Technical Support Report for Regulatory Action

A Study of Methods for Reducing Evaporative Background Hydrocarbon Emissions from New Vehicles

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Notice

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1. Introduction

Evaporative hydrocarbon emissions from gasoline fueled vehicles come from two major sources: 1) fuel evaporation; and 2) background emissions which are given off from hydrocarbon sources such as paints, solvents, plastics, vinyl, etc. Background emissions are high from brand new vehicles (1-10 days old) but decay rapidly to some stabilized level (.5 g or less). Mobile Source transient background emissions (background emissions above the stabilized emission level) probably do not have a significant impact on air quality since they last for a relatively short time (3 to 6 months as opposed to 10 years for fuel and stabilized background evaporative emissions).

A problem arises when evaporative emissions testing is done on new vehicles which still have high transient background emission levels. The proposed method of evaporative emission measurement is the evaporative enclosure method. This test involves putting the test vehicle in a sealed enclosure and measuring the change in hydrocarbon levels within the enclosure over a period of one hour. A test such as this cannot distinguish between fuel evaporative emissions and background emissions. A similar test can be used to measure background emissions only, by removing the fuel system during the test, but again such a test cannot distinguish between transient and stabilized background emissions.

In order to solve the problem of finding a test which will only measure fuel and stabilized background evaporative emissions, testing of very new (2-5 weeks old) vehicles was conducted. The purpose of this study was two fold: 1) determine if the magnitude of transient background levels could be accurately predicted at some point in time by performing total evaporative emission tests; and 2) determine if transient background levels could be artificially lowered to the point of insignificance by elevated temperatures (baking) and/or driving.

2. Summary and Conclusions

It was the objective of this study to determine if transient evaporative background emissions can be predicted by mathematically generating a curve using total evaporative emission data. Also, the feasibility of lowering background emission levels by baking and driving test vehicles was studied.

Tests were conducted on four test vehicles for which total emissions were measured intermittently over a 3-week period. Between emission measurements certain vehicles were baked and/or driven on a dynamometer to attempt to reduce their background emissions. At the end of this testing at least two repeat background emissions tests were conducted on each vehicle.

The results of the curve fitting of total evaporative emission measurements indicated that background emission levels could not be accurately predicted using such a technique.

The results of the background tests on three identical vehicles indicated that baking and driving did result in lower background emission levels than for the control vehicles. The background levels of all tests cars were below .5 grams 40 days after they were built. It is recommended that vehicles tested for evaporative emissions be required to have low background levels as it appears this is feasible and much more reliable than any acceptable prediction techniques now available.

3. Technical Discussion

Recent information resulting from comments to the proposed Evaporative Emission Regulations for light duty vehicles and light duty trucks have increased the understanding of background emission decay. A study done by Ford Motor Company[1] using a fleet of 10 cars showed that background decay follows the following equation form

$$B = aT^b$$

where: B = background emission level
T = Time
a & b = constants.

If the constants a and b are known, then the background level at any time can be calculated. This calculated value (minus the level considered to represent stabilized emission levels) could then be used to adjust the emission levels measured during an evaporative emission test. Thus, a means of determining the constants a and b is needed.

The equation form for background emissions can be transformed (by a logarithmic transformation) to a linear equation form, as shown:

$$\log B = b \log T + \log a$$

Using this equation form, one can determine the coefficients a and b by using a least squares curve fitting technique. Data can be generated by making background emission measurements at several times. (Preferably the tests should be separated by at least 10 days). Background measurements can be made using the SAE J171a (Appendix C)[2] procedure. This procedure calls for total removal of the fuel system. The vehicle then undergoes a cold soak in the SHED. The vehicle is then driven over an Urban Dynamometer Driving Cycle (UDDS), followed by a hot soak in the SHED. The carburetor must be put on prior to the drive portion of the test and then quickly removed prior to the hot soak.

