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Emission Simulations:
GM Lumina, Ford Taurus, GM Impact, and Chrysler TEVan

Prepared for

Midwest Research Institute,
National Renewable Energy Laboratory,
U.S. Department of Energy

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Preface

This report fulfills NREL's requirement under Consultant Agreement ECB-5-15339-01 for Federal Test Procedure (FTP) emissions estimates for the following vehicles /powertrains:

- Chevrolet Lurnina with conventional and hybrid powertrain and standard catalytic converter, quick-light converter, and variable conductance insulation (VCI) converter;
- Ford Taurus with conventional and hybrid powertrain and standard catalytic converter, quick-light converter, and VCI converter;
- GM Impact EV; and
- Chrysler TEVan EV.

The engine and catalyst warmup and cooldown routines of the DSIM powertrain simulation were upgraded for the ICE vehicle analyses as follows:

- The math models for engine-out emissions and fuel consumption behavior under warmup were updated using second-by-second data from EPA and auto manufacturer testing of early 1990s vehicles under the EPA FTP Revision Project, replacing the former default models which were based on pre-1980s vehicles;
- The math models for catalyst efficiency vs. temperature and temperature vs. FTP time were upgraded using data in the 1994 and 1995 technical literature and FTP Revision files; and
- The math models for engine and catalyst performance under cooldown were upgraded for the conventional (standard) catalyst, and expanded to handle quick-light and VCI options.

The DSIM hybrid simulation structure now allows user choice of either of two engine operating strategies: best tailpipe BSNOx or best BSFC, and the engine library was expanded to include emission and fuel consumption data and catalyst efficiencies for each of those two statepoints (from 1990s engine map data). The conventional and hybrid emissions analyzers now allow user choice of standard or quick-light catalyst, with or without VCI.

Because of the numerous possible combinations of engine strategy and catalyst option, intermodule links force all modules to simulate the same powertrain and emission control configuration (seems like a good idea). All print-ready tables and graphics automatically generated by conventional and hybrid runs explicitly include the configuration pedigree.

The output report from hybrid runs now includes explicit bag-by-bag breakouts of the energy, emissions, and fuel consumption impacts of engine starting, catalytic converter function, engine and catalyst warmup and cooldown, and end-of-cycle restoration of initial energy storage system state of charge.

The output report from electric vehicle runs includes calculated utility plant emissions of ROG, CO, NOX, SOX, and PM1O for the Mountain and Pacific grids (emission factors for all other DOE-EIA regions are stored in the simulation for use if needed).

Engine-out Emissions Warming Up

Figure 1 shows the warmup behavior of engine-out emissions and fuel consumption from 14 cars in the FTP Revision Project, and the curves for the updated math model. The data points plotted are 10-second averages aggregated by number of cylinders. Table 1 shows that there is a hint of a monotonic Ncyl dependence of the average C/H ratio (all data, not just the 10-second plot numbers) for HC and fuel but not for CO or NOX.

The updated $C/H = R_0 e^{-kt}$ *[lower limit 1.0]* model is based on eyeball /judgement equations, not a blind delegation of statoosculization to the computer (with data like this I trust a trained eye more; you should too). The data do not support a conclusion that NOX and fuel C/H decay are different. Table 1 shows the Bag 1/Bag 3 implications of the update compared to the old model: the cold penalty for HC and CO starts lower and decays slower, with the net result of a lower Bag 1/Bag 3 ratio; the cold penalty for NOX starts higher and decays slower, so the Bag 1/Bag 3 ratio is higher; fuel didn't change much. While the new algorithms decay all four engine-out H/C ratios to 1.0 ("fully warm") by some 278 seconds, that maybe a little pessimistic for CO; a second-look decay coefficient of about 0.0119 warms CO to 1.0 by 150 seconds giving a Bag 1 /3 ratio of 1.54, but that arguably advisable tweak of the CO algorithm was not done for this study. Discussion later shows it's a good idea to leave a little pessimistic cushion in the system for CO

