69	6
ATL	SPRING	4	29	71	2009	FRWY	HI	FULL	13.6	PREM	LO	SHADE	67	66	72	34
ATL	SPRING	4	29	71	2022	FRWY	HI	FULL	13.8	PREM	MED	SHADE	67	66	70	46
ATL	SPRING	4	29	71	2039	FRWY	HI	PART	5.6	PREM	HI	SHADE	67	66	75	30
ATL	SPRING	4	29	71	2043	FRWY	HI	PART	11.2	PREM	MED	SHADE	67	66	69	26
ATL	SPRING	4	29	71	2051	FRWY	HI	PART	5.6	PREM	HI	SHADE	67	67	71	12
ATL	SPRING	4	29	71	2129	FRWY	HI	PART	8.3	PREM	HI	SHADE	67	68	75	34
ATL	SPRING	4	29	71	2136	FRWY	HI	PART	5.6	PREM	HI	SHADE	67	67	71	14
ATL	SPRING	4	29	71	2155	FRWY	HI	FULL	18.4	PREM	HI	SHADE	67	67	70	19
ATL	SPRING	4	29	71	2204	FRWY	HI	FULL	17.5	PREM	MED	SHADE	67	67	69	73
ATL	SPRING	4	29	71	2225	FRWY	HI	PART	5.6	PREM	HI	SHADE	67	66	69	30
ATL	SPRING	4	29	71	2247	FRWY	HI	PART	5.6	PREM	LO	SHADE	67	67	69	22
ATL	SPRING	4	30	71	0945	FRWY	HI	PART	11.8	PREM	HI	SHADE	56	65	62	***
ATL	SPRING	4	30	71	1000	FRWY	HI	PART	10.0	PREM	HI	SHADE	56	65	61	***

NOTE, '****' MEANS NO DATA

TABLE F - 1. (CONTINUED) FIELD SURVEY TEMPERATURE DATA

CITY	SEASON	**** DATE *** ************* MO	DY	YR	HOUR	SERVICE STATION ******* LOC	VOL	** REFUELING OPERATION *** ************************ FILL	GAL DISP	FUEL GRADE	DISP RATE	SOLAR RAD	TEMP. - DEG F ************* AMB	DISP FUEL	DISPL VAPOR	TIME BETWN FILLS, MIN
ATL	SPRING	4	30	71	1002	FRWY	HI	FULL	4.5	PREM	MED	SHADE	57	64	61	17
ATL	SPRING	4	30	71	1015	FRWY	HI	PART	2.5	PREM	HI	SHADE	58	64	61	15
ATL	SPRING	4	30	71	1016	FRWY	HI	FULL	4.6	PREM	HI	SHADE	58	64	63	14
ATL	SPRING	4	30	71	1017	FRWY	HI	FULL	10.1	PREM	MED	SHADE	59	65	65	2
ATL	SPRING	4	30	71	1020	FRWY	HI	FULL	10.0	REG	HI	SHADE	60	65	62	***
ATL	SPRING	4	30	71	1025	FRWY	HI	FULL	19.1	PREM	HI	SHADE	60	65	64	8
ATL	SPRING	4	30	71	1035	FRWY	HI	FULL	8.0	PREM	MED	SHADE	60	65	63	15
ATL	SPRING	4	30	71	1040	FRWY	HI	FULL	16.9	REG	LO	SHADE	61	66	63	5
ATL	SPRING	4	30	71	1051	FRWY	HI	FULL	24.9	PREM	LO	SHADE	61	65	66	26
ATL	SPRING	4	30	71	1115	FRWY	HI	PART	6.7	REG	MED	SHADE	62	66	64	35
ATL	SPRING	4	30	71	1130	FRWY	HI	FULL	16.9	PREM	HI	SHADE	62	65	64	74
ATL	SPRING	4	30	71	1138	FRWY	HI	FULL	17.3	PREM	MED	SHADE	62	65	65	47
L.A.	SUMMER	8	27	70	1724	NBHD	LO	PART	10.0	PREM	LO	***	88	87	85	***
L.A.	SUMMER	8	27	70	1735	NBHD	LO	PART	10.0	PREM	MED	***	88	89	92	***
L.A.	SUMMER	8	27	70	1748	NBHD	LO	FULL	11.4	PREM	MED	***	88	86	92	***
L.A.	SUMMER	8	27	70	1754	NBHD	LO	FULL	13.5	PREM	MED	***	88	85	89	***
HOUS	SUMMER	9	3	70	1540	FRWY	HI	PART	2.6	****	***	***	96	97	101	***
HOUS	SUMMER	9	3	70	1602	FRWY	HI	FULL	16.1	****	***	***	98	94	92	***
HOUS	SUMMER	9	3	70	1615	FRWY	HI	FULL	22.2	****	***	***	98	92	96	***
HOUS	SUMMER	9	3	70	1725	FRWY	HI	FULL	13.0	****	***	***	94	93	96	***
HOUS	SUMMER	9	3	70	1727	FRWY	HI	FULL	16.5	****	***	***	94	89	88	***
HOUS	SUMMER	9	3	70	1730	FRWY	HI	FULL	18.7	****	***	***	94	89	88	***
HOUS	SUMMER	9	3	70	1736	FRWY	HI	FULL	14.8	****	***	***	95	90	92	***
HOUS	SUMMER	9	3	70	1742	FRWY	HI	FULL	22.4	****	***	***	94	89	92	***
HOUS	SUMMER	9	3	70	1750	FRWY	HI	FULL	14.5	****	***	***	95	89	92	***
HOUS	SUMMER	9	3	70	1805	FRWY	HI	FULL	5.3	****	***	***	94	92	98	***
HOUS	SUMMER	9	3	70	1807	FRWY	HI	PART	5.3	****	***	***	94	92	93	***
HOUS	SUMMER	9	3	70	1836	FRWY	HI	FULL	18.3	****	***	***	91	90	96	***
HOUS	SUMMER	9	3	70	1852	FRWY	HI	PART	5.3	****	***	***	90	92	93	***
HOUS	SUMMER	9	4	70	0936	FRWY	HI	PART	1.0	****	***	***	84	95	92	***
HOUS	SUMMER	9	4	70	0941	FRWY	HI	PART	10.0	****	***	***	83	92	87	***
HOUS	SUMMER	9	4	70	0950	FRWY	HI	FULL	19.6	****	***	***	84	89	93	***

