EVAP 76-3

Technical Support Report for Regulatory Action

In-House Test Program
Report No. 4

Typical Vehicle Diurnal

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Notice

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1. Introduction

A diurnal breathing loss test is defined in the Federal Register as "fuel evaporative emissions as a result of the daily range in temperature to which the fuel system is exposed." The word "diurnal" means "recurring every day" or "having a daily cycle." Test procedures are generally based upon simulating a real-life situation. In the case of diurnal evaporative losses, this situation is simulated in the Federal Test Procedure by artifically heating the fuel tank (and indirectly the fuel itself) over a one hour period, such that the tank fuel undergoes a temperature excursion from 60 to 84°F.

The main parameters of a real-life diurnal process that should be considered in establishing a firm foundation for a simulated test procedure are:

a. Typical daily temperature excursions and how they compare to the present test requirements;

b. Type and amount of fuel in the fuel tank and its effect on diurnal emissions;

c. Length of a typical diurnal.

This report researches what is presently known about these three aspects of fuel tank diurnal losses and compares them with the current test procedure. An evaluation of the important differences between a real-life diurnal and a simulated test procedure is made using data gathered from an instrumented fuel tank. This report primarily focuses on the mechanisms involved in the evolution of hydrocarbon vapors from a vehicle fuel tank.

2. Summary and Conclusions

The purpose of this study was to determine if the current diurnal evaporative emission test simulates a real-life situation. To accomplish this, a literature search was performed to determine the temperature excursion and length of a typical diurnal. Also, the percent volume of fuel typically found in a fuel tank was researched.

The literature search resulted in the following conclusions:

a. A typical daily temperature excursion is from 64-84°F instead of the 60-84°F associated with the heat build currently used in the diurnal test simulation;

b. A typical diurnal occurs over a 10 hour period of time. Currently the diurnal test is conducted over a one hour time period.

c. The normal fuel tank is filled to 59% capacity instead of the 40% capacity currently used in the diurnal test simulation.

Four test procedures using combinations of either a 40% tank fill or a 60% tank fill and either a 60-84°F temperature rise or a 64-84°F temperature rise were performed. Results of this testing showed that a 60-84°F temperature rise results in 12.6% higher emissions than a 64-84°F temperature rise. Also, a 40% fuel fill was found to result in a 10% higher emission level than a 60% fuel fill. Tests using 60% fill and a 64-84°F temperature rise resulted in 19% lower emissions than tests using a 40% fill and a 60-84°F temperature rise.

The evaluation of the length of the diurnal consisted of tests with 1, 2 and 3 hour heat builds from 60 to 84°F. The difference in emission levels measured for these tests was found to be statistically significant. The average value for the 3 hour heat build was 34% higher than for the one hour heat build tests and there was a definite trend of higher emission levels for the longer tests. The evaluation of the vapor temperatures and pressures of the fuel tank showed roughly the same emission levels would have been measured for the three different heat build rates, if the vapor temperatures and pressures would have been allowed to come to equilibrium. To account for these vapors would require extending the one hour test thirty minutes after termination of the heat build.

Tests conducted using a test procedure based on the results of the literature search and the test program (64-84°F heat built over one hour period followed by a 1/2 hour soak with a 60% fuel fill) showed emission levels only 5.9% above (instead of 19% lower without the 1/2 hour soak) emission levels measured for tests conducted using the current procedure

(60-84°F heat build over 1 hour with a 40% fuel fill). Additional testing should be performed on evaporative emission controlled vehicles to substantiate the findings of this study.

The premise established in simulating the diurnal test is that the fuel liquid undergoes the same temperature excursion as the ambient. This has not been substantiated in this study and some data exists that show the fuel temperature never reaches the lowest nor the highest daily ambient temperature. This data should be confirmed (or refuted) by further testing and the further evaluations should be made at that time on the corresponding fuel vapor temperature. The vapor temperature in this study was found to only go through a 14°F temperature excursion when the liquid temperature experienced a 24°F excursion. Since the evolution of hydrocarbon vapors is a function of the vapor temperature excursion (and we have assumed a state of equilibrium), the vapor temperature should also go through a "typical" temperature excursion. This may or may not be the same as the ambient or liquid temperatures and controlling the vapor temperature may lead to better simulation with less variability.

3. Literature Review

Hydrocarbon emissions occur from the fuel tank due to increasing temperatures which cause an expansion of gases in the vapor space. The expanding gases may pass out of the tank vapor space and go into the surrounding atmosphere. In the case of current evaporative controlled vehicles, the gases should pass through a charcoal canister where the hydrocarbons will be adsorbed on the charcoal. If the gases in the vapor space are not allowed to expand, the pressure in the fuel tank will build up.

Based on the above discussion, it is evident that for diurnal emissions we are primarily concerned about periods of increasing temperatures. Decreasing temperatures should have no effect on hydrocarbon emissions. This concept is generally an accepted fact by both the motor vehicle industry and by private researchers (1) (2) (3). Thus, the magnitude and length of the temperature excursion which begins at the lowest temperature of the day (in the early morning) and ends with the maximum temperature of the day (during the late afternoon) needs to be determined in order to be able to simulate a "typical" diurnal for the measurement of evaporative emissions.

A "typical" diurnal temperature excursion will vary from month to month and will also depend on geographic locality. The environmental impact of evaporative emissions will, therefore, also vary throughout the year and from place to place. This fact must be kept in mind so that the diurnal test is typical of times during the year and certain localities for which the problem of evaporate emissions is most severe.

3.1 Typical Daily Temperature Excursions

According to the report on "Fuel System Evaporative Losses" (1), the maximum temperature for the diurnal phase of the evaporative emission test appears to have been based upon, or at least substantiated by, the median smog-day temperatures in Los Angeles during 1955-56. The maximum temperature of 85°F was reported to have been the median smog-day temperature stated in a letter from Dr. L. A. Chambers of the Los Angeles Air Pollution Control District to Mr. O. P. Baker of the AMA (now MVMA) staff.*

Since, for the most part, the problem of hydrocarbon emissions is most acute in the urban area, a typical temperature excursion should be determined using data from major urban areas. The average minimum/maximum temperatures for thirty-one major metropolitan areas were investigated. These standard metropolitan statistical areas were selected from MVMA's 1973/74 report (4) and represented 37% of the registered passenger cars in the U.S., and 37.8% of the country's population.

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*No indication of minimum temperature is given in the referenced report.

It can be seen in Table 3-1 that the Los Angeles metropolitan area has the largest number of registered cars, while New York has the greatest population density. The normal monthly temperatures for the years 1941-70 are cited in a U.S. Department of Commerce publication (5). The overall average minimum/maximum temperatures for the various selected sites, weighted for both population and vehicle density, are shown month by month in Table 3-2. The temperature range, weighted for vehicle density, is shown graphically in Figure 3-1.

Since the most severe smog conditions probably occur during July and August, the test procedure should try to represent the diurnal temperature excursions seen during those months. Table 3-2 and Figure 3-1 indicate that the maximum temperatures likely to occur during July and August are near 85°F. Therefore, the maximum temperature currently used in the diurnal test simulation was, as stated earlier, associated with times with the most severe air pollution problems.

The average minimum/maximum temperatures for all months and for July and August are highlighted in Table 3-2. The data show that the temperature excursion seen for July and August is 64°F to 84°F, and is the same whether the data are weighted by population, by vehicle population or unweighted.

This information is based upon monthly average temperatures for 31 cities. A more detailed analysis is available using the daily temperatures for the months of July and August for five specific metropolitan areas (Chicago, Denver, Detroit, Houston and Los Angeles) which reasonably represent major air quality control regions (6). Composite histograms are shown in Figures 3-2, 3-3 and 3-4. Figures 3-2 and 3-3 show the plot for the daily maximum and minimum temperatures respectively. Figure 3-4 is the composite plot of the daily differential temperatures. It can be seen that the results show a 63.3 to 84.3°F temperature excursion which is very similar to the 64.0 to 84.0°F excursion for the 31 city monthly average. A complete set of histograms for each of the five cities showing daily maximum, minimum and differential temperatures is exhibited in the Appendix.

Since the 5 city detailed analysis approximates the information derived from the 31 city monthly analysis, it appears that a diurnal temperature excursion of 64-84°F accurately describes a summer month diurnal in a typical U.S. urban center.

3.2 Length of Diurnal

Another item of concern is that of determining when the maximum and minimum daily temperatures occur. This will give us an insight into the real-life "length of diurnal."

The duration of a real-life diurnal can be determined from an investigation of local climatological data (6). Using data for the same 5 sites used in Section 3-1 (Chicago, Denver, Detroit, Houston, and Los Angeles) an average summary of hourly temperatures for the years 1973-74 was determined and is presented in Figure 3-5.

CITY	POPULATION		NO. CARS	
	x 1000	%	x 1000	%
Los Angeles	7032	9.15	3597	10.46
New York	11571	15.06	3398	9.88
Chicago	6978	9.08	2815	8.18
Philadelphia	4817	6.27	2124	6.18
Detroit	4199	5.46	1942	5.65
San Francisco	3109	4.05	1510	4.39
Washington, D.C.	2861	3.72	1303	3.79
Pittsburgh	2401	3.12	1058	3.08
St. Louis	2363	3.08	1040	3.02
Cleveland	2064	2.69	1015	2.95
Houston	1985	2.58	970	2.82
Newark	1856	2.42	894	2.60
Minneapolis	1813	2.36	866	2.52
Baltimore	2070	2.69	842	2.45
Dallas	1555	2.02	812	2.36
Anaheim (Santa Ana)	1420	1.85	778	2.26
Atlanta	1390	1.81	747	2.17
Miami	1267	1.65	742	2.16
Patterson	1358	1.77	681	1.98
Denver	1227	1.60	679	1.97
San Diego	1357	1.77	676	1.97
Seattle	1421	1.85	669	1.94
Cincinnati	1384	1.80	655	1.90
Tampa	1012	1.32	600	1.74
Milwaukee	1403	1.83	588	1.71
Kansas City	1253	1.63	586	1.70
San Jose	1064	1.38	561	1.63
Riverside	1143	1.49	683	1.99
Portland	1009	1.31	535	1.56
Buffalo	1349	1.76	522	1.52
Indianapolis	1109	1.44	508	1.48
TOTALS	76840	100	34396	100

Table 3-1 Major Urban Areas by Population & Vehicles

	UNWEIGHTED		WEIGHTED BY POPULATION		WEIGHTED BY # CARS	
MONTH	MIN	MAX.	MIN.	MAX.	MIN.	MAX.
Jan.	29.45	46.08	28.45	44.29	29.42	45.63
Feb.	31.34	48.87	30.18	46.78	31.20	48.14
Mar.	36.88	55.31	36.10	53.67	36.87	54.73
Apr.	45.56	65.28	44.91	64.06	45.42	64.69
May	53.09	73.19	52.78	72.44	53.01	72.72
Jun.	60.50	80.40	60.63	80.05	60.57	80.06
Jul.	64.44	84.46	64.97	84.18	64.82	84.18
Aug.	63.45	83.61	63.82	83.24	63.73	83.34
Sept.	57.92	78.66	58.17	78.04	58.29	78.40
Oct.	49.39	69.91	49.48	69.20	49.79	69.77
Nov.	39.87	58.18	39.87	57.20	40.32	58.09
Dec.	32.15	48.72	31.38	46.98	32.21	48.26
All Mos Comb.	47.01	66.05	46.73	65.01	47.14	65.67
Jul. & Aug.	63.95	84.04	64.39	83.71	64.27	83.76

Table 3-2 Average Monthly Temperatures for 31 Cities

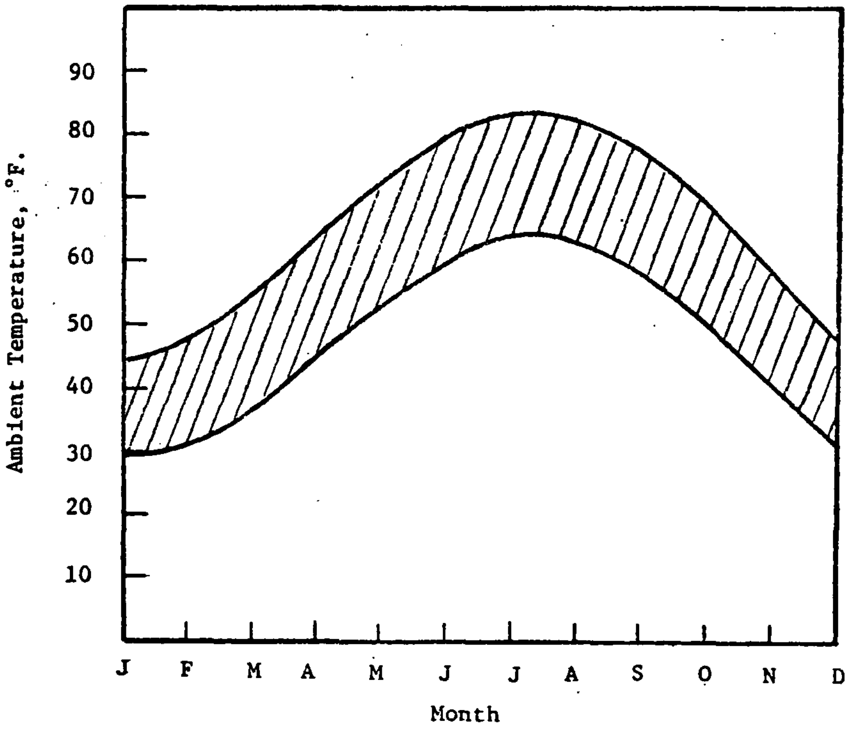

Figure 3-1 Average Min/Max Temperature 1941-70
Weighted by Vehicle Population

```
               NO. OF DAYS
 MAX
 TEMP 0        10        20        30        40        50
      I....+....I....+....I....+....I....+....I....+....I
   65 I
   66 I
   67 I***
   68 I
   69 I*
   70 I*****
   71 I*****
   72 I*********************
   73 I**************************
   74 I************************
   75 I**********************
   76 I**********************
   77 I*******************
   78 I******************
   79 I****************
   80 I************************
   81 I*********************
   82 I*****************************
   83 I*************************
   84 I***********************
   85 I***********************
   86 I******************************
   87 I*********************************
   88 I*********************
   89 I*****************************
   90 I************************
   91 I**********************
   92 I***********************
   93 I*********************************
   94 I*************************
   95 I****************************
   96 I**********
   97 I********
   98 I****
   99 I*
  100 I*
  101 I
  102 I
  103 I*
  104 I
  105 I
  106 I
  107 I
  108 I
  109 I
      I....+....I....+....I....+....I....+....I....+....I
```

