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Final Determination of Hot Running Emissions from FTP Bag Emissions

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Introduction

This document describes our efforts to develop a simple model for estimating hot running 505 (HR505) emissions from FTP data. The HR505 is an extra exhaust emissions "bag" performed immediately following the third "bag" of the standard FTP. This new "bag" is a duplicate in terms of speed/time to the first and third "bags". The only difference between the "bags" is the HR505 does not contain an engine start.

The correlation between the HR505 and the FTP is based on special testing done by EPA. In this program, vehicles were tested on both the HR505 and the FTP with the FTP first and the HR505 following immediately afterward. Because the testing process was sequential, ambient test conditions, fuel properties, and vehicle operator variables were controlled to minimize their effects. These data allow the development of a linear correlation of the form:

HR505 = f(FTP Bag1, FTP Bag2, FTP Bag3)

This correlation form was chosen because of its simplicity and the very high level of correlation which is achieved. Other variables such as model year and fuel injection type, and differences between the various "bags" were tried; also, other fits such as a non-linear fit were tried, but were not used. None produced appreciably better correlation. The correlation between the HR505 and the FTP is important because relatively few data points are available on the HR505; however, many FTP data points exist, and can thus be used to calculate simulated HR505 results.

The HR505 was developed to allow the separation of the emission effects of vehicle start with the effects of hot running operation. This split will allow the separate characterization of start and running emissions for correction factors such as fuel effects and ambient temperature. It also allows a more precise weighting of these two aspects of exhaust emissions for particular situations such as parking lots and freeways. MOBILE6 will allocate vehicle exhaust emissions to either those associated with engine start (start emissions) or those associated with travel (running emissions).

More information regarding start emission and running emissions and the role of the HR505 can be found in the accompanying EPA document entitled "Determination of Start and Running Emissions Deterioration" - M6.EXH.001. This document describes in more detail the methodology and equations used to calculate start and running emissions using the HR505 results.

Sample Selection and Data

The sample for this analysis came from EPA emission factor testing performed at the Automotive Testing Laboratories, Inc., in Ohio, and from testing performed at the EPA Lab in Ann Arbor, Michigan. The Ohio lab performed 50 of the 77 vehicle tests, and the Ann Arbor lab performed the remaining 27 vehicle tests. All of the Ohio vehicles were recruited at Inspection and Maintenance (I/M) lanes run by the State of Ohio, and were tested in an as-received condition (without repairs). Many of these vehicles were I/M failures, and produce excessive emissions (not a random sample). However, except for one vehicle which had an intermittent problem, some care was taken to exclude vehicles with obvious problems (i.e., start/stall problems) that would bias the results. The Ann Arbor vehicles were recruited from extensive mail solicitations of the general public, and were also tested in an as-received condition. The sample contained a total of 77, 1983 through 1996 model year vehicles. It comprised both cars and trucks, and was weighted predominately toward late model year vehicles and newer technology. Since the use of the HR505 regression equation in the MOBILE6 model was primarily on 1981-1993 model year vehicles (and post 1993 model years for CO emissions only), the use of the 1994, 1995 and 1996 model year vehicles in this analysis assumes that the correlation between the Hot505 and the individual bag emission results from the newer vehicles is similar to the correlation for the 1981-1993 model years. Table 1 (a separate Excel spreadsheet titled 'F505.xls') shows the emissions and model year data on all 77 vehicles.

All of the vehicles were tested using the FTP procedure, including an extra test segment (bag) which did not include an engine start. The first, third and extra bag samples from this testing all used the identical driving cycle, sometimes referred to as a "505", since it lasts 505 seconds. The "extra" bag, which uses a 505 but does not include an engine start is the HR505. Appendix A at the end of this document contains additional details regarding the test procedure and vehicle recruitment.

The test program data are shown in Table 1 for all of the 77 vehicles. It shows the FTP emissions (by bag) and the results of the HR505 measurement for total hydrocarbons (HC), carbon monoxide (CO), oxides of nitrogen (NOx), and non-methane hydrocarbons (nmHC). The non-methane hydrocarbon emissions were calculated from the total hydrocarbon emissions by subtracting a methane measurement which was made during all of the tests. All emissions in the tables are reported in grams per mile.

Prior to curve fitting, examination of the data indicated that vehicle #16, a 1989 Buick LeSabre, was an extreme outlier in terms of HR505 CO emissions. This vehicle's running 505 CO emissions were measured at 53.8 grams per mile (g/mi); however, Bag 1 (4.71 g/mi) and Bag 2 (3.33 g/mi) CO emissions were much lower. This was peculiar since both Bag 1 and Bag 3 are expected to be larger (or only slightly smaller due to testing variation) than the running 505 results. This is because both of those bags contain an engine start in addition to running emissions. Examination of the vehicle showed a problem with the block learn multiplier test, indicating that there was probably an intermittent failure of the closed-loop fuel control system on this vehicle. Because of the intermittent nature of the failure and the very large discrepancy between the hot running 505 and the other bags, Vehicle #16 was removed from the model fitting for all three pollutants. The intermittent nature of the failure, and the fact that it is not "start" specific is a problem because in theory it should have the same probability of occurring in either Bag3 or the HR505 or both cycles. Thus, probabililistically a large negative is as likely as a large positive effect. If either of these were to be added to the a small sample size, bias would occur.