This procedure generating the constants a and b of the background equation could be done prior to testing a vehicle for evaporative emissions. However, this procedure has two major problems: 1) the integrity of the fuel system may be destroyed in the process of making background measurements, such that the resulting evaporative emission measurements would be affected; and 2) the background measurement technique is complex and time consuming.

An easier method of predicting background emissions would be to measure total evaporative emissions (including background), and then somehow separate out the background contribution mathematically. The following equation could be used to describe total (fuel and background) evaporative emissions:

$$E = aT^b + F$$

where E = Total evaporative emissions (Fuel and background)
T = Time
F = Fuel evaporative emissions
a & b = constants

This equation assumes that fuel evaporative emissions are constant as a function of time. This is a reasonable assumption from the standpoint that a new fuel system would not deteriorate over the relatively short time period such measurements could be made. However, the variability, $S/\bar{X}$, of fuel evaporative emissions is roughly 10%. Thus, a large number of test points would be required to generate values of a and b with an acceptable level of confidence. Also, the equation form for total evaporative emissions cannot be transformed into a linear form such that a least squares curve fit technique could be used.

Data could be fit to the equation for total evaporative emissions by non-linear methods. There are several methods which could be employed to accomplish this. One way would be to select a value for b, solve for the coefficients a and F using a least squares method and calculate the regression coefficient and standard error. Several values of b could be selected and the one resulting in the best regression coefficient and standard error would be used.

The question that must be answered is how accurate are the background values predicted by an equation arrived at in the way described. The accuracy would depend on the number of observations made, the closeness of the observations (the more time separation the better the accuracy), and the accuracy of each individual measurement. There are, however, practical limits on the number and closeness of test points due to the cost and manpower of conducting tests and the need to determine during a 6 month period, whether or not a given car can meet certification requirements. The question of accuracy will be looked at in this report by subjecting total evaporative emission data to a curve fitting technique.

Another way of pursuing the problem of transient background emissions would be to try and eliminate them. Transient background emissions are known to decay with time. If the decay can be accelerated, or if some or all background sources can be eliminated, then the prediction techniques discussed would not be needed. Background emissions are believed to result from paints, solvents, plastics, etc. An earlier study by Ford Motor Company[3] indicated that subjecting a vehicle to elevated temperatures, and driving a vehicle resulted in lower background emissions than would have normally been expected. This report will analyze the results of a similar study.

3.1 Program Objective

It is the objective of this study to determine if transient evaporative background emissions levels can be predicted by generating total fuel emission data and then curve fitting those data. Another objective of this study is to determine whether or not background levels can be artificially lowered by exposing the vehicle to elevated temperatures and/or by accumulating mileage.

3.2 Program Design

The test program involved the repeat testing of 4 brand new test vehicles over a 2-3 week period. Total evaporative emissions were measured on the four test vehicles five times. These data were then used to determine the accuracy of curve fitting techniques used in predicting transient background levels.

Three of the test vehicles were identical (3 Chrysler Volare´s). These three vehicles were used to determine the relative effectiveness of baking and driving a vehicle in reducing background emission levels. One vehicle was used as a control. It was allowed to soak at a relatively constant temperature in the soak area. A second vehicle was repeatedly baked in a bake oven at roughly 160°F for 12 hours. The third vehicle was baked similarly to the second vehicle and was also driven over 6 Urban Dynamometer Driving Schedules (UDDS's) over a 6 hour period after each baking. Actual background emission measurements were made on all vehicles at the end of the test program to determine the relative magnitude of the background levels.

A fourth vehicle (Chevrolet Nova) was baked and driven similarly to the one Volare´. Tests were conducted on this vehicle to get a further indication of how far background emissions could be lowered.

3.3 Facilities and Equipment

3.3.1 Facilities

All evaporative emission tests took place at the Motor Vehicle Emission Laboratory in Ann Arbor, Michigan. The Light Duty Vehicle evaporative enclosure was used during all evaporative emission tests. The enclosure is nominally 8 feet high x 10 feet wide x 20 feet long and has a measured volume of 1540 ft^3. Calculation of the enclosure volume with a propane injection and recovery test compared within ± 2% of the measured volume. Propane retention tests performed periodically indicated a leakage rate of less than 0.5% per hour.