Min = 67°F
Max = 103°F
Mean = 84.3°F

Figure 3-2 Composite Distribution of Maximum Daily Temperatures - 5 Cities (July & August)

```
                NO. OF DAYS
MIN
TEMP 0         10        20        30        40        50
     I....+....I....+....I....+....I....+....I....+....I
  45 I**
  46 I*
  47 I
  48 I**
  49 I***
  50 I*******
  51 I********
  52 I***********
  53 I***************
  54 I******
  55 I******************************
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  57 I************
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  77 I**
  78 I*
  79 I
  80 I
  81 I
  82 I
  83 I
  84 I
  85 I
  86 I
  87 I
  88 I
  89 I
     I....+....I....+....I....+....I....+....I....+....I
```

Min = 45°F
Max = 78°F
Mean = 63.3°F

Figure 3-3 Composite Distribution of Minimum Daily Temperatures - 5 Cities (July & August)

```
                 NO. OF DAYS
TEMP
DIFF 0         10        20        30        40        50
     I....+....I....+....I....+....I....+....I....+....I
   1 I
   2 I
   3 I*
   4 I*
   5 I*
   6 I
   7 I*******
   8 I*****
   9 I**************
  10 I**********************
  11 I***************************
  12 I*******************************
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  35 I**************
  36 I********
  37 I****
  38 I***
  39 I***
  40 I
  41 I***
  42 I
  43 I
  44 I
  45 I*
     I....+....I....+....I....+....I....+....I....+....I
```

Min = 3°F
Max = 45°F
Mean = 20.9°F

Figure 3-4 Composite Distribution of Differential Daily Temperatures - 5 Cities (July & August)

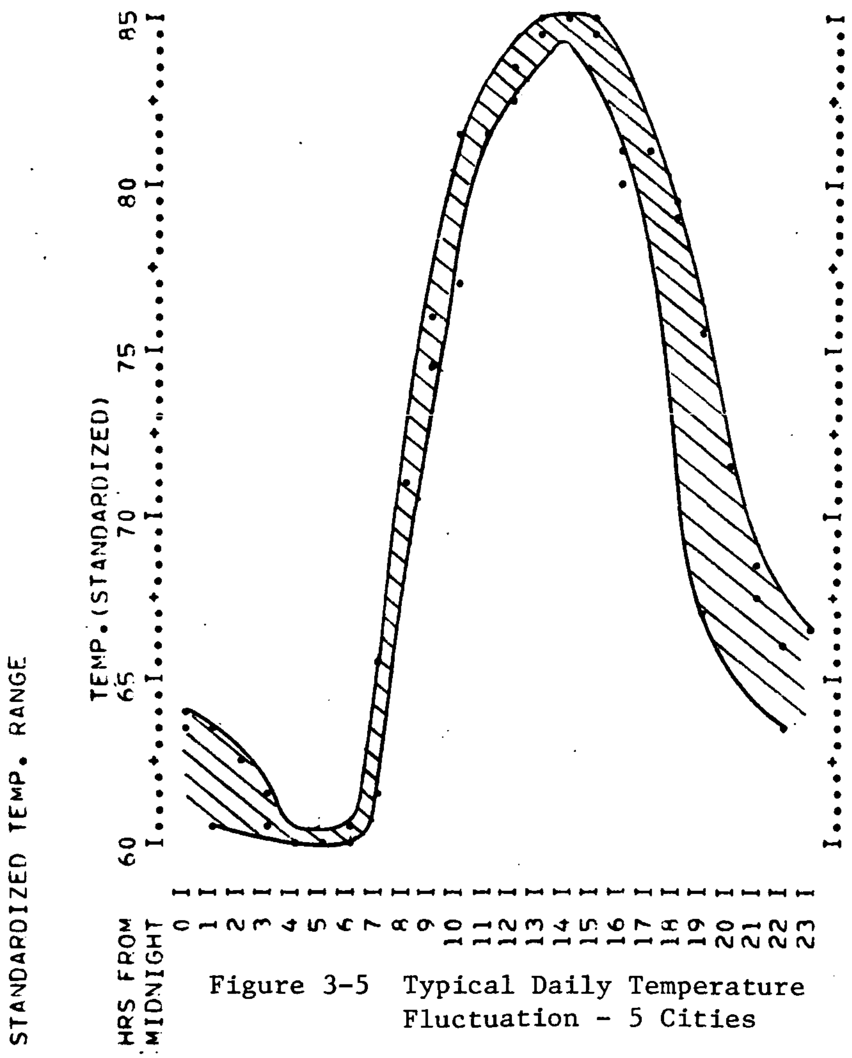
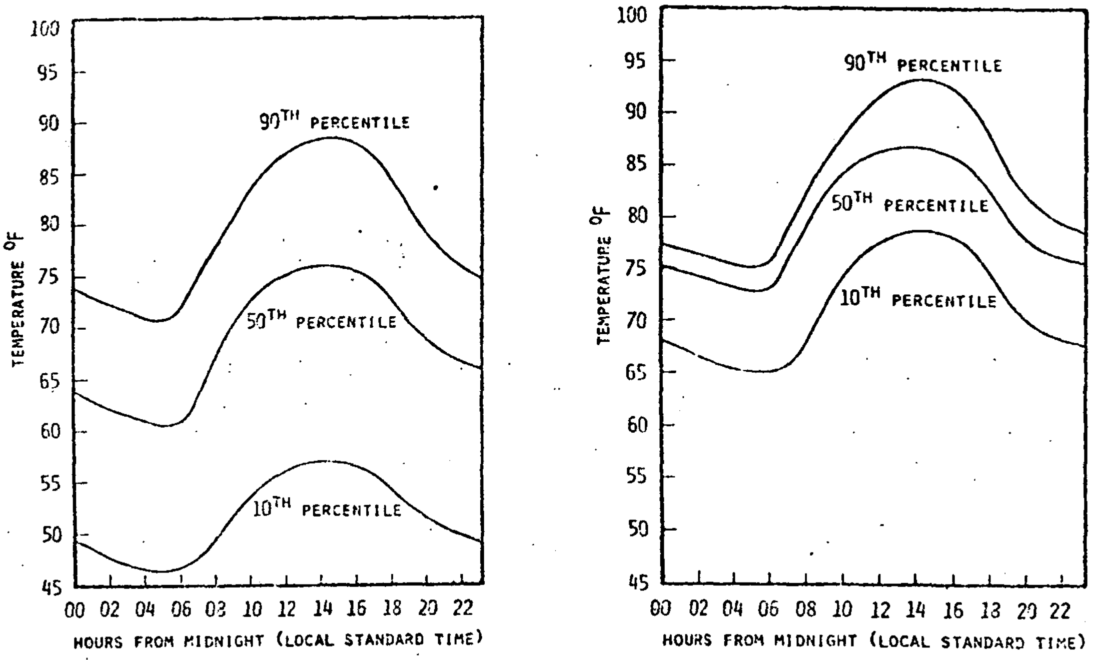


Figure 3-5 Typical Daily Temperature Fluctuation - 5 Cities

The temperatures for the five cities have been standardized to a temperature range of 25°F (60 to 85°F) with the minimum daily temperature shown at 60°F, as shown below:

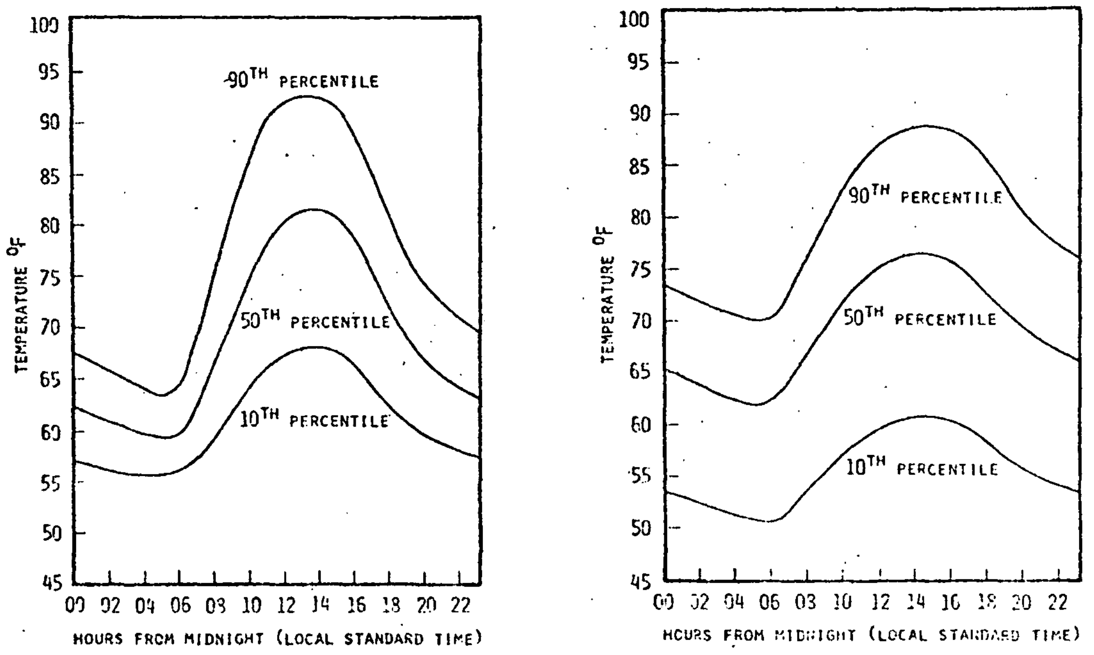
$$T_{std} = (25)\frac{T - T_{min}}{T_{max} - T_{min}} + 60$$

where T is the hourly temperature for a particular city. Since we are mainly concerned with <u>length</u> of diurnal, this standardization has been done for ease of presentation in showing the time period for temperatures within the same range. This temperature range, as shown in Figure 3-2, shows the diurnal, or more specifically, the average daily heat rise occurring over a time period of approximately 10 hours. An in-depth analysis of diurnal ambient temperature profiles was reported by W. F. Biller and others (7). The graphical results of Biller's analysis are shown in Figure 3-6 and presents daily maximum temperatures corresponding to the 10th, 50th, and 90th percentiles. These percentiles were obtained from a cumulative distribution of daily temperatures from May through October. Four cities were used in this analysis, and the maximum temperatures corresponding to the three percentile days are shown



CHICAGO

HOUSTON



LOS ANGELES

NEW YORK

Figure 3-6 Diurnal Temperature Patterns,
May-October, inclusive.
(Reprinted from Ref. 6)

City	10th	50th	90th
Chicago	59.0	78.0	90.0
Houston	80.0	89.3	94.5
Los Angeles	68.5	82.0	93.5
New York	62.3	78.2	90.0

Table 3-3 Maximum Temperatures Corresponding to 10th, 50th & 90th Percentile Days

in Table 3-3. It is interesting to note that the average maximum temperature for the four cities (50th percentile) is 81.88°F, while the average maximum temperature for the same period (May through October) for the 31 cities used in this report (Table 3-2), is 79.60°F. In either case, when we compare the graphical illustrations of both data, the natural diurnal heat build time is approximately 10 hours.

On the average, the diurnal heat rise starts around 5:00 AM and peaks at approximately 3:00 PM. Therefore, we know that the typical vehicle is likely to have been in operation during the diurnal heat rise. If we accept the premise that fuel tank emissions occur anytime the fuel tank liquid temperature increases, then we can conclude that such emissions will occcur whether the vehicle is parked or in operation. This conclusion is in agreement with Biller's assumption in Appendix B of his report (7).

3.3 Amount of Fuel in the Fuel Tank

As was previously mentioned, fuel tank losses are a result of thermal expansion. As Ellsworth (8) points out, "when vapor space and temperature decrease, the amount of fuel evaporated decreases." Thus, it can be said that the amount of fuel in the tank (remaining from overnight parking) directly influences the evaporative losses during the daily heat rise. Simulation of a diurnal test, therefore, must establish a repeatable volume of gasoline as part of the test requirements. Presently, the Federal Test Procedures require the fuel tank to be filled to a capacity of 40% of the nominal fuel tank volume rounded off to the nearest whole gallon. Rounding to the nearest whole gallon implies a tolerance of ± 0.5 gallons. It also introduces an error in establishing the typical fuel fill volume. The effect of this is probably minimal. However, with presently available equipment, it is easy enough to control the tank fill to the nearest tenth of a gallon. It is recommended that the tank fill volume be determined to the nearest tenth of a gallon to achieve greater consistency.

The results of a 1969 six city survey (9) reported overnight fuel tank readings, as shown in Table 3-4, averaged 59% full for weekday parking, and 55% full for weekend parking. These data are shown graphically in Figure 3-7 as a cumulative frequency distribution plot.

3.4 Summary of Literature Review

In summary, the typical diurnal experienced by a vehicle consists of the following:

a. Average temperature excursion for the months of July and August is 64 to 84°F;

b. The daily heat rise, on the average, for the months of July and August, cover a 10 hour period of time from 5:00 AM to 3:00 PM, local standard time:

c. The average fuel tank is filled to 59% of capacity.