Table 1 — Engine-Out Cold-to-Hot Ratios

Averages	HC	CO	NOx	Fuel	
4 Cyl	1.44	1.81	1.40	1.40	
6 Cyl	1.36	2.00	1.31	1.23	
8 Cyl	1.26	1,65	1.69	1.17	
New Model	HC	CO		Fuel	
R_0	2.30	6.00	1.80	1.80	ratio at T_0
k =	0.0030	0.0080	0.0023	0.0023	decay coefficient
Bag I/Bag 3	1.31	1.81	1.19	1.19	integral under curve
Old Model	HC	CO	NOx	Fuel	
Ro =	8.35	10.36	1.21	1.64	
k =	0.0085	0.0093	0.00076	0.0020	
Bag 1/Bag 3	2.23	2.50	1.05	1.14	

Figure 2 shows how exponential decay models of emissions and fuel consumption versus *coolant temperature* combine with a simple but adequate linear model of coolant temperature vs. time to yield the time-based decay equations. The model's thermostat is a tad hotter than real cars.

Figure 1 — Engine-Out Cold-to-Hot Ratios vs. Time

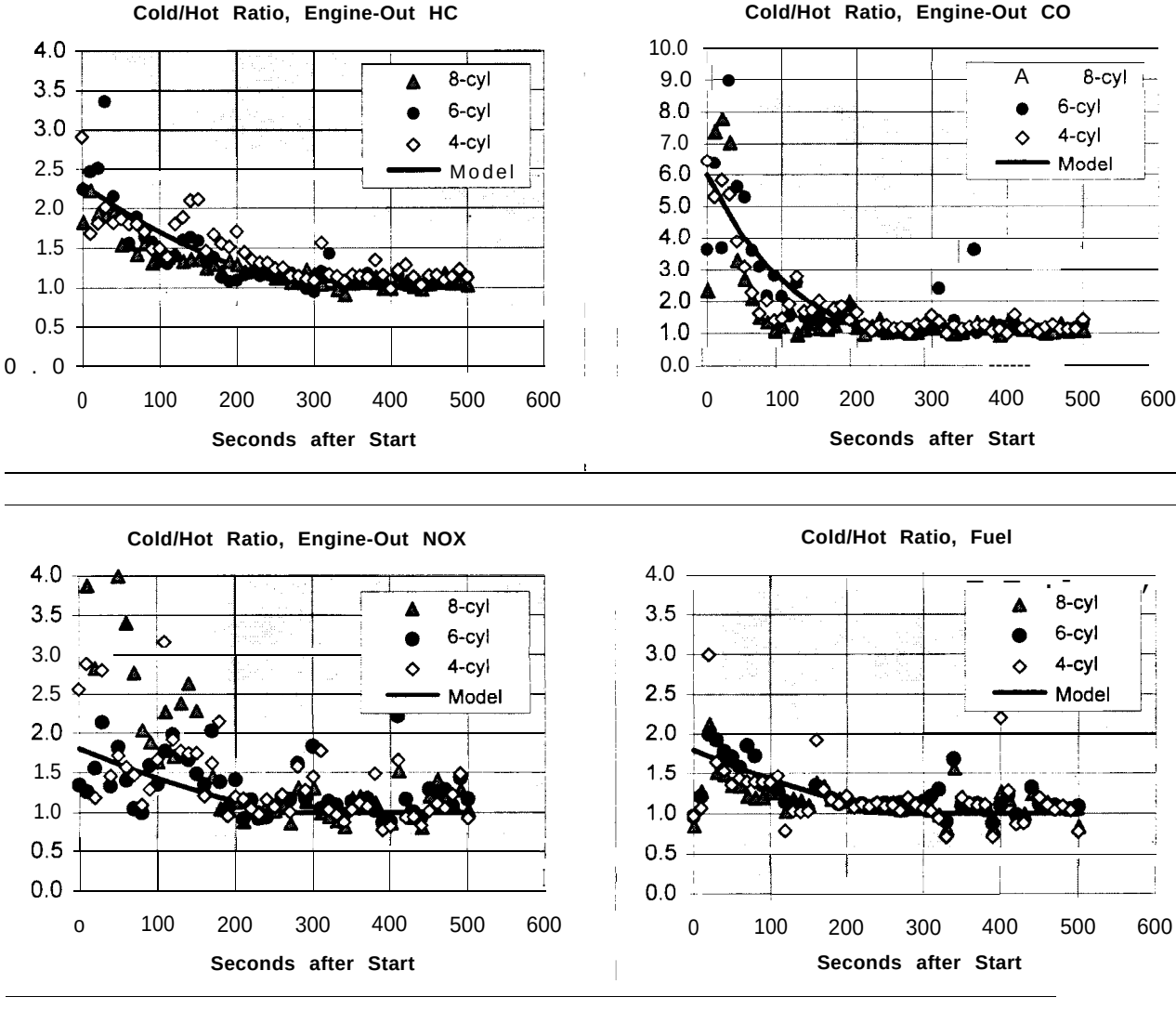
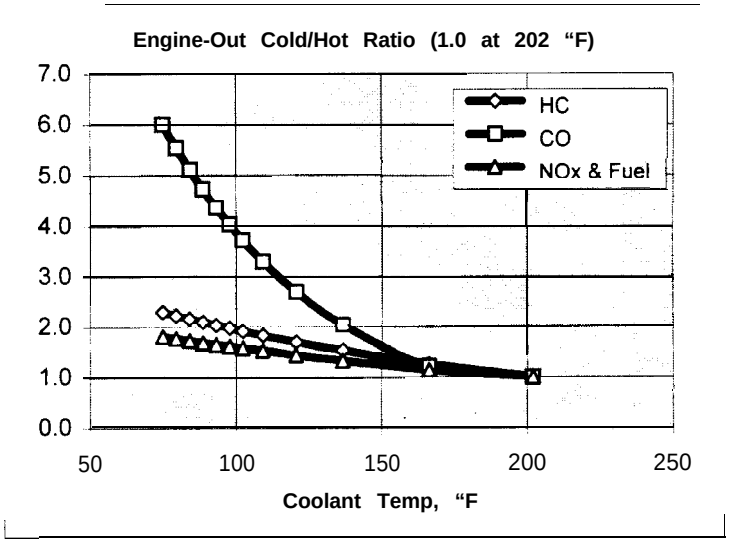
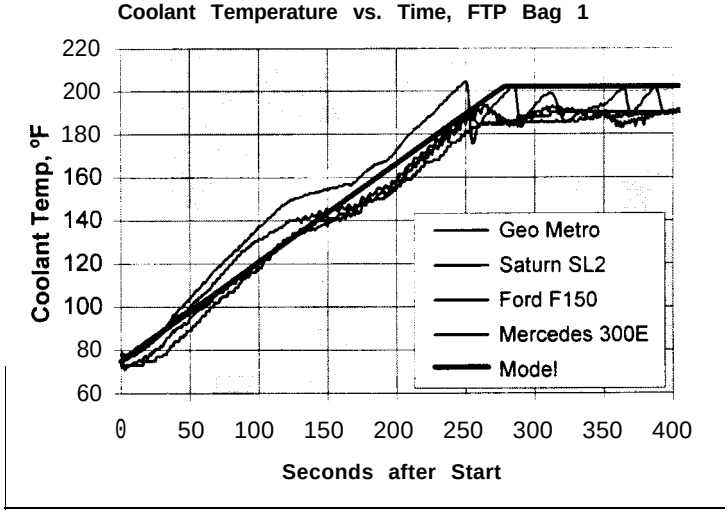
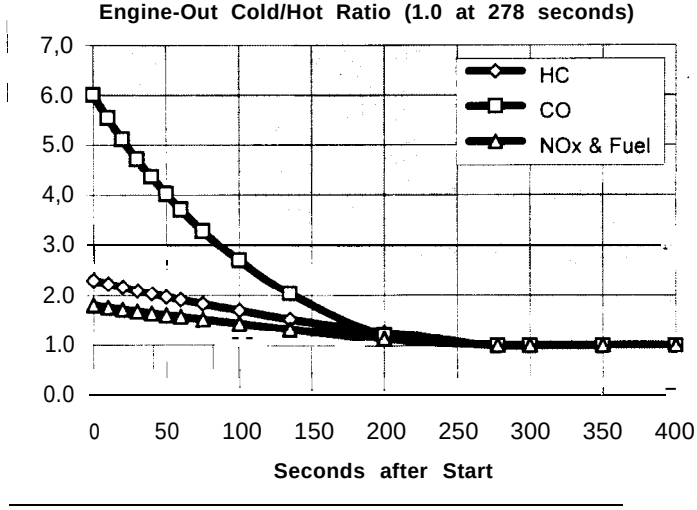


Figure 2 — Engine-Out Cold-to-Hot Ratios, Coolant Temperature, and Time







Catalyst Efficiency Warming Up

Figure 3 shows the warmup history for modern catalysts; the HC, CO, and NOX conversion efficiency of a state-of-the-art mostly-palladium, no-rhodium catalyst at lambda 1; and the linear models that result from combining them.