As a result, the vehicle was removed from the analysis. Table 2 shows the emissions statistics for the sample with and without vehicle #16.

Vehicle #219 was also a very high CO emitter with higher emissions for the HR505 than for Bag3. It was retained in the analysis because no intermittent performance problem could be identified. Also, the absolute difference between the HR505 and Bag3 is large for Vehicle #219, but the relative difference is not as greater as the relative difference for Vehicle #16.

Analyses

Several models to predict HR505 emissions versus FTP emissions were fitted using least squares regression analysis. The regressions included simple linear regressions as well as non-linear and logarithm transformed regressions. They utilized several dependent variables such as the individual FTP bag results and the model year. In choosing a final model, several formulations were considered. Beginning with Bags 1, 2 and 3 for all three pollutants and the vehicle model year parameter as independent variables, standard variable selection methods were applied in order to reduce the number of predictors. Not surprisingly, the best models include Bag 2 and Bag 3 of the pollutant being predicted. Models using these two variables account for a high percentage of the variation in the dependent variable. While the Bag 1 logs of emissions are not statistically significant, it was decided to include this variable in the final models in order to more fully utilize the available information. The model year variable was found to be adding little to the predictive power of the model and be non-significant; thus, it was dropped from the model. For all three pollutants, the final model is the transformed value of the linear fit of the logs of Bags 1, 2, and 3:

$$HR505 = Exp[(A * LN(Bag\ 1)) + (B * LN(Bag\ 2)) + (C*LN(Bag\ 3)) + D + LogTrans\ Factor]$$

where A, B, C, D, and the LogTrans Factor are unknown constants. Table 3a shows the coefficients for the above formulation for each pollutant along with the R-square and T significance statistics.

LogTrans Factor is a logarithm transformation constant. Numerically, it is the mean squared error of the regression divided by 2. It is added to the predicted value of HR505 to account for the bias which occurs when the data distribution is changed from log to linear. This bias occurs because the 'logged' distribution is approximately normal with the mean equal to the median. However, the linear distribution of emission data is positively skewed with an unequal mean and median. The LogTrans Factor is an approximation technique to overcome the bias. It is referenced in Kendall & Stuart, "The Advanced Theory of Statistics", 1967. The individual values of this log transformation constant are shown in Table 3a.

A similar linear regression model of the HR505 versus the three FTP bags in linear space (non-log transformed) were also performed. The results are shown in Table 3b. Although these regressions produced significant T statistics and generally higher r-squared values than the log transformed models, they were not selected based on the diagnostics from the regression residual P-P plots. These standardized P-P plots are shown in Charts 1 and 2 for HC. Similar plots were obtained for CO and Nox. These plots suggest a non-normal distribution of the regression residuals when working in linear space (the residuals do not follow a 45-degree line). When transformed into log space the distribution becomes more normal (better approximate a 45-degree line). Thus, the fundamental assumptions of linear regression are more closely met by transforming the data into natural log space.

Conclusion

The regression coefficients presented in Table 3a are EPA's best estimate of the correlation between FTP Bag1, Bag2 and Bag3 emission results versus the Hot Running 505 emission results. It is proposed that this correlation will be used to generate Hot Running 505 emission factors and start emission factors from standard FTP test data.

Response to Stakeholder and Peer Review Comments

Significant stakeholder comments were not received for this document. However, three separate paid and independent peer reviewers were used, and provided the following comments. Their comments were either addressed directly in the document or are discussed below.

1. One reviewer thought that the sample of 77 vehicles was insufficient, and that it was too heavily weighted towards late model year vehicles and high emitters.

   Given the high cost of FTP type emission testing, a small vehicle sample size is usually the norm. Compared with other vehicle testing programs, a sample of 77 vehicles is fairly large. The skewness towards late model year vehicles could not be avoided in the testing program due to a desire to test newer model year vehicles (1994-1996) for other purposes. The inclusion of newer model years also proved beneficial since these regression equations were extended for use in post 1994 model year CO emission factor development. The inclusion of a higher percentage of high emitters in the sample than in the overall fleet may also add some uncertainty to the analysis. However, limited analysis using a dummy high emitter classification variable suggested that emitter classification was not statistically significant.

2. One reviewer questioned whether other models for predicting Hot Running 505 results or determining cold start emission effects were considered for use. One other method which was considered, consisted of examining the second by second emission results from the FTP cycles, and determining how long in the FTP cycle (in terms of either cycle

time or cycle percentage) it takes to warm up a vehicle and light off the catalyst. This approach may have allowed for the estimation of cold start or hot start in terms of a percentage of Bag1 or Bag3, respectively. Unfortunately, this approach could not be pursued due to a complete lack of second by second data on the FTP cycle.