		NYC		TWC		CHI		CIN		HOU		LA		SIX CITY	
	READING	N	%	N	%	N	%	N	%	N	%	N	%	N	%
Weekday	Empty	23	2.1	25	4.7	24	3.1	27	4.5	29	0.3	66	8.3	194	4.6
	1/4	215	20.2	135	25.2	177	22.9	150	25.3	103	22.4	181	22.9	961	22.8
	1/2	274	25.7	157	29.3	215	27.9	180	30.3	105	22.8	202	25.5	1133	26.9
	3/4	301	28.3	114	21.3	174	22.6	133	22.4	106	23.0	162	20.4	990	23.5
	Full	252	23.7	105	19.5	181	23.5	104	17.5	117	25.5	181	22.9	940	22.2
	Total	1065		536		771		594		460		792		4218	
Weekend	Empty to 1/4	89	28.3	58	32.9	62	23.5	72	32.9	50	27.2	82	32.8	413	29.4
	1/2	83	26.3	53	30.1	61	23.1	58	26.5	59	32.1	82	32.8	396	28.1
	3/4	70	22.2	36	20.5	72	27.3	37	16.9	42	22.8	53	21.2	310	22.0
	Full	73	23.2	29	16.5	69	26.1	52	23.7	33	17.9	33	13.2	289	20.5
	Total	315		176		264		219		184		250		1408	

Table 3-4 Overnight Fuel Tank Readings

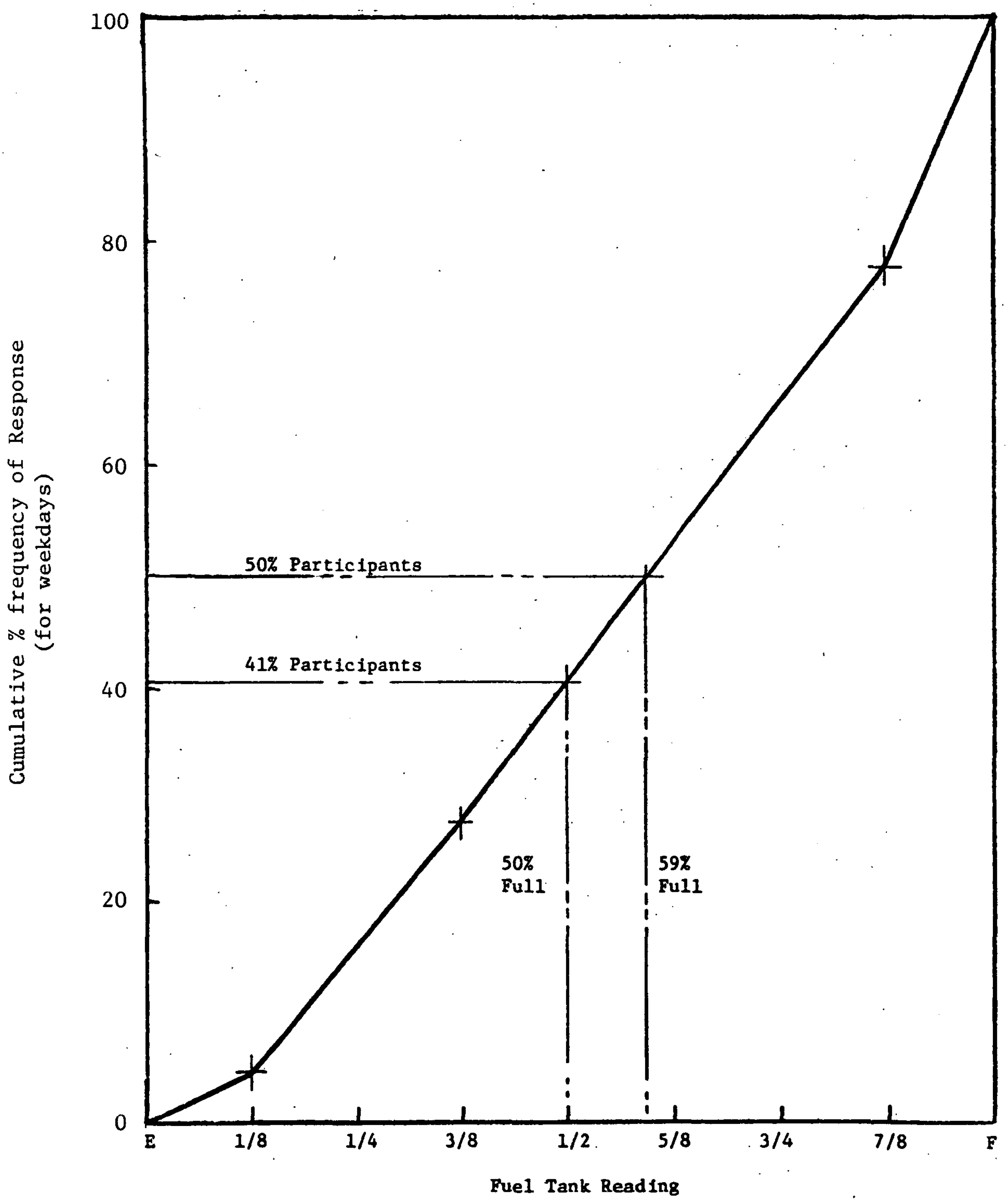


Figure 3-7 Cumulative Frequency Diagram of Fuel Tank Readings from Six City Survey

4. Technical Discussion

Based on the information obtained from the literature search, the diurnal test, in order to simulate an average real-life diurnal, would have to be run for a period of 10 hours over a 64-84°F temperature range with the fuel tank filled to 60% capacity. The temperature excursion (64 to 84°F) and filling the fuel tank to 60% capacity do not present any practical problems. A 10 hour test on the other hand is excessively long, would be vastly more expensive than a shorter test, and would put a much heavier burden on testing facilities.

The diurnal evaporative emission test procedure currently accepted for enclosure measurements is based upon the test procedure described in J171a of the SAE Handbook (10). This test specifies the following:

a. Temperature excursion is 60 to 84°F.

b. The fuel tank is filled to 40% capacity.

c. Heat rise is conducted over a one hour period.

There are definite differences in the test procedure recommended by SAE and the test procedure which resulted from the literature search. A temperature excursion of 60-84°F would be expected to result in higher emission levels than a 64-84°F excursion because a greater expansion of gases in the vapor space should occur. A 40% fuel fill would be expected to result in higher emissions than a 60% fill due to the greater vapor volume with the 40% fill. These expected differences should be explored in order to determine the magnitude of the actual effect. Regardless of the magnitude of the effect, the more representative values for the test are a 64-84°F temperature excursion and a 60% fuel fill.

The SAE procedure stipulates that the test should be performed over a one hour period. Considering the premise that emission levels are only a function of the expansion of gases in the vapor space, then the length of the test shouldn't matter. This may only be true up to a point. If the fuel is heated too quickly, it may result in an unrepresentative test due to a pressure build-up in the tank, because gases cannot pass out of the tank quickly enough. The fuel tank and control system design will affect tank pressure build-up.

During a real-life diurnal, it might be assumed that the fuel liquid and vapor temperatures undergo the same temperature excursion (64-84°F) as the ambient. However, data from a study conducted by Scott Research Laboratories (11) indicate that the liquid temperature lags the ambient temperature (by approximately 2 hours) and never reaches the same maximum or minimum value. In the data presented by Scott the ambient temperature went from 61.0 to 87.1°F, whereas the fuel temperature saw a change of 63.9 to 84.0°F. This information (with a standard deviation of values in each time point ranged from 3.4 to 9.8) was the mean value developed for an 80-car fleet undergoing a 24-hour soak period.

This study did not attempt to evaluate the relationship of fuel temperature versus ambient temperature, but rather assumed, as previously stated, that the fuel temperature was in a state of equilibrium with the ambient and experienced the same total excursion.

During the present evaporative emission certification test and the SAE procedure, the temperature excursion is controlled from the mid-volume of the liquid fuel. The length of the test and the temperature of the fuel tank prior to the start of the test may limit the temperature excursions of the fuel vapor. It is not yet known whether, in an actual diurnal, the liquid and vapor temperatures are in equilibrium. If an equilibrium process is the case, and since the temperature excursion of the vapor causes the vapor expulsion, the test should be long enough to allow equilibrium to occur. This may require a test longer than one hour.

4.1 Program Objective

The purpose of this study was to examine the differences in emissions when the vehicle underwent various diurnal conditions and to determine if significantly different emission levels exist.

4.2 Program Design

To determine the significant effects of the different procedures, it was decided to study the mechanisms by which the hydrocarbon vapors were generated rather than determine the effects on an actual vehicle control system.

Therefore, an instrumented fuel tank was prepared without any vapor control system. The fuel tank was vented into a sealed enclosure where the hydrocarbon concentration was continuously monitored. This made it possible to evaluate the effects of different temperature excursions, two fuel levels, and various heat-build times.

The temperature excursions evaluated were 60-84°F based upon the SAE J171a recommended practice (1) and 64-84°F as determined from the literature survey. Two fuel levels were examined for their effect on the generation of hydrocarbon losses. A 40% fuel fill was used based on the SAE recommended practice, and a 60% fill was used based on the literature survey. Three heat-build times of 1, 2, and 3 hours were conducted to evaluate the effect of test length.

4.3 Facilities and Equipment

4.3.1 Facilities

The LDV Evaporative Enclosure as shown in Figures 4-1 and 4-2 was used for all tests. The enclosure is nominally 8 feet high x 10 feet wide x 20 feet long, and has a measured volume of 1540 cubic feet. Calibration of the enclosure with a propane injection and recovery test compared within ± 2 percent. Propane retention tests of 2 and 4 hours were performed periodically and indicated a leakage rate of less than 0.1 g/hr.

Figure 4-1 Evaporative Enclosure (front view).

Figure 4-2 Evaporative Enclosure (rear view).

4.3.2 Equipment

A 1974 Chevrolet Impala fuel tank with a nominal capacity of 22 gallons was instrumented with pressure gauges and thermocouples (see Figure 4-3) to provide the following information:

a. Fuel liquid temperature;

b. Fuel vapor temperature and pressure;

c. Tank skin temperature.

4.3.3. Test Fuel

Indolene Type HO (8.7 - 9.2 psi RVP) test fuel was used throughout the program.

4.4 Test Procedures

All diurnal comparative tests were conducted in the evaporative enclosure using the instrumented fuel tank. Fresh fuel was used for each test. The fuel was delivered from a fuel conditioning cart into the tank at a temperature of approximately 50°F and allowed to naturally heat to the appropriate starting temperature. A 2000 watt heat blanket was attached to the bottom of the tank and provided the heat for all diurnal tests. The fuel was heated at a linear rate over the specified period of time.

4.4.1 Temperature Excursion and Fuel Volume Tests

To determine the significance of the daily temperature excursion (60-84°F versus 64-84°F) and the significance of the amount of fuel in the fuel tank (40% fill versus 60% fill), a minimum of four replicate tests of the following four test procedures were conducted:

a. 60 min., 60-84°F heat-build with 40% fill;

b. 60 min., 64-84°F heat-build with 40% fill;

c. 60 min., 60-84°F heat-build with 60% fill;

d. 60 min., 64-84°F heat-build with 60% fill.

Performing the testing in this manner allowed for comparative evaluations of one variable at a time. In addition, the fuel tank was allowed to remain in the enclosure for one hour after the heat was turned off in order to determine at what point emissions cease when the temperature rise stops. Vapor temperatures were monitored to determine

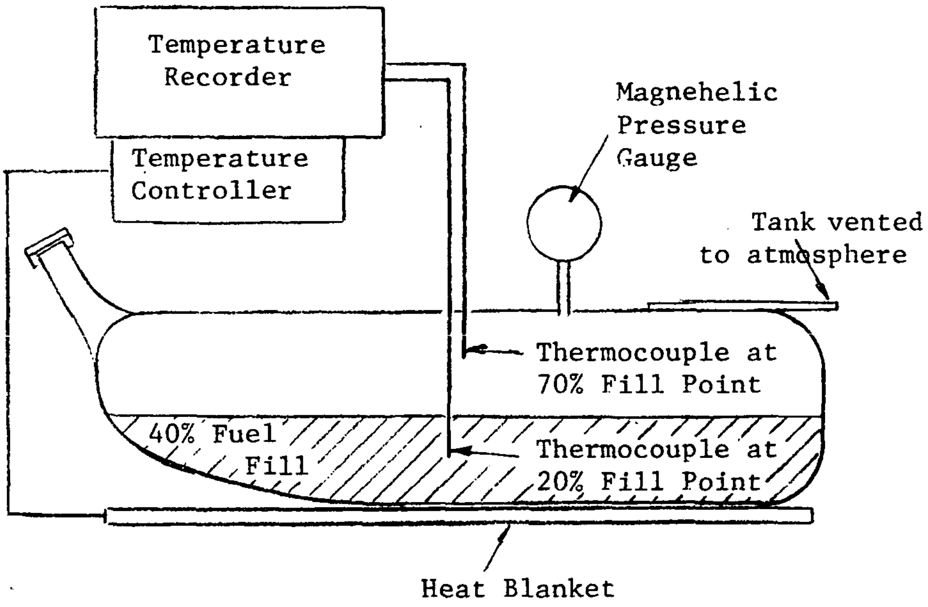


Figure 4-3 Schematic of Instrumented Fuel Tank Used for Testing

when temperatures stopped rising in the vapor space. The programmed heat build rates for these tests are shown in Figure 4-4.

4.4.2 Length of Diurnal

Using the instrumented fuel tank with a fuel volume of 40% of capacity, a series of diurnal tests were conducted with heat-build times of either 1, 2, or 3 hours. For the 1 and 2 hour heat-build times, the tank was left in the enclosure for an additional hour. Final temperatures and hydrocarbon readings were taken at the end of the additional hour. The programmed heat builds are shown graphically in Figure 4-5.