Figure 3 — Catalyst Efficiency Model

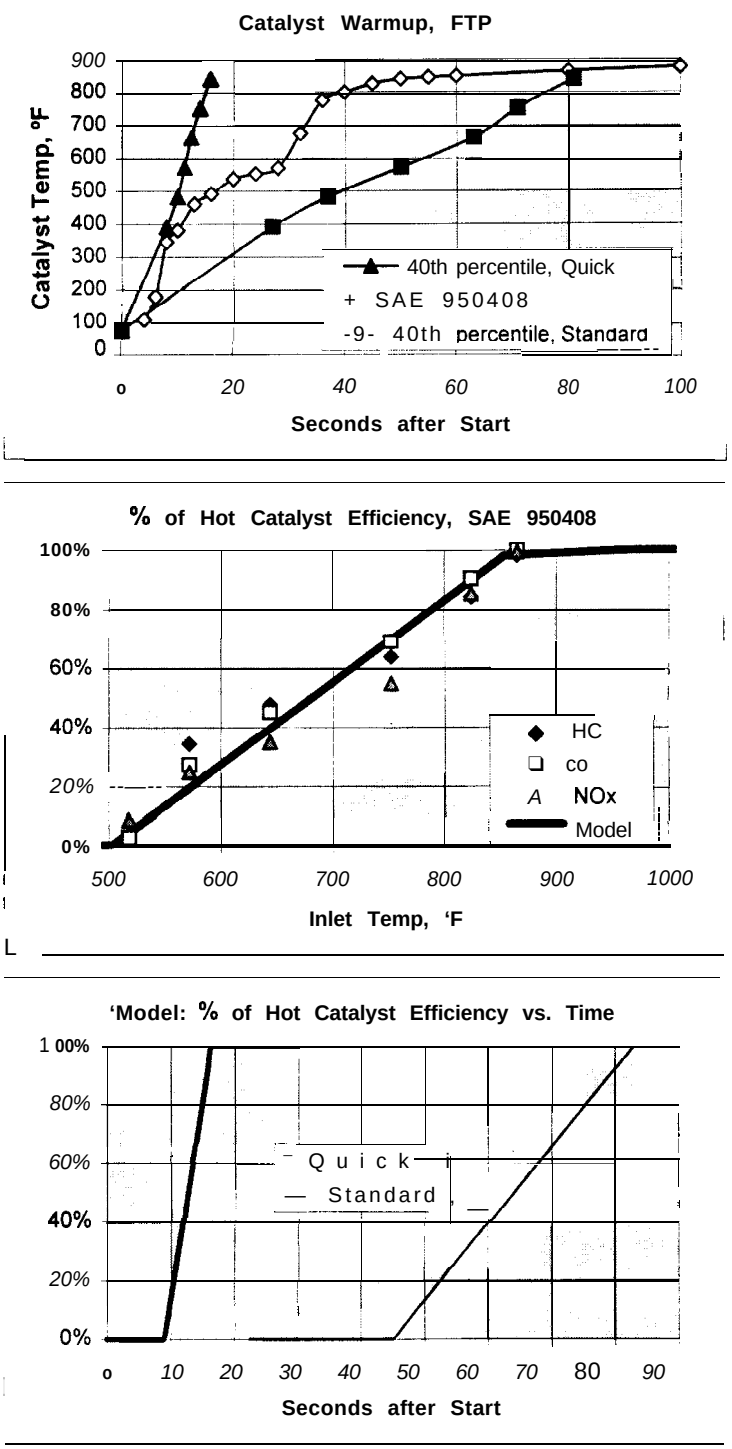
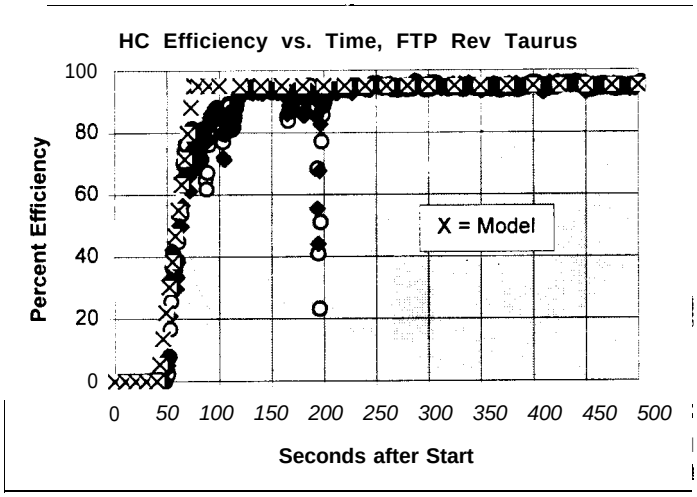