Another proposed approach was to use only the third Bag of the FTP cycle in the correlation and drop Bags 1 and 2. This approach was analyzed and found to produce statistically inferior results to the logarithm based regression of all three FTP bags.

3. A reviewer also suggested that Table 1 should be updated to include the Hot Running 505 emission factor produced from this study. Table 1 was not updated; however, this comment has been incorporated in this final draft as an attached Excel Spreadsheet titled 'F505.xls'.

								TABLE 1					
		FTP	FTP	FTP	Bag 1	Bag 1	Bag 1	Bag 2	Bag 2	Bag 2	Bag 3	Bag 3	Bag 3
Veh	**Myr**	**HC**	**NOx**	**CO**	**HC**	**NOx**	**CO**	**HC**	**NOx**	**CO**	**HC**	**NOx**	**CO**
001	88	0.27	2.47	2.54	0.67	3.71	4.18	0.13	1.89	1.82	0.23	2.63	2.69
002	89	0.76	5.58	5.33	1.11	5.76	5.97	0.63	5.63	5.03	0.73	5.35	5.40
003	91	0.32	0.89	1.24	0.70	1.23	4.49	0.22	0.60	0.19	0.22	1.20	0.80
005	91	0.24	0.58	3.42	0.54	1.08	5.49	0.14	0.34	3.02	0.19	0.67	2.63
006	89	0.56	0.56	4.14	0.97	0.90	5.60	0.41	0.42	3.70	0.53	0.58	3.87
007	88	0.16	0.23	1.74	0.55	0.56	3.88	0.04	0.04	0.95	0.11	0.33	1.64
009	89	2.88	4.41	53.40	2.82	4.92	58.23	3.35	3.49	61.93	2.03	5.79	33.45
010	93	0.13	0.21	1.69	0.54	0.59	7.18	0.02	0.09	0.19	0.04	0.15	0.42
011	93	0.26	0.50	3.43	0.93	0.73	13.08	0.04	0.37	0.56	0.16	0.57	1.61
012	88	0.75	2.40	4.66	1.34	2.54	8.17	0.45	1.95	3.37	0.86	3.15	4.46
013	93	0.09	0.18	1.62	0.38	0.54	4.92	0.01	0.07	0.60	0.02	0.13	1.10
014	91	0.53	0.32	8.95	1.32	0.29	19.91	0.32	0.24	7.10	0.35	0.49	4.20
015	93	0.08	0.41	1.11	0.32	0.67	4.37	0.01	0.29	0.18	0.02	0.45	0.42
016	89	0.16	0.26	1.90	0.50	0.64	4.71	0.01	0.13	0.05	0.18	0.23	3.33
017	91	0.17	0.13	3.06	0.63	0.44	7.44	0.02	0.03	1.64	0.09	0.09	2.47
018	95	0.13	0.10	1.93	0.56	0.36	7.72	0.01	0.03	0.42	0.04	0.04	0.46
019	90	0.92	1.69	18.87	0.63	2.80	8.06	1.23	1.06	27.98	0.56	2.04	9.62
020	92	0.19	0.63	2.68	0.69	1.09	6.41	0.04	0.38	1.91	0.11	0.75	1.32
021	95	0.14	0.10	2.20	0.58	0.36	7.42	0.02	0.02	0.85	0.04	0.04	0.82
022	89	0.30	0.79	2.80	0.82	1.37	7.62	0.13	0.50	1.54	0.24	0.90	1.59
023	88	0.38	0.96	3.97	0.77	1.41	8.24	0.25	0.70	2.77	0.34	1.12	3.05
024	91	0.97	0.36	30.52	1.58	0.47	44.92	0.57	0.34	17.65	1.28	0.30	44.23
025	91	0.24	0.57	4.00	0.79	1.08	9.98	0.07	0.32	2.29	0.15	0.67	2.77
026	89	3.46	1.28	71.18	3.98	1.25	77.52	3.65	1.37	76.04	2.72	1.15	57.12
027	92	1.78	2.16	6.49	3.76	2.81	11.07	1.15	1.65	4.20	1.48	2.65	7.40
028	93	2.10	2.54	10.07	2.45	2.90	14.26	2.19	2.38	9.63	1.64	2.58	7.73
