Technical Support Report for Regulatory Action

Evaporative Emission Enclosure (SHED) Procedure Analysis of Surveillance Program Data

by

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June 1975

Notice

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Standards Development and Support Branch
Emission Control Technology Division
Office of Mobile Source Air Pollution Control
Office of Air and Waste Management
U.S. Environmental Protection Agency

Reprinted 7-76

This report is a summary of the data analysis performed at EPA for the SHED enclosure testing for evaporative emissions performed during FY 71, 72 and 73 surveillance programs. Included are descriptions of the data handling and documentation of it's current whereabouts. Also included are the results of various analyses done to evaluate the effects of testing and vehicle parameters on evaporative emission levels.

Table I lists the testing programs in which data were collected. The raw data were supplied to EPA and subsequently transcribed onto standard data sheets. The data analysis could only be performed for test trains 60, 61, 62, 63, and 65. The analyzer calibration curve data were not supplied or were lost for train 64 and therefore analysis of these data was impossible. However, the preliminary evaporative emissions discussion paper (1) does summarize some analysis done for the FY 72 Denver data.

Train No.	City of testing	Contractor	FY	No. of tests	Model Year
60	Denver	AESi	71	22	'71
61	Los Angeles	AESi	71	136	'59-'71
62	Los Angeles	AESi	72	20	'72
63	Los Angeles	AESi	73	20	'73
64	Denver	ATL	72	22	'72
65	Denver	ATL	73	20	'73

Table I. Surveillance Test Programs

After the data were transcribed onto the standard data sheet shown in Appendix A, they were keypunched and entered into a computer file. A computer progam was developed to calculate the Diurnal loss, hot soak loss and grams per vehicle mile based on the calculations shown in Appendix B. The program was also designed to develop certain other data files from which subsequent data analysis could be performed easily. The formats of these files are shown in Appendix C.

The final step in the data handling was auditing the data for various errors. From the auditing process errors were corrected and several invalid tests were discovered and omitted from further analysis. There were various reasons for omitting tests which included erratic readings and tests conducted over a very small range of deflections of the analyzer. A listing of the deleted tests is given in Appendix D. Appendix E is a summary of the results for each test conducted including figures showing the frequency distribution of diurnal, hot soak and total HC losses.

General Emission Levels:

Standard statistical analyses were performed for the data from each of the five test programs. Means and standard deviations of the diurnal, hot soak and gram per mile values were calculated for each test program. Composite values for all Denver tests or for all Los Angeles tests were not looked at as it is felt that there are important test program to test program differences. Most important of the differences between the test programs was the difference in fuel types used. This aspect of the different testing programs will be discussed later. Table II shows the different statistical values for each of the test programs. Figure 1 shows graphically the diurnal and hot soak values for each test program and Figure 2 shows the gram per mile values.

The general emission levels also show to what extent current vehicles would need to improve in order to meet the 2 gram per test standard. The Denver and Los Angeles FY 71 data included 1970 and 1971 vehicles and the same test fuel was used in both programs. The average emissions for those model year vehicles was 31 grams diurnal loss and 21 grams hot soak loss giving an average total loss of 52 grams. It is evident that, for those model years, the evaporative emissions were much greater than the 2 gram standard. The Denver FY 73 and Los Angeles FY 72 and FY 73 programs tested 1972 and 1973 model year evaporative emission controlled vehicles. For those three test programs combined the average diurnal loss was 14.3 grams and the average hot soak loss was 13.8 grams. The total loss per car per test was 28 grams or 14 times the 2 gram standard for evaporative emissions. The FY 73 programs showed the same or higher emissions than the FY 72 program. It should also be noted from the histrograms in Appendix E showing the total loss test data, that no test conducted in any program was less than the 2 gram standard. The EPA in-house study will conduct baseline tests on 1975 vehicles and, therefore, these data will give the most up-to-date evaluation of the effectiveness of evaporative controlled vehicles. However, until these data are available the data from surveillance testing show that on the average better than a 90% reduction in evaporative emissions would be required to meet the current 2 gram standard.

Shed Enclosure versus Canister Trap Testing

The surveillance programs conducted in Denver and Los Angeles for FY 73 did comparative testing to evaluate the shed enclosure measurement as compared to the canister trap method currently used in the certification process. The same vehicles were tested by each of the two test methods. The Denver FY 73 program showed an average total hydrocarbon

Test Program	Diurnal loss			Hot Soak loss			Grams/mile		
	Number of tests	Mean loss grams	Standard Deviation	Number of tests	Mean Loss Grams	Standard Deviation	Number of tests	Mean Loss GPM	Standard Deviation
Denver FY 71 (train 60)	18	42.9	29.5	17	32.5	18.6	13	5.32	3.04
Los Angeles FY 71 (train 61)	124	24.2	17.9	131	13.9	9.43	121	2.58	1.45
Los Angeles FY 72 (train 62)	15	12.5	8.9	17	10.6	5.63	13	2.00	.978
Los Angeles FY 73 (train 63)	17	15.1	14.6	18	14.1	7.02	15	2.41	1.20
Denver FY 73 (train 65)	17	15.1	10.3	20	16.4	9.62	17	2.60	1.34

Table II: Means and Standard deviations Diurnal, Hot Soak, and gram per mile losses for the in dividual surveillance test programs.

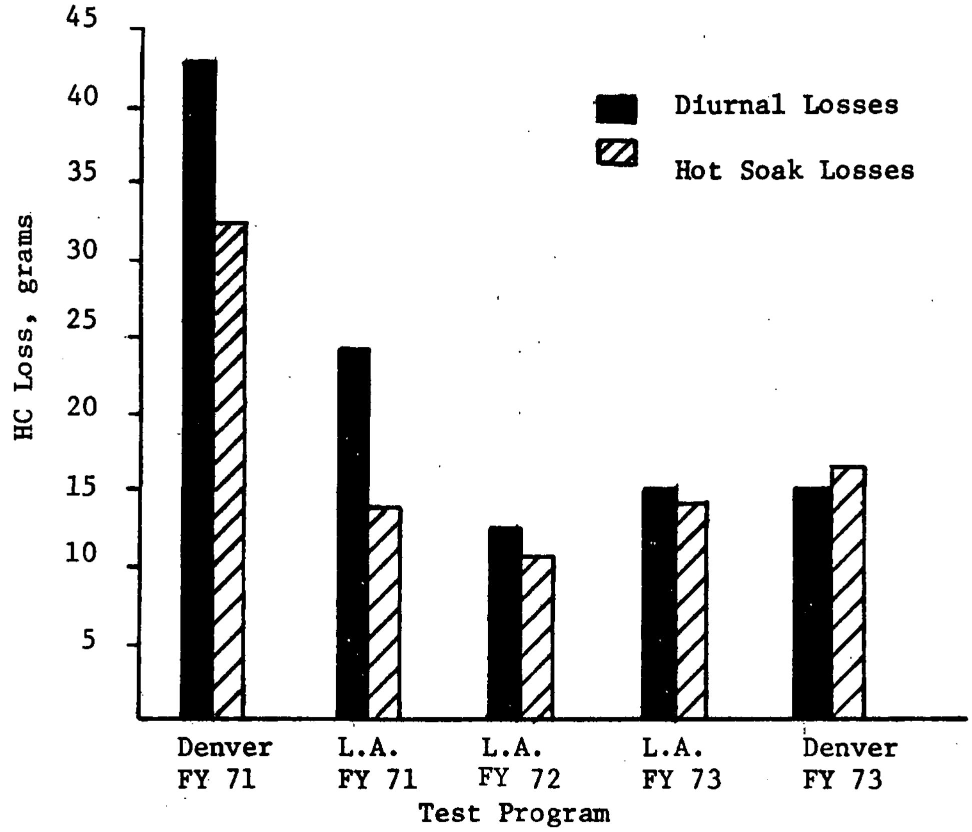


Figure 1 Diurnal and Hot Soak losses for each surveillance test program.

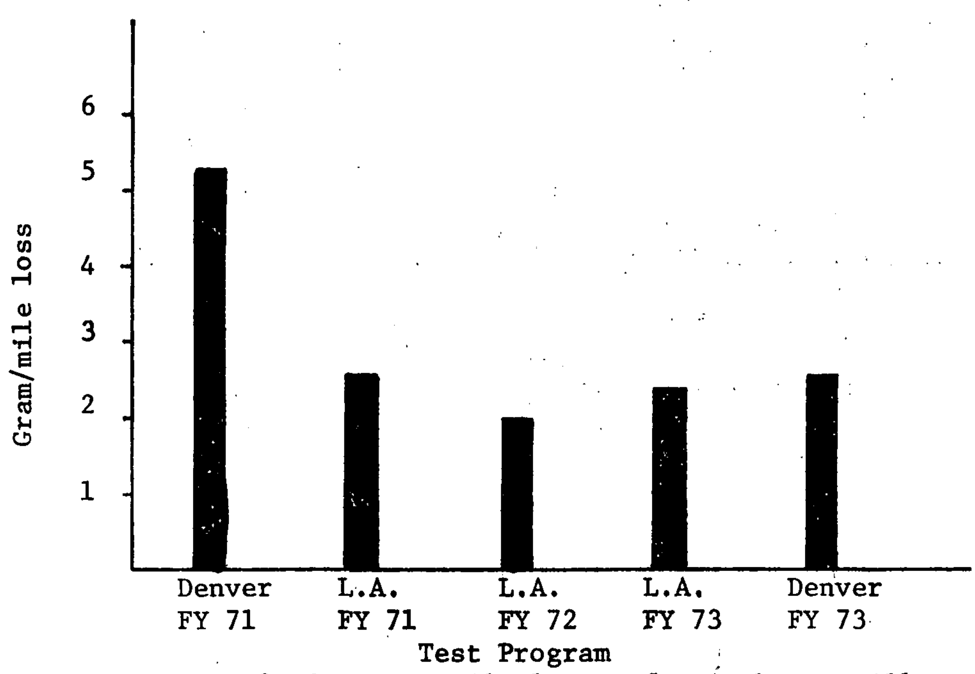


Figure 2 Gram per mile losses for each surveillance test program.

loss of .39 grams for canister tested vehicles as opposed to a 31 gram total loss measured by the enclosure method. This represents a 79 times higher result when the enclosure testing method is used. The Los Angeles FY 73 program showed an average total loss of 0.52 grams for vehicles tested using the canister trap method as opposed to a 29.2 grams loss for vehicles tested using the shed enclosure technique. This represents a 56 times higher result when the enclosure method is used to test the vehicles. This is very strong evidence that the canister trap method only measures a very small percentage of the total evaporative emissions.

Effect of Atmospheric Pressure:

The emission levels from testing done in Denver and Los Angeles can be compared to evaluate the effect of different atmospheric pressures. The atmospheric pressure in Los Angeles was generally 5 in. Hg. higher than it was in Denver. One might suspect that emissions in Denver would be higher because the lower atmospheric pressure would allow the fuel to have a lower Initial Boiling Point (IBP). This was the conclusion, drawn from the surveillance programs, reported on in the preliminary discussion paper on evaporative emissions. In that paper emission levels from the Denver FY 72 and Los Angeles FY 72 surveillance programs were compared. It was found in that analysis that the Denver values were indeed higher and that atmospheric pressure had an important influence on evaporative emissions. In those test programs the vehicles used were of the same model year and all vehicles were controlled for evaporative emissions with charcoal canisters.

For the analysis performed at EPA the data for the Denver FY 72 program were not usable because the FID calibration curves were not available. Therefore, the most reliable sets of data for comparing the effects of atmospheric pressure were the results from the Denver FY 73 and Los Angeles FY 73 program. These programs also used similar vehicles (1973 Models) and all vehicles were canister controlled. In addition the fuel used in both programs was indolene 30 and the Reid Vapor Pressure (RVP) and IBP were similar for both programs.

The diurnal losses were found to be the same for both Denver and Los Angeles. The hot soak emissions were 16% higher for Denver than they were for Los Angeles. It was found, however, that due to the large variance of the data a low confidence can be placed in the conclusion that there is a difference in hot soak emission levels. The general magnitude of the difference in hot soak emission levels was the same as that found in the position paper when Denver FY 72 and Los Angeles FY 72 programs were compared.

One could go further and attempt to compare the Denver FY 73 and Los Angeles FY 72 programs. The only intended difference between the two programs was that the Denver program used all 1973 vehicles and the Los Angeles program used all 1972 vehicles. There may also have been other differences between the two programs such as differences in fuel characteristics. A comparison between these two programs would show a difference in emission levels for both diurnal and hot soak tests. The conclusion that the difference was due to atmospheric pressure, however, may be incorrect because a similar comparison between the Los Angles FY 72 program and the Los Angeles FY 73 program show the same differences. The differences seen between the two Los Angeles programs cannot be attributed to atmospheric pressure. The logical conclusion from these two comparisons would be that a difference existed due to the model year of the vehicles tested and not due to atmospheric pressure. A great deal of confidence cannot be placed in this conclusion either, because other differences such as the effects of fuel composition may have been responsible for the observed differences.

In conclusion, the results of this analysis and the analysis done in the preliminary discussion paper show that different conclusions can be drawn depending on which two test programs are compared. It is felt that while a difference in emission levels may indeed exist due to differences in atmospheric pressure, a test program which would be designed to specifically test for differences due to atmospheric pressure would need to be conducted in order to quantify the effects of atmospheric pressure and to gain sufficient confidence that a difference does or does not exist.

Controlled Vehicles versus Uncontrolled Vehicles

Another important aspect of the surveillance program was the analysis of the effectiveness of the charcoal canister as an evaporative emission control device. The Los Angeles FY 71 test program tested both canister controlled and uncontrolled vehicles. The other programs tested only canister controlled vehicles and, therefore, the analysis done to evaluate the canister's effectiveness was done on vehicles from the Los Angeles FY 71 program only. Table III shows the diurnal and hot soak emission levels for both controlled and uncontrolled vehicles. The diurnal losses were reduced by 28% and the hot soak emissions were reduced by 28% due to the charcoal canister. A high confidence can be placed in the conclusion that there is indeed an improvement in evaporative emission levels due to the charcoal canister. However, due to high variability in the tests a more precise quantification of the charcoal canister's effect on evaporative emissions would require more testing.

Test Type		Mean HC loss, grams	Standard Deviation	Range @95% confidence
Diurnal	controlled	18.47	2.64	14.84-22.1
	uncontrolled	25.73	19.34	21.89-29.57
Hot Soak	controlled	10.6	6.30	8.27-12.93
	uncontrolled	14.86	10.04	12.88-16.84

Table III: Mean HC loss for diurnal and hot soak tests for evap. controlled and uncontrolled vehicles L.A. FY 71 data only.

Effects of Fuel and Enclosure Temperature

The preliminary discussion paper cites references addressing the effects of fuel parameters such as RVP and IBP on emission levels. The testing done during the surveillance program showed certain trends that would be expected due to differences in RVP and IBP. However, due to the many uncontrolled parameters such as vehicle type, fuel tank size, engine size, barometric pressure, and test site, any attempt to quantify the effects of fuel differences would be invalid. In order to quantify any differences, controlled testing would need to be performed.

Trends, however, were found and are illustrated graphically in figures 3 and 4. Figure 3 shows the diurnal and hot soak emission levels in Denver and Los Angeles for Indolene 30 and commercial leaded fuels. Figure 4 represents the fuel parameters of RVP and IBP for indolene 30 and commercial leaded fuels used in Denver and Los Angeles. The RVP would be expected to primarily affect diurnal emission levels, whereas the IBP would primarily affect the hot soak emission levels. This analysis was done for evaporative controlled vehicles only, in order to eliminate variance due to that parameter.

The diurnal losses for commercial leaded fuel were higher than diurnal losses for tests using indolene 30 in both Denver and Los Angeles. In both cases the RVP of the fuel was much higher for the commercial leaded fuel and one would expect higher evaporative emissions when a fuel with a higher RVP is used. The amount of vapors generated during the hot soak test would be expected to be higher when the IBP of the fuel is lower. This is the case for hot soak emissions in Denver but not in Los Angeles. The Los Angeles values for hot soak losses are very close even though the IBP for the Indolene fuel is higher. This does not adhere to the expected trend, but is probably due to some vehicle or test parameter other than fuel type.