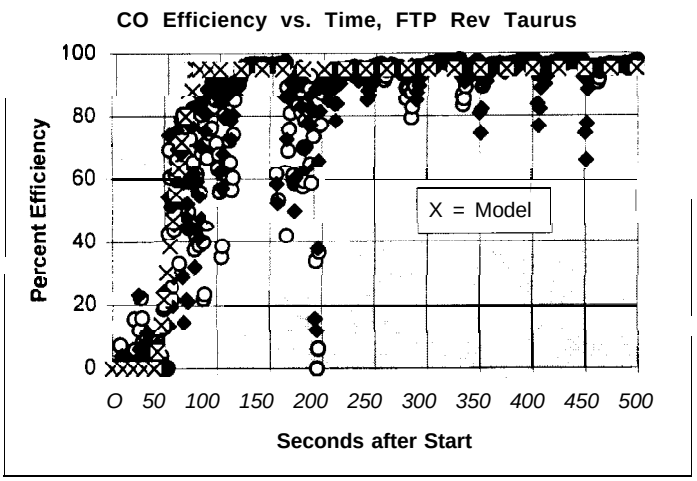
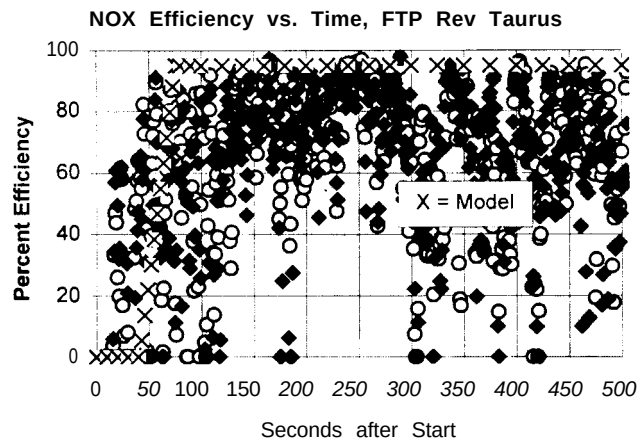