Mileage accumulation and vehicle operation prior to the hot soak tests were done on Clayton DDVIF dynamometers.

Baking was done in a local paint shop oven. The oven used forced hot air and the oven temperature was kept between 155°F and 165°F. The windows and trunks of the vehicles were opened during baking. The fuel tank was vented to the outside of the oven by use of a specially fitted gas cap and a length of nylon tubing. This was done as a safety precaution and to prevent abnormally loading the evaporative control system.

3.3.2 Test Equipment

Evaporative emission enclosure hydrocarbon measurements were taken using a Flame Ionization Detector (FID). A continuous sample was taken.

3.3.3 Test Vehicles

Four 1976 MY vehicles were used during testing. The criteria for vehicle selection were: 1) the vehicles had to be less than 3 weeks old; and 2) the vehicles had to have low mileage (less than 250 miles). All vehicles were assembled during the week of April 11, 1976. The four vehicles were 3 Plymouth Volare's and a Chevrolet Nova. Table 3-1 gives specific information about these vehicles.

3.3.4 Test Fuel

Indolene type HO lead-free test fuel was used throughout the program. The RVP of the fuel was between 8.7 and 9.2 psi.

3.4 Test Procedures

The test procedures used during the total evaporative emission measurement portion of the test program are shown in Figure 3-1. Baseline tests were conducted and then the vehicles went through the remaining sequence four times. The bake portion of the test involved baking the vehicles for 12 hours (overnight) at approximately 160°F. The driving portion of the test consisted of driving a UDDS cycle once each hour for 6 hours. In this way the engine could be expected to stay hot for a period of several hours. The evaporative emission test consisted of a cold soak in the SHED for one hour, followed by a UDDS driving cycle; followed immediately (less than 5 minutes) by a one hour hot soak in the SHED.

Background emission tests were taken in a similar fashion as the total evaporative emissions tests except the fuel system components were either removed or plugged during the tests. The fuel tank, carburetor, and evaporative canister were removed from each of the vehicles. Fuel lines, lines connected to the canister, the opening to the intake manifold, dipstick hole, lines to and from the fuel pump, and the exhaust pipe

	Nova	White Volare´	Copper Volare´	Blue Volare´
Age at Baseline, days	18	20	21	18
Age at final test, days	38	42	43	39
Mileage at baseline	227 miles	30 miles	28 miles	28 miles
Mileage at final test	520 miles	105 miles	154 miles	320 miles
Type of testing	Baked and driven	Control (soaked only)	Baked	Baked and driven
Vinyl Top	NO	YES	YES	YES
Vinyl Seats	NO	YES	YES	YES
Undercoated	NO	NO	NO	NO