NOTE, '****' MEANS NO DATA

TABLE F - 1. (CONTINUED) FIELD SURVEY TEMPERATURE DATA

CITY	SEASON	**** DATE *** NO	DY	YR	HOUR	SERVICE STATION LOC	VOL	** REFUELING OPERATION *** FILL	GAL DISP	FUEL GRADE	DISP RATE	SOLAR RAD	TEMP. - DEG F AMB	DISP FUEL	DISPL VAPOR	TIME BETWN FILLS, MIN
HOUS	SUMMER	9	4	70	1020	FRWY	HI	FULL	15.3	****	***	***	84	89	87	***
HOUS	SUMMER	9	4	70	1035	FRWY	HI	FULL	23.3	****	***	***	85	90	90	***
HOUS	SUMMER	9	4	70	1053	FRWY	HI	FULL	12.2	****	***	***	88	89	90	***
HOUS	SUMMER	9	4	70	1109	FRWY	HI	FULL	18.1	****	***	***	88	86	89	***
HOUS	SUMMER	9	4	70	1128	FRWY	HI	FULL	11.7	****	***	***	87	90	92	***
HOUS	SUMMER	9	4	70	1145	FRWY	HI	FULL	13.9	****	***	***	89	91	93	***
HOUS	SUMMER	9	4	70	1150	FRWY	HI	FULL	18.8	****	***	***	89	90	90	***
HOUS	SUMMER	9	4	70	1204	FRWY	HI	PART	5.0	****	***	***	88	90	94	***
HOUS	SUMMER	9	4	70	1623	FRWY	HI	FULL	15.9	****	***	***	94	92	94	***
HOUS	SUMMER	9	4	70	1632	FRWY	HI	FULL	19.7	****	***	***	93	90	92	***
HOUS	SUMMER	9	4	70	1648	FRWY	HI	FULL	8.9	****	***	***	93	92	98	***
HOUS	SUMMER	9	4	70	1710	FRWY	HI	PART	2.8	****	***	***	91	93	96	***
HOUS	SUMMER	9	4	70	1755	FRWY	HI	FULL	13.9	****	***	***	90	92	90	***
HOUS	SUMMER	9	4	70	1808	FRWY	HI	FULL	21.3	****	***	***	89	90	94	***
HOUS	SUMMER	9	4	70	1820	FRWY	HI	FULL	14.2	****	***	***	89	90	96	***
HOUS	SUMMER	9	4	70	1830	FRWY	HI	FULL	23.6	****	***	***	89	90	93	***
HOUS	SUMMER	9	4	70	1942	FRWY	HI	FULL	14.2	****	***	***	85	91	99	***
CHI	SUMMER	9	8	70	1510	NBHD	HI	FULL	12.5	****	***	***	78	79	73	***
CHI	SUMMER	9	8	70	1552	NBHD	HI	FULL	11.9	****	***	***	73	77	73	***
CHI	SUMMER	9	8	70	1556	NBHD	HI	PART	7.5	****	***	***	73	76	78	***
CHI	SUMMER	9	8	70	1610	NBHD	HI	PART	5.0	****	***	***	73	76	76	***
CHI	SUMMER	9	8	70	1646	NBHD	HI	FULL	11.2	****	***	***	74	76	76	***
CHI	SUMMER	9	8	70	1653	NBHD	HI	PART	5.0	****	***	***	74	78	81	***
CHI	SUMMER	9	8	70	1702	NBHD	HI	PART	5.0	****	***	***	73	79	84	***
CHI	SUMMER	9	8	70	1710	NBHD	HI	****	5.0	****	***	***	73	79	82	***
CHI	SUMMER	9	8	70	1805	NBHD	HI	****	12.5	****	***	***	72	79	76	***
CHI	SUMMER	9	9	70	1007	NBHD	HI	PART	5.0	****	***	***	72	82	79	***
CHI	SUMMER	9	9	70	1130	NBHD	HI	FULL	13.4	****	***	***	72	78	76	***
CHI	SUMMER	9	9	70	1133	NBHD	HI	PART	5.0	****	***	***	72	76	72	***
CHI	SUMMER	9	9	70	1252	NBHD	HI	PART	7.5	****	***	***	76	78	82	***
CHI	SUMMER	9	9	70	1305	NBHD	HI	FULL	17.5	****	***	***	82	78	79	***
CHI	SUMMER	9	9	70	1630	NBHD	HI	FULL	12.5	****	***	***	82	82	68	***