029	89	5.83	0.96	137.34	6.29	0.84	121.88	6.02	0.97	146.58	5.13	1.05	131.38
030	86	5.73	2.46	103.88	8.64	1.10	149.31	5.96	1.78	123.10	3.09	4.80	32.94
031	88	2.90	3.18	10.80	3.44	3.27	16.04	2.85	2.81	9.62	2.59	3.82	9.08
032	85	2.80	0.59	11.03	1.73	1.25	11.97	4.20	0.40	11.91	0.94	0.44	8.64
033	87	1.20	0.42	11.20	1.63	0.53	11.78	1.06	0.34	11.01	1.14	0.47	11.14
034	85	2.01	1.04	14.31	2.71	1.26	23.96	1.79	0.83	12.24	1.90	1.26	10.98
035	87	3.10	0.73	81.82	3.99	0.92	88.68	2.82	0.66	80.22	2.96	0.71	79.69
036	87	0.98	0.65	16.10	2.22	0.73	37.49	0.36	0.62	2.97	1.24	0.66	25.01
037	83	2.90	2.75	48.52	2.30	3.13	43.87	3.08	2.36	50.10	3.03	3.21	49.01
038	96	0.14	0.34	1.67	0.57	0.83	6.96	0.01	0.14	0.07	0.07	0.35	0.74
039	88	2.23	2.50	13.80	2.46	2.88	19.81	2.16	2.19	10.82	2.20	2.79	14.96
040	89	0.66	1.36	7.30	1.11	1.62	8.72	0.54	1.18	7.51	0.54	1.50	5.85
041	87	0.98	0.64	7.06	3.25	0.91	24.16	0.25	0.52	1.73	0.67	0.66	4.35
042	85	5.98	2.91	99.79	5.82	4.29	92.27	6.35	2.21	106.62	5.41	3.20	92.41
043	89	1.01	1.85	9.93	1.27	2.16	12.26	1.02	1.63	9.54	0.80	2.05	8.90
044	88	11.19	0.17	191.22	10.78	0.30	150.03	11.58	0.10	229.43	10.77	0.21	149.39
045	93	0.24	0.98	4.02	0.75	1.70	7.44	0.07	0.75	2.67	0.17	0.90	4.03
046	85	6.24	4.06	95.04	6.31	4.51	107.29	6.83	3.69	103.89	5.06	4.43	68.89
047	91	0.82	0.85	6.32	1.32	1.42	19.12	0.74	0.64	2.86	0.59	0.82	3.29
048	89	1.54	2.22	11.93	2.10	2.78	17.29	1.43	1.85	10.82	1.32	2.52	9.99
049	86	0.46	4.47	1.69	1.17	4.00	3.78	0.23	4.43	0.50	0.37	4.92	2.38
050	85	1.74	1.18	23.43	4.55	2.38	42.73	0.94	0.79	19.36	1.13	1.05	16.62
051		0.95	0.31	6.33	1.13	0.68	7.10	1.00	0.16	5.40	0.74	0.30	7.53
207	94	0.33	0.40	3.89	1.16	0.90	14.73	0.06	0.18	0.57	0.23	0.44	2.05
208	90	2.12	3.23	13.93	2.28	3.64	17.20	2.30	2.85	13.82	1.67	3.66	11.67
209	96	0.13	0.19	2.42	0.50	0.34	9.84	0.02	0.11	0.23	0.05	0.25	1.00
210	90	0.45	0.97	5.05	1.16	1.57	10.56	0.20	0.65	3.68	0.41	1.11	3.50
211	96	0.10	0.12	0.58	0.40	0.32	2.54	0.01	0.08	0.01	0.02	0.05	0.18
217	96	0.07	0.14	0.72	0.29	0.46	2.88	0.01	0.03	0.13	0.02	0.14	0.21
218	92	0.19	0.36	4.62	0.56	0.54	7.92	0.09	0.29	3.98	0.12	0.34	3.36
219	92	11.55	0.10	203.42	7.86	0.40	130.72	14.37	0.01	253.71	8.94	0.05	162.32
220	94	0.48	0.85	1.26	0.65	0.94	3.05	0.40	0.76	0.51	0.52	0.95	1.36
221	96	0.12	0.46	1.41	0.33	0.79	6.38	0.06	0.29	0.00	0.09	0.54	0.36
222	92	0.37	1.21	3.68	1.02	1.74	9.17	0.20	0.87	2.34	0.21	1.47	2.09
223	96	0.16	0.39	1.53	0.62	0.86	6.38	0.02	0.17	0.00	0.08	0.47	0.77
224	92	0.22	0.57	4.73	0.58	0.99	6.48	0.08	0.42	3.41	0.23	0.54	5.92