Table 3-1 Vehicle Information

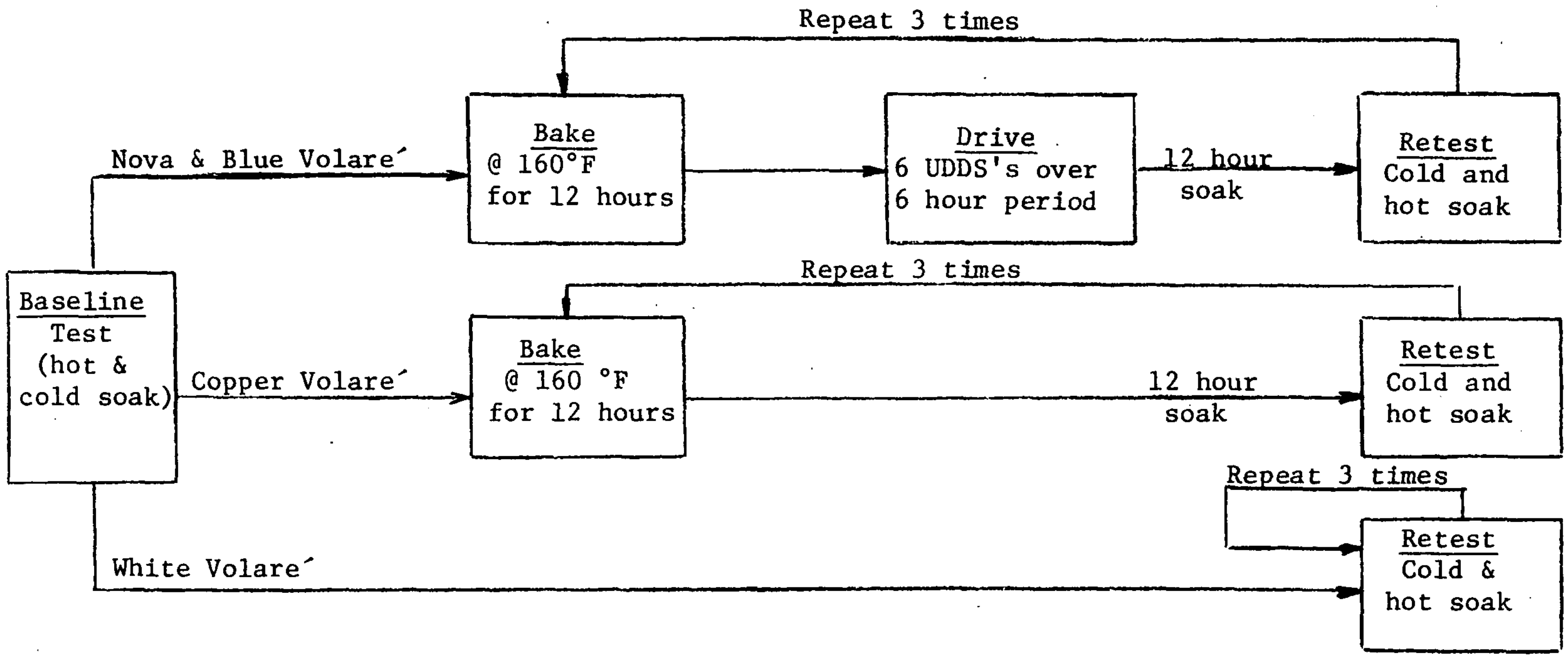

Figure 3-1 Test Procedure Flowchart for Evaluation of Total Evaporative Emissions.

were all sealed during these tests. The UDDS cycle was driven with the carburetor in place fueled with an auxillary fuel tank outside the vehicle. After vehicle operation, the carburetor was removed and the intake and exhaust pipe were sealed. This procedure was essentially the same as prescribed in Appendix C of the SAE J171a recommended test procedure[2].

4. Test Results

4.1 Total Evaporative Emission Tests

The emission test results for the four vehicles are given in Table 4-1, for cold soak, hot soak and total emissions. The hot and cold soak test results for the four vehicles are shown graphically in figures 4-1 and 4-2 respectively. Figure 4-3 shows the total emission results for each of the four vehicles as a function of time and also shows the best fit curve of the data in the equation form $E = aT^b + F$. The equations shown were derived by trying several values of b, solving for a and F, and then picking the set of coefficients which gave the best correlation coefficient.

Figure 4-3 shows that the curves generated fit the data reasonably well but the large scatter in data for certain vehicles resulted in equations which do not fit the physical situation. The equation for the Copper Volaré predicts a negative fuel emission term. The equations for the blue and white Volaré's predict negative background emissions for any time. The equation which describes the data for the Nova is the only one which fits the actual situation (fuel and background emissions are positive and the function is continuously decreasing). The predicted background emission line is also given in the figure for the Nova. It shows that a background emission level of 3.28 g and 3.18 g would be expected at 37 days and 38 days old, respectively. Actual background emission measurements were made at these times and showed actual levels of .41 g and .35 g.