NOTE, '****' MEANS NO DATA

TABLE F - 1. (CONTINUED) FIELD SURVEY TEMPERATURE DATA

		**** DATE ***				SERVICE STATION		** REFUELING OPERATION ***					TEMP. - DEG F			TIME BET.N FILLS,
CITY	SEASON	MO	DY	YR	HOUR	LOC	VOL	FILL	GAL DISP	FUEL GRADE	DISP RATE	SOLAR RAD	AMB	DISP FUEL	DISPL VAPOR	MIN
CHI	SUMMER	9	9	70	1645	NBHD	HI	FULL	14.7	****	***	***	81	79	79	***
CHI	SUMMER	9	9	70	1656	NBHD	HI	FULL	6.9	****	***	***	81	79	81	***
CHI	SUMMER	9	9	70	1745	NBHD	HI	PART	2.5	****	***	***	80	86	89	***
CHI	SUMMER	9	9	70	1754	NBHD	HI	FULL	12.5	****	***	***	80	79	87	***
CHI	SUMMER	9	9	70	1806	NBHD	HI	FULL	20.5	****	***	***	80	76	78	***
CHI	SUMMER	9	9	70	1858	NBHD	HI	FULL	14.3	****	***	***	77	79	79	***
CHI	SUMMER	9	9	70	1910	NBHD	HI	FULL	21.2	****	***	***	75	76	77	***
CHI	SUMMER	9	9	70	1939	NBHD	HI	FULL	14.0	****	***	***	74	76	78	***
NYC	SUMMER	9	15	70	1115	FRWY	HI	FULL	16.3	****	***	***	60	67	69	***
NYC	SUMMER	9	15	70	1109	FRWY	HI	FULL	17.9	****	***	***	59	54	53	***
NYC	SUMMER	9	15	70	1152	FRWY	HI	FULL	10.9	****	***	***	59	57	52	***
NYC	SUMMER	9	15	70	1532	FRWY	HI	PART	4.8	****	***	***	63	60	54	***
NYC	SUMMER	9	15	70	1544	FRWY	HI	PART	4.8	****	***	***	63	49	61	***
NYC	SUMMER	9	15	70	1555	FRWY	HI	PART	7.2	****	***	***	63	59	54	***
NYC	SUMMER	9	15	70	1603	FRWY	HI	FULL	15.5	****	***	***	63	57	57	***
NYC	SUMMER	9	16	70	1430	FRWY	HI	FULL	17.9	****	***	***	87	81	87	***
NYC	SUMMER	9	16	70	1445	FRWY	HI	FULL	19.1	****	***	***	88	81	93	***
NYC	SUMMER	9	16	70	1528	FRWY	HI	FULL	15.9	****	***	***	92	79	83	***
NYC	SUMMER	9	16	70	1541	FRWY	HI	PART	4.8	****	***	***	93	79	89	***
NYC	SUMMER	9	16	70	1745	FRWY	HI	FULL	14.3	****	***	***	87	82	82	***
NYC	SUMMER	9	16	70	1811	FRWY	HI	FULL	13.4	****	***	***	86	78	81	***
NYC	SUMMER	9	16	70	1925	FRWY	HI	FULL	20.5	****	***	***	81	76	78	***
NYC	SUMMER	9	16	70	1945	FRWY	HI	FULL	21.5	****	***	***	77	78	83	***
ATL	SUMMER	9	21	70	1512	FRWY	HI	FULL	13.2	PREM	MED	***	85	85	87	***
ATL	SUMMER	9	21	70	1607	FRWY	HI	FULL	18.4	PREM	HI	***	85	82	83	***
ATL	SUMMER	9	21	70	1619	FRWY	HI	FULL	16.3	PREM	MED	***	85	83	85	***
ATL	SUMMER	9	21	70	1626	FRWY	HI	FULL	11.7	PREM	HI	***	86	83	86	***
ATL	SUMMER	9	21	70	1634	FRWY	HI	FULL	16.1	PREM	MED	***	86	87	90	***
ATL	SUMMER	9	21	70	1655	FRWY	HI	FULL	15.2	PREM	HI	***	84	85	97	***
ATL	SUMMER	9	21	70	1720	FRWY	HI	FULL	14.3	PREM	MED	***	84	85	96	***
ATL	SUMMER	9	21	70	1729	FRWY	HI	FULL	16.7	PREM	HI	***	84	85	92	***
ATL	SUMMER	9	22	70	0938	FRWY	HI	FULL	18.5	PREM	MED	***	79	88	92	***