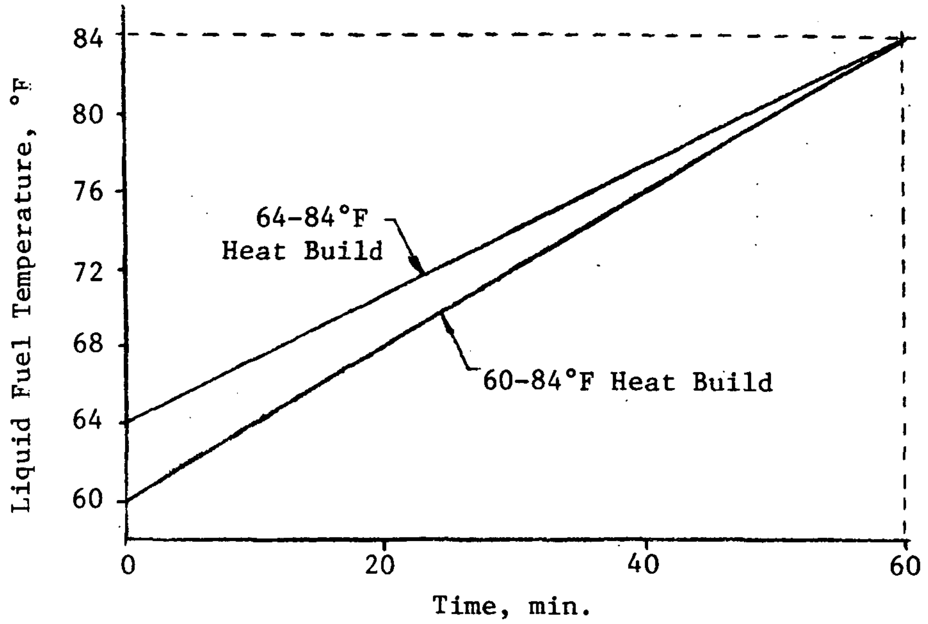


Figure 4-4 Heat Build Rates for Analysis of Temperature Excursions

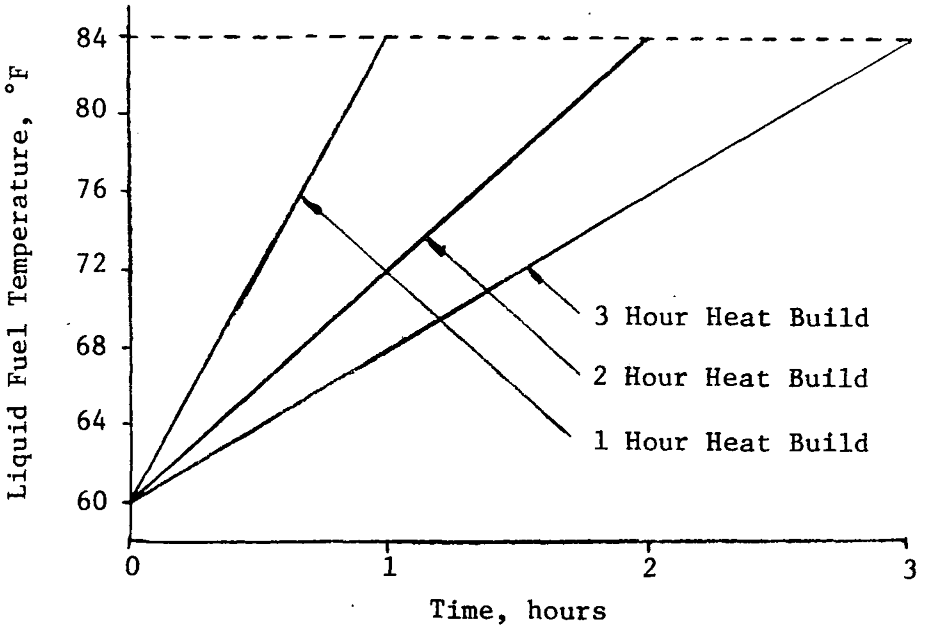


Figure 4-5 Heat Build Rates for Analysis of Length of Diurnal

5. Test Results

A total of 27 diurnal tests were conducted using the instrumented fuel tank. The individual test results are given in the Appendix.

5.1 Temperature Excursion and Fuel Volume Comparison

Figure 5-1 shows the liquid and vapor fuel temperatures for the four different test procedures used to analyze the effect of both the temperature excursion and the percent fuel fill. The graphs shown in Figure 5-1 indicate that the programmed temperature excursions were maintained reasonably well for the actual tests. The curves also show that liquid temperatures continued to increase slightly after the termination of the 60 minute heat build. Vapor temperatures continued to increase until roughly 70 to 80 minutes into the test. Thus, hydrocarbon emissions would be expected to continue to increase somewhat after the termination of the heat build.

Hydrocarbon emissions for a 60 to 84°F temperature rise were 8.3% higher for a 40% fuel fill and 17% higher for a 60% fuel fill than corresponding tests for a 64 to 84°F temperature rise. Thus, tests with a 60 to 84°F resulted in 12.6% higher emissions on the average than tests with a 64 to 84°F temperature rise. Figures 5-2 and 5-3 graphically show the differences between the two temperature excursions for tests with a 40% and a 60% fill respectively.

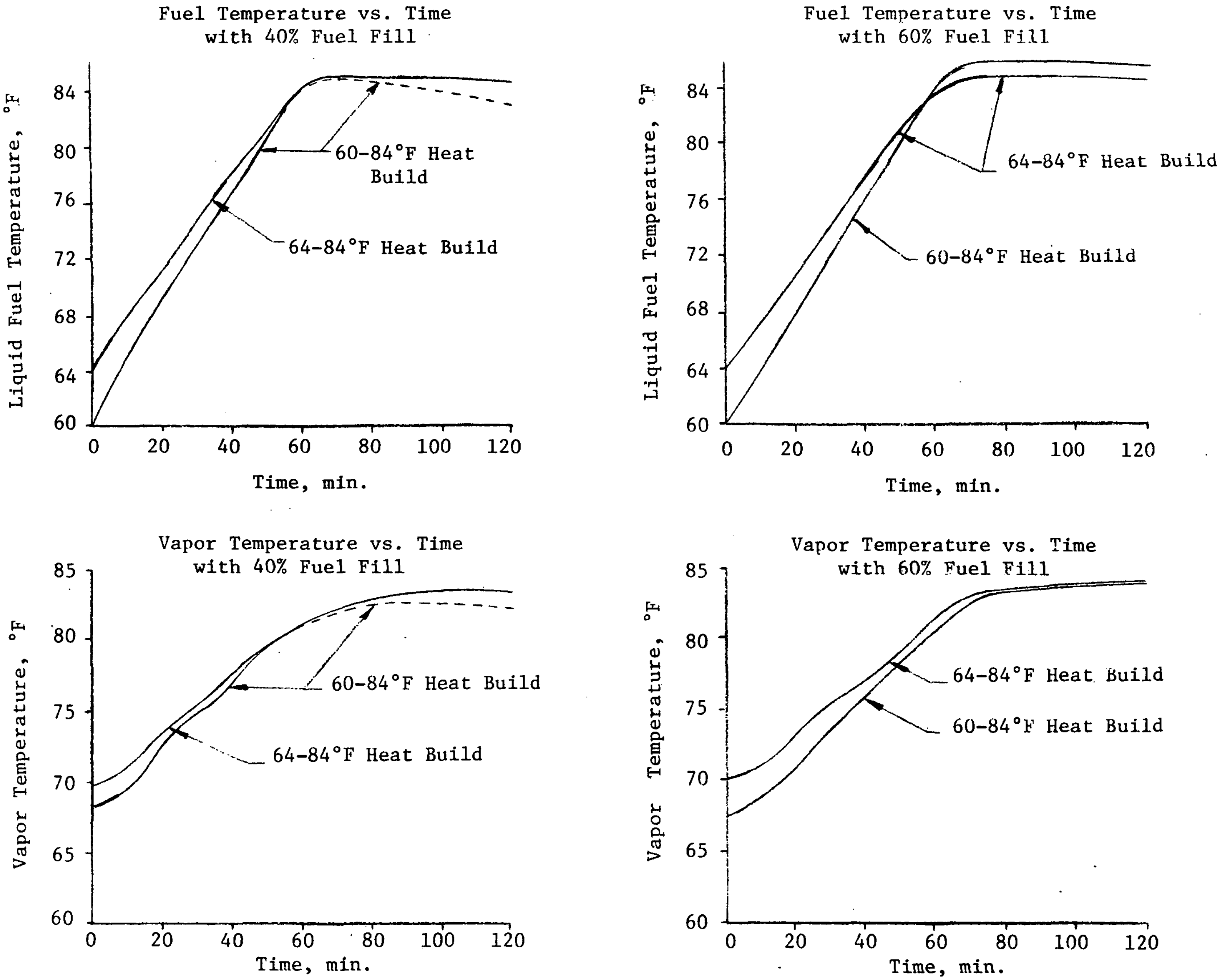
Hydrocarbon emissions for a 40% fuel fill were 5.8% higher for a 60 to 84°F temperature rise and 14.3% higher for a 64 to 84°F temperature rise than a 60% fuel fill. Thus, tests with a 40% fuel fill would be expected to result in 10% higher emissions on the average than tests with a 60% fuel fill. Figures 5-4 and 5-5 graphically show the differences between tests with the two fuel fills for temperature excursions of 60 to 84°F and 64 to 84°F respectively.

In order to investigate the data to determine if these differences are "statistically" significant, the following hypotheses will be tested:

H_{OA} = Hydrocarbon loss for a 60-84°F temperature excursion is equal to the hydrocarbon loss for a 64-84°F temperature excursion.

H_{OB} = Hydrocarbon loss with a 40% tank fill is equal to the hydrocarbon loss with a 60% tank fill.

Rejection or non-rejection of the above hypotheses will be based on a t-test evaluation. Table 5-1 is a summary of this evaluation.



*Dotted lines indicate that data between 60 and 120 min. readings were unavailable.

Figure 5-1 Liquid and Vapor Fuel Temperatures vs. Time for 40% and 60% Fuel Fills, and 60-84°F and 64-84°F Heat Builds

Figure 5-2

Hydrocarbon Loss vs. Time
with 40% Tank Fill

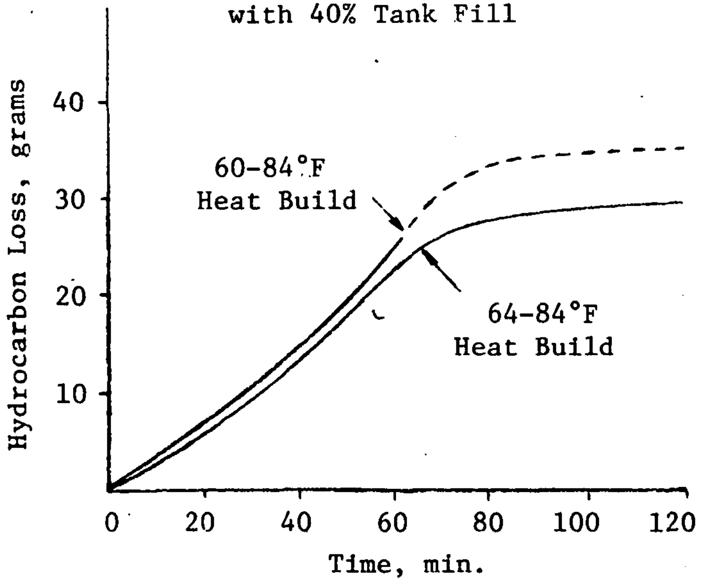


Figure 5-3

Hydrocarbon Loss vs. Time
with 60% Tank Fill

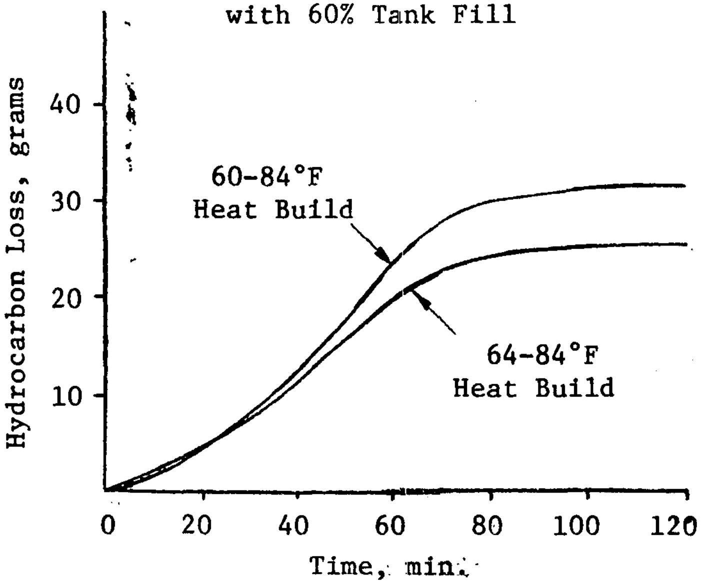


Figure 5-4

Hydrocarbon Loss vs. Time
for 60-84°F Heat Build

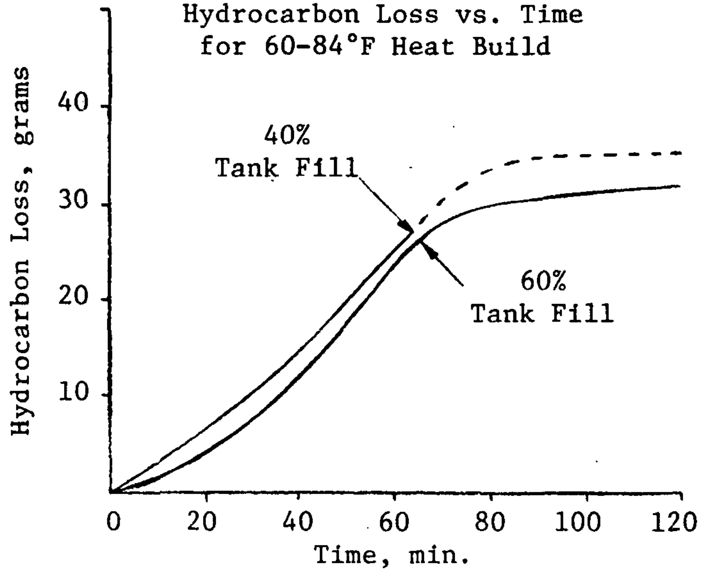
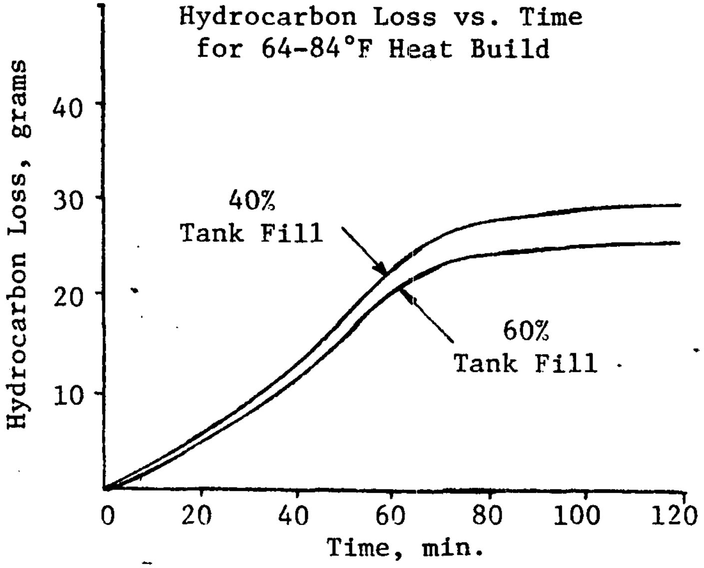


Figure 5-5

Hydrocarbon Loss vs. Time
for 64-84°F Heat Build



*Dotted lines indicate that data between 60 and 120 min. readings were unavailable.