4.2 Background Emission Tests

The results of the hot plus cold background evaporative emission tests are given in Table 4-2 for the four test vehicles. The results are also shown graphically in Figure 4-4. The most striking result of these tests is that the background levels are quite low for the age of the vehicles. Even the control Volaré (which was not baked or driven) had less than .4g total background after 40 days. Baking and driving the vehicles appeared to do some good in lowering background emissions as the blue Volaré (baked and driven) had lower background levels than the copper Volaré (baked only). The control vehicle had the highest final background emission levels which were almost double the levels of the blue Volaré. As stated earlier the Nova showed low background levels of .41 and .35 g at 37 and 38 days respectively.

Vehicle	Type of Test	Baseline		Retest #1		Retest #2		Retest #3		Retest #4	
		Age, days	HC loss, grams	Age, days	HC loss, grams	Age, days	HC loss, grams	Age, days	HC loss, grams	Age, days	HC loss, grams
Nova (baked and driven)	Cold	18	0.39	22	0.40	25	0.29	30	0.25	35	0.20
	Hot	18	9.62	22	9.72	25	8.17	30	7.87	35	7.36
	Total	18	10.01	22	10.12	25	8.46	30	8.12	35	7.56
White Volare´ (Control)	Cold	20	0.68	23	0.58	27	0.51	30	0.57	34	0.66
	Hot	20	4.62	23	4.58	27	3.15	30	3.07	34	2.09
	Total	20	5.30	23	5.16	27	3.66	30	3.64	34	2.75
Copper Volare´ (baked)	Cold	21	0.54	23	0.35	27	0.35	31	0.49	36	0.38
	Hot	21	5.23	23	7.61	27	3.38	31	1.14	36	3.57
	Total	21	5.77	23	7.96	27	3.73	31	1.63	36	3.95
Blue Volare´ (baked and driven)	Cold	18	0.50	21	0.32	25	0.22	28	0.31	33	0.29
	Hot	18	3.58	21	4.31	25	2.45	28	2.52		*
	Total	18	4.08	21	4.63	25	2.67	28	2.83		*

*Hot soak test voided due to loose carburetor fitting.

Table 4-1 Evaporative Emission Test Results

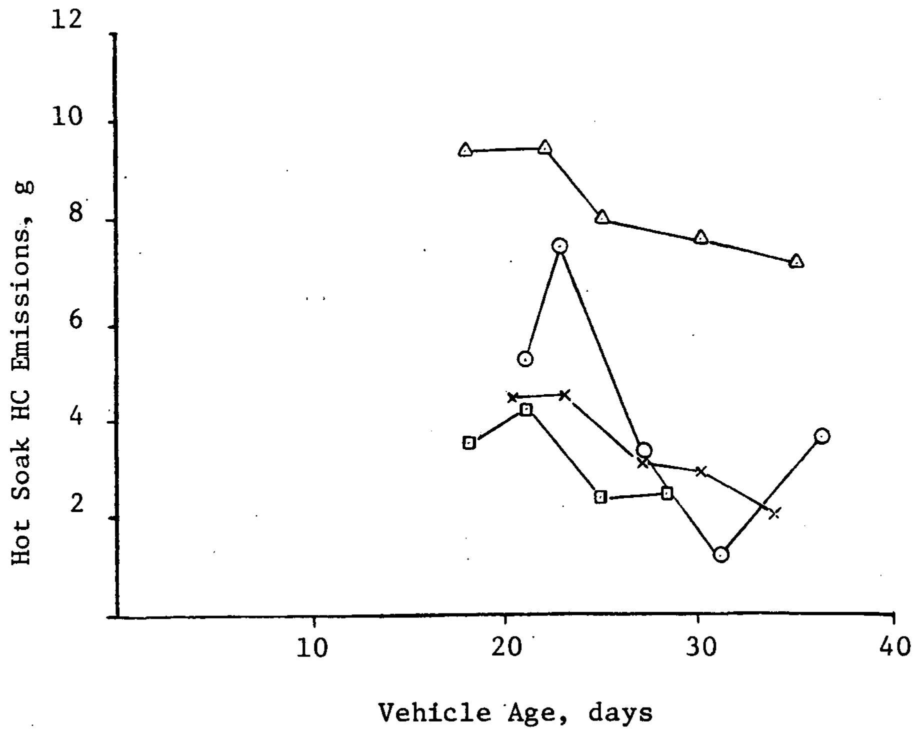

Figure 4-1 Hot soak emissions vs. time for 4 test vehicles.