NOTE, '****' MEANS NO DATA

TABLE F - 1. (CONTINUED) FIELD SURVEY TEMPERATURE DATA

CITY	SEASON	**** DATE *** NO	DY	YR	HOUR	SERVICE STATION LOC	VOL	** REFUELING OPERATION *** FILL	GAL DISP	FUEL GRADE	DISP RATE	SOLAR RAD	TEMP. - DEG F AMB	DISP FUEL	DISPL VAPOR	TIME [illegible] FILLS, MIN
ATL	SUMMER	9	22	70	1450	FRWY	HI	FULL	11.8	PREM	MED	***	90	86	90	***
ATL	SUMMER	9	22	70	1645	FRWY	HI	FULL	17.0	PREM	MED	***	85	85	90	***
ATL	SUMMER	9	22	70	1707	FRWY	HI	FULL	16.3	PREM	MED	***	84	83	92	***
ATL	SUMMER	9	22	70	1720	FRWY	HI	FULL	23.8	PREM	MED	***	86	83	85	***
ATL	SUMMER	9	22	70	1727	FRWY	HI	FULL	16.8	PREM	MED	***	83	85	90	***
ATL	SUMMER	9	22	70	1758	FRWY	HI	FULL	13.6	PREM	HI	***	84	85	90	***
L.A.	FALL	1	5	71	1232	FRWY	HI	FULL	14.7	PREM	HI	***	54	61	59	***
L.A.	FALL	1	5	71	1240	FRWY	HI	PART	5.9	PREM	HI	***	54	63	64	***
L.A.	FALL	1	5	71	1315	FRWY	HI	FULL	19.2	PREM	HI	***	56	64	64	***
L.A.	FALL	1	5	71	1430	FRWY	HI	PART	5.9	PREM	HI	***	52	61	61	***
L.A.	FALL	1	5	71	1645	FRWY	HI	FULL	10.6	PREM	HI	***	50	60	58	***
L.A.	FALL	1	5	71	1716	FRWY	HI	FULL	17.5	PREM	HI	***	48	61	61	***
L.A.	FALL	1	6	71	0610	FRWY	HI	PART	6.7	PREM	HI	***	33	46	42	***
L.A.	FALL	1	6	71	0625	FRWY	HI	FULL	12.9	PREM	HI	***	34	56	51	***
L.A.	FALL	1	6	71	0730	FRWY	HI	FULL	9.6	REG	MED	***	36	54	47	***
L.A.	FALL	1	6	71	0915	FRWY	HI	PART	5.9	PREM	HI	***	44	54	48	***
L.A.	FALL	1	6	71	0955	FRWY	HI	PART	8.9	PREM	MED	***	47	58	51	***
L.A.	FALL	1	6	71	1055	FRWY	HI	FULL	9.3	PREM	HI	***	52	60	60	***
L.A.	FALL	1	6	71	1200	FRWY	HI	PART	3.0	PREM	HI	***	54	57	60	***
L.A.	FALL	1	6	71	1210	FRWY	HI	FULL	10.5	REG	MED	***	54	56	55	***
L.A.	FALL	1	6	71	1225	FRWY	HI	FULL	12.7	PREM	HI	***	54	61	62	***
L.A.	FALL	1	6	71	1250	FRWY	HI	FULL	11.4	PREM	HI	***	55	62	62	***
L.A.	FALL	1	6	71	1320	FRWY	HI	PART	6.7	REG	HI	***	55	58	62	***
L.A.	FALL	1	6	71	1330	FRWY	HI	FULL	10.1	PREM	MED	***	56	57	57	***
L.A.	FALL	1	6	71	1408	FRWY	HI	FULL	16.1	PREM	HI	***	56	58	60	***
L.A.	FALL	1	7	71	1125	FRWY	HI	FULL	6.7	PREM	HI	***	51	61	62	***
L.A.	FALL	1	7	71	1130	FRWY	HI	FULL	17.9	PREM	MED	***	51	61	62	***
L.A.	FALL	1	7	71	1145	FRWY	HI	PART	5.9	PREM	HI	***	51	59	[illegible]	***
L.A.	FALL	1	7	71	1155	FRWY	HI	FULL	14.2	PREM	MED	***	51	61	61	***
L.A.	FALL	1	7	71	1201	FRWY	HI	FULL	11.1	PREM	MED	***	51	62	60	***
L.A.	FALL	1	7	71	1322	FRWY	HI	FULL	16.2	PREM	HI	***	53	59	59	***
L.A.	FALL	1	7	71	1340	FRWY	HI	PART	3.4	REG	HI	***	54	54	53	***