Test	Degrees Freedom	"t" Calculated	"t" - Table $\alpha = 0.20$	Hypothesis
60-84°F vs. 64-84°F heat-build at 40% fill	9	.94	.88	Reject H_{OA} 80% C.L.
60-84°F 64-84°F heat-build at 60% fill	6	1.42	.906	Reject H_{OA} at 80% C.L.
40% vs. 60% fill with 60-84°F heat-build	7	.55	.896	Cannot reject H_{OB}
40% vs. 60% fill with 64-84°F heat-build	8	1.46	.889	Reject H_{OB} at 80% C.L.

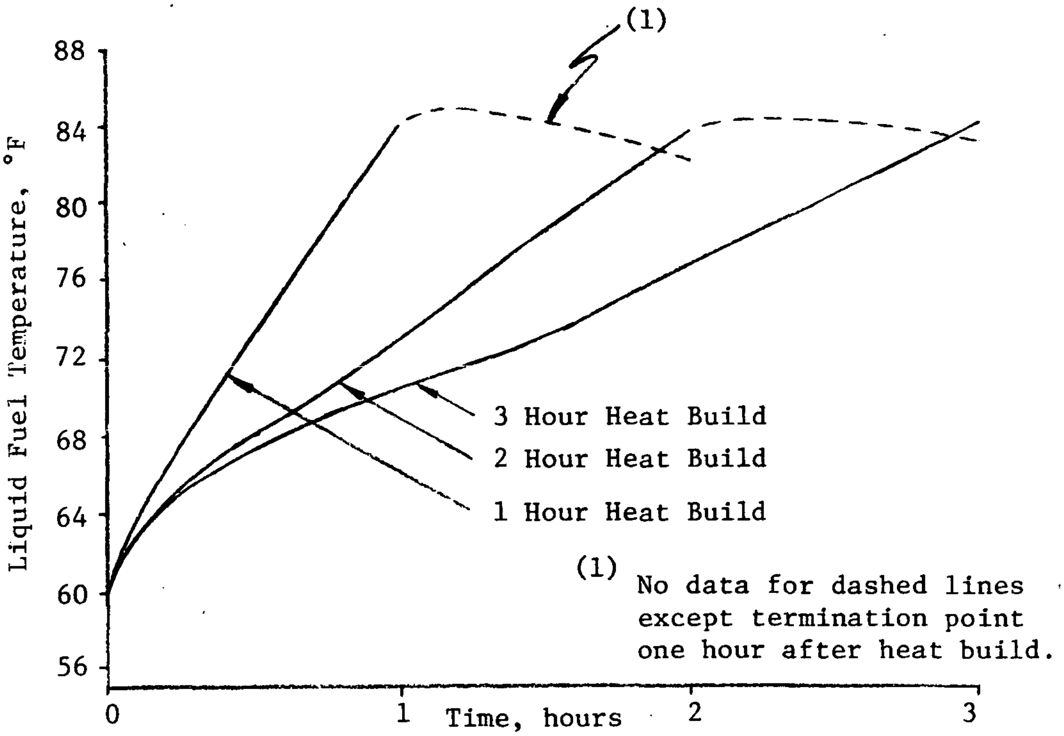
Table 5-1. T-Test Evaluation of Temperature Excursion and Fuel Volume.

Table 5-1 shows that with either a 60% or a 40% tank fill, the test data indicated that (at 80% confidence) the 60-84°F heat-build produced higher emission levels than a 64-84°F heat-build. The Table also shows that (at 80% confidence) the tests with a 60% tank fill resulted in lower emissions than with a 40% tank fill with a heat-build of 64-84°F. The data for 60-84°F heat-builds did not support rejecting the hypothesis at a 80% confidence level, but the trend was similar.

5.2 Length of the Diurnal

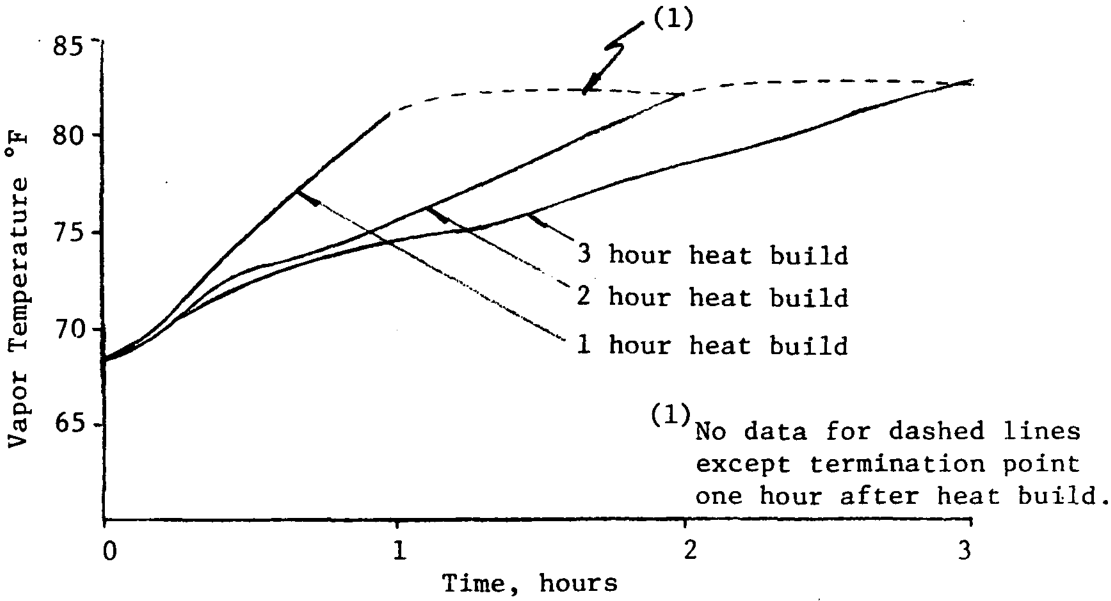
The liquid and vapor temperature excursion for the one, two and three hour heat build times are shown in Figures 5-6 and 5-7 respectively. Figure 5-6 indicates that the liquid fuel went through programmed heat builds reasonably well.

Figure 5-7 shows that the initial vapor temperatures were roughly the same for the three heat build times. It should be noted that the initial vapor temperatures were nearly 8°F higher than the initial liquid fuel temperatures. The final vapor temperatures were slightly higher for longer heat build times (1.7°F higher for the 3 hour test compared with the one hour test) due to the additional time for heat transfer from the liquid to the vapor. The final temperatures were still 1 - 2°F lower than the 84°F final temperature of the liquid fuel. The overall temperature excursion in the vapor space was about 14°F compared to the 24°F rise (60-84°F) of the liquid fuel.



(1) No data for dashed lines except termination point one hour after heat build.

Figure 5-6 Liquid Fuel Temperature vs. Time for 1, 2 and 3 Hour Heat Builds



(1) No data for dashed lines except termination point one hour after heat build.

Figure 5-7 Vapor Temperature vs. Time for 1, 2 and 3 Hour Heat Builds

Figure 5-8 shows the tank pressure changes for the three heat build rates. The one hour heat build showed much more erratic pressure changes than the 2 or 3 hour tests and the pressures were increasingly higher for the shorter test times.

Figure 5-9 shows the hydrocarbon loss versus time plots for the three heat-build times. The figure also indicates the range of data at the end of the heat build for the three tests. On the average, the two hour heat build resulted in 10.5% higher emissions than a one hour heat build, and the three hour heat build resulted in 34% higher emission than a one hour heat-build.

The test data for the effect of the length of the diurnal test (1 hour vs. 2 hours vs. 3 hours) must also be statistically analyzed. A one dimensional analysis of variance test can be applied to the test data for the three test lengths to test the following hypothesis:

H_o: Hydrocarbon emission for a one hour heat-build (60-84°F with a 40% tank fill) are equal to emissions from a two hour test and equal to emissions from a three hour test.

Table 5-2 summarizes this evaluation.

	Sum of Squares	Degrees of Freedom	Mean Square	Mean Square Ratio	F at a 95% Confidence Level
Test Length	137.90	2	68.95	6.31	4.26
Residual	98.26	9	10.92		
Total	236.16	11	21.47		

Table 5-2. Analysis of Variance for 3 Different Test Lengths.

On the basis of the above analysis, it can be concluded with 95% confidence that a significant difference in emissions occurs for the three heat-builds.

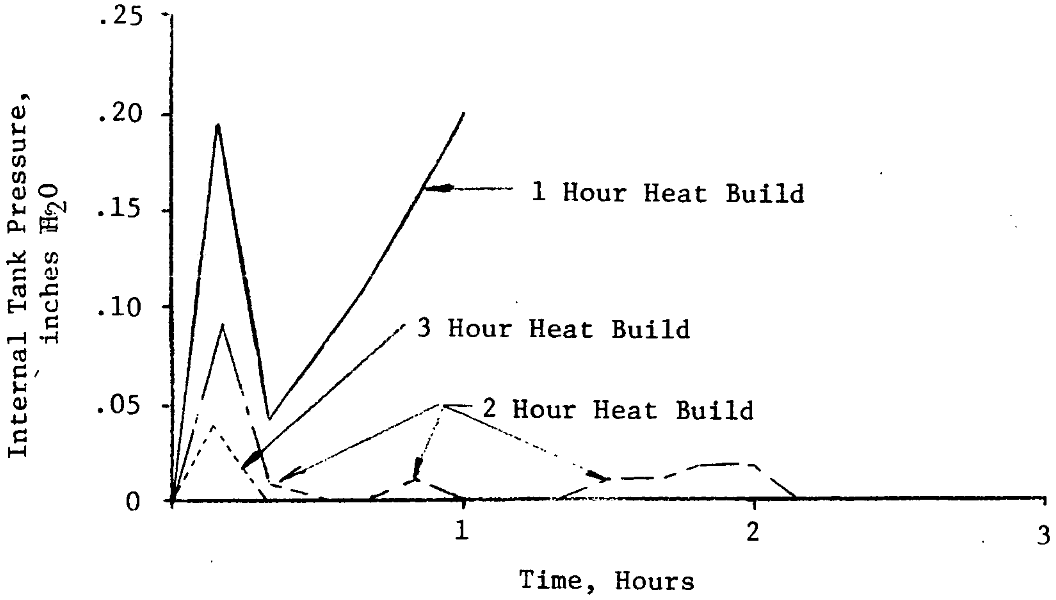


Figure 5-8 Tank Pressure vs. Time for 1, 2 and 3 Hour Heat Builds

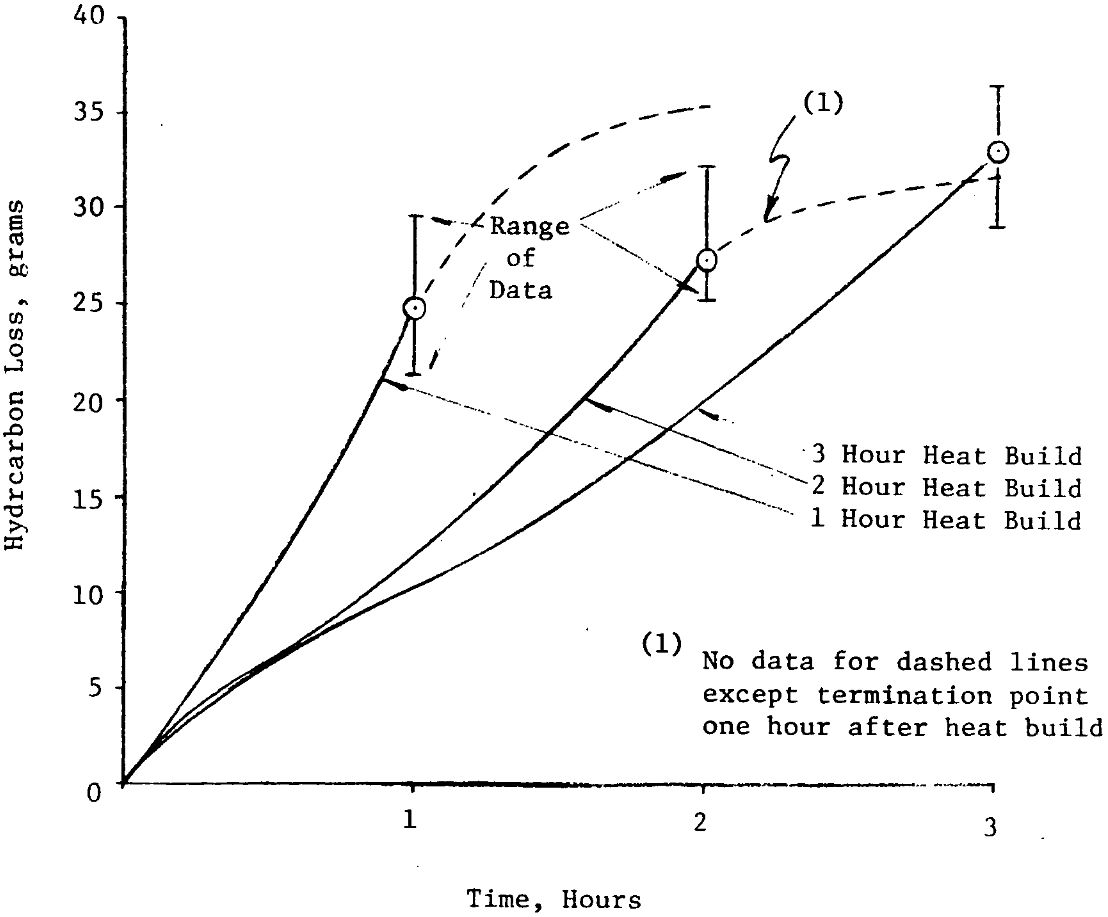


Figure 5-9 Hydrocarbon Loss vs. Time for 1, 2 and 3 Hour Heat Builds

6. Discussion of Test Results

6.1 Temperature Excursion and Fuel Volume Comparison

The current recommended practice of a 60-84°F temperature excursion and a 40% fuel fill were not found to accurately represent a "typical" diurnal. Tests using a 64-84°F temperature rise and a 60% fuel fill resulted in 19% lower emission levels than tests with the recommended 60-84°F and 40% fuel fill. Emission levels were 6% higher for the 64-84°F temperature rise and 60% fuel fill when HC were measured 1/2 hour after the end of the heat build. The use of these values supported by the literature search should not impact the practicality of the test and should be very easy to implement.