Figure 4 shows catalyst efficiency (Bag 1) from one of the FTP Rev cars and, superimposed, the standard-catalyst linear model applied to a 95% hot efficiency figure for all three pollutants.

Figure 4 — Catalyst Efficiency Data, with Standard-Catalyst Model







The closed and open symbols in Figure 4 denote two separate tests of the car. The lightoff and hot stable performance of the model tracks the actual HC and CO efficiency histories very well except for some droopy low-efficiency points. But those HC and CO droops are *not* random scatter. Look at them closely and note when after-lightoff vehicle accelerations occur in Bag 1:

56-89 see, 94-113, 164-181, 188-205, 214-240, 271-281, 347-372, 403-415, and 448-470

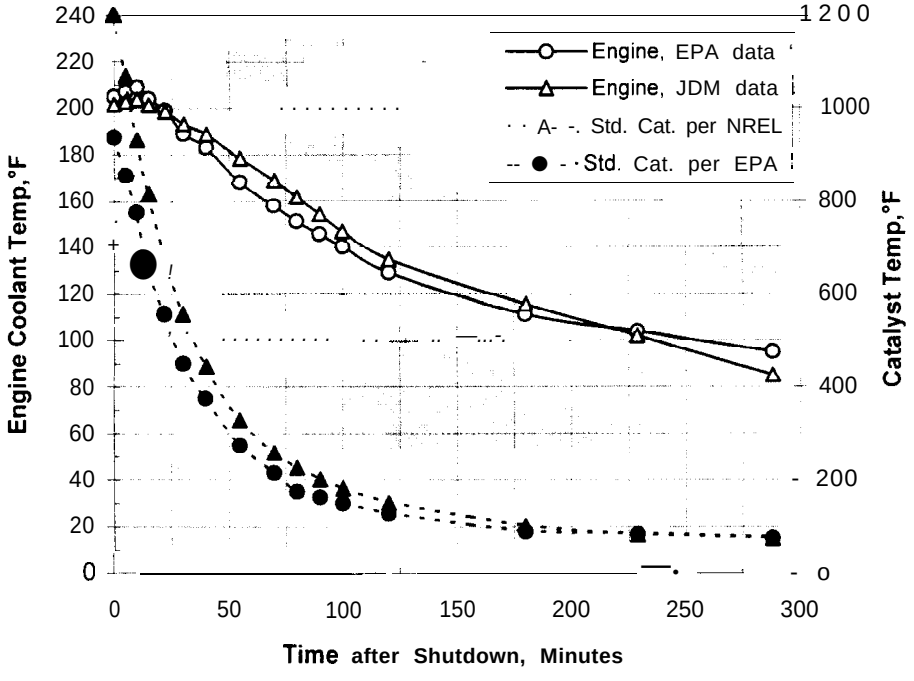
The CO data shows it best: *all* of the droops occur during these vehicle acceleration periods, during which air-fuel ratio enrichment would occur. The worst droopage happens in the neighborhood of 195 seconds, the Harbor Freeway on-ramp acceleration, legendary for drawing the peak power demand in the LA-4 cycle. In the gaps where there are no accelerations, post-lightoff catalyst efficiency remains high and tight, no droops; note especially the acceleratiordess 114-163 second interval — clean as a whistle.

The NOX data for this car are hopelessly scattered, with no handy glib explanation.

Cooldown

Figure 5 shows the data basis for the cooldown model. The model uses the average of the two engine cooldown curves, and the average of the two catalyst curves.

Figure 5 — Engine and Catalyst Cooldown



For the VCI catalyst, the model uses the cooldown curve in Figure 2 of Burch et al (NREL & Chrysler authors), SAE Paper 950409,1995.

The foregoing were combined into the time-based model below. The next four pages depict the model's time histories of tailpipe C/H ratio, using 95% hot catalyst efficiency for illustration.

Tailpipe emissions = Engine-out hot emissions x Tailpipe C/H ratio,

Tailpipe C/H = Engine-out C/H x (1 – η) where η = catalyst efficiency

WARMUP

Emissions

In all cases, the engine starts at 75 'F, with the engine-out C/H ratios at the Table 1 values: 2.30 for HC, 6.00 CO, 1.80 NOX; from that point the C /H ratio decays exponentially until the catalyst comes into play.

For the non-VCI cases, the catalyst starts at 75 'F and follows the appropriate (standard or quick) warmup curve; when catalyst efficiency comes off the peg, a steeper slope in C/H ratio ensues with time as lightoff proceeds. When lightoff is completed and the catalyst is reducing engine-out C/H by a factor of η_{hot}, the gentler engine-out exponential decay is reestablished until the engine is fully warm and engine-out C/H = 1.0, tailpipe C/H = 1 – η_{hot}. That is why the emission curves, based on %°/0 catalyst efficiencies for illustration, stabilize at C /H = 0.05.

For the VCI cases, initial catalyst temperature is assumed to be that after a 24-hour shutdown from hot running, 518 'F per the NREL cooldown curve. At this temperature the catalyst conversion efficiencies are 4.5% of hot efficiency, thus VCI provides the equivalent of a 9-second head start for the quick-light catalyst and a 46-second head start for the standard one (see the bottom graph of Figure 3 at 4.5% of hot efficiency). For VCI systems the C/H ratios at start are therefore engine-out C/H x (1 -0.955 x η) or, for a 95% catalyst, 2.20 HC, 5.74 CO, and 1.72 NOX.