NOTE. '****' MEANS NO DATA

TABLE F - 1. (CONTINUED) FIELD SURVEY TEMPERATURE DATA

CITY	SEASON	**** DATE *** MO	DY	YR	HOUR	SERVICE STATION LOC	VOL	** REFUELING OPERATION *** FILL	GAL DISP	FUEL GRADE	DISP RATE	SOLAR RAD	TEMP. - DEG F AMB	DISP FUEL	DISPL VAPOR	TIME BETW. FILLS, MIN
L.A.	FALL	1	7	71	1415	FRWY	HI	PART	5.9	PREM	HI	***	54	58	55	***
L.A.	FALL	1	7	71	1417	FRWY	HI	PART	3.0	PREM	MED	***	54	62	63	***
L.A.	FALL	1	7	71	1500	FRWY	HI	FULL	18.2	PREM	MED	***	54	62	62	***
L.A.	FALL	1	7	71	1510	FRWY	HI	FULL	19.4	REG	HI	***	54	62	65	***
L.A.	FALL	1	7	71	1550	FRWY	HI	FULL	15.5	REG	MED	***	54	60	62	***
L.A.	FALL	1	7	71	1556	FRWY	HI	PART	8.9	PREM	MED	***	54	60	60	***
L.A.	FALL	1	8	71	1150	FRWY	HI	FULL	18.6	PREM	LO	***	57	63	61	***
L.A.	FALL	1	8	71	1155	FRWY	HI	FULL	8.4	PREM	HI	***	57	61	59	***
L.A.	FALL	1	8	71	1215	FRWY	HI	FULL	18.6	REG	MED	***	57	60	61	***
L.A.	FALL	1	8	71	1255	FRWY	HI	FULL	8.6	PREM	HI	***	57	59	61	***
L.A.	FALL	1	8	71	1317	FRWY	HI	FULL	16.1	PREM	MED	***	57	64	69	***
L.A.	FALL	1	8	71	1420	FRWY	HI	FULL	6.9	REG	MED	***	57	62	66	***
L.A.	FALL	1	8	71	1453	FRWY	HI	FULL	17.3	PREM	LO	***	56	63	67	***
L.A.	FALL	1	8	71	1510	FRWY	HI	FULL	8.6	REG	LO	***	56	62	60	***
L.A.	FALL	1	8	71	1521	FRWY	HI	FULL	13.9	PREM	MED	***	55	60	62	***
L.A.	FALL	1	8	71	1526	FRWY	HI	FULL	13.6	PREM	MED	***	55	64	62	***
L.A.	FALL	1	8	71	1535	FRWY	HI	FULL	13.0	PREM	LO	***	55	64	67	***
L.A.	FALL	1	8	71	1607	FRWY	HI	FULL	13.3	PREM	MED	***	52	63	70	***
CHI	FALL	12	7	70	1041	NBHD	HI	FULL	19.0	PREM	MED	***	32	45	44	***
CHI	FALL	12	7	70	1047	NBHD	HI	FULL	7.9	PREM	MED	***	32	43	37	***
CHI	FALL	12	7	70	1058	NBHD	HI	FULL	16.3	REG	HI	***	31	46	42	***
CHI	FALL	12	7	70	1102	NBHD	HI	PART	10.0	PREM	HI	***	31	43	37	***
CHI	FALL	12	7	70	1111	NBHD	HI	FULL	15.7	PREM	HI	***	31	45	39	***
CHI	FALL	12	7	70	1129	NBHD	HI	FULL	12.3	PREM	MED	***	32	45	42	***
CHI	FALL	12	7	70	1150	NBHD	HI	FULL	15.9	REG	MED	***	33	45	41	***
CHI	FALL	12	7	70	1200	NBHD	HI	FULL	17.4	REG	HI	***	33	47	43	***
CHI	FALL	12	7	70	1210	NBHD	HI	PART	11.2	REG	HI	***	33	46	41	***
CHI	FALL	12	7	70	1217	NBHD	HI	FULL	16.9	PREM	MED	***	33	44	39	***
CHI	FALL	12	7	70	1435	NBHD	HI	PART	2.4	REG	MED	***	39	43	41	***
CHI	FALL	12	7	70	1440	NBHD	HI	PART	4.5	PREM	MED	***	39	42	42	***
CHI	FALL	12	7	70	1450	NBHD	HI	PART	7.3	REG	HI	***	37	45	40	***
CHI	FALL	12	7	70	1504	NBHD	HI	FULL	9.9	REG	MED	***	36	45	42	***