6.2 Length of the Diurnal

The testing performed to evaluate the effect of the length of the test on diurnal emissions consisted of tests of either 1, 2 or 3 hours duration. Although it was determined that a "typical" diurnal occurs over a 10 hour period, it was felt that the 1, 2 and 3 hour tests would be sufficient to establish any important trends. Also, a 10 hour test is much too long to be practical as it would be an excessive burden on test facilities.

The differences in emission levels for the three test lengths were found to be statistically significant, and there did exist a trend of increasing emissions with test length that showed sizable differences between the one and three hour results. This fact does not agree well with the presumption that emissions only depend on the temperature rise and not on time.

Wade (3) presents a theoretical equation for predicting diurnal losses. His equation shows that diurnal emissions are a function of the vapor temperature, the vapor pressure of the fuel, the tank pressure, and the vapor space. The tank pressure during the one hour diurnal was shown to increase by 0.2 inches of water, whereas during the 3 hour diurnal there was no increase. A 0.2 inch of water difference is very small, however, compared to a 33 feet of water total pressure of the tank. Also, the volume of the vapor space would not have significantly affected the results of the 1, 2 or 3 hour diurnal tests. Therefore, the vapor temperature is the parameter which would affect diurnal emissions the most.

If one assumes that the fuel and vapor are in equilibrium, the Wade equation would predict that the 3 hour diurnal tests would have had 16% higher emission levels than the one hour test (based on the measured vapor temperatures). There exists a discrepancy between this value and the observed 25% difference. The assumption that the diurnal heat build is an equilibrium process in the way the test is conducted could be responsible for the discrepancy. The three hour heat build would be expected to be closer to an equilibrium process than the one hour heat build. If this is the case, the difference between a one and three hour diurnal would be expected to be as shown, larger than 16%. Without actual data, however, quantification of the degree of equilibrium of the two heat build rates is not possible.

The emission level measured one hour after the end of the one hour heat build was approximately (within 6%) the same as at the end of the three hour heat build. The vapor temperature also increased slightly during the hour following the one hour heat build so that the vapor temperature rise was roughly the same as for the three hour heat build test. This fact implies that liquid-vapor equilibrium was not totally accomplished during the one hour heat build. If it were, the emissions after the second hour probably would not have increased, and not been as large as for the three-hour test. Thus, the primary problem appears to be the lack of temperature equilibium for the shorter heat build times.

Vapor temperature profiles presented in Figure 5-1 for tests evaluating the effect of the temperature excursion and the fuel fill also showed that vapor temperatures continued to increase during a 10 to 20 minute period following the end of the heat build (as mentioned above). If measurements were continued for 1/2 hour after the end of the heat build the emission levels for a one, two and three hour test would probably have been nearly the same. Thus, a short test (one hour) may be able to simulate a 10 hour diurnal, if the test is extended slightly to allow the vapor temperature to stabilize. This of course tends to indicate a need to control the vapor temperature rise rather than the liquid temperature rise.

6.3 Recommendations for Further Study

The above discussion indicates that a diurnal test procedure utilizing a 60% tank fill and consisting of a one hour, 64 to 84°F heat build followed by a 1/2 hour soak would adequately simulate a "typical" vehicle diurnal. Since emission measurements were continued for an additional hour after the heat build termination, a direct comparison between the SAE test parameters, [40%, 60-84°F, 1 hr.], and the parameters developed as a result of this study, [60%, 64-84°F, 1 1/2 hrs] can be made. The SAE procedure resulted in an average of 24.8 g/test (Appendix Table 4-C); whereas, the average emission level from the developed procedure [60%, 64-84°F, 1 1/2 hr.] was 26.2 g/test (Appendix Table 1-C). Thus, even though the measurement period of the developed procedure was increased 1/2 hour beyond the heat build, the decrease in vapor volume and temperature excursion limited the increase to only 5.6% over the SAE recommended practice. Although a change from the SAE method to the developed procedure may result in a better simulation of a typical diurnal, the resulting level of emissions may not be significantly different.

It is recommended that further tests of one, two and three hour heat build times on controlled vehicles be performed and that temperature and emission data be gathered beyond the end of the one and two hour heat builds. Should such a study confirm that the difference in emission levels is less than 6% between the developed procedure and the SAE recommended procedure, then a change in the currently recommended procedure would only lengthen the test and would therefore be undesirable.

Another area of concern which was brought out by the test data is the difference between the temperature rise of the vapor space and the temperature rise of the liquid fuel. It was found that while the liquid fuel underwent a 24°F temperature rise, the vapor space only saw a 14°F temperature rise. The initial temperature of the tank was several degrees higher than the 60°F initial temperature for the heat builds. Since the premise is that emissions are a result of gas expansion brought about by an increasing vapor temperature, a possibility exists that controlling the temperature excursion of the vapor space will provide a more representative simulation of the real-life condition and bring about a better equilibrium process. Further investigation in this area is warranted, not only in providing a more accurate test, but also in the practicality of performing such a test.

7. References

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10. "Measurement of Fuel Evaporative Emissions from Gasoline Powered Passenger Cars and Light Trucks using the Enclosure Technique," SAE Recommended Practice, SAE J171a, SAE Handbooks.

11. "Time-Temperature Histories of Specified Fuel Systems, Volume I", Coordinating Research Council, Cape-5-68, October, 1969.

Appendix

```
                 NO. OF DAYS
MAX
TEMP 0         10        20        30        40        50
     I....+....I....+....I....+....I....+....I....+....I
  65 I
  66 I
  67 I**
  68 I
  69 I
  70 I***
  71 I*
  72 I*
  73 I*
  74 I****
  75 I***
  76 I*****
  77 I*******
  78 I******
  79 I*********
  80 I******
  81 I*********
  82 I*********
  83 I*****
  84 I****
  85 I******
  86 I********
  87 I******
  88 I****
  89 I*********
  90 I*
  91 I*
  92 I****
  93 I****
  94 I*
  95 I****
  96 I
  97 I*
  98 I
  99 I
 100 I
 101 I
 102 I
 103 I
 104 I
 105 I
 106 I
 107 I
 108 I
 109 I
     I....+....I....+....I....+....I....+....I....+....I
```

Min. = 67°F
Max. = 97°F
Mean = 82.6°F

Chicago, Illinois O'Hare Int. Airport
Elevation 658 ft.

Figure 1 Distribution of Max. Daily Temp. - Chicago

```
                 NO. OF DAYS
MIN
TEMP 0         10        20        30        40        50
     I....+....I....+....I....+....I....+....I....+....I
  45 I
  46 I
  47 I
  48 I
  49 I
  50 I
  51 I**
  52 I
  53 I***
  54 I
  55 I****
  56 I**
  57 I***
  58 I*********
  59 I********
  60 I**********
  61 I*****
  62 I************
  63 I********
  64 I*******
  65 I****
  66 I*
  67 I**********
  68 I******
  69 I******
  70 I****
  71 I***
  72 I******
  73 I***
  74 I****
  75 I****
  76 I
  77 I
  78 I
  79 I
  80 I
  81 I
  82 I
  83 I
  84 I
  85 I
  86 I
  87 I
  88 I
  89 I
     I....+....I....+....I....+....I....+....I....+....I
```

Min. = 51°F
Max. = 75°F
Mean = 63.8°F

Chicago, Illinois O'Hare Int. Airport
Elevation 658 ft.

Figure 2 Distribution of Min. Daily
Temp. - Chicago

```
                NO. OF DAYS
TEMP
DIFF 0         10        20        30        40        50
     I....+....I....+....I....+....I....+....I....+....I
   1 I
   2 I
   3 I*
   4 I*
   5 I*
   6 I
   7 I**
   8 I**
   9 I**
  10 I***
  11 I*
  12 I**
  13 I****
  14 I*********
  15 I********
  16 I******
  17 I*********
  18 I**************
  19 I*******
  20 I***********
  21 I***********
  22 I*********
  23 I***
  24 I********
  25 I****
  26 I********
  27 I*
  28 I***
  29 I***
  30 I
  31 I
  32 I**
  33 I
  34 I
  35 I
  36 I
  37 I
  38 I
  39 I
  40 I
  41 I
  42 I
  43 I
  44 I
  45 I
     I....+....I....+....I....+....I....+....I....+....I
```

Min. = 3°F
Max. = 32°F
Mean = 18.8°F

Chicago, Illinois O'Hare Int. Airport
Elevation 658 ft.

Figure 3 Distribution of Daily
Diff. Temp. - Chicago

```
                NO. OF DAYS
MAX
TEMP 0         10        20        30        40        50
     I....+....I....+....I....+....I....+....I....+....I
  65 I
  66 I
  67 I*
  68 I
  69 I
  70 I*
  71 I
  72 I
  73 I*
  74 I
  75 I**
  76 I*
  77 I*
  78 I**
  79 I**
  80 I****
  81 I***
  82 I****
  83 I***
  84 I****
  85 I*****
  86 I**************
  87 I***********
  88 I***
  89 I*******
  90 I*********
  91 I************
  92 I******
  93 I********
  94 I**********
  95 I*****
  96 I*
  97 I*
  98 I
  99 I*
 100 I*
 101 I
 102 I
 103 I*
 104 I
 105 I
 106 I
 107 I
 108 I
 109 I
     I....+....I....+....I....+....I....+....I....+....I
```

Min. = 67°F
Max. = 103°F
Mean = 87.8°F

Denver, Colorado Stapleton Int. Airport
Elevation 5283 ft.

Figure 4 Distribution of Max. Daily Temp. - Denver

```
                   NO. OF DAYS
MIN
TEMP 0         10        20        30        40        50
     I....+....I....+....I....+....I....+....I....+....I
  45 I**
  46 I*
  47 I
  48 I**
  49 I**
  50 I***
  51 I*****
  52 I*****
  53 I*********
  54 I******
  55 I****************
  56 I**********
  57 I*****
  58 I*************
  59 I**********
  60 I**************
  61 I****
  62 I********
  63 I*****
  64 I**
  65 I
  66 I
  67 I**
  68 I
  69 I
  70 I
  71 I
  72 I
  73 I
  74 I
  75 I
  76 I
  77 I
  78 I
  79 I
  80 I
  81 I
  82 I
  83 I
  84 I
  85 I
  86 I
  87 I
  88 I
  89 I
     I....+....I....+....I....+....I....+....I....+....I
```

Min. = 45°F
Max. = 67°F
Mean = 56.6°F

Denver, Colorado Stapleton Int. Airport
Elevation 5283 Ft.

Figure 5 Distribution of Min. Daily Temp. - Denver

```
                NO. OF DAYS
TEMP
DIFF 0         10        20        30        40        50
     I....+....I....+....I....+....I....+....I....+....I
   1 I
   2 I
   3 I
   4 I
   5 I
   6 I
   7 I
   8 I
   9 I
  10 I
  11 I
  12 I
  13 I
  14 I
  15 I****
  16 I
  17 I
  18 I
  19 I
  20 I**
  21 I**
  22 I
  23 I*
  24 I
  25 I***
  26 I*****
  27 I*****
  28 I*********
  29 I*****
  30 I***********
  31 I*************
  32 I**************
  33 I***********
  34 I*******
  35 I*************
  36 I********
  37 I**
  38 I**
  39 I***
  40 I
  41 I***
  42 I
  43 I
  44 I
  45 I*
     I....+....I....+....I....+....I....+....I....+....I
```

Min. = 15°F
Max. = 45°F
Mean = 31.1°F

Denver, Colorado Stapleton Int. Airport
Elevation 5283 Ft.

Figure 6 Distribution of Daily
Diff. Temp. - Denver

```
                NO. OF DAYS
MAX
TEMP 0         10        20        30        40        50
     I....+....I....+....I....+....I....+....I....+....I
  65 I
  66 I
  67 I
  68 I
  69 I*
  70 I
  71 I
  72 I**
  73 I**
  74 I*
  75 I*
  76 I***
  77 I*
  78 I*****
  79 I****
  80 I**********
  81 I*******
  82 I***************
  83 I**************
  84 I********
  85 I**********
  86 I******
  87 I********
  88 I*******
  89 I****
  90 I****
  91 I*
  92 I*****
  93 I*
  94 I*
  95 I*
  96 I*
  97 I*
  98 I
  99 I
 100 I
 101 I
 102 I
 103 I
 104 I
 105 I
 106 I
 107 I
 108 I
 109 I
     I....+....I....+....I....+....I....+....I....+....I
```

Min. = 69°F
Max. = 97°F
Mean = 83.6°F

Detroit, Michigan Metropolitan Airport
Elevation 633 ft.