An analysis was done to try and evaluate effect of the enlosure (SHED) temperature on evaporative emissions. Only hot soak test data were evaluated since higher enclosure temperatures could be expected due to the transfer of heat from the hot engine. Tests were grouped in 2 degree intervals of maximum shop temperature minus IBP, such that when the maximum shop temperature equalled the IBP the data were placed in the zero degree interval. The tests in the different intervals were averaged and the data were plotted in Figure 5. In addition the average engine size for each interval was calculated and is also plotted in Figure 5. The Figure shows that there is a definite increase in emissions as the maximum SHED temperature approaches and surpasses the IBP of the fuel. This could be attributed to the fact that larger engines could produce more emissions and more heat. However, the data of average engine size does not bear this out, as equally large engines are found over the entire range. The observed trend could also be due to a larger average carburetor bowl

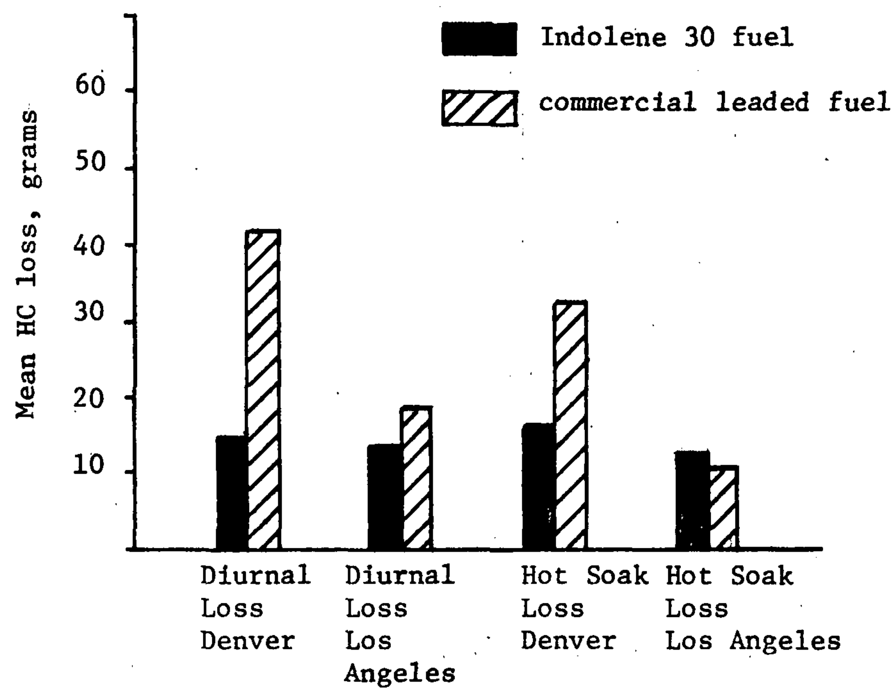


Figure 3 Mean HC loss for Indolene or Commercial Leaded Fuels for Denver and Los Angeles.

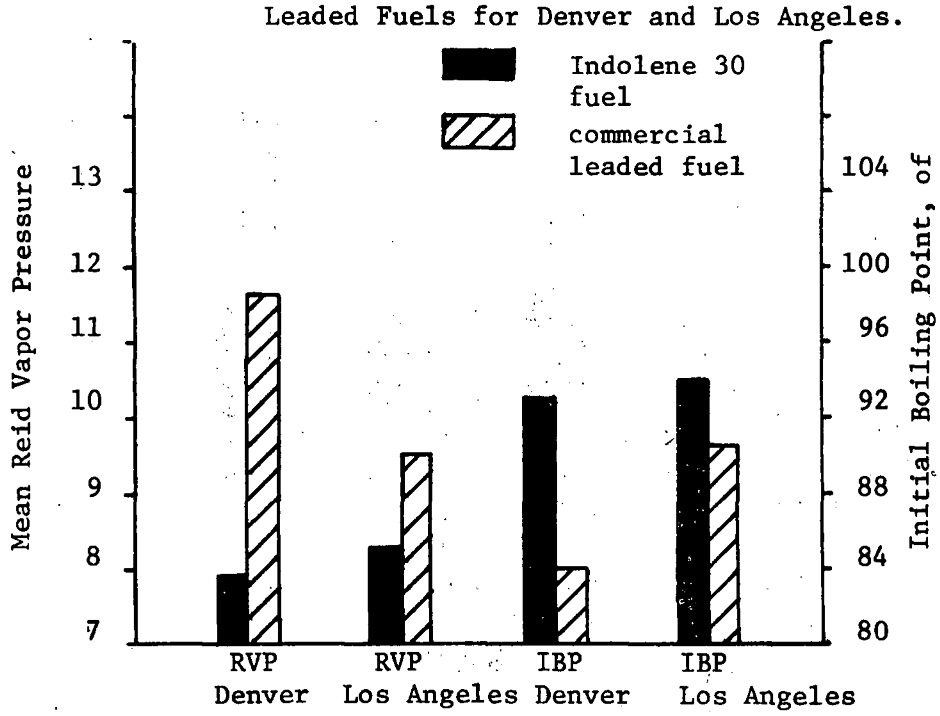


Figure 4 Mean RVP and IBP values for Indolene or commercial leaded fuels for Denver and Los Angeles.

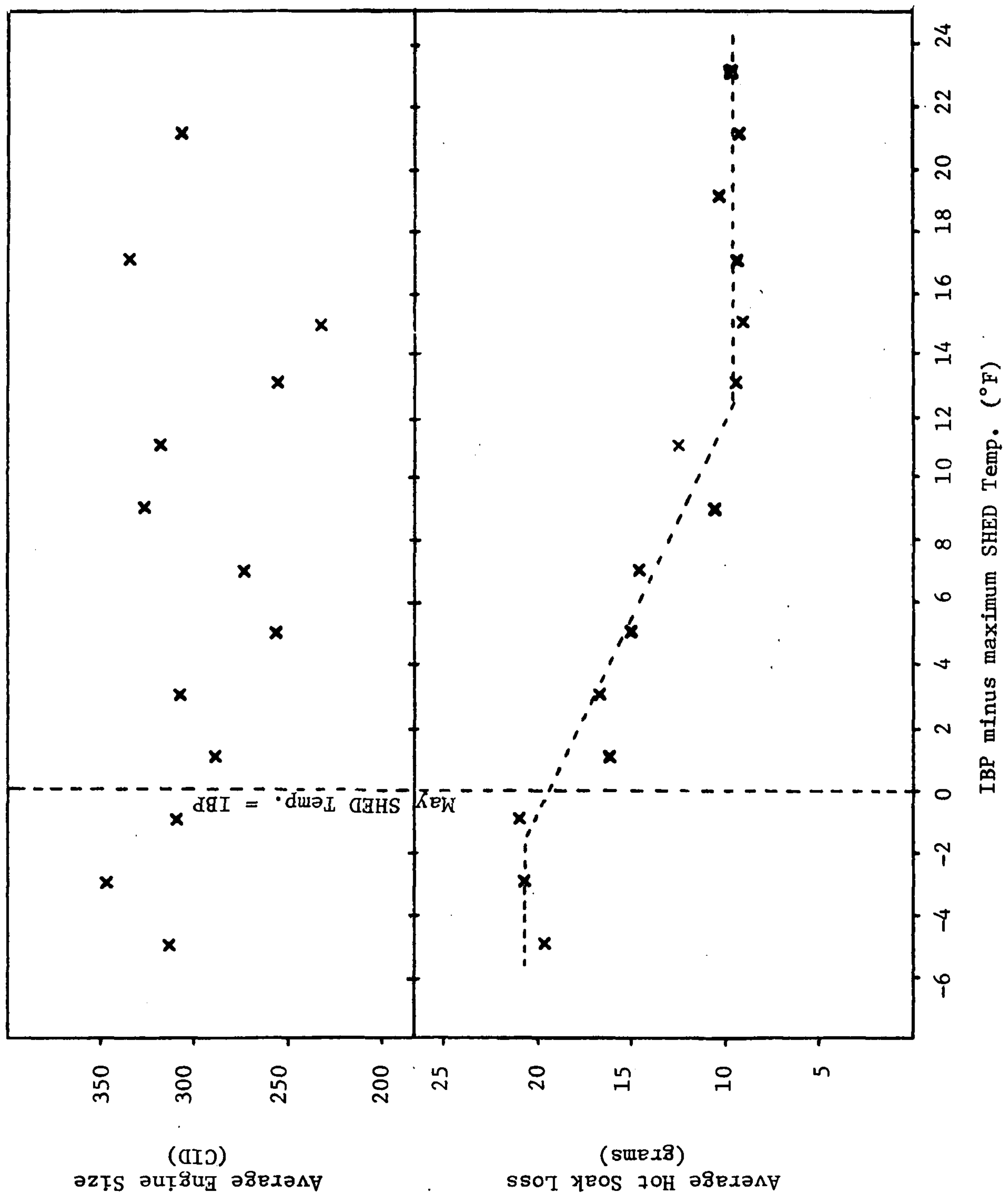


Figure 5. Average hot soak losses and average engine size (CID) as a function of maximum SHED Temperature - IBP.

	% of tests where shed temperature exceeded		
Test Program	80°F	90°F	IBP
Denver FY 71	86.96	17.39	73.91
L.A. FY 71	71.85	.74	16.30
L.A. FY 72	95	5	5
L.A. FY 73	95	0	0
Denver FY 73	95	35	15

Table IV % of tests for each test program where the shed temperature exceeded 80°F, 90°F or IBP.

volume for those groupings showing higher evaporative losses. However, carburetor bowl volume data were not available and therefore this hypothesis could not be tested. Lastly, the higher hot soak emissions exhibited for tests where the enclosure temperature was greater than the IBP of the fuel could be attributed to increased emissions from the fuel tank as the fuel surpasses its IBP. This conclusion, although feasible, cannot be totally supported, but it would help explain the high hot soak emissions for the Denver FY71 testing. Table IV shows the % of tests for each train in which the enclosure temperature exceeded 80°, 90°F and the IBP. It is evident that the large percent of tests where the maximum SHED temperature exceeded the IBP for the Denver FY71 program could have been the cause of the high hot soak emissions for that test program.

The maximum enclosure temperature never exceeded the IBP of the fuels used for any diurnal test during any of the test programs. However, the IBP of the fuel used during the Denver FY71 program was at or below 84°F for 77% of the tests conducted during that program. The prescribed ending fuel tank temperature for the diurnal test is 84°F $\pm$ 2°F. Therefore, the high diurnal losses exhibited during the Denver FY71 program are probably due to the low IBP of the test fuel used.

In conclusion, the trends expected due to the fuel parameters of RVP and IBP do show up for all but Los Angeles hot soak values. There are published reports available that experimentally quantify the effects of fuel composition on evaporative emissions which give much more reliable results than the surveillance data.

Since fuel does have a marked effected on both hot soak and diurnal emission results, it is recommended that tight specifications on fuel type be used and a maximum shed enclosure temperature be specified.

Analysis of Diurnal Emission Tests

The parameters felt to have an important effect on diurnal emissions were analysed to determine if they influenced the levels of diurnal emissions and, if possible, to quantify their influence. The parameters that were analyzed were the length of test, the fuel tank volume, and the RVP of the test fuel.

The effect the length of the diurnal test has on evaporative emissions was looked at in two ways. First, plots of hydrocarbon concentration divided by the maximum hydrocarbon concentration versus time divided by total length of the diurnal test were made. These plots for each test program are shown in figures 6 through 10. These plots show the general rate of evolution of hydrocarbons with time and specifically show what is occurring at the end of the diurnal test. It can be seen that the diurnal emissions are continuing to be evolved at the end of the test at a substantial rate. Ten percent of the total hydrocarbon loss occurs in the last 10% or approximately 6 minutes of the test time. The current time tolerance specified for the certification procedure and in the SAE procedure is 60 min $\pm$ 10 min. A question that needs to be answered, then, is whether or not the 10 min. tolerance on the diurnal test length is too liberal.

It should be noted that these figures as well as figures showing the hot soak emissions as a function of time do not always show the maximum HC levels at the end of the test. One would expect the [HC]/[HC] max value to equal 1.0 at the end of the test. However, due to averaging tests where the maximum hydrocarbon concentration occurred before the end of the test, some figures do not end at a [HC]/[HC] max value of 1.0.

Another analysis of the data from the Los Angeles FY 71 was done to look at the emission levels for tests which ended in either 50, 55, 60, 65 or 70 minutes. For this analysis, only tests where the final temperature was 84° $\pm$ .5°F were considered. The results of this analysis are shown in figure 11. It can be seen from this figure that the longer the test the higher the emissions and that a 70 minute test might result in 400% higher emissions than a 50 minute test. It can be seen from the 95% confidence limits in the figure that an accurate assessment of the effect of the length of the diurnal test cannot be made. Further testing would be required to make a quantitative evaluation of the proper time tolerances for the diurnal test and this is being planned for current in-house EPA testing. It can be concluded, however, that time may be an important aspect of the diurnal test and there is a need to quantify its effect.

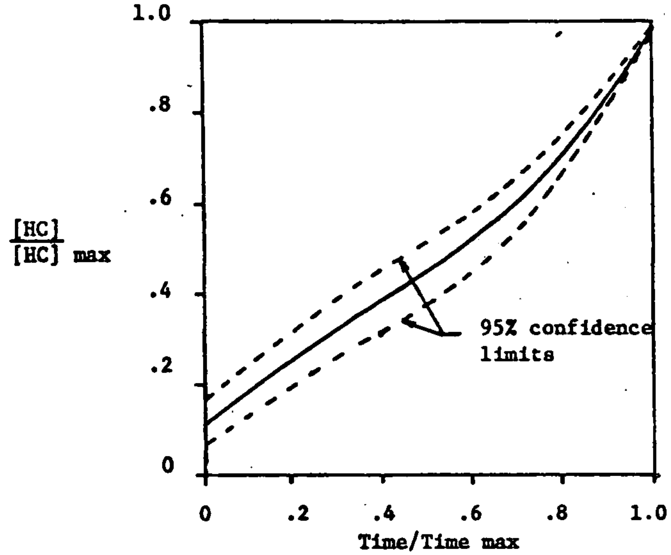


Figure 6. Denver FY 71 program.

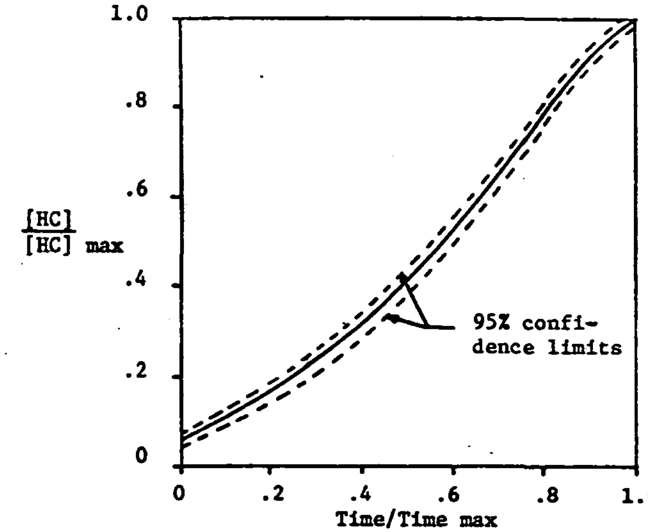


Figure 7. Los Angeles FY 71 program.

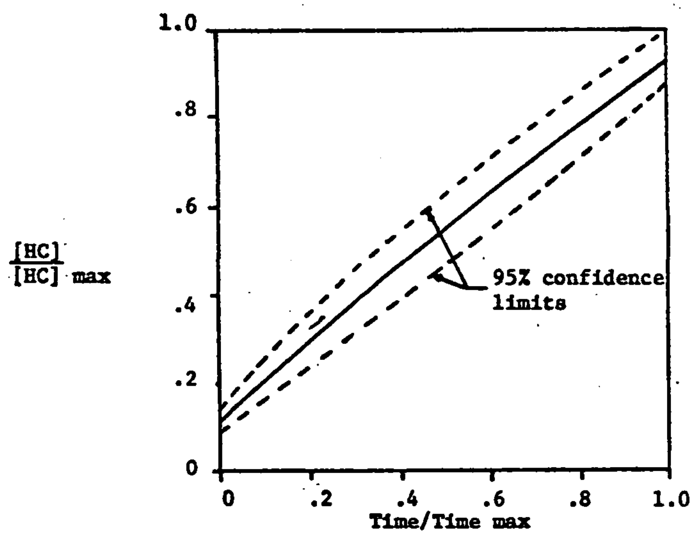


Figure 8, Los Angeles FY 72 program.

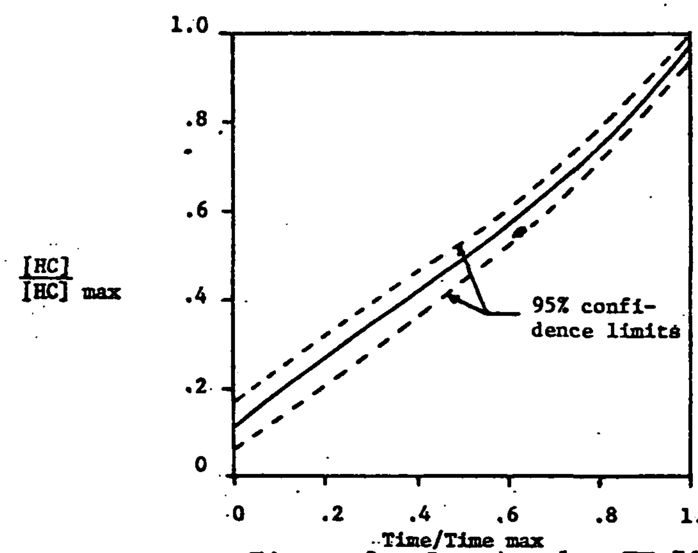


Figure 9. Los Angeles FY 73 program.