Fuel Consumption

The fuel consumption C/H time history is unaffected by all of the above goings-on in the catalyst and simply follows the engine-out decay curve until it stabilizes at 1.0.

COOLDOWN

The C/H ratios retrace their warmup histories backwards, with engine and catalyst following the much slower rates corresponding to the cooldown curves.

WARMUP/COOLDOWN CYCLING

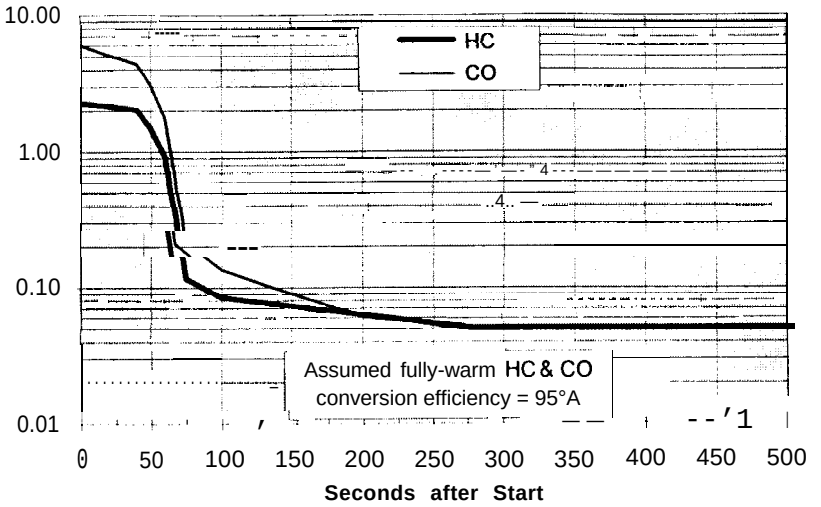
As discussed above, warmup from a cold start is presumed to proceed to completion and cooldown is presumed to start with things fully warm and also proceed to completion. In the general case, since time serves as an exact surrogate for temperature and the C/H ratio histories in either direction are monotonic functions of time (a.k.a. temperature), the model can alternate between interrupted warming and cooling precisely.

If the engine starts and engine and catalyst begin to warm, then the engine stops, the extant C/H ratio at time τ_W (corresponding to engine temperature T_e, catalyst temperature T_k) on the warmup curve has a unique back-solution, time τ_C (also corresponding to engine temperature T_e, catalyst temperature T_k) on the cooldown curve. Knowing at a given time that (a) one second ago the C/H ratio was X and (b) whether the situation is a warming one (engine is running) or a cooling one (not running), it is a straightforward matter to increment the next second's worth of AC/H ratio according to the appropriate local derivative of C /H ratio with time (a.k.a. temperatures).

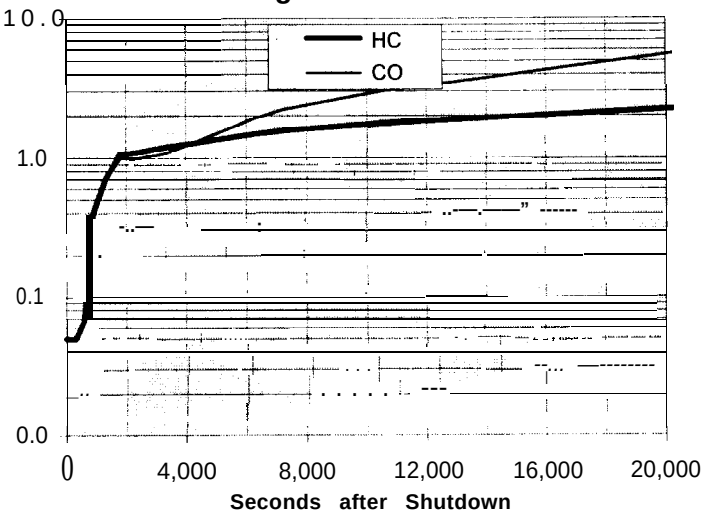
Task2rpt.