LEGEND

- △—△ Nova (baked & driven)
- ×—× White Volare´ (control)
- ○—○ Copper Volare´(baked)
- □—□ Blue Volare´(baked & driven)

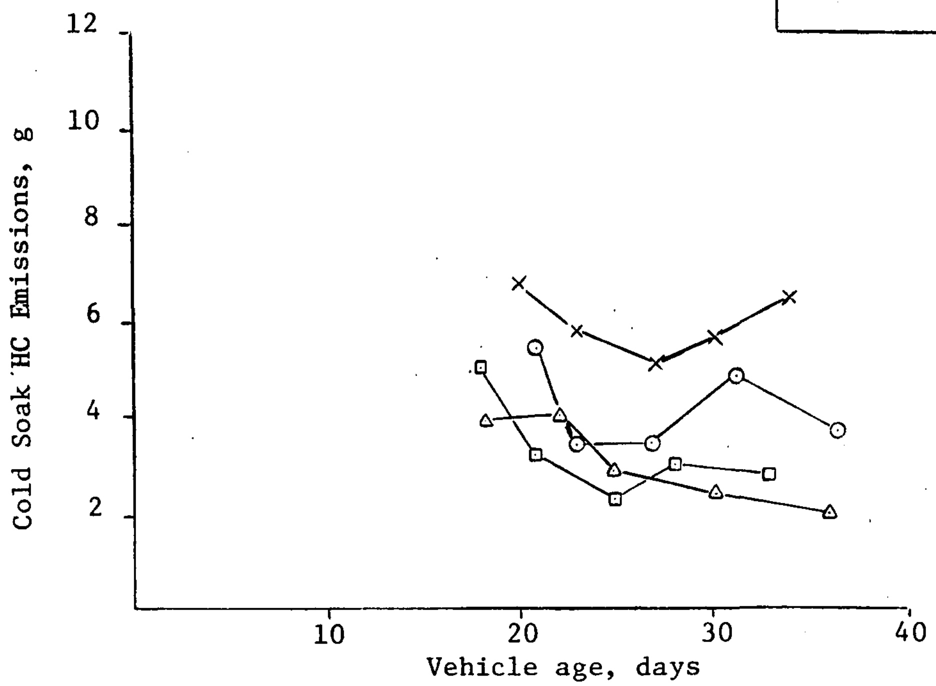

Figure 4-2 Cold Soak Emissions vs Time For 4 Test Vehicles

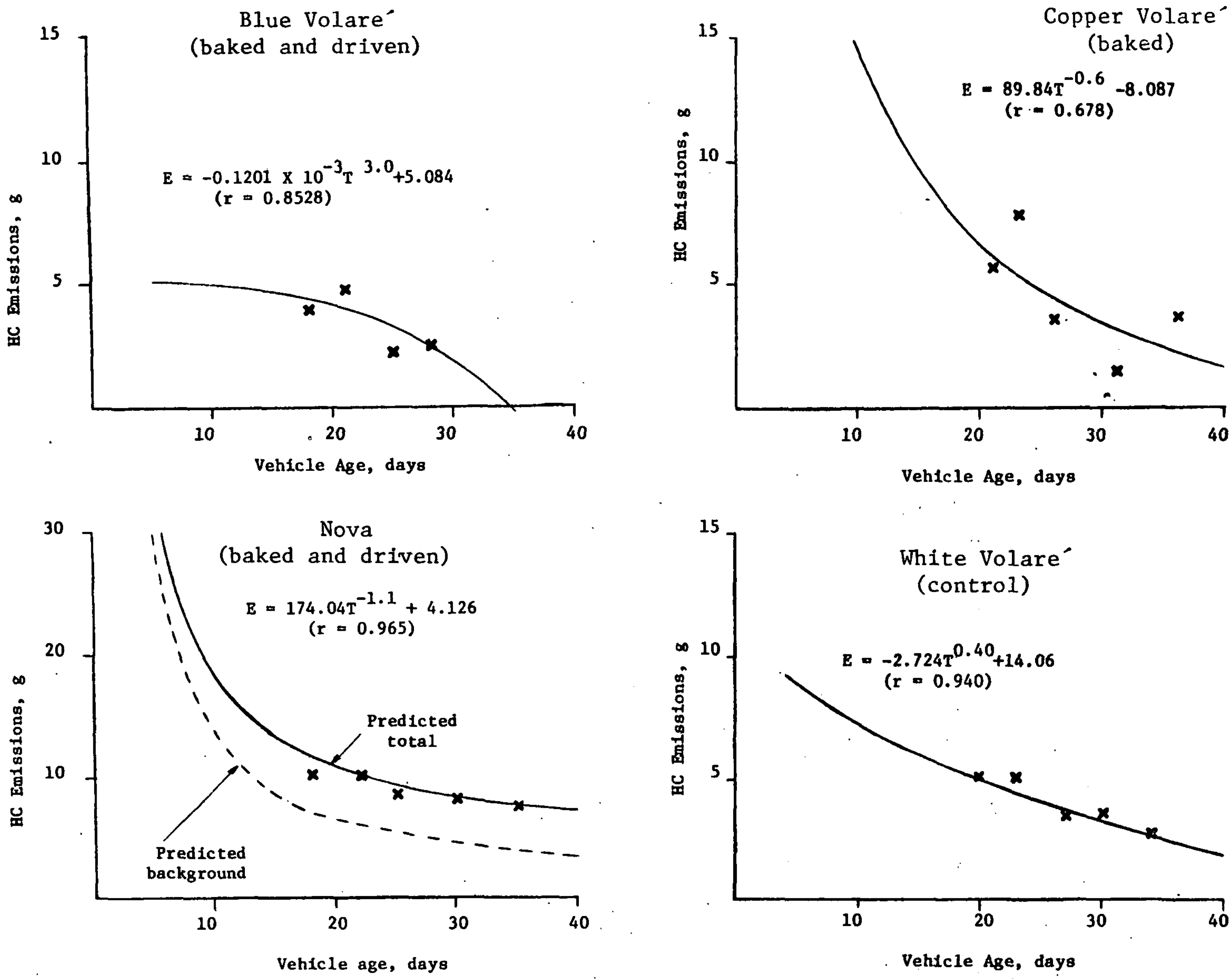

Figure 4-3 Evaporative HC Emissions vs. Age for 4 Test Vehicles

Vehicle	Test No.	Age, days	Background Emissions, grams		
			Cold Soak	Hot Soak	Total
Nova (Baked and driven)	1	37	0.132	0.275	0.407
	2	38	0.062	0.290	0.352
White Volare´ (Control)	1	41	0.126	0.272	0.398
	2	42	0.132	0.257	0.389
Copper Volare´ (baked)	1	38	0.115	0.506	0.621
	2	41	0.064	0.203	0.267
	3	42	0.074	0.217	0.291
	4	44	0.060	0.150	0.210
Blue Volare´ (baked and driven)	1	36	0.117	0.275	0.392
	2	39	0.042	0.178	0.220