Table 2

Sample Descriptive Statistics

	Sample without vehicle #16				Full Sample (77 cases)			
	Mean	Std Dev	Min	Max	Mean	Std Dev	Min	Max
FTP HC	1.35	2.19	0.07	11.55	1.34	2.18	0.07	11.55
FTP CO	19.66	39.90	0.58	203.43	19.43	39.68	0.58	203.43
FTP NOx	1.16	1.17	0.08	5.58	1.15	1.16	0.08	5.58
Bag 1 HC	1.83	2.03	0.29	10.78	1.82	2.02	0.29	10.78
Bag 2 HC	1.29	2.51	0.01	14.37	1.27	2.50	0.01	14.37
Bag 3 HC	1.11	0.22	0.01	10.77	1.10	0.21	0.01	10.77
Running 505 HC	0.91	1.80	0.01	11.04	0.92	1.79	0.01	11.04
Bag 1 CO	23.57	34.68	2.54	150.03	23.33	34.52	2.54	150.03
Bag 2 CO	20.02	47.22	0.00	253.71	19.76	46.96	0.00	253.71
Bag 3 CO	16.02	32.55	0.04	162.32	15.86	32.37	0.04	162.32
Running 505 CO	15.88	37.24	0.04	224.70	16.37	37.24	0.04	224.70
Bag 1 NOx	1.56	1.23	0.22	5.76	1.55	1.22	0.22	5.76
Bag 2 NOx	0.92	1.09	0.01	5.63	0.91	1.09	0.01	5.63
Bag 3 NOx	1.32	1.38	0.04	5.79	1.30	1.37	0.04	5.79
Running 505 NOx	1.19	1.33	0.01	5.47	1.17	1.33	0.01	5.47
(Bag 1 HC - Running 505 HC)	0.92	1.02	-3.17	5.99	0.90	1.03	-3.17	5.99
(Bag 1 CO - Running 505 CO)	7.70	20.01	-93.98	120.22	6.96	20.90	-93.98	120.22
(Bag 1 NOx - Running 505 NOx)	0.37	0.64	-3.62	1.88	0.37	0.63	-3.62	1.88

Table 3a

Final Model Regression Coefficients (log-log)

Dependent Variable	LN(Running 505 HC)	
	Coefficient	T Test Sig
LN(Bag 1 HC)	0.2236 (A)	0.0658
LN(Bag 2 HC)	0.5010 (B)	0.0000
LN(Bag 3 HC)	0.3333 (C)	0.0110
(Constant)	-0.5065 (D)	0.0000
Log Trans Factor	0.0733	
R Square 0.9531		

Dependent Variable	LN(Running 505 CO)	
	Coefficient	T Test Sig
LN(Bag 1 CO)	0.0005071 (A)	0.9958
LN(Bag 2 CO)	0.4304 (B)	0.0000
LN(Bag 3 CO)	0.5375 (C)	0.0000
(Constant)	-0.0674 (D)	0.7250
Log Trans Factor	0.099	
R Square 0.9410		

Dependent Variable	LN(Running 505 NOx)	
	Coefficient	T Test Sig
LN(Bag 1 NOx)	0.0209 (A)	0.8685
LN(Bag 2 NOx)	0.4655 (B)	0.0001
LN(Bag 3 NOx)	0.5328 (C)	0.0001
(Constant)	0.0416 (D)	0.6267
Log Trans Factor	0.0747	
R Square 0.9220		

Table 3a Con't

Final Model Regression Coefficients (log-log)

Dependent Variable	LN(Running 505 NMHC)	
	Coefficient	T Test Sig
LN(Bag 1 nmHC)	0.4162 (A)	0.0144
LN(Bag 2 nmHC)	0.5379 (B)	0.0000
LN(Bag 3 nmHC)	0.2232 (C)	0.0371
(Constant)	-0.6634 (D)	0.0000
Log Trans Factor	0.1986	
R Square 0.9487		

Table 3b

Alternative Model Regression Coefficients (linear)

Dependent Variable (Running 505 HC)

	Coefficient	T Test Sig
(Bag 1 HC)	-0.1472 (A)	0.0039
(Bag 2 HC)	0.4487 (B)	0.0000
(Bag 3 HC)	0.4918 (C)	0.0000
(Constant)	0.0609 (D)	0.3112

R Square 0.9644

Dependent Variable (Running 505 CO)

	Coefficient	T Test Sig
(Bag 1 CO)	-0.3452 (A)	0.0000
(Bag 2 CO)	0.3480 (B)	0.0000
(Bag 3 CO)	0.9700 (C)	0.0000
(Constant)	1.5050 (D)	0.0685

R Square 0.9806

Dependent Variable (Running 505 NOx)

	Coefficient	T Test Sig
(Bag 1 NOx)	-0.0989 (A)	0.0424
(Bag 2 NOx)	0.1770 (B)	0.0168
(Bag 3 NOx)	0.9027 (C)	0.0001
(Constant)	-0.0123 (D)	0.7667