NOTE, '****' MEANS NO DATA

TABLE F - 1. (CONTINUED) FIELD SURVEY TEMPERATURE DATA

		**** DATE ***				SERVICE STATION		** REFUELING OPERATION ***					TEMP. - DEG F			TIME BETWN FILLS,
CITY	SEASON	MO	DY	YR	HOUR	LOC	VOL	FILL	GAL DISP	FUEL GRADE	DISP RATE	SOLAR RAD	AMB	DISP FUEL	DISPL VAPOR	MIN
CHI	FALL	12	7	70	1510	NBHD	HI	PART	5.0	REG	HI	***	36	43	40	***
CHI	FALL	12	7	70	1545	NBHD	HI	PART	7.3	REG	MED	***	35	43	38	***
CHI	FALL	12	7	70	1558	NBHD	HI	PART	4.3	PREM	HI	***	34	43	39	***
CHI	FALL	12	7	70	1615	NBHD	HI	FULL	17.1	REG	MED	***	34	46	43	***
CHI	FALL	12	7	70	1645	NBHD	HI	PART	2.4	REG	HI	***	34	40	35	***
CHI	FALL	12	7	70	1655	NBHD	HI	FULL	15.4	REG	MED	***	34	45	42	***
CHI	FALL	12	7	70	1702	NBHD	HI	FULL	20.8	REG	MED	***	34	47	46	***
CHI	FALL	12	7	70	1710	NBHD	HI	FULL	4.3	REG	MED	***	34	46	44	***
CHI	FALL	12	7	70	1726	NBHD	HI	PART	9.8	REG	HI	***	34	45	41	***
CHI	FALL	12	8	70	0920	NBHD	HI	FULL	12.0	REG	MED	***	38	43	42	***
CHI	FALL	12	8	70	0951	NBHD	HI	FULL	13.1	REG	HI	***	40	43	42	***
CHI	FALL	12	8	70	1020	NBHD	HI	FULL	21.7	PREM	MED	***	39	44	44	***
CHI	FALL	12	8	70	1041	NBHD	HI	FULL	13.0	PREM	HI	***	40	44	45	***
CHI	FALL	12	8	70	1110	NBHD	HI	FULL	18.9	PREM	MED	***	42	44	45	***
CHI	FALL	12	8	70	1120	NBHD	HI	FULL	6.8	REG	MED	***	43	43	43	***
CHI	FALL	12	8	70	1125	NBHD	HI	FULL	13.9	PREM	HI	***	43	44	45	***
CHI	FALL	12	8	70	1135	NBHD	HI	PART	7.3	REG	MED	***	43	44	44	***
CHI	FALL	12	8	70	1136	NBHD	HI	FULL	19.3	PREM	MED	***	43	45	46	***
CHI	FALL	12	8	70	1145	NBHD	HI	FULL	14.9	REG	HI	***	43	45	45	***
CHI	FALL	12	8	70	1155	NBHD	HI	FULL	12.2	REG	MED	***	43	44	45	***
CHI	FALL	12	8	70	1210	NBHD	HI	FULL	19.0	PREM	MED	***	44	45	46	***
CHI	FALL	12	8	70	1217	NBHD	HI	FULL	16.2	PREM	HI	***	45	45	47	***
CHI	FALL	12	8	70	1230	NBHD	HI	PART	4.9	REG	MED	***	45	45	47	***
CHI	FALL	12	8	70	1240	NBHD	HI	PART	6.7	PREM	HI	***	46	47	50	***
CHI	FALL	12	8	70	1300	NBHD	HI	FULL	6.0	PREM	HI	***	47	45	48	***
CHI	FALL	12	8	70	1308	NBHD	HI	FULL	14.4	REG	MED	***	48	45	49	***
CHI	FALL	12	8	70	1310	NBHD	HI	FULL	12.0	REG	MED	***	48	45	47	***
CHI	FALL	12	8	70	1318	NBHD	HI	FULL	13.0	PREM	MED	***	47	45	48	***
CHI	FALL	12	8	70	1330	NBHD	HI	FULL	18.3	PREM	MED	***	47	45	46	***
CHI	FALL	12	8	70	1335	NBHD	HI	FULL	6.3	REG	MED	***	47	45	47	***
CHI	FALL	12	8	70	1345	NBHD	HI	FULL	12.8	REG	HI	***	47	45	47	***
CHI	FALL	12	8	70	1407	NBHD	HI	FULL	9.3	PREM	LO	***	47	45	46	***