Figures 6-9: $\frac{[HC]}{[HC]\ max}$ vs. $\frac{Time}{Time\ max}$ for diurnal tests.

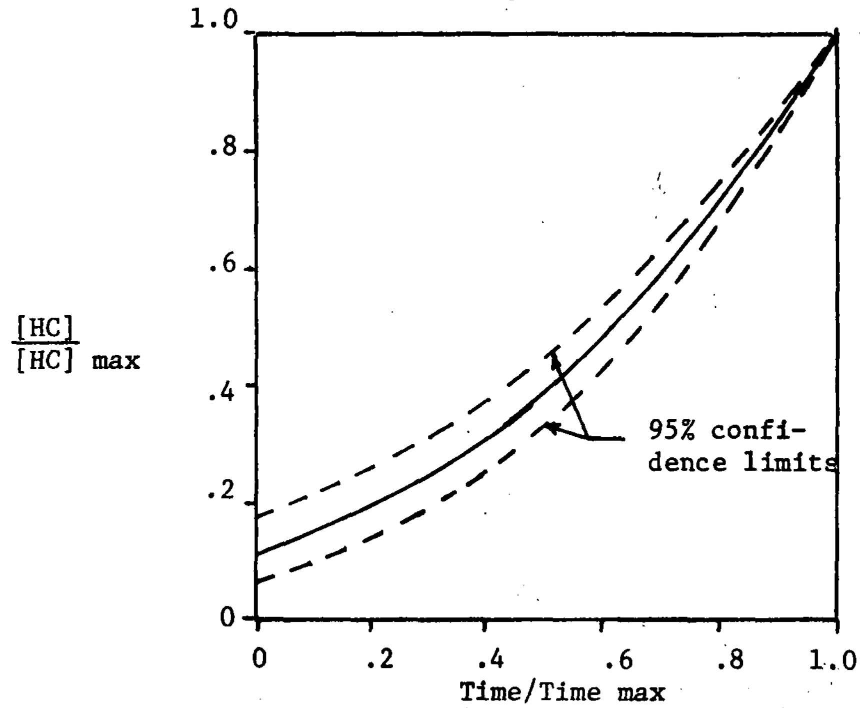


Figure 10 $\frac{[HC]}{[HC]\ max}$ vs. $\frac{Time}{Time\ max}$ for diurnal tests conducted during the Denver FY 73 surveillance program.

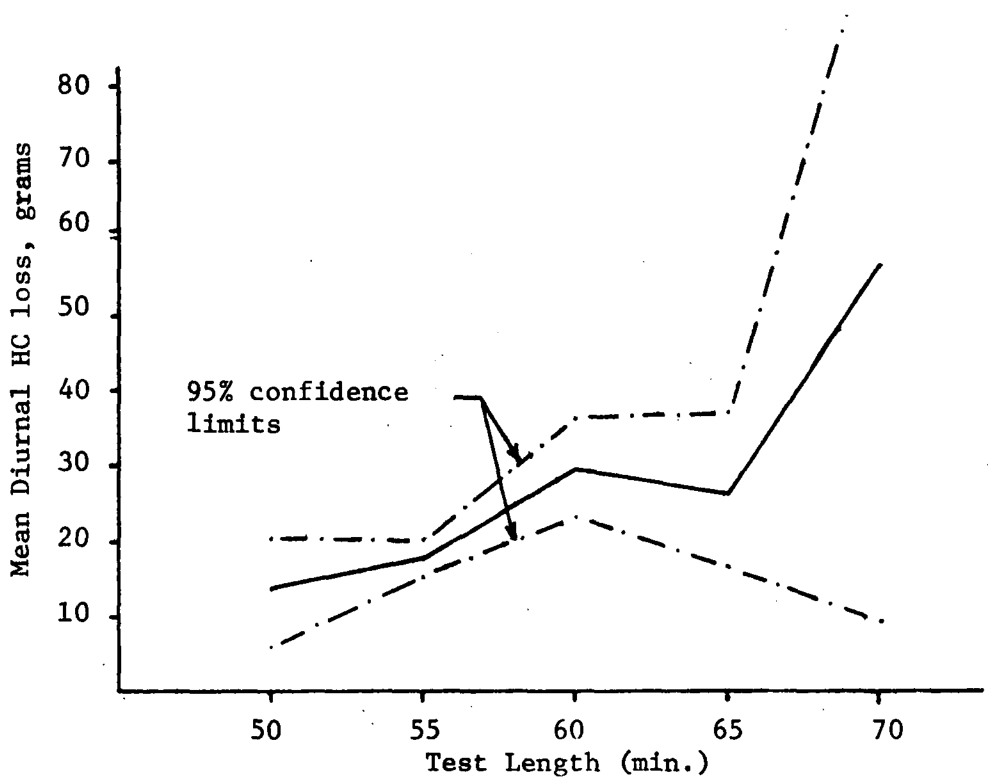


Figure 11 Mean diurnal HC loss vs. length of test for Denver FY 71 data only. (All tests ended at 84°F ± .5°F)

A similar analysis was performed to evaluate the effect of different temperature rises on diurnal emissions. Only tests ending in 60 min. were evaluated. The tests were grouped according to whether a 20, 22, 24, 26, or 28 degree temperature rise was conducted. The average values for each interval were then calculated. This analysis did not provide any noticeable trend even though one might suspect that higher emissions would be exhibited for vehicles subjected to a larger temperature rise. One cannot, however, conclude that the temperature rise has no effect because the experiment was not controlled for other parameters. In addition there were no data for temperature rises of 20°F or 28°F. Therefore, the effects of the extreme temperature tolerances could not be evaluated as 20°F and 28°F are the minimum and maximum temperature rises respectively allowable by the current tolerances. It is planned for the EPA in-house study on evaporative emissions to perform controlled experiments in order to evaluate the effect of the temperature tolerances.

The effect that the fuel tank volume has on diurnal emissions was also analyzed. A regression analysis was run to determine if a correlation existed between fuel tank volume and diurnal emissions. The Los Angeles FY 72 and FY 73 and the Denver FY 73 programs exhibited the best correlation coefficients. However, the correlation coefficients were low and scatter plots of the data for these programs showed a wide scatter of data. These plots are shown in figures 12-14. It is recommended that a more controlled experiment be performed to determine if any correlation truly exists and to quantify its effect.

An attempt to quantify the effect of RVP was also performed for the different test programs. A regression of RVP versus diurnal emissions showed very low correlation coefficients. As was stated earlier, there have been studies performed that have anlayzed and quantified the effects of RVP on diurnal emissions.

Analysis of Hot Soak Emission Tests

The general hydrocarbon versus time relationships were determined for hot soak emissions as well as analyses done to evaluate the effects of engine parameters such as engine size (displacement), number of cylinders and number of barrels. Figures 15 through 19 show the general emissions versus time relationships for each test program for a one hour hot soak. It can be seen that the emission level increases rapidly for the first half of the test and then begins to level off during the last half of the test. The emissions do, however, continue to increase up to the end of the test and presumably continue past one hour. The extent to which the emissions continue to increase should be evaluated to determine if they reach a constant value in a fixed amount of time or if they continue to increase indefinitely.

The engine size (displacement) was analyzed to determine whether the enclosure temperature rise during the hot soak test was affected. The analysis done for the Los Angeles FY 72 program showed some cor-

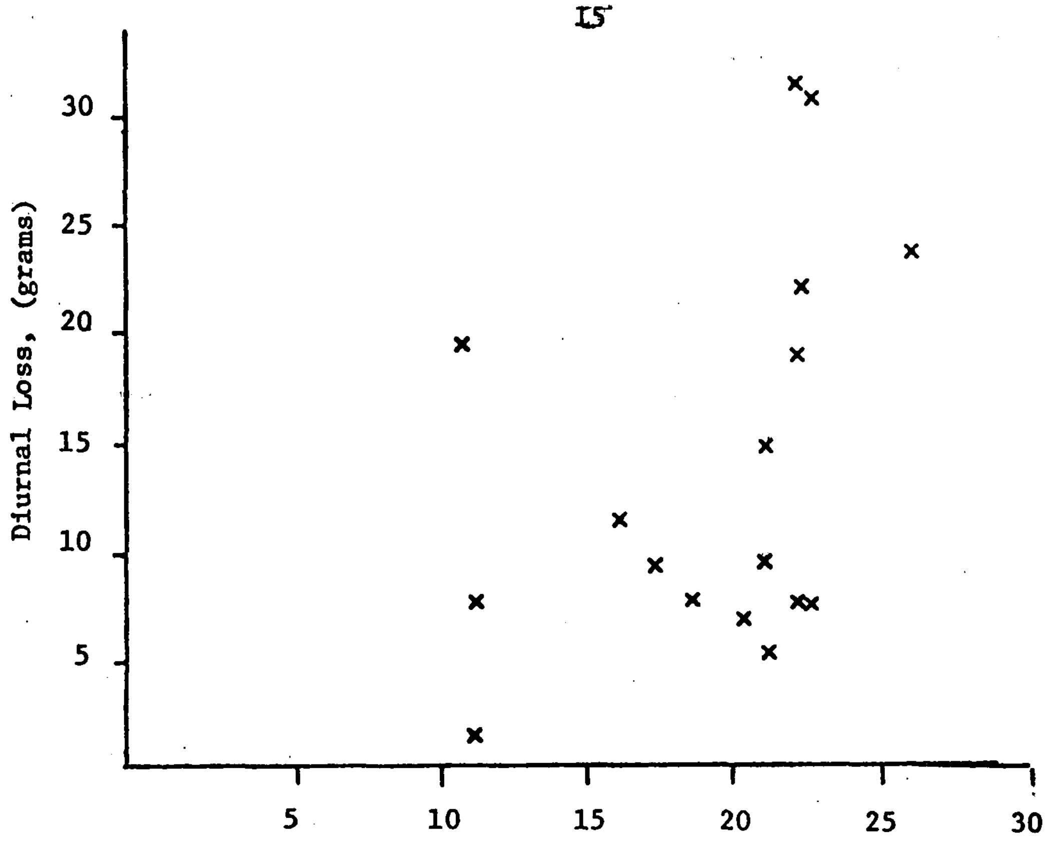


Figure 12 Diurnal Loss vs. Fuel tank volume for the Denver FY 73 surveillance program.

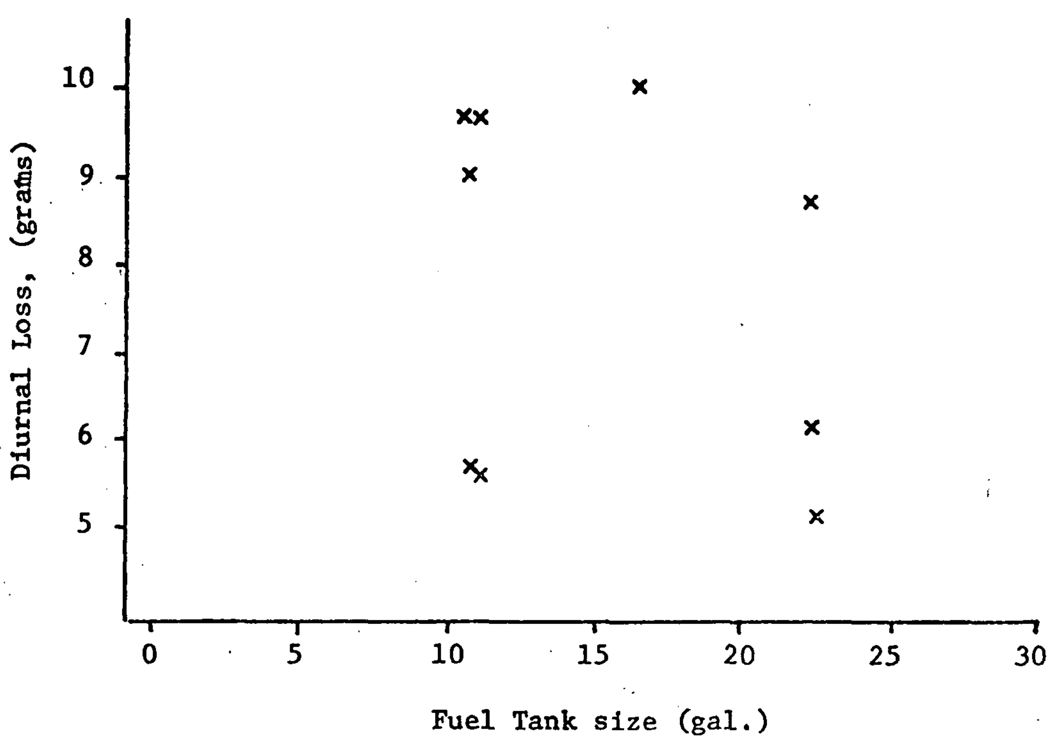
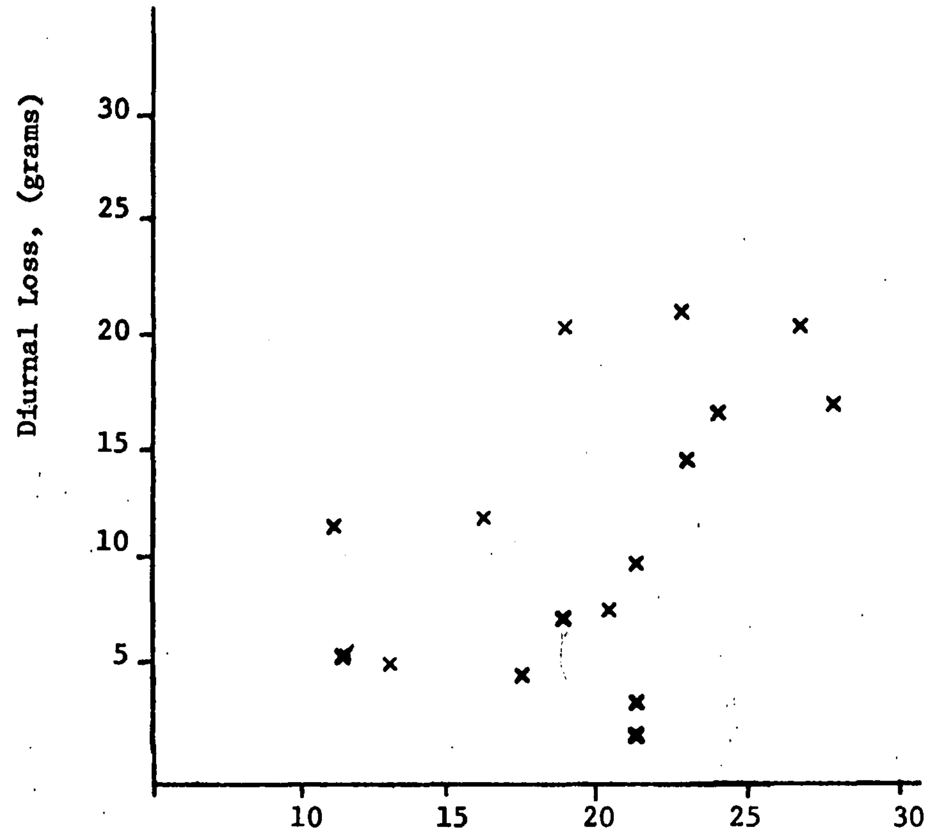


Figure 13 Diurnal loss vs. Fuel tank volume for the L.A. FY 73 surveillance program.



Fuel Tank size (gal.)
Figure 14 Diurnal Loss vs. Fuel tank volume for the L.A. FY 72 surveillance program.

relation. It showed that a 350 CID engine produced a 2.3°F greater enclosure temperature rise than a 200 CID engine. It was stated earlier that the maximum enclosure temperature has an effect on hot soak emissions when it approaches the IBP of the fuel. This would mean, therefore, that a larger engine might cause the maximum shed temperature to exceed the IBP whereas a smaller engine would not. Again, in order to quantify the effect of engine size, a more controlled experiment would be required. It would seem, however, that specifying a maximum enclosure temperature as the SAE procedure does would eliminate any problems that would arise. The SAE procedure specifies a 90°F maximum Shed temperature.

The number of cylinders in the engine and the number of barrels in the carburetor were compared with hot soak emission levels to determine if a correlation existed. Table V shows the results of an anlaysis of the number of cylinders for vehicles tested in the Los Angeles FY 71 test program. Only one test program was analyzed, to eliminate any variability between test programs and the Los Angeles FY 71 program was used because of the large sample size. The vehicles with 8 cylinders emitted 80% more evaporative emissions than did vehicles with 4 cylinders. A high confidence was found to exist that a difference between the two sets of data actually existed.