R Square 0.9785

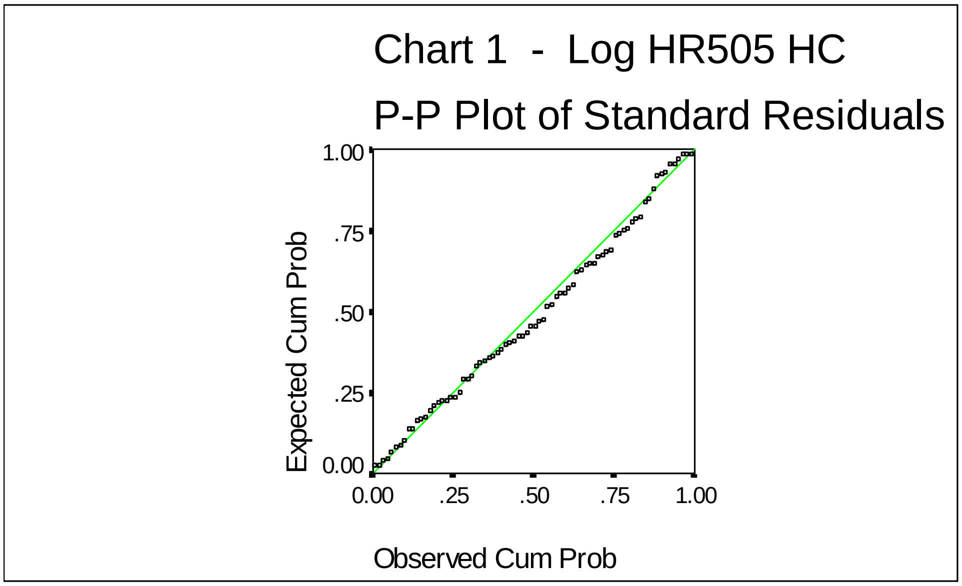
Chart 1 - Log HR505 HC
P-P Plot of Standard Residuals
Expected Cum Prob
1.00
.75
.50
.25
0.00
0.00
.25
.50
.75
1.00
Observed Cum Prob

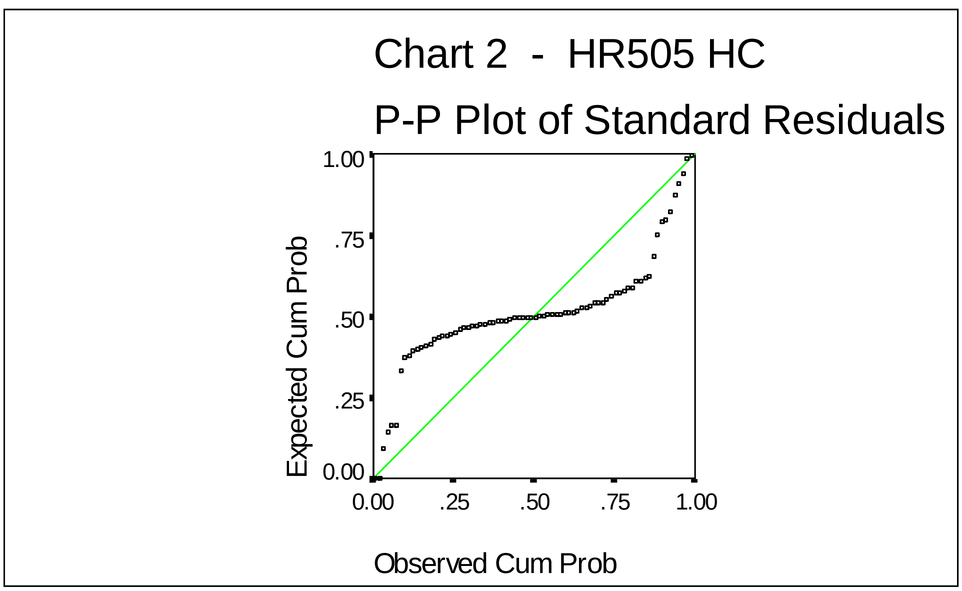
Chart 2 - HR505 HC
P-P Plot of Standard Residuals
Expected Cum Prob
1.00
.75
.50
.25
0.00
0.00
.25
.50
.75
1.00
Observed Cum Prob

Appendix A

Amendment 1 : Work Assignment 1-03
Contract 68-C5-0006

Statement of Work

Inventory Cycle Data Collection

I. BACKGROUND

EPA's "MOBILE" computer model is used by regions, states, and municipalities in estimating in-use emissions from mobile sources. This model was derived from data obtained from previous testing programs around the country and most recently from data obtained at the EPA's National Vehicle and Fuel Emissions Laboratory in Ann Arbor and from operating laboratories and I/M lanes in Hammond IN and Phoenix AZ. EPA has the responsibility of updating its model to provide the latest information on regional driving patterns and modeling strategies for current driving behaviors.

This work assignment will gather emissions data from light-duty vehicles (LDV) being run on various inventory cycles (ICs) to provide additional information for the MOBILE database. Each IC models an atypical (e.g., non-standard road conditions, traffic congestion, non-FTP speeds) LDV trip. Changes in a vehicle's expected emissions when it is operated over one of these ICs are used to calculate area-specific emissions for the LDV fleet within the MOBILE model. Exhaust emission measurements will also be conducted.