Table 4-2 Background Emission Test Results

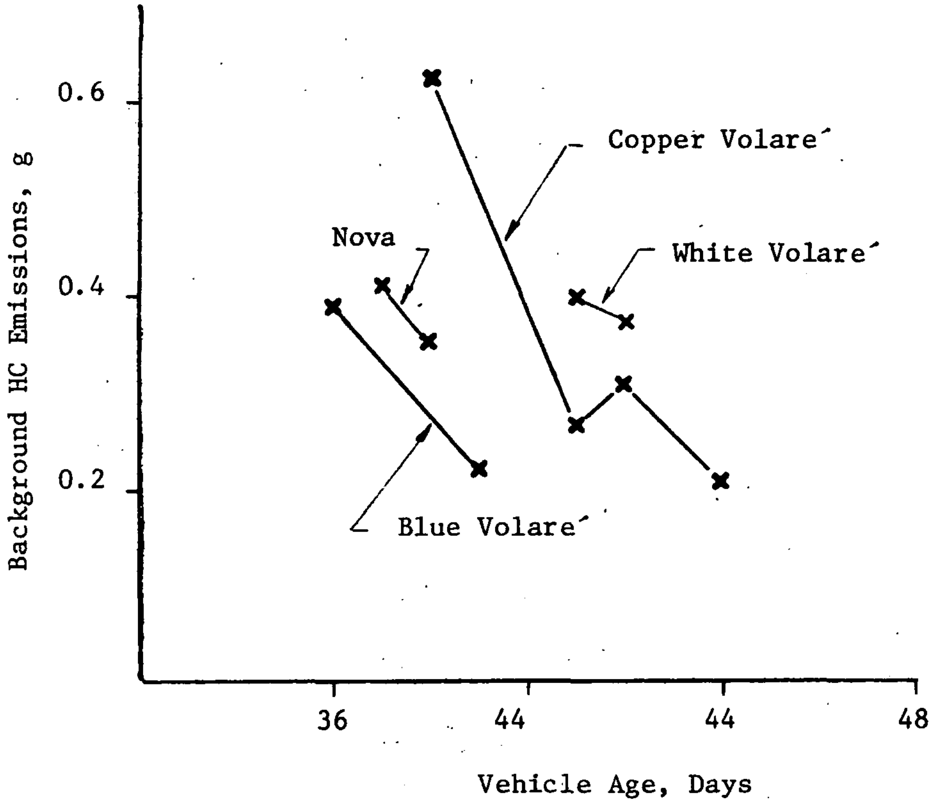

Figure 4-4 Background HC Emissions vs Age For 5 Test Vehicles

5. Discussion

Two possible ways of dealing with transient background emissions have been explored. The first method was to measure total vehicle emissions and use a mathematical curve fitting technique to generate predicted background emission levels at some future time. The test results generated indicated that this technique does not generate accurate predicted values. Of the four sets of test data, three resulted in equations which did not correspond to real world conditions, and the fourth predicted emission levels eight times higher than actual levels. This result was most likely due to the expected variability of fuel evaporative emissions. If future improvements in the test procedure can reduce test variability significantly, this method of accounting for transient background emissions could work. However, on the basis of these tests, it is recommended that other ways of handling background emissions be investigated.

The other way of handling background emissions was to attempt to artificially lower the background levels of new vehicles by baking and/or driving vehicles. The results of this study indicated that background levels were lowered when vehicles were driven and/or baked. More significantly, however, was the fact that a vehicle which was neither baked nor driven had low background levels (less than .4g) at 40 days old. The methods for lowering the background levels used are only a couple of many methods that can be used. Vehicles can be built without plastic or vinyl components, without paint, without sound deadening, etc. The use of several of these techniques together should produce vehicles with background levels much below expected stabilized background levels. It is recommended, therefore, that low background vehicles be required for testing rather than using some analytical test method for predicting background emission levels.

6. References

1. Ford Motor Company's Submission of Comments to the January 13, 1976 Notice of Proposed Rulemaking for Evaporative Emission Regulations, February 27, 1976.

2. "Measurement of Fuel Evaporative Emissions from Gasoline Powered Passenger Cars and Light Trucks using the Enclosure Technique," SAE Recommended Practice, SAEJ171a, SAE Handbook.

3. EPA Technical Memorandum, "Background Test Evaluation at Ford Motor Co.," Memo from Gary Wilson, EPA, to Charles Gray, EPA, April 9, 1976.