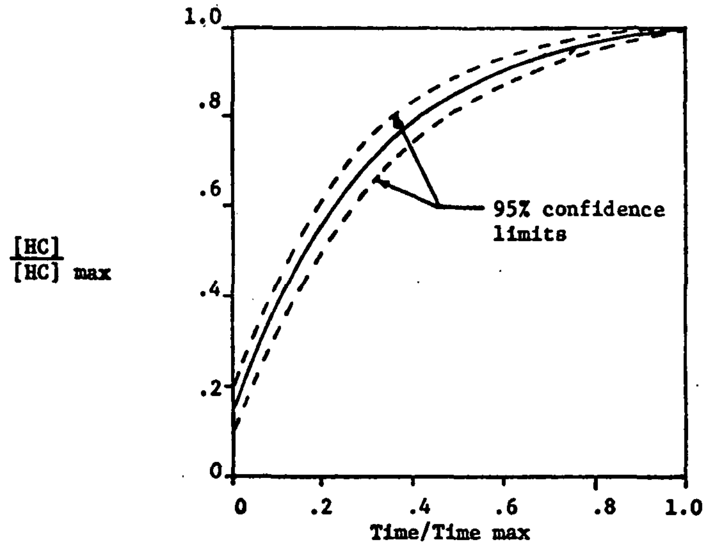


Figure 15. Denver FY 71 program.

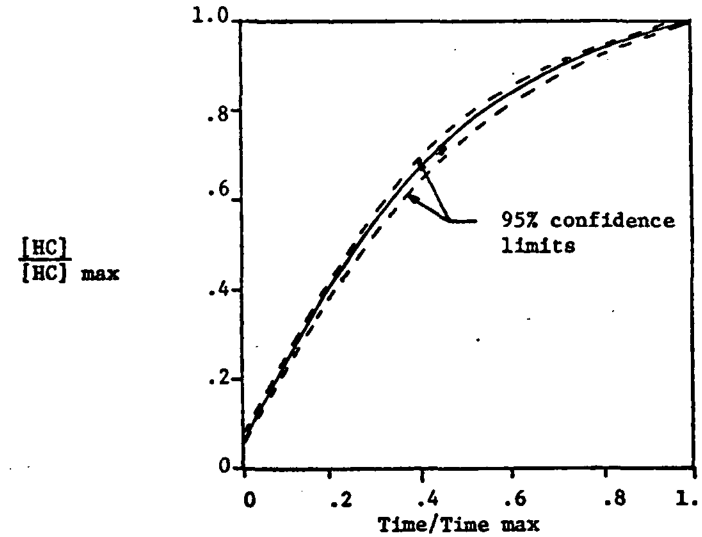


Figure 16. Los Angeles FY 71 program.

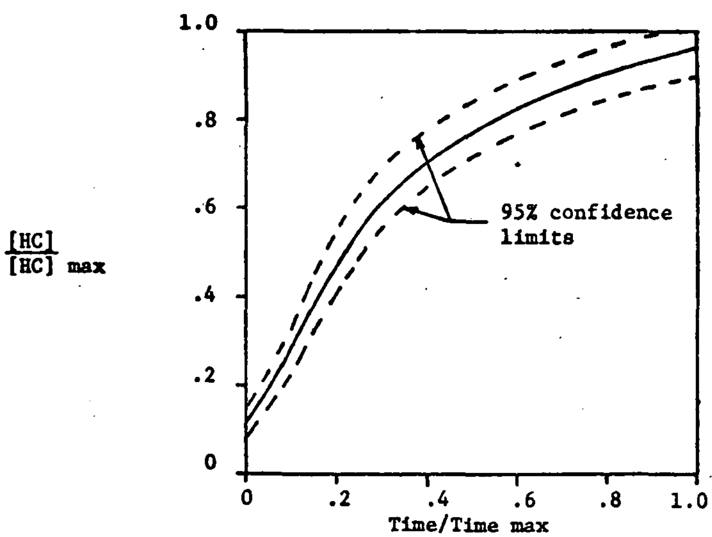


Figure 17. Los Angeles FY 72 program.

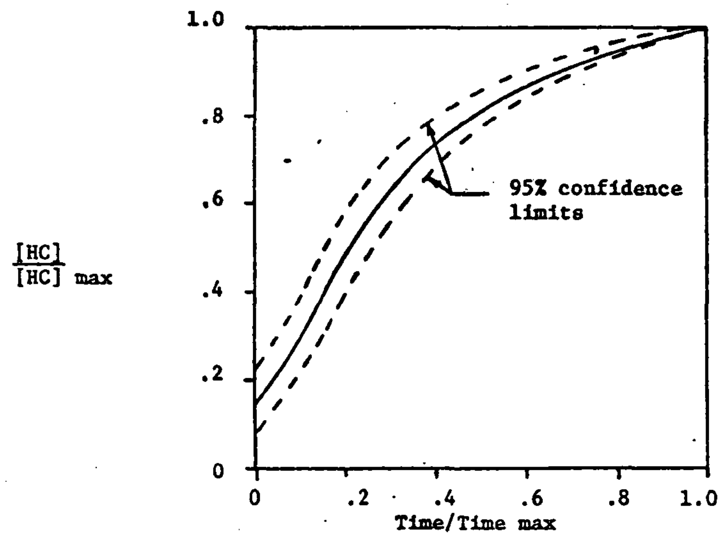


Figure 18. Los Angeles FY 73 program.

Figures 15-18. $\frac{[HC]}{[HC]\ max}$ vs. $\frac{Time}{Time\ max}$ for hot soak tests.

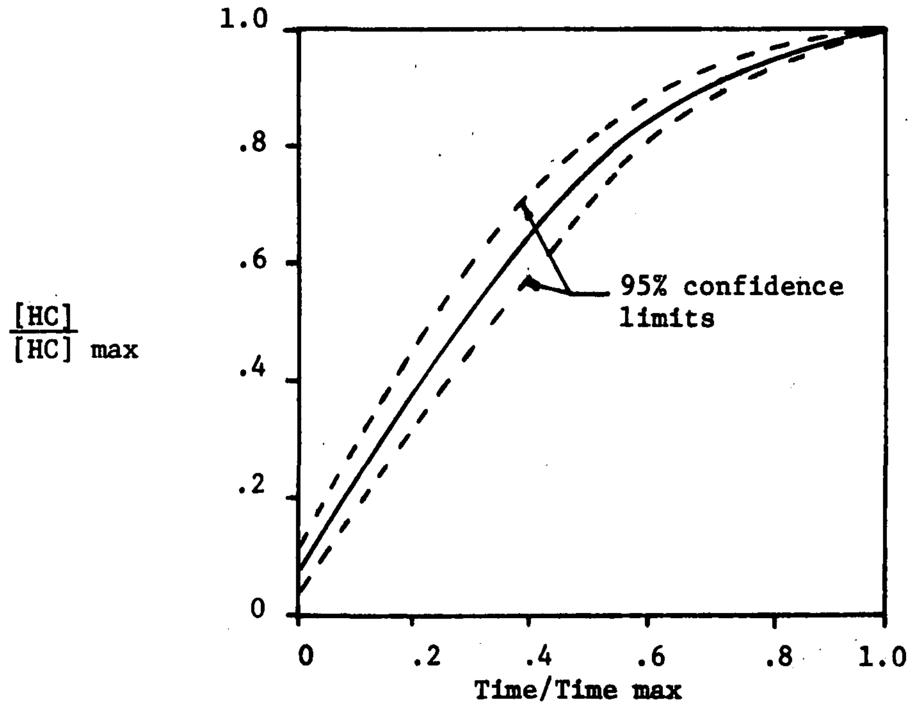


Figure 19 $\frac{[HC]}{[HC]\ max}$ vs. $\frac{Time}{Time\ max}$ for hot soak tests conducted during the Denver FY 73 surveillance program.

No. of Cylinders	No. of tests	Mean Hot soak loss, (gms)	Standard Deviation
4	15	8.32	6.59
6	18	13.50	6.91
8	97	14.97	9.89

Table V : Mean hot soak losses for vehicles with 4, 6 or 8 cylinders. L.A. FY 71 data only.

Table VI shows the results of an analysis performed to test the effect of the number of carburetor barrels. It was determined by means of a t-test that there was not a high confidence that any difference in hot soak emissions existed due to the number of barrels. However, it does appear that a trend may exist such that higher emissions would result for vehicles with a greater number of barrels.

No. of Barrels	No. of tests	Mean hot soak Loss (grams)	Standard Deviation
1	22	12.10	7.63
2	69	13.96	10.92
4	39	14.98	7.43

Table VI : Mean hot soak losses for vehicles with 1, 2 or 4 barrels. L.A. FY 71 data only.

The effect of carburetor bowl volume was not analyzed because bowl volume data were not readily available. It is believed that bowl volume may have an effect on hot soak emissions, but further studies would be required to determine this. In order to gain a more precise evaluation of differenct engine parameters, controlled testing would need to be performed. In the evaluation of the effect the number of cylinders or number of barrels had on hot soak emissions, the fuel tank volumes, engine size (displacement), evaporative control systems, carburetor bowl size and type of caburetor were not controlled. Therefore, it is difficult to attribute differences in emission levels to one parameter only such as the number of cylinders. It is believed that families of vehicles with similar engine, and fuel system characteristics would produce similar emission levels. This cannot be confirmed through analysis of the surveillance data, however.

The data for total evaporative losses were also grouped by different manufacturer. This grouping is shown in Table VII. It should be noted that the controlled and uncontrolled vehicles are different vehicles and that in some cases a very small number of tests were conducted. For these reasons these data should not be considered as indicative of all vehicles made by that manufacturer. It should also be noted that the vehicles tested were tested in the condition they were in when they came to the test facility, and that they were in-use vehicles. These do, however, show that all manufacturers will have to achieve a considerable reduction in evaporative losses in order to meet a 2 gram standard.

An attempt was made to separate groups of vehicles by manufacturer, engine size, model year, and fuel tank volume. The groups of vehicles were small in number and showed a very large variance in emission levels. Nine groups of vehicles were found where the sample size was greater than 3. These groups are described in Table VIII and the emissions levels are summarized in Table IX. For diurnal emissions the standard deviations for the different groups ranged from 33% of the mean value to 125% of the mean. For hot soak emissions the standard deviations for the different groups ranged from 12% of the mean to 106% of the mean. These values show that even groups of similar vehicles show wide variability in evaporative emission families. The variance exhibited in the groups of similar vehicles can be attributed at least in part to test variability. Eight of the nine groups came from the Los Angeles FY 71 program. During this program nine replicate tests on the same vehicle were run. From these replicate tests it was found the the difference in diurnal emissions between two tests averaged 23% of their mean value and for hot soak emissions the difference averaged 37.1% of the mean value. It should also be noted that most of the groups consisted of non-evaporative controlled vehicles. Controlled vehicles may show less test to test variability and this can be evaluated with the replicate testing done during the EPA in-house study.

Conclusion and Recommendations

1) The current evaporative emission levels as measured by the SHED technique are fourteen times higher than the 2 gram standard. A 90% improvement in evaporative emissions would be required to meet the 2 gram standard.

2) The shed enclosure method was found to measure between 56 and 79 times higher evaporative emissions than the canister trap technique. It is recommended that the shed enclosure testing method be used for evaporative emission testing instead of the canister trap method.

Manufacturer	Control Vehicles		Uncontrolled Vehicles	
	N	Total loss, grams	N	Total loss, grams
AMC	2	28.9	1	37.7
Chrysler	2	52.8	1	35.4
Dodge	3	21.5	4	23.8
Plymouth	2	27.7	2	18.9
All Chrysler	7	32.2	7	24.1
Ford	10	25.2	10	44.0
Mercury	3	36.5	2	49.3
All Ford Mo. Co.	13	27.8	12	44.9
Buick	3	39.0	2	69.7
Cadillac	2	42.0	1	42.1
Chevrolet	9	22.1	9	45.8
Oldsmobile	3	36.9	2	28.1
Pontiac	1	36.8	2	73.0
All GM	18	30.4	16	49.7
Nissan			1	18.9
Toyo Kogyo	1	53.6		
Toyota	1	13.0	1	55.9
Volkswagen	2	18.5	1	16.6

Table VII. Average total evaporative hydrocarbon losses for controlled and uncontrolled vehicles by manufacturer.

Group No.	Manufacturer	Model Yrs.	Engine size (in^3.)	Fuel tank size (gal.)	No. of vehicles in group
1	Ford	before 1965	251-300	15-20	5
2	Ford	before 1965	351-400	15-20	4
3	Ford	1965-1969	251-300	15-20	5
4	Chevrolet	before 1965	251-300	15-20	6
5	Chevrolet	1965-1969	251-300	15-20	4
6	Chevrolet	1965-1969	301-350	15-20	6
7	Chevrolet	1970-1971	301-350	15-20	4
8	Chevrolet	1970-1971	301-350	20-25	5
9	Volkswagen	1965-1969	50-100	10-15	6

Table VIII Characteristics of groups of similar vehicles.

Group No.	No. of vehicles	Diurnal tests		Hot Soak tests		Grams/mile	
		Mean HC Loss, (grams)	Standard Deviation	Mean HC Loss, (grams)	Standard Deviation	Mean GPM Loss	Standard Deviation
1	5	33.9	42.3	13.2	3.16	2.74	1.51
2	4	23.3	10.9	12.8	1.57	2.39	.495
3	5	20.8	6.8	15.8	2.58	2.73	.456
4	6	21.7	16.2	9.40	4.31	1.89	.978
5	4	49.2	40.1	7.85	3.29	2.46	1.25
6	6	29.5	27.7	13.6	4.72	2.68	1.00
7	4	24.6	10.2	11.4	3.57	2.25	.763
8	5	57.6	34.6	23.6	12.0	4.83	2.28
9	6	28.9	23.2	8.59	9.15	1.98	1.81

Table IX. Evaporative Emission Statistics for groups of similar vehicles.

3) Further testing would be needed to accurately assess the effects of atmospheric pressure on evaporative emissions. It was found that hot soak emissions were higher in Denver than in Los Angeles by approximately 16%, but a high confidence in the conclusion that atmospheric pressure has a significant effect on either diurnal or hot soak losses was not found to exist.

4) Evaporative controlled vehicles were found to have 28% lower evaporative emissions levels than uncontrolled vehicles for both diurnal and hot soak tests.

5) The Reid Vapor Pressure (RVP) and Initial Boiling Point (IBP) of the test fuel appeared to have significant effects on evaporative losses. It was not possible to quantify the effects of RVP and IBP due to the large varity of vehicles used. However, there have been studies done which quantify the effects of RVP and IBP. Tight specifications should be placed on the test fuel used.

6) The maximum shed temperature had an effect on the hot soak losses and, therefore, it is recommended that a maximum shed temperature be specified for testing. The SAE procedure currently specifies a 90°F maximum enclosure temperature.

7) The length of the diurnal test appeared to have a significant effect on the diurnal losses, but, due to large test variability and a small number of tests run at 50 or 70 minutes, further testing needs to be done to accurately quantify its effect. It is recommended that additional testing be done to evaluate the effect of the time tolerance on diurnal emissions.

8) The fuel tank volume was not found to have a quantified effect on diurnal emissions. No conclusions could be drawn from the data.

9) Hydrocarbon levels appeared to increase beyond the 1 hour hot soak test. It is recommended that further testing be done to determine to what extent the emission levels continue to increase.

10) Further testing should be conducted in order to quantify the effects of engine size (displacement), the number of cylinders and the number of barrels on hot soak emissions. It did appear, however, that higher hot soak emission levels existed for vehicles with more cylinders or more barrels and the enclosure temperature rise was greater for larger engines.

References

1. C. Don Paulsell, Mobile Source Evaporative Emissions (Draft), June 1974.

EVAPORATIVE EMISSION (SHED) DATA SHEET

Card 01: MANF. CODE | VEHICLE IDENTIFICATION NO. | MODEL | MOD. YR. | ENGINE FAMILY I.D. | SOURCE CODE | RATED GVW | CURB WT. | INERTIA | ACTUAL DYNO HP | REQUESTOR | DATE | CARD 0 1

Card 02: DISPL. | UNITS | ENG. TYPE | NO. CYL. | NO. CARB. | NO. BBLS. | CARB. MODEL | BOWL VOL. (CC) | F.E. SHUTOFF | CONTROL SYSTEM: TYPES, NAME | EVAP. | CCASE | FUEL TANK: NO., SIZE | ODOMETER | VEH. VOL. (FT³) | 0 2

Card 03: FUEL | H/C RATIO | RVP. | FUEL DISTILLATION TEMPERATURES (°F): IBP., 5%, 10%, 15%, 20%, 30%, 40%, 50%, 90%, FBP. | FUEL IN TANK | OPERATOR | TEST DATE | 0 3

Card 04: DIURNAL | RUNNING | HOT SK. | PROP. INJ. | REFUEL | W.B. (°F) | D.B. (°F) | SHED NO. | TEST TIME (MIN.): DL, HS. | CYL. MASS (GMS) TANK (GAL.): BEFORE, AFTER | PROPANE INJECTION, RUNNING LOSS, REFUELING LOSS: HC BGND. (RNG., READING), HC START (RNG., READING), HC FINAL (RNG., READING), TEMP (°F), BARO. (IN. HG.), SAMPLE TIME (SEC.) | CVS TEST NO. | EVAP TEST NO. | 0 4

Card 05: REQUESTOR COMMENTS | LABORATORY COMMENTS | 0 5

Card columns numbered 5, 10, 15, 20, 25, 30, 35, 40, 45, 50, 55, 60, 65, 70, 75, 80.