Figure 7 Distribution of Max. Daily Temp. - Detroit

```
              NO. OF DAYS
MIN
TEMP 0        10        20        30        40        50
     I....+....I....+....I....+....I....+....I....+....I
  45 I
  46 I
  47 I
  48 I
  49 I*
  50 I****
  51 I*
  52 I******
  53 I***
  54 I
  55 I**********
  56 I**
  57 I****
  58 I******
  59 I*******
  60 I*******
  61 I******
  62 I*********
  63 I*******
  64 I***********
  65 I******
  66 I*********
  67 I******
  68 I*******
  69 I****
  70 I**
  71 I**
  72 I**
  73 I
  74 I*
  75 I*
  76 I
  77 I
  78 I
  79 I
  80 I
  81 I
  82 I
  83 I
  84 I
  85 I
  86 I
  87 I
  88 I
  89 I
     I....+....I....+....I....+....I....+....I....+....I
```

Min. = 49°F
Max. = 75°F
Mean = 61.5°F

Detroit, Michigan Metropolitan Airport
Elevation 633 ft.

Figure 8 Distribution of Min. Daily Temp. - Detroit

```
               NO. OF DAYS
TEMP
DIFF  0        10        20        30        40        50
      I....+....I....+....I....+....I....+....I....+....I
   1  I
   2  I
   3  I
   4  I
   5  I
   6  I
   7  I
   8  I
   9  I*
  10  I**
  11  I
  12  I
  13  I*
  14  I****
  15  I*****
  16  I*****
  17  I****
  18  I******
  19  I*********
  20  I*****************
  21  I******
  22  I*************
  23  I*******
  24  I******
  25  I***********
  26  I*****
  27  I*
  28  I*****
  29  I**
  30  I****
  31  I**
  32  I**
  33  I**
  34  I
  35  I*
  36  I
  37  I**
  38  I*
  39  I
  40  I
  41  I
  42  I
  43  I
  44  I
  45  I
      I....+....I....+....I....+....I....+....I....+....I
```

Min. = 9°F
Max. = 38°F
Mean = 22.1°F

Detroit, Michigan Metropolitan Airport
Elevation 633 ft.

Figure 9 Distribution of Daily
Diff. Temp. - Detroit

```
              NO. OF DAYS
 MAX
 TEMP 0         10        20        30        40        50
      I....+....I....+....I....+....I....+....I....+....I
   65 I
   66 I
   67 I
   68 I
   69 I
   70 I
   71 I
   72 I
   73 I
   74 I
   75 I
   76 I
   77 I
   78 I
   79 I
   80 I
   81 I
   82 I
   83 I*
   84 I****
   85 I*
   86 I*
   87 I*******
   88 I*******
   89 I*********
   90 I**********
   91 I********
   92 I********
   93 I********************
   94 I*************
   95 I******************
   96 I********
   97 I*****
   98 I****
   99 I
  100 I
  101 I
  102 I
  103 I
  104 I
  105 I
  106 I
  107 I
  108 I
  109 I
      I....+....I....+....I....+....I....+....I....+....I
```

Min. = 83°F
Max. = 98°F
Mean = 92.1°F

Houston, Texas Intercontinental Airport
Elevation 96 ft.

Figure 10 Distribution of Max. Daily
Temp. - Houston

```
                NO. OF DAYS
MIN
TEMP 0         10        20        30        40        50
     I....+....I....+....I....+....I....+....I....+....I
  45 I
  46 I
  47 I
  48 I
  49 I
  50 I
  51 I
  52 I
  53 I
  54 I
  55 I
  56 I
  57 I
  58 I
  59 I
  60 I
  61 I
  62 I
  63 I
  64 I*
  65 I
  66 I***
  67 I****
  68 I*******
  69 I***
  70 I************************
  71 I*****************************
  72 I**********************
  73 I***********
  74 I**********
  75 I****
  76 I***
  77 I**
  78 I*
  79 I
  80 I
  81 I
  82 I
  83 I
  84 I
  85 I
  86 I
  87 I
  88 I
  89 I
     I....+....I....+....I....+....I....+....I....+....I
```

Min. = 64°F
Max. = 78°F
Mean = 71.3°F

Houston, Texas Intercontinental Airport
Elevation 96 ft.

Figure 11 Distribution of Min. Daily Temp. - Houston

```
                NO. OF DAYS
TEMP
DIFF 0         10        20        30        40        50
     I....+....I....+....I....+....I....+....I....+....I
   1 I
   2 I
   3 I
   4 I
   5 I
   6 I
   7 I
   8 I
   9 I
  10 I
  11 I
  12 I***
  13 I**
  14 I*****
  15 I****
  16 I****
  17 I*******
  18 I********
  19 I********
  20 I**************
  21 I***********
  22 I**************
  23 I****************
  24 I*******
  25 I*********
  26 I****
  27 I****
  28 I**
  29 I*
  30 I*
  31 I
  32 I
  33 I
  34 I
  35 I
  36 I
  37 I
  38 I
  39 I
  40 I
  41 I
  42 I
  43 I
  44 I
  45 I
     I....+....I....+....I....+....I....+....I....+....I
```

Min. = 12°F
Max. = 30°F
Mean = 20.8°F

Houston, Texas Intercontinental Airport
Elevation 96 ft.

Figure 12 Distribution of Daily
Diff. Temp. - Houston

```
              NO. OF DAYS
MAX
TEMP 0         10        20        30        40        50
     I....+....I....+....I....+....I....+....I....+....I
  65 I
  66 I
  67 I
  68 I
  69 I
  70 I*
  71 I****
  72 I******************
  73 I**********************
  74 I*******************
  75 I****************
  76 I*************
  77 I**********
  78 I*****
  79 I*
  80 I****
  81 I**
  82 I*
  83 I**
  84 I***
  85 I*
  86 I*
  87 I*
  88 I
  89 I
  90 I
  91 I
  92 I
  93 I
  94 I
  95 I
  96 I
  97 I
  98 I
  99 I
 100 I
 101 I
 102 I
 103 I
 104 I
 105 I
 106 I
 107 I
 108 I
 109 I
     I....+....I....+....I....+....I....+....I....+....I
```

Min. = 70°F
Max. = 87°F
Mean = 75.2°F

Los Angeles, California International Airport
Elevation 97 ft.

Figure 13 Distribution of Max. Daily Temp. - Los Angeles

```
               NO. OF DAYS
MIN
TEMP 0         10        20        30        40        50
     I....+....I....+....I....+....I....+....I....+....I
  45 I
  46 I
  47 I
  48 I
  49 I
  50 I
  51 I
  52 I
  53 I
  54 I
  55 I
  56 I
  57 I
  58 I**
  59 I*
  60 I**********
  61 I****************
  62 I*****************
  63 I***************************
  64 I****************
  65 I**********
  66 I***********
  67 I******
  68 I****
  69 I***
  70 I*
  71 I
  72 I
  73 I
  74 I
  75 I
  76 I
  77 I
  78 I
  79 I
  80 I
  81 I
  82 I
  83 I
  84 I
  85 I
  86 I
  87 I
  88 I
  89 I
     I....+....I....+....I....+....I....+....I....+....I
```

Min. = 58°F
Max. = 70°F
Mean = 63.4°F

Los Angeles, California International Airport
Elevation 97 ft.

Figure 14 Distribution of Min. Daily Temp. - Los Angeles

```
                   NO. OF DAYS
TEMP
DIFF 0         10        20        30        40        50
     I....+....I....+....I....+....I....+....I....+....I
   1 I
   2 I
   3 I
   4 I
   5 I
   6 I
   7 I*****
   8 I***
   9 I***********
  10 I*****************
  11 I**************************
  12 I**************************
  13 I********
  14 I**************
  15 I***
  16 I*****
  17 I**
  18 I
  19 I*
  20 I*
  21 I*
  22 I
  23 I
  24 I
  25 I
  26 I
  27 I*
  28 I
  29 I
  30 I
  31 I
  32 I
  33 I
  34 I
  35 I
  36 I
  37 I
  38 I
  39 I
  40 I
  41 I
  42 I
  43 I
  44 I
  45 I
     I....+....I....+....I....+....I....+....I....+....I
```

Min. = 7°F
Max. = 27°F
Mean = 11.9°F

Los Angeles, California International Airport
Elevation 97 ft.

Figure 15 Distribution of Daily Diff. Temp. - Los Angeles

Table 1. 60 min., 64-84°F Heat Build Test Data (with 60% Tank Fill).

Table 1-A. Liquid Fuel Temperatures, °F, at the Following Times, min.

	000	010	020	030	040	050	060	070	080	090	100	110	120
	64.00	67.20	70.50	73.90	77.30	80.20	83.80	84.90	84.80	84.20	84.20	84.50	84.50
	64.00	67.50	70.90	74.50	76.80	80.10	84.00	84.80	84.20	84.20	84.20	84.50	84.50
	64.00	67.00	70.10	74.00	76.40	80.00	83.00	84.50	84.60			84.50	84.20
	64.00	67.00	71.00	74.20	77.30	80.00	83.00	84.80	85.00	84.80	84.50	84.80	84.50
NO. TEST	4	4	4	4	4	4	4	4	4	3	3	4	4
MEAN	64.00	67.17	70.63	74.15	76.95	80.07	83.45	84.75	84.65	84.40	84.30	84.57	84.42

Table 1-B. Vapor Temperatures, °F, at the Following Times, Min.

	000	010	020	030	040	050	060	070	080	090	100	110	120
	70.00	70.90	72.90	74.50	76.90	78.80	81.30	82.80	83.30	83.20	83.20	83.80	83.60
	69.80	70.50	73.10	75.20	76.30	79.10	81.70	83.10	83.10	83.00	83.00	83.50	83.50
	70.50	70.80	72.80	75.00	76.70	78.90	81.00	82.90	83.40			83.40	83.70
	70.80	70.90	73.30	75.80	77.50	79.10	81.20	83.00	83.80	83.80	83.50	83.80	83.90
NO. TEST	4	4	4	4	4	4	4	4	4	3	3	4	4
MEAN	70.27	70.77	73.02	75.13	76.85	78.97	81.30	82.95	83.40	83.33	83.23	83.63	83.67

Table 1-C. Hydrocarbon Loss, grams, at the Following Times, min.

	000	010	020	030	040	050	060	070	080	090	100	110	120
	0.0	1.57	4.42	6.91	10.33	14.03	18.23	21.78	23.08	23.43	23.43	23.49	23.77
	0.0	2.42	5.76	9.55	13.92	18.39	23.73	27.36	28.73	29.32	29.82	30.13	30.63
	0.0	1.44	3.58	6.23	9.60	13.25	17.70	20.62	21.61			21.76	21.77
	0.0	1.65	4.30	7.52	11.38	15.63	20.41	24.35	25.55	25.99	26.50	26.64	27.06
NO. TEST	4	4	4	4	4	4	4	4	4	3	3	4	4
MEAN	0.0	1.77	4.51	7.55	11.31	15.32	20.02	23.53	24.74	26.25	26.58	25.50	25.81

Table 2. 60 min., 64-84°F Heat Build Test Data (with 40% Tank Fill).

Table 2-A. Liquid Fuel Temperatures, °F, at the Following Times, min.

	000	010	020	030	040	050	060	070	080	090	100	110	120
	64.00	69.60	72.00	75.80	78.80	82.40	85.00	85.60	85.80	86.10	85.80	85.30	85.20
	64.00	69.00	71.50	75.20	78.10	81.20	85.00	85.80	85.60	85.50	85.50	85.70	85.50
	64.00	68.00	71.00	74.20	78.10	80.80	84.00	84.00	84.30	84.20	84.50	84.10	83.80
	64.00	68.00	71.20	74.90	78.00	80.50	84.20	84.50	84.80	84.50	84.00	84.00	84.20
	64.00	67.20	70.20	73.70	77.30	80.80	83.50	84.00	84.00	84.20	84.20	84.00	83.80
	64.00	68.00	71.20	75.00	77.90	80.80	84.00	84.50	84.30	84.60	84.40	84.30	84.00
NO. TEST	6	6	6	6	6	6	6	6	6	6	6	6	6
MEAN	64.00	68.30	71.18	74.80	78.03	81.08	84.28	84.73	84.80	84.85	84.73	84.57	84.42

Table 2-B. Vapor Temperatures, °F, at the Following Times, min.

	000	010	020	030	040	050	060	070	080	090	100	110	120
	70.00	71.40	73.80	75.80	77.80	79.70	81.20	82.10	82.70	83.80	84.00	83.40	83.40
	71.30	72.20	74.50	76.00	77.90	79.50	81.20	82.90	83.20	83.70	84.00	84.10	84.20
	69.00	70.00	72.80	74.20	77.00	78.00	80.80	81.90	82.80	82.90	83.40	83.30	82.80
	69.80	71.20	73.90	75.80	77.80	79.20	81.30	82.80	83.30	83.00	83.00	83.30	83.10
	70.00	70.80	72.80	74.50	77.00	79.20	81.00	81.90	82.80	83.00	83.30	83.30	83.00
	69.50	71.00	73.80	75.80	77.80	79.60	81.30	82.80	83.30	83.50	83.50	83.30	83.00
NO. TEST	6	6	6	6	6	6	6	6	6	6	6	6	6
MEAN	69.93	71.10	73.60	75.35	77.55	79.20	81.13	82.40	83.02	83.32	83.53	83.45	83.25

Table 2-C. Hydrocarbon Loss, grams, at the Following Times, min.