NOTE. '***' MEANS NO DATA

TABLE F - 1. (CONTINUED) FIELD SURVEY TEMPERATURE DATA

		**** DATE ***				SERVICE STATION		** REFUELING OPERATION ***					TEMP. - DEG F			TIME BETWN FILLS,
CITY	SEASON	MO	DY	YR	HOUR	LOC	VOL	FILL	GAL DISP	FUEL GRADE	DISP RATE	SOLAR RAD	AMB	DISP FUEL	DISPL VAPOR	MIN
CHI	FALL	12	8	70	1419	NBHD	HI	FULL	15.4	PREM	HI	***	46	45	46	***
CHI	FALL	12	8	70	1442	NBHD	HI	FULL	18.2	PREM	MED	***	46	45	50	***
CHI	FALL	12	8	70	1453	NBHD	HI	FULL	10.2	REG	HI	***	45	45	45	***
CHI	FALL	12	8	70	1505	NBHD	HI	FULL	8.8	REG	MED	***	45	45	45	***
CHI	FALL	12	8	70	1510	NBHD	HI	PART	9.8	REG	HI	***	45	45	47	***
CHI	FALL	12	8	70	1525	NBHD	HI	FULL	16.1	REG	HI	***	45	45	46	***
CHI	FALL	12	8	70	1550	NBHD	HI	FULL	9.0	PREM	MED	***	45	45	48	***
CHI	FALL	12	8	70	1600	NBHD	HI	FULL	15.6	PREM	MED	***	45	45	49	***
CHI	FALL	12	8	70	1605	NBHD	HI	PART	9.4	REG	MED	***	45	45	45	***
NYC	FALL	12	1	70	1152	NBHD	HI	FULL	11.4	PREM	MED	***	49	51	49	***
NYC	FALL	12	1	70	1207	NBHD	HI	PART	7.0	UNLD	MED	***	50	51	51	***
NYC	FALL	12	1	70	1220	NBHD	HI	PART	5.0	UNLD	MED	***	50	52	52	***
NYC	FALL	12	1	70	1228	NBHD	HI	PART	4.6	PREM	***	***	49	55	51	***
NYC	FALL	12	1	70	1225	NBHD	HI	FULL	21.3	PREM	***	***	52	51	49	***
NYC	FALL	12	1	70	1317	NBHD	HI	FULL	19.1	PREM	***	***	51	52	49	***
NYC	FALL	12	1	70	1328	NBHD	HI	FULL	8.6	REG	***	***	52	50	49	***
NYC	FALL	12	1	70	1423	NBHD	HI	FULL	12.7	UNLD	HI	***	49	51	51	***
NYC	FALL	12	1	70	1540	NBHD	HI	FULL	7.5	REG	HI	***	49	51	49	***
NYC	FALL	12	1	70	1616	NBHD	HI	FULL	10.9	REG	MED	***	48	51	51	***
NYC	FALL	12	1	70	1635	NBHD	HI	FULL	13.8	REG	HI	***	47	51	51	***
NYC	FALL	12	1	70	1710	NBHD	HI	PART	7.5	REG	HI	***	45	49	50	***
NYC	FALL	12	1	70	1711	NBHD	HI	PART	4.8	REG	HI	***	45	45	46	***
NYC	FALL	12	1	70	1734	NBHD	HI	PART	8.3	REG	HI	***	45	51	52	***
NYC	FALL	12	1	70	1745	NBHD	HI	PART	4.3	PREM	HI	***	45	46	47	***
NYC	FALL	12	2	70	1138	NBHD	HI	FULL	4.7	UNLD	HI	***	60	60	62	***
NYC	FALL	12	2	70	1212	NBHD	HI	FULL	4.6	PREM	HI	***	62	58	59	***
NYC	FALL	12	2	70	1230	NBHD	HI	FULL	5.8	UNLD	MED	***	64	59	61	***
NYC	FALL	12	2	70	1245	NBHD	HI	FULL	10.0	REG	HI	***	64	53	58	***
NYC	FALL	12	2	70	1303	NBHD	HI	FULL	11.5	PREM	HI	***	65	55	58	***
NYC	FALL	12	2	70	1620	NBHD	HI	FULL	19.6	REG	HI	***	64	53	54	***
NYC	FALL	12	2	70	1626	NBHD	HI	FULL	17.8	REG	HI	***	64	53	55	***
NYC	FALL	12	2	70	1637	NBHD	HI	FULL	10.9	PREM	MED	***	62	54	66	***