Cards 06–20: TIME (MIN.) | DIURNAL: TEMPERATURE (°F): ENCL., TANK (INT.), TANK (EXT.); BARO. (IN. HG.); HC.: RNG., READING | HOT SOAK: TEMPERATURE (°F): ENCL., TANK (INT.), TANK (EXT.), CARB.; BARO. (IN. HG.); HC.: RNG., READING

Card 06: X X X . X X X X X X X X B A C K G R O U N D — 0 6

Card 07: 0 0 0 — 0 7

Cards: 0 8, 0 9, 1 0, 1 1, 1 2, 1 3, 1 4, 1 5, 1 6, 1 7, 1 8, 1 9, 2 0

Appendix A - Sample Evap Data Sheet

Appendix B

Calculations for Diurnal and Hot Soak losses and Grams per Vehicle Mile used for analysis of Surveillance Data

I. Diurnal and Hot Soak loss calculation.

$$Y_{HC} = .208\text{x}10^{-4}\ (12 + H/C)\ (V - V_{vh})\ (P)\ \frac{[C_f - C_b]}{T_f - T_b}$$

where, Y_{HC} = hydrocarbon loss (Diurnal or Hot Soak), (grams).

H/C = Hydrogen - Carbon ratio (2.33 used for diurnal loss, 2.20 used for hot soak loss)

V = Shed Volume, (ft^3).

V_{vh} = Vehicle volume (assumed to be 50 ft^3)

P = Atmospheric pressure, (in. Hg).

C_f = Final hydrocarbon concentration, (ppm C).

C_b = Background hydrocarbon concentration, (ppm C).

T_f = Final Shed enclosure temperature, (°R).

T_b = Background Shed enclosure temperature, (°R).

II. Grams per vehicle mile.

$$GPM = \frac{D_{hc} + 4.7\ HS_{wc}}{35}$$

where, GPM = Grams per vehicle mile.

D_{hc} = Diurnal hydrocarbon loss, (grams).

HS_{wc} = Hot soak hydrocarbon loss, (grams).

Appendix C

Data File Contents

A. EVAP-A data file.

Columns	Content
2-8	Train and test Number**
15-19	Rated GVW* (lbs.)
25-29	Curb Wt.* (lbs.)
37-41	Inertia Wt. (lbs.)
44-47	Actual Dyno. Horsepower
50-55	Displacement and Units
62-63	Engine Type**
68-69	Number of Cylinders
76-77	Number of carburetors
84-85	Number of Barrels
86-95	Control System types**
99-100	Evap System**
105-106	Crankcase type**
119-120	Fuel type**
121-170	Fuel Distillation temperatures (IBP, 5%, 10%, 15%, 20%,30%, 40% 50%, 90%, FBP)
172-176	H/C ratio
177-181	Reid Vapor Pressure, psi
186-190	Fuel in tank (gal.)*
199-200	No. of fuel tanks
206-210	Fuel tank Size (gal.)
211-218	Diurnal HC loss, grams
219-228	Hot Soak loss, grams
229-235	Total HC loss, grams
236-242	Grams per vehicle mile

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* data not recorded during surveillance program.

** see codes at end of file descriptions.

B. EVAP - B data file

Colums	Contents
2-8	Train and test No.*
10-14	Wet bulb temperature, °F
15-19	Dry bulb temperature, °F
20-24	Shed Number*
25-30	Shed Volume, ft^3
31-35	Length of Diurnal test, min.
36-42	Length of Hot Soak Test, min.
	Diurnal Test Data
43-47	initial
49-53	final Enclosure temp., °F
55-59	peak
61-65	initial
67-71	final Internal tank temp., °F
73-77	peak
79-83	initial
85-89	final External tank temp., °F
91-95	peak
97-101	Barometer reading, in. Hg.
102-107	initial
108-114	final HC concentration, ppm C
115-121	peak
122-131	Diurnal loss, grams
	Hot Soak Test Data
132-136	initial
137-141	final Enclosure temp., °F
142-146	peak
147-151	initial
152-156	final Internal tank temp., °F
157-161	peak
162-166	initial
167-171	final External tank temp., °F
172-176	peak
177-182	Barometer reading, in. Hg.
184-189	initial
190-196	final HC concentration, ppm C
197-203	peak
207-217	hot soal loss, grams
218-227	grams per vehicle mile

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* see codes at end of data file listings.

C. EVAP-C data file.

Column	Content
2-8	Train and test number*
	<u>Diurnal test data (HC concentration)</u>
11-17	Background
18-24	0 min.
25-31	5 "
32-38	10 "
39-45	15 "
46-52	20 "
53-59	25 "
60-66	30 "
67-73	35 "
74-80	40 "
81-87	45 "
88-94	50 "
95-101	55 "
102-108	60 "
109-115	65 "
116-122	70 "
	<u>Hot Soak test data (HC concentration, ppm C)</u>
124-130	Background
131-137	0 min.
138-144	5 "
145-151	10 "
152-158	15 "
159-165	20 "
166-172	25 "
173-179	30 "
180-186	35 "
187-193	40 "
194-200	45 "
201-207	50 "
208-214	55 "
215-221	60 "
222-228	65 "
229-235	70 "

* See codes at the end of data file listings.

D. EVAP Data date file.

Data from EVAP data sheets are stored in a line file in the same positions as it appears on the data sheets shown in Appendix A.

Codes

A. Engine Type
01 I-Block
02 V-Block
03 Rotary
04 Opposed
05 Turbine
06 Ex (Steam)
07 Ex (FREON)
08 Diesel
09 Stirling
10 Electric
11 Stratified

B. Exhaust System Types(s)
01 Air Injection
02 Engine Mod
03 Fuel Injection
04 Other
05 Thermal Reactor
06 Catalytic Reactor
07 Turbocharger
08 Exhaust Gas Recycle
09 None

C. Evap System Type
01 Crankcase
02 Canister
03 Tank
04 None

D. Crankcase System Type
01 Closed
02 Other

E. Fuel Type
01 Indolene 30
02 Commercial leaded

F. Shed No.
40 AESi Denver
41 AESi L.A.
42 ATL Denver

G. Train No.

60	AESi	Denver	FY 71
61	AESi	L.A.	FY 71
62	AESi	L.A.	FY 72
63	AESi	L.A.	FY 73
64	ATL	Denver	FY 72
65	ATL	Denver	FY 73

Appendix D

Tests omitted from data Analysis

Diurnal Tests

Train	Test
60	0094
60	0105
60	0110
60	0141
60	0152
61	0023
61	0029
61	0033
61	0034
61	0098
61	0099
61	R110
61	0118
61	0156
61	0168
61	0182
62	0012
62	0016
62	0170
62	0172
62	0178
63	0011
63	0017
63	0021
65	0032
65	0037
65	0039

Hot Soak Tests

Train	Test
60	0016
60	0051
60	0141
60	0145
60	0155
60	R167
61	0043
61	0096
61	0099
61	0111
61	0116
62	0133
62	0178
62	0179
63	0033
63	0044

MSAPC Evaporative Enclosure (SHED) Test Results

AESI Denver FY71 Train 60

	DIURNAL TEST					HOT SOAK TEST						
Test No.	Test Time (min.)	Encls. Temp., °F	Initial Tank Temp., °F	Final Tank Temp., °F	HC Loss, Grams	Test Time (min.)	Encls. Temp., °F	Initial Tank Temp., °F	Final Tank Temp., °F	HC Loss, Grams	Total Loss, Grams	Grams Per Mile
0016	60	78.0	0.0	0.0	72.69	60	81.0	94.5	83.8	0.0	72.69	2.08
0051	60	83.0	61.0	85.0	60.58	60	88.0	94.0	95.0	0.0	60.58	1.73
0061	60	79.0	61.0	84.2	7.99	60	84.0	91.2	90.0	15.92	23.92	2.37
0076	60	80.0	0.0	0.0	29.61	60	82.0	88.0	85.0	26.32	55.93	4.38
0078	60	76.0	60.0	84.0	15.73	60	86.0	84.0	86.0	30.66	46.39	4.57
0086	60	72.0	60.0	85.7	52.19	60	79.0	89.0	90.0	60.82	113.01	9.66
0094	60	74.0	61.0	84.0	31.61	60	81.0	89.0	89.0	37.21	68.82	5.90
0095	60	74.0	59.0	83.0	18.01	60	82.0	84.0	87.0	61.15	79.16	8.73
0105	60	78.0	60.0	85.0	81.62	60	88.0	95.0	93.0	31.08	112.71	6.51
0110	60	79.0	60.0	84.0	3.63	55	81.0	83.0	82.0	20.74	24.37	2.89
0114	60	75.0	59.0	85.0	95.54	60	88.0	84.0	86.0	44.55	140.09	8.71
0132	60	78.0	60.0	84.0	15.98	60	81.0	95.0	93.0	73.06	89.03	10.27
0140	60	72.0	60.0	84.0	20.86	60	88.0	87.0	83.0	20.02	40.88	3.28
R140	60	72.0	60.0	84.0	20.86	60	88.0	87.0	83.0	20.02	40.88	3.28
0141	60	76.0	60.0	83.5	118.29	60	85.0	88.0	85.5	16.98	135.27	5.66
0145	60	71.0	60.0	83.0	72.81	60	81.0	104.5	95.5	0.0	72.81	2.08
0152	60	77.0	60.0	84.2	7.17	60	81.0	89.0	94.5	44.79	51.95	6.22
0155	60	80.0	59.5	84.5	77.92	60	84.0	97.0	94.5	0.0	77.92	2.23
0163	60	71.0	59.4	84.0	90.22	60	83.0	95.0	95.0	23.69	113.91	5.76
0167	60	78.0	60.5	83.8	7.99	60	79.0	87.0	87.0	11.02	19.01	1.71

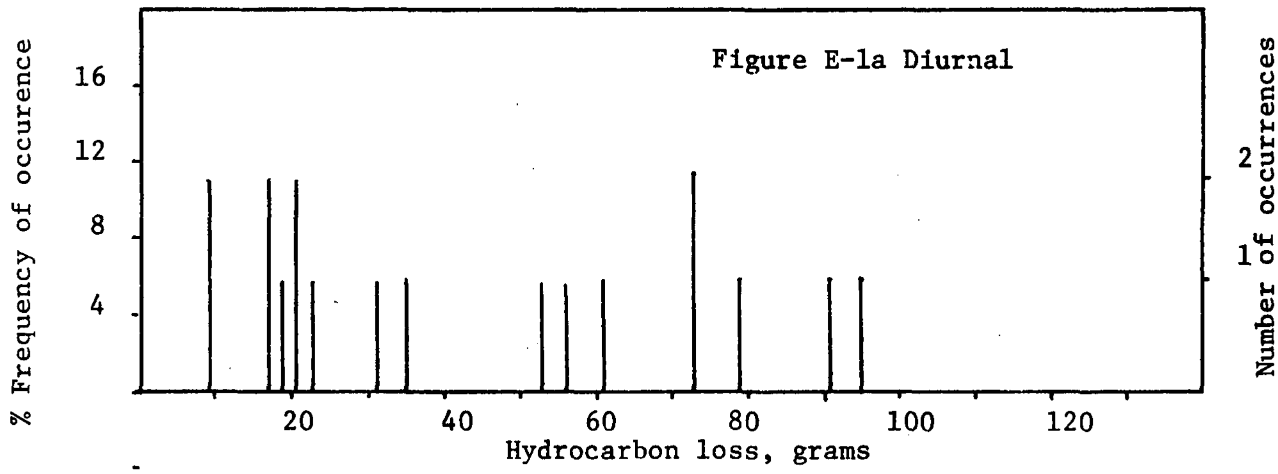
*Test not used in data analysis.

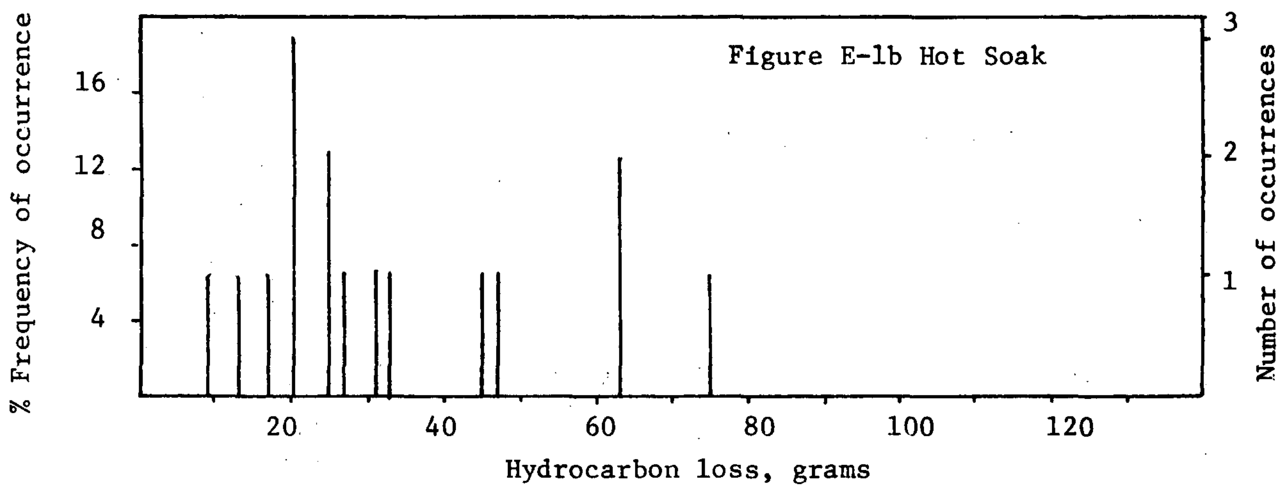
MSAPC Evaporative Enclosure (SHED) Test Results

AESI Denver FY71 Train 60

	DIURNAL TEST					HOT SOAK TEST						
Test No.	Test Time (min.)	Encls. Temp., °F	Initial Tank Temp., °F	Final Tank Temp., °F	HC Loss, Grams	Test Time (min.)	Encls. Temp., °F	Initial Tank Temp., °F	Final Tank Temp., °F	HC Loss, Grams	Total Loss, Grams	Grams Per Mile
R167	60	76.0	59.8	84.3	33.78	60	77.0	88.5	87.0	0.0	33.78	0.97
T167	60	79.0	60.0	84.1	21.99	60	75.0	85.0	83.0	8.51	30.50	1.77
0172	60	72.0	59.8	84.0	57.16	60	85.0	87.0	87.0	22.95	80.11	4.71

*Test not used in data analysis.





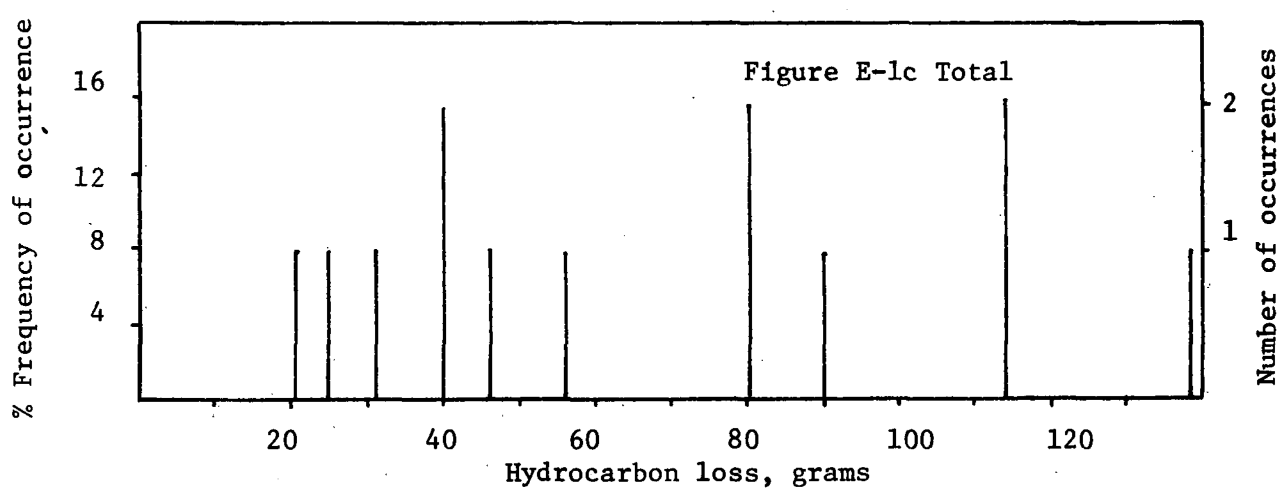


Figure E-1 Histograms of Diurnal, Hot Soak, and Total loss data for Denver FY71 program.