II. OBJECTIVE

Several ICs as detailed in Appendices X, Y, and Z shall be run on vehicles recruited at a centralized I/M facility. This will allow EPA to add more fleet characteristics emission data to its MOBILE model. A secondary purpose shall be to gather data on cold start emissions using a ST01 start cycle. All vehicles shall receive a FTP exhaust emissions test, as well.

III. RECRUITMENT

The contractor shall recruit a total of 50 vehicles that have completed an I/M test lane: 1) 35 light-duty vehicles and 5 light-duty trucks from model year 1988 and newer; 2) 5 light-vehicles from pre-1988 model year; and 3) 5 light-duty trucks from 1988 to present light-duty cars. The vehicles will be a naturally occurring mix of carbureted and fuel injected systems. Every attempt will be made to locate at

least half of each sample failing the I/M240 test with either high NOx (oxides of nitrogen) or high combined HC-CO (hydrocarbon-carbon monoxide) emissions, but not both. The vehicles shall be recruited as shown in the table below:

Model Year	**Pass**	**Fail NOx**	**Fail HC-CO**
1988-Newer	**50% (12)**	**12.5% (4)**	**37.5% (9)**

IV. LANE TESTING

The I/M240 test will be run on each vehicle. The Contractor shall use the results from the state contractor's test. These tests will form the basis for vehicle recruitment. These tests will be performed over the entire 239 seconds of the I/M240 (no fast pass or fast fail allowed) and the composite HC, CO, and NO_x results in grams per mile shall be recorded and reported. The lane procedures are shown in Appendix X1.

V. LABORATORY TESTING

The Contractor shall perform the ST01 start cycle (the first 258 seconds of EPA's SC03 cycle), the "area-wide" inventory cycle (similar to CARB's "Unified " cycle), CARB's LA92, the New York City Cycle, and 11 other inventory cycles (see detail in section "VI TEST SEQUENCE" of this work assignment). The ST01 cycle shall be run as a cold start test and all cycle data shall be collected modally second-by-second on a twenty-inch (20") roll dynamometer. The Contractor also shall perform a cold-start FTP (exhaust) test on each LDV with an additional fourth bag 505 on a Clayton dynamometer and the data collected non-modally. A flowchart showing the sequence of events is included as Attachment 1.

VI. TEST SEQUENCE

The test sequence shall include:

1) Cold ST01 start cycle (see Appendix Q of the Statement of Work)

2) A hot start LA-4 to measure and qualify bag vs. modal (second by second).

3) All of the following cycles for each test vehicle, run in random order for each LDV:

1. LOS A-C Freeway Trace (8.60 mins) ;
2. LOS D Freeway Trace (6.80 mins);
3. LOS E Freeway Trace (7.77 mins);
4. LOS F Freeway Trace (7.45 mins);
5. LOS G Freeway Trace (6.52 mins);
6. Ramp (4.43 mins)
7. LOS AB Arterial Trace (12.28 mins);
8. LOS CD Arterial Trace (10.48 mins);
9. LOS EF Arterial Freeway Trace (8.40 mins);
10. Local Roadways (8.75 mins);
11. Areawide Non-Freeway
12. LA92
13. NYCC
14. High-Speed

3) Cold-start FTP (exhaust portion) (see Appendix F, FTP SEQUENCE)

VII. REPORTING REQUIREMENTS

A. Weekly Reports

All of the raw and processed data will be reported according to the basic contract and the attached formats. Submittal of these data will be on a weekly basis and may be made using electronic transfer either by modem or over the Internet. A spreadsheet for each task will be submitted that includes sufficient information to identify the vehicle being tested and the results of each individual test performed. A narrative description which notes any unusual problems encountered or identifies any maintenance performed shall be included as part of the weekly report.

A narrative summary of the week's activity will be included in the normal weekly report for each active work assignment under this contract. This will include the number of vehicles tested to date along with any significant observances for that week. A table showing the overall status of the work assignment will also be included and updated each week. This narrative may also be submitted electronically over the Internet.

Recruitment statistics shall also be included in this report. These statistics will include a count of each and every vehicle owner approached. The data shall be

broken down month by month (when sufficiently far into work assignment) into those vehicles that were ineligible to participate, those who agreed to be tested but were not, and those who refused to participate in the program. These three groups are to be further broken down into specific reasons for the vehicle not participating. The contractor shall attempt to achieve as close to 100% participation as possible.

B. <u>Monthly Reports</u>

Monthly reporting will be as required by the contract and will include a summary of all work performed under the above subject tasks as well as results of all calibrations on all equipment used.

C. <u>Final Report</u>

The final report shall be a narrative describing the testing in detail and including any changes made during the performance of the work assignment. Furthermore, the final report shall contain a summary of any problems encountered and their resolution. It shall also list all tests and test results on all canisters in the program.

Recruitment statistics shall also be included in this report. See *Weekly Reports* for specifics on the reporting of recruitment statistics.