	000	010	020	030	040	050	060	070	080	090	100	110	120
	0.0	2.74	5.93	9.40	13.17	17.48	23.54	26.93	28.66	29.36	29.59	29.82	30.17
	0.0	1.99	5.48	8.75	12.60	16.43	22.06	25.95	27.11	27.60	27.74	27.79	29.16
	0.0	2.74	5.77	9.39	13.36	17.53	22.78	26.62	28.13	28.83	28.80	29.39	30.10
	0.0	3.02	6.47	10.12	14.37	18.40	23.91	27.64	29.44	30.16	30.88	30.86	30.98
	0.0	2.45	5.20	8.94	12.99	17.06	22.45	26.64	27.83	28.18	28.88	29.25	29.66
	0.0	3.10	6.20	9.94	13.68	17.86	22.55	26.38	27.44	28.25	28.55	28.70	29.22
NO. TEST	6	6	6	6	6	6	6	6	6	6	6	6	6
MEAN	0.0	2.67	5.84	9.42	13.36	17.46	22.88	26.69	28.10	28.73	29.07	29.30	29.88

Table 3. 60 min., 60-84°F Heat Build Test Data (with 60% Tank Fill).

Table 3-A. Liquid Fuel Temperatures, °F, at the Following Times, min.

	000	010	020	030	040	050	060	070	080	090	100	110	120
	60.00	65.00	68.00	72.00	76.50	80.80	84.80	86.00	85.30	85.80	86.00	86.00	85.20
	60.00	63.60	67.70	71.90	75.80	79.00	83.30	85.20	85.50	85.20	85.00	85.20	85.30
	60.00	63.80	67.50	72.00	75.80	79.50	83.80	85.20	85.80	85.80	85.80	85.20	85.20
	60.00	63.80	67.80	72.00	76.00	79.20	84.00	85.80	86.00	85.80	85.60	85.80	85.80
NO. TEST	4	4	4	4	4	4	4	4	4	4	4	4	4
MEAN	60.00	64.05	67.75	71.97	76.02	79.63	83.97	85.55	85.65	85.65	85.60	85.55	85.38

Table 3-B. Vapor Temperatures, °F, at the Following Times, min.

	000	010	020	030	040	050	060	070	080	090	100	110	120
	66.00	68.70	70.50	73.50	76.00	78.80	81.40	83.00	83.20	83.80	84.00	84.20	83.80
	68.20	69.20	71.00	73.80	75.80	77.80	80.10	82.80	83.10	83.20	83.20	83.70	84.00
	68.30	68.80	70.80	73.50	75.80	78.00	80.50	82.80	83.70	83.60	84.00	83.80	83.80
	67.70	68.00	70.50	73.00	75.40	77.60	80.30	82.80	83.50	83.50	83.80	84.00	84.10
NO. TEST	4	4	4	4	4	4	4	4	4	4	4	4	4
MEAN	67.55	68.67	70.70	73.45	75.75	78.05	80.57	82.85	83.38	83.52	83.75	83.92	83.92

Table 3-C. Hydrocarbon Loss, grams, at the Following Times, min.

	000	010	020	030	040	050	060	070	080	090	100	110	120
	0.0	1.29	4.16	7.28	11.46	16.56	21.80	26.49	27.93	28.66	29.36	29.43	29.59
	0.0	1.43	4.43	8.30	13.09	18.31	25.23	30.44	32.36	33.59	34.15	34.83	35.14
	0.0	1.49	4.34	7.75	12.15	17.27	23.71	28.61	30.46	31.46	31.81	31.99	32.35
	0.0	1.30	3.89	7.57	11.62	16.50	22.97	27.88	29.24	29.99	30.12	30.45	30.84
NO. TEST	4	4	4	4	4	4	4	4	4	4	4	4	4
MEAN	0.0	1.38	4.20	7.72	12.08	17.16	23.43	28.35	30.00	30.92	31.36	31.67	31.98

Table 4. 60 min., 60-84°F Heat Build Test Data (with 40% Tank Fill)

Table 4-A. Liquid Fuel Temperatures, °F, at the Following Times, min.

	000	010	020	030	040	050	060	120
	60.00	65.20	69.30	73.80	77.50	81.50	85.80	83.60
	60.00	65.20	69.00	72.20	76.50	80.20	83.50	82.40
	60.00	65.40	68.90	72.20	76.10	79.90	83.90	82.50
	60.00	65.50	68.50	72.80	75.90	80.00	83.50	82.90
	60.00	66.00	69.50	73.80	77.00	80.20	84.00	83.20
NO. TEST	5	5	5	5	5	5	5	5
MEAN	60.00	65.46	69.04	72.96	76.60	80.36	84.14	82.92

Table 4-B. Vapor Temperatures, °F, at the Following Times, min.

	000	010	020	030	040	050	060	120
	69.00	69.80	72.70	74.70	77.00	79.00	81.60	82.60
	68.00	69.00	72.40	74.50	76.90	79.00	81.10	81.80
	68.10	69.10	72.30	74.00	76.50	78.90	81.00	82.00
	67.90	69.00	72.00	75.00	76.10	79.00	80.90	82.00
	68.20	69.80	73.30	75.90	77.20	79.20	81.20	82.20
NO. TEST	5	5	5	5	5	5	5	5
MEAN	68.24	69.34	72.54	74.82	76.74	79.02	81.16	82.12

Table 4-C. Hydrocarbon Loss, grams, at the Following Times, min.

	000	010	020	030	040	050	060	120
	0.0	3.42	7.64	12.27	17.10	22.95	29.68	43.08
	0.0	3.36	7.02	10.73	14.78	19.72	25.20	36.95
	0.0	3.02	6.47	9.71	14.23	18.70	24.42	34.21
	0.0	2.67	5.50	8.46	11.93	16.25	21.31	27.72
	0.0	2.89	6.50	10.04	13.73	18.21	23.27	34.65
NO. TEST	5	5	5	5	5	5	5	5
MEAN	0.0	3.07	6.63	10.24	14.35	19.17	24.78	35.32

Table 4-D. Tank Pressure, in. H_2O, at the Following Times, min.

	000	010	020	030	040	050	060	120
	0.01	0.20	0.09	0.13	0.16	0.21	0.28	0.0
	0.0	0.20	0.04	0.07	0.10	0.13	0.18	0.0
	0.0	0.20	0.03	0.07	0.10	0.13	0.17	0.0
	0.0	0.18	0.03	0.07	0.10	0.13	0.18	0.0
	0.0	0.21	0.03	0.08	0.10	0.13	0.18	0.0
NO. TEST	5	5	5	5	5	5	5	5
MEAN	0.00	0.20	0.04	0.08	0.11	0.15	0.20	0.0

Table 5. 120 min., 60-84°F Heat Build Data (with 40% Tank Fill)

Table 5-A. Liquid Fuel Temperatures, °F, at the Following Times, min.

	000	010	020	030	040	050	060	070	080	090	100	110	120	[illegible]
	60.00	64.30	66.50	67.80	69.10	71.00	72.30	74.00	76.50	78.30	80.40	81.80	83.20	83.30
	60.10	63.90	66.50	67.90	69.00	71.00	72.20	74.50	76.80	78.20	80.00	81.70	83.90	83.50
	60.00	64.00	66.30	68.00	69.10	71.00	72.70	74.50	76.60	78.10	80.10	82.00	84.00	83.00
	60.00	64.50	67.00	68.60	70.00	71.50	73.00	74.90	77.00	78.90	80.30	82.00	84.00	83.20
NO. TEST	4	4	4	4	4	4	4	4	4	4	4	4	4	4
MEAN	60.02	64.17	66.57	68.07	69.30	71.13	72.55	74.47	76.72	78.38	80.20	81.88	83.77	83.25

Table 5-B. Vapor Temperatures, °F, at the Following Times, min.

	000	010	020	030	040	050	060	070	080	090	100	110	120	180
	68.00	68.80	70.80	72.00	73.00	74.00	75.10	76.00	75.60	78.90	80.00	80.60	82.00	82.60
	68.00	69.00	71.30	72.90	73.10	74.00	75.10	76.50	77.80	78.70	79.80	80.20	82.00	82.80
	69.10	69.80	71.60	73.00	73.60	74.30	75.80	76.50	77.70	78.50	79.90	80.80	82.00	82.60
	69.00	70.00	72.00	73.80	74.10	74.90	75.90	76.90	78.10	79.10	80.00	80.90	82.00	82.20
NO. TEST	4	4	4	4	4	4	4	4	4	4	4	4	4	4
MEAN	68.52	69.40	71.42	72.92	73.45	74.30	75.47	76.47	77.30	78.80	79.92	80.63	82.00	82.55

Table 5-C. Hydrocarbon Loss, grams, at the Following Times, min.

	000	010	020	030	040	050	060	070	080	090	100	110	120	180
	0.0	2.59	4.32	5.61	6.83	8.85	10.64	12.80	14.95	17.38	19.38	22.05	25.00	29.28
	0.0	2.30	4.45	6.03	7.39	9.33	11.20	13.29	15.81	18.24	20.83	23.97	27.04	31.93
	0.0	3.37	5.96	7.90	9.55	12.07	14.29	16.88	19.32	22.13	25.54	28.61	32.14	37.92
	0.0	2.38	4.61	6.33	7.41	9.00	11.01	12.80	14.94	17.24	19.62	22.27	25.36	28.51
NO. TEST	4	4	4	4	4	4	4	4	4	4	4	4	4	4
MEAN	0.0	2.66	4.83	6.47	7.79	9.81	11.78	13.94	16.25	18.75	21.34	24.22	27.38	31.91

Table 5-D. Tank Pressure, in. H_2O, at the Following Times, min.

	000	010	020	030	040	050	060	070	080	090	100	110	120	180
	0.0	0.06	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.01	0.0
	0.0	0.07	0.0	0.0	0.0	0.0	0.0	0.01	0.0	0.01	0.01	0.03	0.03	0.0
	0.01	0.12	0.01	0.0	0.0	0.01	0.0	0.0	0.0	0.01	0.01	0.03	0.03	0.0
	0.0	0.10	0.01	0.0	0.0	0.01	0.0	0.0	0.01	0.0	0.0	0.01	0.03	0.0
NO. TEST	4	4	4	4	4	4	4	4	4	4	4	4	4	4
MEAN	0.00	0.09	0.01	0.0	0.0	0.01	0.0	0.00	0.00	0.01	0.01	0.02	0.02	0.0

Table 6. 180 min., 60-84°F Heat Build Test Data (with 40% Tank Fill)

Table 6-A. Liquid Fuel Temperatures, °F, at the Following Times, min.

	000	010	020	030	040	050	060	070	080	090	100	110	120	130	140	150	160	170	180
	60.00	64.00	66.10	67.50	68.10	69.10	70.00	70.90	71.50	72.90	74.20	76.00	77.50	78.00	79.00	80.60	81.00	83.00	84.00
	60.00	63.30	65.50	66.80	67.80	69.10	70.30	71.00	71.50	73.00	74.50	75.50	77.50	78.10	79.20	80.10	82.00	83.20	84.30
	60.00	64.50	66.80	67.50	69.00	70.00	71.00	71.80	72.10	73.20	74.70	76.20	77.50	78.50	79.20	80.80	82.20	83.20	84.70
	60.00	64.20	66.30	67.00	68.20	69.90	70.30	71.00	71.50	73.00	74.80	76.10	77.20	78.20	79.20	80.20	81.80	83.20	84.10
NO. TEST	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
MEAN	60.00	64.00	66.17	67.20	68.27	69.52	70.40	71.17	71.65	73.02	74.55	75.95	77.42	78.20	79.15	80.42	81.75	83.15	84.27

Table 6-B. Vapor Temperatures, °F, at the Following Times, min.

	000	010	020	030	040	050	060	070	080	090	100	110	120	130	140	150	160	170	180
	67.50	68.70	70.80	71.90	72.90	73.20	74.10	74.50	75.00	74.90	76.30	77.10	78.80	79.00	79.00	80.30	81.20	82.00	82.40
	67.80	69.00	70.70	72.00	72.70	73.80	74.50	75.20	75.20	75.90	77.00	77.80	78.80	79.00	79.80	80.20	81.90	82.50	83.00
	69.30	70.20	72.30	73.00	73.80	74.80	75.50	76.00	76.00	76.00	77.30	78.20	79.00	79.80	79.80	80.50	81.80	82.50	83.50
	67.80	69.20	71.20	71.80	73.20	73.80	74.70	75.00	75.20	75.80	76.80	77.50	78.50	79.00	79.40	80.00	81.20	82.00	82.30
NO. TEST	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
MEAN	68.10	69.27	71.25	72.17	73.15	73.90	74.70	75.17	75.35	75.65	76.85	77.65	78.77	79.20	79.50	80.25	81.52	82.25	82.80

Table 6-C. Hydrocarbon Loss, grams, at the Following Times, min.

	000	010	020	030	040	050	060	070	080	090	100	110	120	130	140	150	160	170	180
	0.0	2.59	4.74	6.47	7.91	9.34	10.42	11.50	12.58	14.39	16.17	17.94	20.09	22.05	24.44	26.69	29.26	31.56	34.43
	0.0	1.70	3.84	5.62	6.89	8.10	10.00	10.92	12.22	13.77	15.61	17.05	19.05	20.85	22.98	25.19	27.38	29.79	32.70
	0.0	3.55	5.97	8.11	9.82	11.24	12.65	13.92	15.08	16.71	18.63	20.45	22.57	24.78	26.80	29.13	31.37	33.78	36.56
	0.0	2.03	3.85	5.32	6.90	8.13	8.42	10.16	11.11	12.56	14.22	15.88	17.46	19.21	21.84	22.83	25.49	27.36	29.09
NO. TEST	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
MEAN	0.0	2.47	4.60	6.38	7.88	9.20	10.37	11.62	12.75	14.36	16.16	17.83	19.79	21.72	24.02	25.96	28.38	30.62	33.19

Table 6-D. Tank Pressures, in. H_2O, at the Following Times, min.

	000	010	020	030	040	050	060	070	080	090	100	110	120	130	140	150	160	170	180
	0.0	0.04	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	0.0	0.09	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	0.0	0.04	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
NO. TEST	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
MEAN	0.0	0.04	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0