MSAPC Evaporative Enclosure (SHED) Test Results

AESI Los Angeles FY71 Train 61

	DIURNAL TEST					HOT SOAK TEST						
Test No.	Test Time (min.)	Encls. Temp., °F	Initial Tank Temp., °F	Final Tank Temp., °F	HC Loss, Grams	Test Time (min.)	Encls. Temp., °F	Initial Tank Temp., °F	Final Tank Temp., °F	HC Loss, Grams	Total Loss, Grams	Grams Per Mile
0002	55	69.0	60.0	84.0	39.92	60	80.0	75.0	77.0	26.38	66.30	4.68
0003	60	70.0	61.5	84.0	38.83	60	82.0	87.0	88.0	13.01	51.84	2.86
0016	65	78.0	66.5	82.5	59.64	60	80.0	68.0	68.0	8.70	68.34	2.87
0017	60	71.0	0.0	0.0	12.42	60	84.0	0.0	86.0	25.13	37.55	3.73
0018	60	82.5	0.0	0.0	8.45	60	85.0	84.5	84.0	14.35	22.80	2.17
0019	55	76.0	60.0	84.0	34.73	60	75.0	78.0	78.0	2.23	36.96	1.29
0020	55	80.0	60.0	84.0	10.12	60	84.0	84.0	86.0	23.90	34.02	3.50
0021	60	71.0	60.0	84.0	27.93	50	81.0	86.0	86.0	19.96	47.89	3.48
0022	60	68.5	61.0	84.0	40.66	55	78.0	88.0	85.0	14.24	54.90	3.07
0023	55	69.0	62.0	84.0	28.61	60	75.5	86.0	79.0	13.18	41.79	2.59
0025	55	70.0	0.0	0.0	42.32	60	80.0	90.0	86.0	7.41	49.73	2.20
0026	55	70.0	61.0	85.0	27.99	60	80.0	82.0	82.0	14.53	42.51	2.75
0027	60	68.0	62.0	84.0	41.67	60	80.0	88.0	86.0	15.09	56.76	3.22
0029	55	70.0	60.0	84.0	32.85	60	78.0	84.0	85.0	15.78	48.62	3.06
0030	60	68.0	63.0	84.0	12.10	60	80.0	76.0	82.0	13.31	25.41	2.13
0032	55	74.0	65.0	84.0	14.49	55	76.0	72.0	75.0	2.22	16.71	0.71
0033	60	68.0	63.0	84.0	5.88	60	76.0	80.0	84.0	4.24	10.12	0.74
0034	55	75.0	70.0	84.0	29.75	60	82.0	87.0	85.0	14.82	44.58	2.84
0036	55	74.0	64.0	84.0	14.92	60	81.0	85.0	84.0	14.06	28.98	2.31
0037	60	74.0	65.0	84.0	21.96	60	81.0	84.0	83.0	17.41	39.37	2.97

*Test not used in data analysis.

MSAPC Evaporative Enclosure (SHED) Test Results

AESI Los Angeles FY71 Train 61

	DIURNAL TEST					HOT SOAK TEST						
Test No.	Test Time (min.)	Encls. Temp., °F	Initial Tank Temp., °F	Final Tank Temp., °F	HC Loss, Grams	Test Time (min.)	Encls. Temp., °F	Initial Tank Temp., °F	Final Tank Temp., °F	HC Loss, Grams	Total Loss, Grams	Grams Per Mile
0038	60	71.0	61.0	84.0	27.72	60	82.0	83.0	85.0	24.31	52.03	4.06
0039	55	73.0	66.0	84.0	25.12	60	82.0	75.0	84.0	11.96	37.08	2.32
0040	55	73.0	61.0	84.0	15.75	60	80.0	84.0	84.0	16.31	32.06	2.64
0041	55	70.0	62.0	84.0	14.13	60	81.0	96.0	86.0	7.12	21.25	1.36
0043	55	74.0	63.0	84.0	17.88	60	78.0	84.0	83.0	70.35	88.24	9.96
0044	55	69.0	62.0	84.0	15.72	60	79.0	82.0	82.0	16.35	32.07	2.64
0045	60	72.0	61.0	84.0	59.54	60	84.0	91.0	88.0	17.08	76.63	4.00
0046	55	77.0	61.0	84.0	26.73	60	84.0	88.0	85.0	10.01	36.74	2.11
R046	55	75.0	61.5	84.0	26.69	60	83.0	90.0	89.0	18.43	45.32	3.24
0047	55	72.0	60.5	84.0	20.26	60	77.0	82.0	82.0	10.14	30.40	1.94
0048	55	74.0	61.0	83.0	30.96	60	85.0	72.0	82.0	12.94	43.90	2.62
0049	65	68.0	61.5	84.0	35.50	60	80.0	68.0	80.0	15.42	50.92	3.08
0050	55	76.0	61.0	84.0	12.07	60	82.0	82.0	82.5	11.20	23.27	1.85
0051	55	79.0	62.0	84.0	10.65	60	79.0	86.0	83.0	8.27	18.92	1.42
0052	55	77.0	61.0	84.0	24.07	60	76.0	82.0	86.0	14.99	39.06	2.70
R052	65	70.0	61.0	84.0	71.62	65	67.0	76.0	80.0	24.44	96.06	5.33
0053	55	76.0	61.0	84.0	19.01	60	76.0	77.0	74.0	4.17	23.18	1.10
R053	60	79.0	61.0	84.0	20.23	60	79.0	80.0	80.0	2.66	22.89	0.93
0054	70	74.0	61.0	84.0	26.55	60	85.0	88.0	88.0	36.58	63.14	5.67
0055	55	76.0	61.0	84.0	25.61	60	82.0	84.0	85.0	19.12	44.74	3.30

*Test not used in data analysis.

MSAPC Evaporative Enclosure (SHED) Test Results

AESI Los Angeles FY71 Train 61

	DIURNAL TEST					HOT SOAK TEST						
Test No.	Test Time (min.)	Encls. Temp., °F	Initial Tank Temp., °F	Final Tank Temp., °F	HC Loss, Grams	Test Time (min.)	Encls. Temp., °F	Initial Tank Temp., °F	Final Tank Temp., °F	HC Loss, Grams	Total Loss, Grams	Grams Per Mile
0056	60	73.0	61.5	84.0	36.34	60	85.0	87.0	88.0	22.19	58.53	4.02
0057	65	69.0	61.0	84.0	40.88	60	69.0	69.0	69.0	4.97	45.86	1.84
0058	65	74.0	61.5	84.0	37.14	60	84.0	84.0	86.0	15.12	52.26	3.09
R058	65	68.0	61.5	84.0	26.93	60	79.0	79.0	78.0	11.96	38.89	2.38
0060	60	70.0	61.0	84.0	13.13	55	79.0	78.0	78.0	18.64	31.77	2.88
0061	60	69.0	61.0	84.0	22.95	60	80.0	81.0	80.5	15.74	38.68	2.77
0062	65	69.0	60.0	84.0	18.02	60	79.0	74.5	76.0	10.24	28.26	1.89
0063	55	70.0	61.0	84.5	27.61	60	79.0	88.0	89.0	13.30	40.91	2.57
0064	65	69.0	61.0	84.0	23.75	55	77.0	82.0	81.0	11.15	34.89	2.18
0065	65	70.0	60.0	84.0	40.67	60	79.0	83.0	82.0	23.41	64.08	4.30
0066	65	71.0	61.0	83.5	19.22	60	86.0	83.0	87.0	25.03	44.25	3.91
0067	60	69.0	61.0	84.0	13.32	60	80.0	82.0	83.0	10.03	23.35	1.73
0068	60	69.0	60.0	84.0	15.44	60	87.0	82.0	85.0	26.68	42.13	4.02
0069	55	73.0	61.0	84.0	22.79	55	89.0	85.0	88.0	19.38	42.17	3.25
0070	60	69.0	60.0	84.0	80.29	55	80.0	82.0	83.0	11.60	91.90	3.85
0071	55	77.0	61.0	84.0	16.65	55	83.0	86.0	92.0	13.92	30.57	2.35
0072	60	68.0	60.0	84.0	24.04	60	85.0	82.0	84.0	14.15	38.19	2.59
0073	60	72.0	0.0	0.0	28.14	60	82.0	87.0	85.0	13.38	41.51	2.60
0075	60	72.0	61.0	84.0	26.89	55	87.0	91.0	95.0	19.44	46.33	3.38
0076	60	75.0	62.0	84.0	26.64	55	85.0	95.0	99.0	86.17	112.81	12.33

*Test not used in data analysis.

MSAPC Evaporative Enclosure (SHED) Test Results

ÁESI Los Angeles FY71 Train 61

	DIURNAL TEST					HOT SOAK TEST						
Test No.	Test Time (min.)	Encls. Temp., °F	Initial Tank Temp., °F	Final Tank Temp., °F	HC Loss, Grams	Test Time (min.)	Encls. Temp., °F	Initial Tank Temp., °F	Final Tank Temp., °F	HC Loss, Grams	Total Loss, Grams	Grams Per Mile
0079	60	70.0	61.0	84.0	28.52	60	81.0	84.0	84.0	20.64	49.16	3.59
0080	60	71.0	61.0	84.0	53.36	60	80.0	79.0	82.0	15.86	69.22	3.65
0081	60	73.0	60.0	84.0	44.67	60	79.0	83.0	87.0	27.55	72.21	4.98
0082	70	73.0	60.0	84.0	47.64	60	81.0	89.0	90.0	29.66	77.30	5.34
0085	60	71.0	61.0	84.0	11.57	50	73.0	74.0	70.0	2.89	14.46	0.72
0086	60	69.0	60.0	84.0	17.62	60	76.0	80.0	82.0	15.45	33.07	2.58
0087	70	70.0	60.0	84.0	85.43	60	73.0	74.0	73.0	13.92	99.35	4.31
0088	60	70.0	0.0	0.0	50.08	60	78.0	0.0	0.0	19.20	69.28	4.01
0089	60	70.0	61.0	84.0	107.85	60	74.0	76.0	72.0	8.08	115.93	4.17
0090	70	70.0	61.0	84.0	109.34	60	79.0	82.0	78.0	16.79	126.12	5.38
0092	60	70.0	60.0	84.0	23.30	60	82.0	85.0	86.0	37.57	60.88	5.71
0094	60	74.0	61.0	84.0	13.77	60	91.0	89.0	89.0	16.21	29.98	2.57
0096	70	72.0	60.0	84.0	18.40	60	79.0	85.0	81.0	0.0	18.40	0.53
0098	65	82.0	60.0	85.0	1.11	60	78.0	93.0	86.0	0.74	1.85	0.13
0099	60	71.0	60.0	84.0	0.29	60	78.0	90.0	84.0	2.29	2.58	0.32
0100	60	80.0	60.0	84.0	11.12	60	75.0	81.0	82.0	5.05	16.17	1.00
R100	55	72.0	59.0	84.0	10.34	60	76.0	81.0	82.0	7.05	17.39	1.24
0101	60	73.0	60.0	84.0	12.92	60	80.0	89.0	87.0	11.05	23.97	1.85
0103	55	73.0	61.0	84.0	14.15	60	80.0	86.0	85.0	17.17	31.32	2.71
0104	60	77.0	60.0	84.0	19.26	60	80.0	99.0	93.0	8.94	28.19	1.75

*Test not used in data analysis.

MSAPC Evaporative Enclosure (SHED) Test Results

AESI Los Angeles FY71 Train 61

	DIURNAL TEST					HOT SOAK TEST						
Test No.	Test Time (min.)	Encls. Temp., °F	Initial Tank Temp., °F	Final Tank Temp., °F	HC Loss, Grams	Test Time (min.)	Encls. Temp., °F	Initial Tank Temp., °F	Final Tank Temp., °F	HC Loss, Grams	Total Loss, Grams	Grams Per Mile
0105	60	77.0	61.0	84.0	18.35	65	82.0	93.0	90.0	8.34	26.69	1.64
0106	55	71.0	60.0	84.0	13.21	60	74.0	80.0	79.0	12.36	25.57	2.04
0107	65	72.0	60.0	84.0	23.85	60	81.0	90.0	87.0	20.53	44.38	3.44
0109	50	64.0	60.0	84.0	21.69	60	80.0	82.0	83.0	3.94	25.63	1.15
0110	55	75.0	60.0	84.0	12.06	60	75.0	83.0	83.0	11.23	23.29	1.85
R110	55	75.0	60.0	84.0	12.06	60	75.0	83.0	83.0	11.23	23.29	1.85
0111	60	79.0	60.0	84.0	16.09	60	86.0	90.0	90.0	0.0	16.09	0.46
0112	60	74.0	60.0	84.0	13.92	60	80.0	89.0	86.0	11.55	25.47	1.95
0113	50	72.0	60.0	84.0	16.08	60	76.0	84.0	81.0	11.77	27.85	2.04
0114	55	70.0	61.0	84.0	12.16	60	75.0	85.0	83.0	7.35	19.51	1.33
0115	55	75.0	61.0	84.0	12.60	60	80.0	86.0	86.0	14.97	27.58	2.37
0116	60	75.0	60.0	84.0	39.92	60	80.0	89.0	85.0	0.0	39.92	1.14
0117	55	80.0	60.0	84.0	11.02	60	82.0	86.0	85.0	22.02	33.04	3.27
0118	50	77.0	61.0	84.0	1.25	60	80.0	90.0	88.0	6.21	7.46	0.87
0123	60	79.0	60.0	84.0	17.03	60	75.0	89.0	85.0	8.07	25.09	1.57
0125	65	84.0	60.0	84.0	13.48	60	84.0	96.0	94.0	8.82	22.30	1.57
0126	70	84.0	60.0	86.0	17.66	60	78.0	85.0	84.0	3.86	21.53	1.02
0128	60	77.0	61.0	76.0	12.69	60	78.0	90.0	86.0	3.85	16.54	0.88
0129	60	79.0	59.0	84.0	16.55	60	83.0	86.0	88.0	11.08	27.63	1.96
0130	60	75.0	59.0	84.0	24.42	60	84.0	89.0	93.0	16.34	40.76	2.89

*Test not used in data analysis.

MSAPC Evaporative Enclosure (SHED) Test Results

AESI Los Angeles FY71 Train 61

	DIURNAL TEST					HOT SOAK TEST						
Test No.	Test Time (min.)	Encls. Temp., °F	Initial Tank Temp., °F	Final Tank Temp., °F	HC Loss, Grams	Test Time (min.)	Encls. Temp., °F	Initial Tank Temp., °F	Final Tank Temp., °F	HC Loss, Grams	Total Loss, Grams	Grams Per Mile
0131	50	80.0	60.0	84.0	25.81	60	80.0	91.0	91.0	10.61	36.42	2.16
0132	60	76.0	61.0	83.0	25.51	60	84.0	84.0	85.0	8.07	33.58	1.81
0133	55	81.0	60.0	84.0	5.86	60	85.0	87.0	90.0	7.50	13.36	1.17
R133	55	80.0	60.0	84.0	7.22	60	79.0	90.0	88.0	5.02	12.24	0.88
0134	60	76.0	61.0	84.0	11.25	60	80.0	86.0	85.0	10.89	22.14	1.78
R134	55	78.0	60.0	84.0	10.86	60	80.0	90.0	87.0	13.33	24.19	2.10
0135	50	81.0	60.0	84.0	10.49	60	83.0	90.0	89.0	17.78	28.26	2.69
0136	55	72.0	60.0	84.0	14.26	60	72.0	84.0	87.0	7.50	21.76	1.41
0138	65	73.0	60.0	84.0	9.68	60	72.0	84.0	82.0	10.74	20.42	1.72
0139	55	80.0	60.0	84.0	11.42	60	80.0	86.0	86.0	16.33	27.75	2.52
0140	55	68.0	59.0	84.0	14.49	60	70.0	80.0	79.0	3.42	17.91	0.87
0142	55	80.0	60.0	84.0	11.67	60	76.0	88.0	86.0	6.61	18.28	1.22
0143	55	69.0	59.0	84.0	12.39	60	70.0	87.0	87.0	9.98	22.37	1.69
0144	55	73.0	59.0	84.0	21.75	60	84.0	102.0	98.0	16.60	38.35	2.85
0147	60	75.0	60.0	84.0	17.81	60	75.0	87.0	88.0	10.52	28.34	1.92
0148	55	69.0	60.0	84.0	19.31	60	71.0	85.0	81.0	8.71	28.02	1.72
0149	50	69.0	61.0	84.0	3.75	60	76.0	65.0	73.0	3.06	6.82	0.52
0150	55	74.0	59.0	84.0	16.81	60	73.0	84.0	82.0	4.87	21.68	1.13
0151	50	68.0	59.0	83.0	16.70	60	72.0	89.0	90.0	15.58	32.28	2.57
0152	60	71.0	61.0	85.0	8.55	60	72.0	80.0	81.0	8.39	16.94	1.37

*Test not used in data analysis.