Within 30 calendar days after completion of the last test sequence performed for this work assignment, the contractor shall submit for technical and editorial review by the Project Officer a draft final report in both written and electronic formats. The written draft shall be typed, double-spaced, and shall include all illustrations, tables, drawings, charts, data sheets, and any other pertinent material required in the approved final report. The Project Officer will notify the contractor of approval or rejection of the draft report within 30 calendar days and shall provide comments citing any changes, corrections, or additions required for approval. Within 30 calendar days after receipt of the comments, the contractor shall submit to the Project Officer a final report in both electronic and written formats. The written report shall include the single spaced original manuscript and five copies of the approved final report.

Appendix X1
Test Procedures

IM Lane Procedures

An I/M240 test will be run on each vehicle at a centralized, i.e., state-mandated, testing facility. The I/M240 testing facility must be within 100 miles of the Contractor's vehicle testing facility. The Contractor shall recruit vehicles for this WA on the basis of the results of the state contractor's I/M240 test. In each case, the composite HC, CO, and NOx results in grams per mile shall be recorded and reported with any purge and/or pressure data. A potential test vehicle must be on-site at the Contractor's testing facility within twenty-four (24) hours or by close-of-business the day following its recruitment from a centralized I/M240 facility.

TEST FUEL

During this work assignment, all vehicles shall be tested with the same lot of indolene-type fuel which complies with Code of Federal Regulations (CFR) §86.113-91, having a preferred RVP of 9.0 psi (not to exceed 9.05 psi and not to be less than 8.70 psi). The Contractor shall measure and record the RVP of the fuel dispensed at each vehicle's fueling prior to the ST01 cycle run (see Appendix 1). The contractor must provide EPA with a complete analysis of each lot of the test fuel. The contractor must obtain approval of the Project Officer before using any test fuel.

INITIAL TEST CONDITIONS

Each vehicle will be pre-conditioned as per CFR §86.132-96 (a)(1); a LA-4 pre-conditioning drive shall be performed.

The data shall be recorded continuously and reported in second-by second increments in comma separated form (C.V.) on a completed vehicle basis for modal testing. For a FTP test, data shall be reported in as described in CFR §86.135-94. The procedures used to calculate the HC emissions shall comply with §86.144-78.

BETWEEN-CYCLE TRANSITIONS

The Contractor shall use a random number generator to randomize the test sequence order of the fourteen cycles (1 through 14), for each of the 50 test vehicles. The acceleration rate found at the end of each cycle will be extended for 10 seconds past the end of the sample period. The acceleration rate found at the beginning of the next cycle will be extended for 10 seconds prior to the start of that cycle. A forty second transition period will be used to connect the extended speeds, for a total of 60 seconds between cycles. A "worst case" transition of 0 mph to 80 mph in 40 seconds would result in an acceleration/deceleration rate of 2.0 mph/sec. There shall be no emission measurements done during these transitions, but they will be documented with speed versus time data.

Each test vehicle shall have a unique driving schedule for whole test program based on the above random test sequence of test cycles. The cycles will be combined into groups of two or three. If the cumulative time for the first group two cycles is less than thirty minutes, the next cycle test sequence shall be added to that group.

Bag samples will be collected at the same time the dilute modal samples are collected and measured. The bag samples will be analyzed following the completion of the group's two or three driving cycles.

The test vehicle shall be preconditioned prior to each group of cycles with an un sampled hot transient phase (hot 505) of the FTP if less than one hour has transpired since the last vehicle operation. An un sampled "LA-4" shall be performed if that period exceeds one hour and less than four hours.

All subsequent vehicles will follow the same procedure until all fifty LDVs have been tested on the test sequence.

APPENDIX F

FTP SEQUENCE

Upon completion of set of the ICs, the vehicle is soaked as long as necessary or overnight to achieve the specified FTP test start temperature. The vehicle will then undergo a cold start FTP (exhaust portion) as shown in CFR §86.135-94. Immediately following the hot transient phase (hot bag 3) of FTP, the contractor will perform a repeat hot 505 without a key off and restart. The contractor shall use a special driving cycle consisting of two consecutive 505 cycles form the FTP.

The CVS system used during the FTP test shall maintain the tail pipe exhaust pressure to within ± 1 inch H_2O of the pressure experienced by the tail pipe with no attachments during the FTP cycle. Care shall be taken to verify the device used to measure the pressure in the line is one which does not itself alter the pressure significantly. The system shall be tested using both a large displacement (more than 4L) and a small displacement (less than 1.7L) engine. This will verify that the system functions properly under different extremes of exhaust volume. Results of this test shall be reported to and discussed with the Project Officer prior to initiation of testing.

Modal versus Bag Data Analysis and Quality Control

Each IC and hot LA-4 shall include both bag and modal test results. The contractor shall compare the difference between all Bag and Modal emissions. They shall report the comparisons to the Project Officer to be reviewed for each cycle. The bag vs. modal comparisons for the hot LA-4 test shall be within ± 5%.