NOTE. '****' MEANS NO DATA

TABLE F - 1. (CONTINUED) FIELD SURVEY TEMPERATURE DATA

		**** DATE ***				SERVICE STATION		** REFUELING OPERATION ***					TEMP. - DEG F			TIME
CITY	SEASON	MO	DY	YR	HOUR	LOC	VOL	FILL	GAL DISP	FUEL GRADE	DISP RATE	SOLAR RAD	AMB	DISP FUEL	DISPL VAPOR	BETWN FILLS, MIN
NYC	FALL	12	2	70	1720	NBHD	HI	FULL	8.5	UNLD	HI	***	59	53	55	***
NYC	FALL	12	2	70	1738	NBHD	HI	FULL	7.0	UNLD	HI	***	58	52	56	***
NYC	FALL	12	2	70	1746	NBHD	HI	FULL	18.9	PREM	MED	***	58	51	56	***
NYC	FALL	12	2	70	1827	NBHD	HI	FULL	20.9	PREM	HI	***	56	51	61	***
NYC	FALL	12	2	70	1848	NBHD	HI	FULL	13.3	REG	HI	***	55	54	55	***
NYC	FALL	12	2	70	1825	NBHD	HI	FULL	18.2	PREM	MED	***	55	51	56	***
ATL	FALL	12	13	70	0940	FRWY	HI	FULL	11.6	PREM	HI	***	44	54	47	***
ATL	FALL	12	13	70	1001	FRWY	HI	PART	12.2	PREM	MED	***	44	56	53	***
ATL	FALL	12	13	70	1135	FRWY	HI	PART	8.5	PREM	HI	***	46	56	52	***
ATL	FALL	12	13	70	1145	FRWY	HI	PART	2.7	REG	HI	***	46	55	57	***
ATL	FALL	12	13	70	1155	FRWY	HI	FULL	14.9	REG	HI	***	46	58	58	***
ATL	FALL	12	13	70	1220	FRWY	HI	PART	5.4	REG	HI	***	48	56	58	***
ATL	FALL	12	13	70	1230	FRWY	HI	PART	12.3	PREM	HI	***	47	55	53	***
ATL	FALL	12	13	70	1300	FRWY	HI	PART	4.9	PREM	MED	***	47	55	54	***
ATL	FALL	12	14	70	1255	FRWY	HI	PART	12.2	PREM	HI	***	50	54	56	***
ATL	FALL	12	14	70	1352	FRWY	HI	PART	4.9	PREM	HI	***	52	56	57	***
ATL	FALL	12	14	70	1500	FRWY	HI	FULL	19.0	REG	HI	***	52	56	57	***
ATL	FALL	12	15	70	1015	FRWY	HI	FULL	14.8	UNLD	MED	***	42	46	43	***
ATL	FALL	12	15	70	1017	FRWY	HI	FULL	9.5	REG	MED	***	42	53	48	***
ATL	FALL	12	15	70	1045	FRWY	HI	PART	7.4	PREM	HI	***	44	50	50	***
ATL	FALL	12	15	70	1035	FRWY	HI	PART	2.8	REG	HI	***	47	49	47	***
ATL	FALL	12	15	70	1155	FRWY	HI	FULL	17.6	PREM	HI	***	47	54	47	***
ATL	FALL	12	15	70	1215	FRWY	HI	FULL	16.0	REG	HI	***	48	55	54	***
ATL	FALL	12	15	70	1220	FRWY	HI	PART	2.8	REG	HI	***	48	55	53	***
ATL	FALL	12	15	70	1225	FRWY	HI	FULL	8.3	PREM	MED	***	48	54	51	***
ATL	FALL	12	15	70	1307	FRWY	HI	FULL	8.9	PREM	MED	***	48	52	51	***
ATL	FALL	12	15	70	1317	FRWY	HI	FULL	13.0	REG	HI	***	48	67	58	***
ATL	FALL	12	15	70	1321	FRWY	HI	FULL	8.2	REG	HI	***	48	57	53	***

NOTE, '****' MEANS NO DATA