MSAPC Evaporative Enclosure (SHED) Test Results

AESI-Los Angeles FY71 Train 61

Test No.	DIURNAL TEST: Test Time (min.)	Encls. Temp., °F	Initial Tank Temp., °F	Final Tank Temp., °F	HC Loss, Grams	HOT SOAK TEST: Test Time (min.)	Encls. Temp., °F	Initial Tank Temp., °F	Final Tank Temp., °F	HC Loss, Grams	Total Loss, Grams	Grams Per Mile
R152	55	74.0	60.0	84.0	8.16	60	74.0	83.0	82.0	9.87	18.03	1.56
0154	60	70.0	60.0	84.0	9.34	60	84.0	88.0	90.0	8.19	17.53	1.37
0156	60	72.0	60.0	84.0	1.34	60	84.0	86.0	87.0	6.52	7.86	0.91
0158	50	73.0	59.0	84.0	26.16	60	80.0	88.0	86.0	16.93	43.09	3.02
0159	60	80.0	61.0	84.0	24.25	60	80.0	88.0	87.0	16.06	40.31	2.85
0161	65	74.0	60.0	84.0	11.83	60	76.0	90.0	91.0	24.44	36.26	3.62
0163	55	75.0	59.0	84.0	20.83	60	89.0	94.0	93.0	16.91	37.74	2.87
0164	55	78.0	60.0	84.0	18.74	60	87.0	91.0	95.0	16.66	35.40	2.77
0166	55	79.0	60.0	84.0	10.34	60	78.0	86.0	86.0	18.49	28.83	2.78
0167	50	84.0	60.0	84.0	18.24	60	82.0	100.0	98.0	11.13	29.36	2.02
0168	50	74.0	60.0	84.0	1.29	60	82.0	90.0	92.0	2.83	4.12	0.42
0170	55	74.0	61.0	84.0	19.06	60	82.0	97.0	94.0	7.06	26.12	1.49
0171	60	72.0	60.0	84.0	15.48	60	80.0	88.0	87.0	13.29	28.77	2.23
0174	50	76.0	60.0	84.0	17.44	60	81.0	86.0	85.0	6.61	24.05	1.39
0182	65	75.0	60.0	84.0	2.40	60	84.0	95.0	98.0	7.85	10.25	1.12

*Test not used in data analysis.

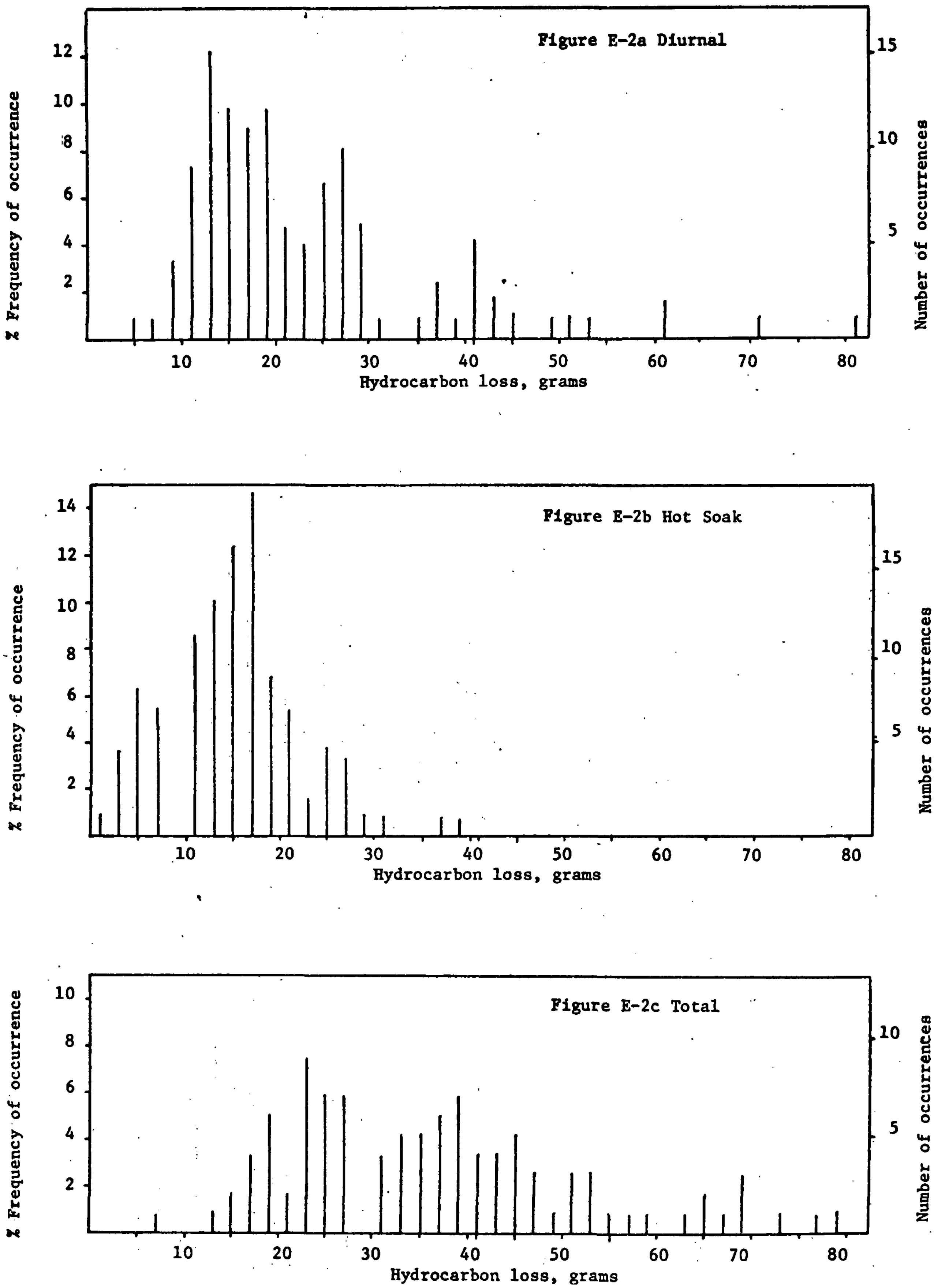


Figure E-2 Histograms of Diurnal, Hot Soak, and Total loss data for L.A. FY71 program.

MSAPC Evaporative Enclosure (SHED) Test Results

AESI Los Angeles FY72 Train 62

	DIURNAL TEST					HOT SOAK TEST						
Test No.	Test Time (min.)	Encls. Temp., °F	Initial Tank Temp., °F	Final Tank Temp., °F	HC Loss, Grams	Test Time (min.)	Encls. Temp., °F	Initial Tank Temp., °F	Final Tank Temp., °F	HC Loss, Grams	Total Loss, Grams	Grams Per Mile
0009	60	78.0	61.0	84.0	3.16	60	90.0	95.0	102.0	6.83	9.99	1.01
0012	60	78.0	61.0	84.0	3.34	60	79.0	90.0	86.0	5.31	8.65	0.81
0016	60	80.0	59.0	85.0	12.26	60	84.0	95.0	94.0	6.97	19.23	1.29
0026	60	81.0	59.0	84.0	21.50	60	86.0	87.0	87.0	14.92	36.42	2.62
0028	60	80.0	59.0	84.0	20.41	60	88.0	94.0	94.0	19.86	40.26	3.25
0112	60	74.0	60.0	83.0	16.56	60	86.3	91.0	94.1	7.26	23.82	1.45
0133	60	77.0	59.0	84.0	4.80	60	83.0	99.0	95.0	0.0	4.80	0.14
0140	60	73.0	60.0	84.0	14.03	60	87.0	99.0	100.0	15.14	29.17	2.43
0143	60	77.0	61.0	84.0	4.68	60	84.0	90.0	88.0	8.32	13.01	1.25
0146	60	74.0	61.0	84.0	6.83	60	85.0	96.0	97.0	7.40	14.23	1.19
0153	60	80.0	60.0	84.0	9.56	60	90.0	80.0	94.0	15.45	25.01	2.35
0156	60	77.0	60.0	84.0	11.59	60	88.0	92.0	93.0	16.53	28.11	2.55
0158	60	83.0	60.0	83.0	4.12	60	89.0	98.0	99.0	7.48	11.60	1.12
0163	60	73.0	60.0	84.0	16.70	60	88.0	96.0	99.0	13.14	29.84	2.24
0164	60	75.0	59.0	83.0	10.66	60	77.0	80.0	80.0	2.61	13.26	0.65
0169	60	80.0	60.0	84.1	36.54	60	90.0	103.0	103.0	21.54	58.09	3.94
0170	60	73.0	61.0	83.0	4.46	60	82.0	97.0	93.0	6.70	11.16	1.03
0172	60	75.0	61.0	84.0	6.29	60	84.0	93.0	92.0	5.50	11.79	0.92
0178	60	78.0	61.0	84.0	4.11	60	90.0	104.0	102.0	2.77	6.88	0.49
0179	60	77.0	59.0	83.5	7.02	60	88.0	95.0	96.0	0.0	7.02	0.20

*Test not used in data analysis.

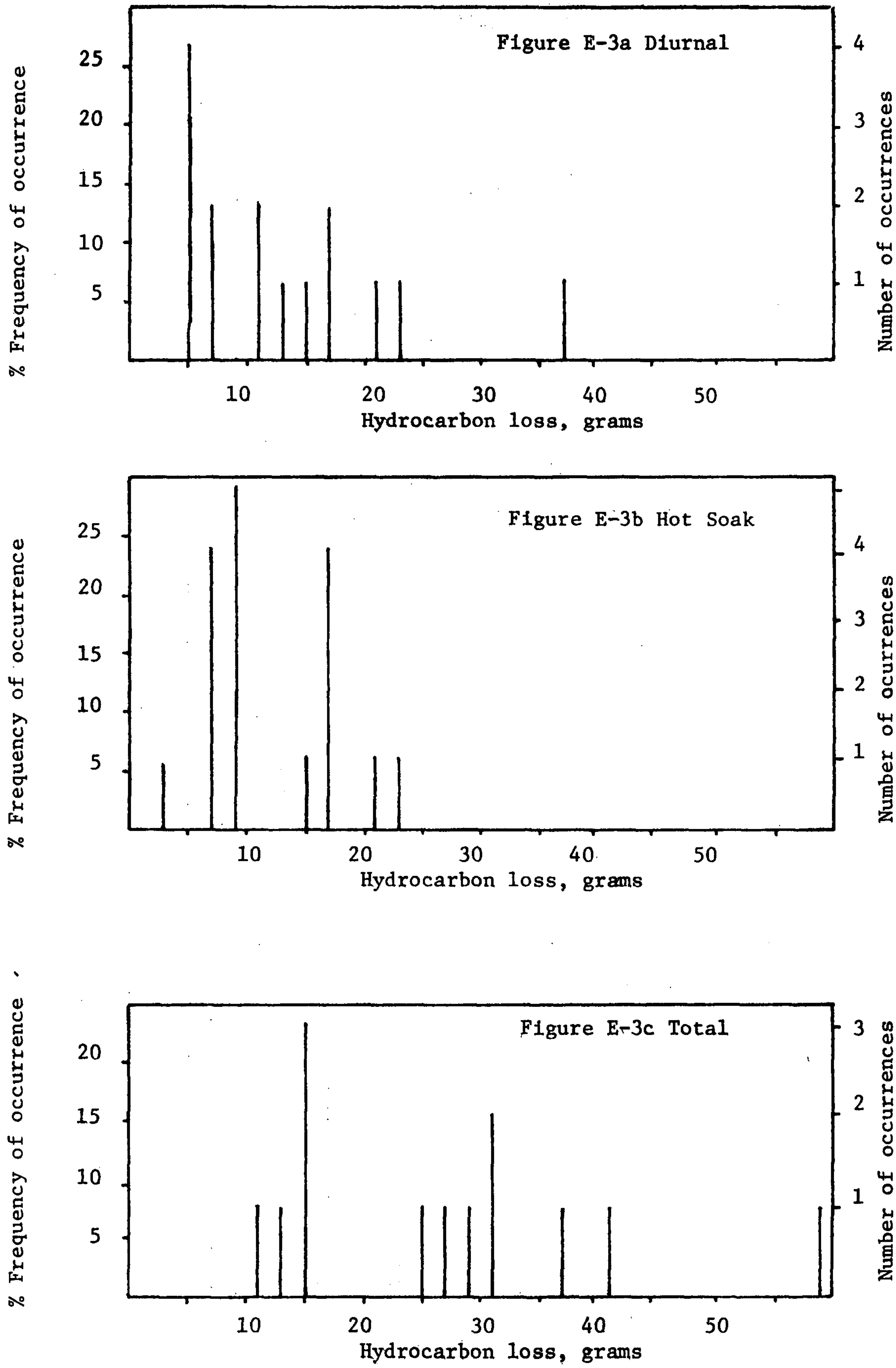


Figure E-3 Histograms of Diurnal, Hot Soak, and Total loss data for LA FY72 program

MSAPC Evaporative Enclosure (SHED) Test Results

AESI Los Angeles FY73 Train 63

	DIURNAL TEST					HOT SOAK TEST						
Test No.	Test Time (min.)	Encls. Temp., °F	Initial Tank Temp., °F	Final Tank Temp., °F	HC Loss, Grams	Test Time (min.)	Encls. Temp., °F	Initial Tank Temp., °F	Final Tank Temp., °F	HC Loss, Grams	Total Loss, Grams	Grams Per Mile
0011	60	82.0	60.0	83.0	4.86	60	84.0	96.0	95.0	12.48	17.34	1.81
0012	60	82.0	59.5	84.0	5.11	60	89.0	100.0	100.0	11.77	16.88	1.73
0013	60	76.0	60.0	83.0	25.14	60	83.0	96.0	97.0	16.92	42.06	2.99
0014	60	78.5	60.0	84.0	26.71	60	86.0	100.0	100.0	27.58	54.29	4.47
0016	60	80.0	59.0	84.0	9.80	60	81.0	100.0	95.0	7.72	17.52	1.32
0017	60	80.0	59.0	84.0	2.76	60	86.5	87.0	89.0	12.39	15.14	1.74
0021	60	78.0	60.5	83.0	23.94	60	77.0	103.0	100.0	10.11	34.05	2.04
0023	60	78.0	60.0	83.5	9.84	60	83.0	97.0	98.0	10.29	20.13	1.66
0024	60	84.0	60.0	84.0	65.73	60	85.0	86.0	85.0	16.66	82.39	4.11
0026	60	77.5	60.0	84.7	10.70	60	81.0	91.0	92.0	3.26	13.96	0.74
0028	60	84.0	60.0	84.0	5.60	60	85.0	97.0	97.5	8.40	14.00	1.29
0031	60	79.0	60.0	85.0	9.04	60	85.0	95.0	99.0	26.57	35.61	3.83
0032	60	83.5	60.0	84.0	8.73	60	84.5	95.0	97.0	18.93	27.66	2.79
0033	60	82.0	61.0	84.0	12.75	60	86.0	94.0	98.0	0.0	12.75	0.36
0034	60	84.0	60.0	82.0	6.17	60	83.0	92.0	95.0	21.22	27.38	3.03
0036	60	78.0	59.0	84.0	12.85	60	83.0	87.0	89.0	19.73	32.58	3.02
0037	60	78.0	60.0	84.0	21.77	60	85.0	98.0	96.0	15.49	37.26	2.70
0039	60	82.0	60.0	82.0	10.07	60	85.5	96.0	95.0	2.14	12.21	0.58
0043	60	81.0	60.0	84.9	10.30	60	84.0	96.0	98.0	12.22	22.52	1.94
0044	60	74.0	60.0	84.0	5.67	60	80.0	88.0	87.0	0.0	5.67	0.16

*Test not used in data analysis.

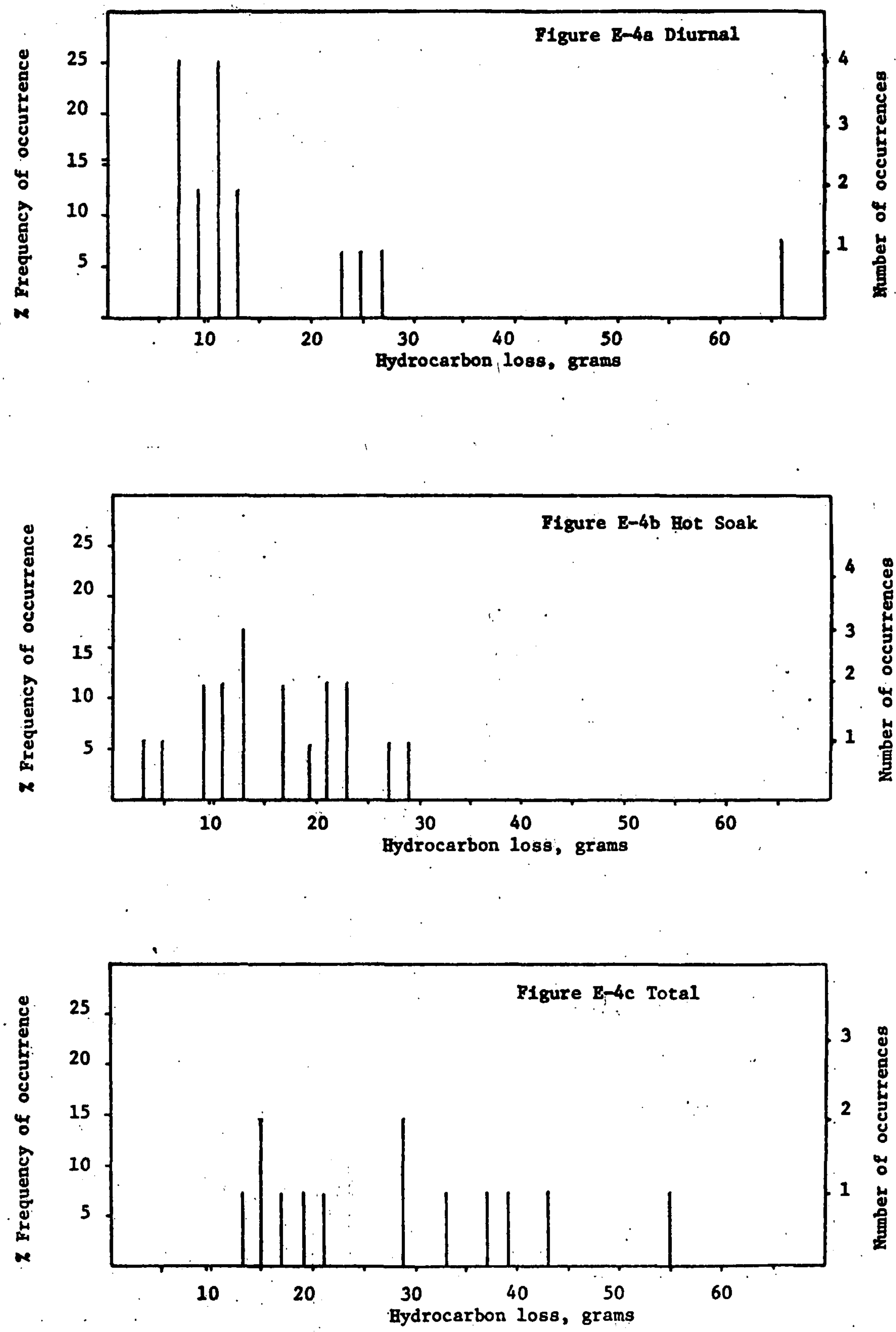


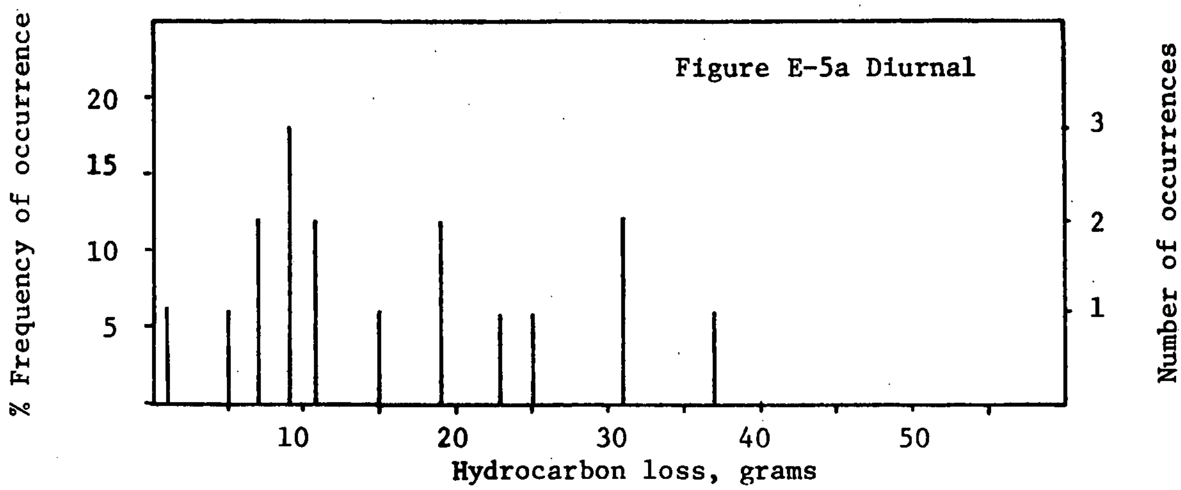
Figure E-4 Histograms of Diurnal, Hot Soak and Total loss data for L.A. FY73 program.

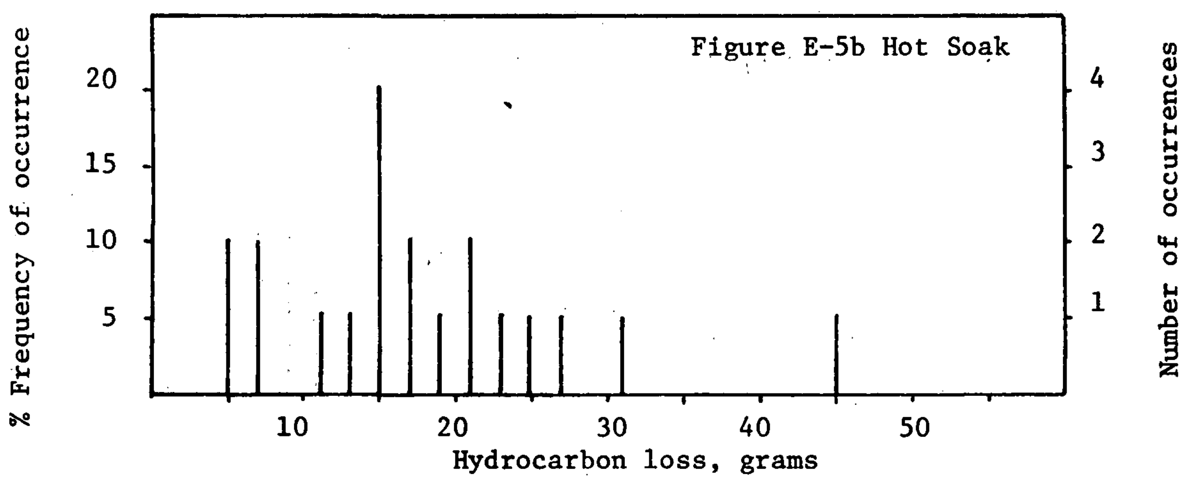
MSAPC Evaporative Enclosure (SHED) Test Results

ATL Denver FY73 Train 65

Test No.	DIURNAL TEST: Test Time (min.)	DIURNAL TEST: Encls. Temp., °F	DIURNAL TEST: Initial Tank Temp., °F	DIURNAL TEST: Final Tank Temp., °F	DIURNAL TEST: HC Loss, Grams	HOT SOAK TEST: Test Time (min.)	HOT SOAK TEST: Encls. Temp., °F	HOT SOAK TEST: Initial Tank Temp., °F	HOT SOAK TEST: Final Tank Temp., °F	HOT SOAK TEST: HC Loss, Grams	Total Loss, Grams	Grams Per Mile
0011	60	79.0	60.0	84.0	14.14	60	82.0	94.0	94.0	15.54	29.68	2.49
0016	60	84.0	60.0	84.0	0.71	60	82.0	101.0	100.0	10.61	11.32	1.45
0017	60	81.5	60.0	83.0	4.76	60	87.0	102.0	99.0	15.23	19.99	2.18
0020	60	87.0	60.0	84.0	7.23	60	83.0	98.0	95.0	5.31	12.54	0.92
0021	60	79.0	59.0	83.0	21.60	60	84.0	94.0	97.0	14.53	36.12	2.57
0023	60	74.0	59.0	84.0	35.62	60	84.0	101.0	103.0	20.26	55.89	3.74
0026	60	73.0	60.0	86.0	10.76	60	78.0	86.0	86.0	3.70	14.45	0.80
0028	60	78.0	60.0	84.0	7.64	60	80.0	88.0	91.0	12.29	19.93	1.87
0031	60	77.0	60.0	84.0	6.14	60	85.0	94.0	96.0	13.36	19.49	1.97
0032	60	85.0	61.0	83.0	12.63*	60	89.0	101.0	104.5	19.63	32.25	3.00
0033	60	83.0	60.0	84.0	9.20	60	86.0	97.0	99.0	23.56	32.77	3.43
0034	60	82.0	60.0	84.0	7.05	60	83.0	92.0	93.0	17.35	24.40	2.53
0035	60	79.0	60.0	85.0	8.75	60	91.5	97.0	108.0	44.56	53.31	6.23
0036	60	80.0	59.0	85.0	30.46	60	88.0	101.0	101.0	21.55	52.01	3.76
0037	60	76.0	60.0	83.0	32.11	60	89.5	99.0	100.5	28.80	60.91	4.78
0038	60	78.0	59.0	83.0	18.96	60	84.0	108.0	109.0	25.24	44.20	3.93
0039	60	80.0	61.0	84.0	8.36	60	80.0	90.0	92.0	5.19	13.55	0.94
0040	60	83.0	60.0	85.0	29.88	60	86.0	95.0	97.0	13.56	43.44	2.67
0042	60	85.0	60.0	86.0	23.98	60	82.0	94.0	97.0	12.95	36.93	2.42
0044	60	85.0	59.0	85.0	19.11	60	79.0	83.0	80.0	4.89	24.00	1.20

*Test not used in data analysis.





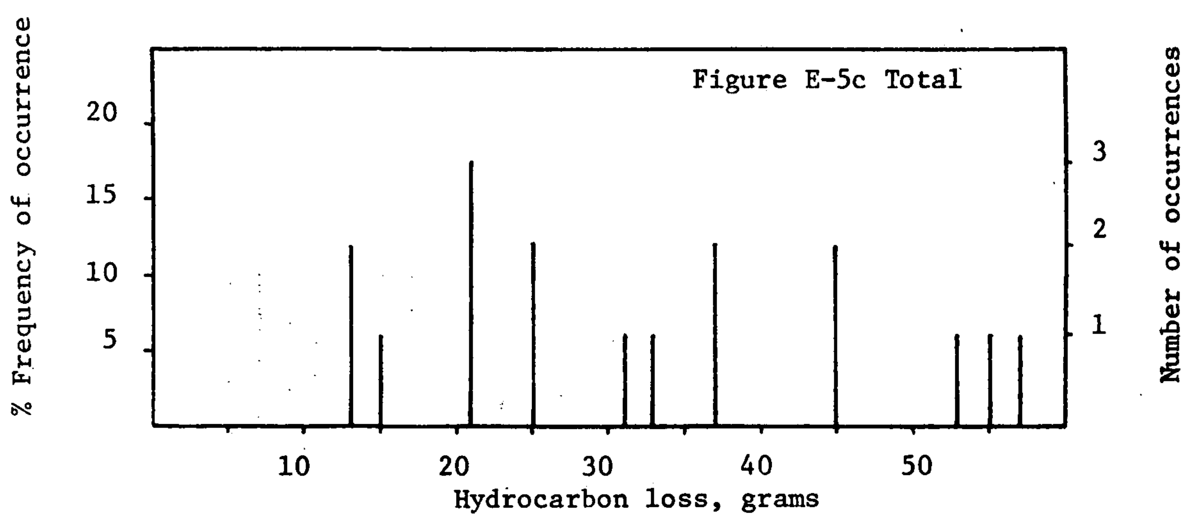
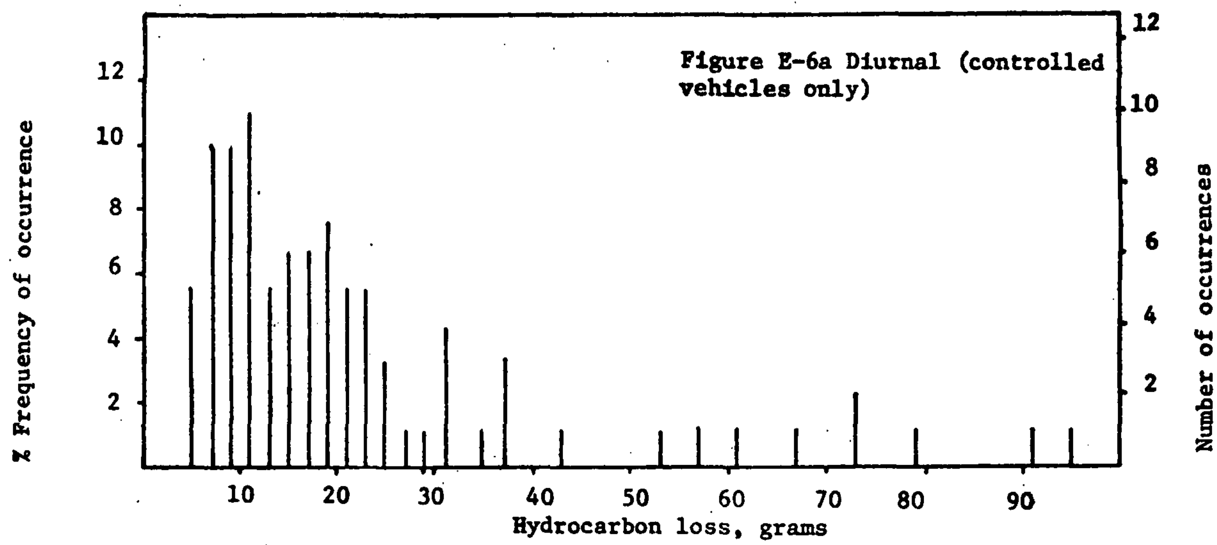
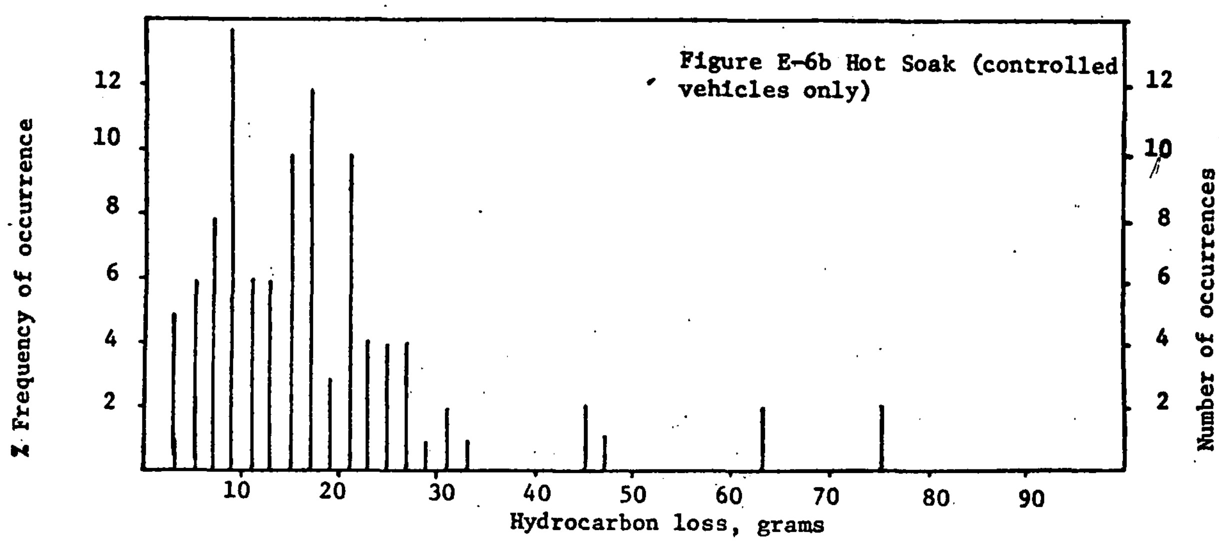


Figure E-5 Histograms of Diurnal, Hot Soak, and Total loss data for Denver FY 73 program.





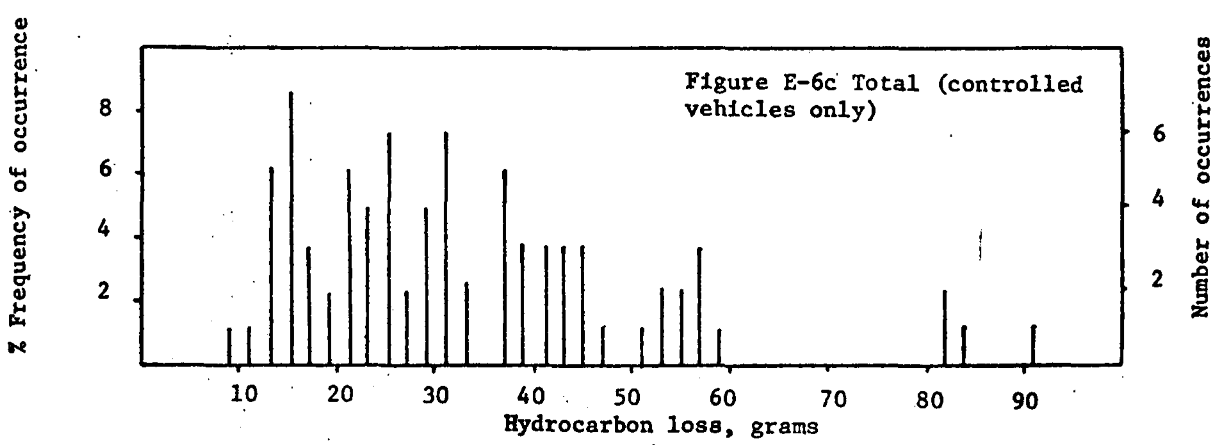


Figure E-6 Histograms of Diurnal, Hot Soak and Total loss data for all test programs (controlled vehicles only).