1/5/96 **Tailpipe Cold-to-Hot Ratios (Engine-out hot = 1.00)** **Engine: Normal** **Catalyst: Normal**

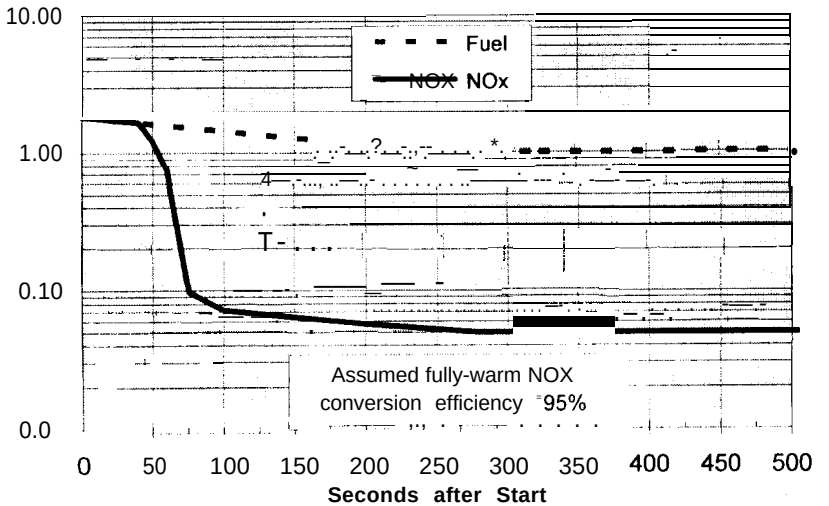
Warming from 24-hour Soak After Hot Shutoff



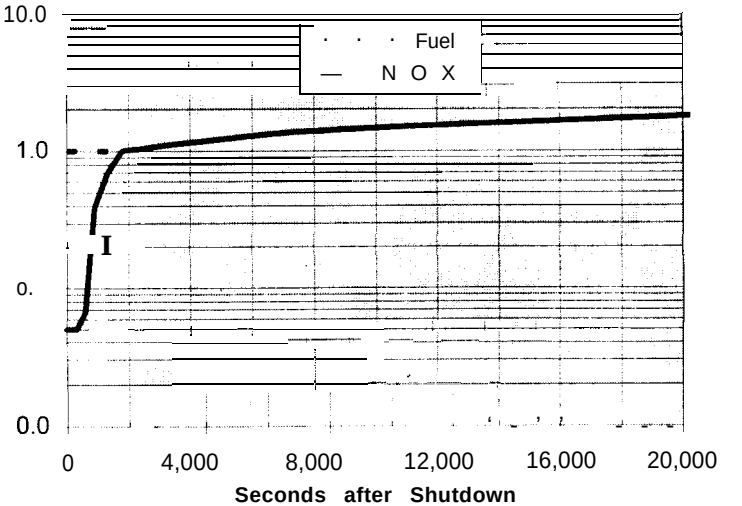
Cooling from Hot Shutoff



Warming from 24-hour Soak After Hot Shutoff



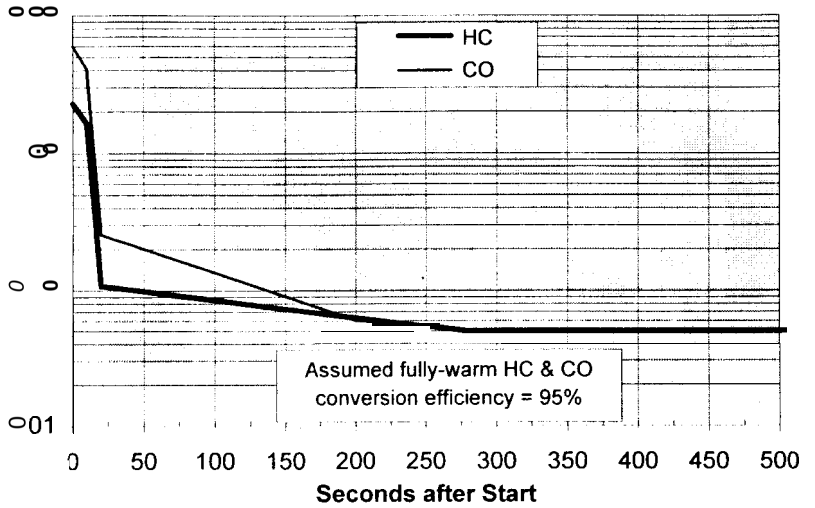
Cooling from Hot Shutoff



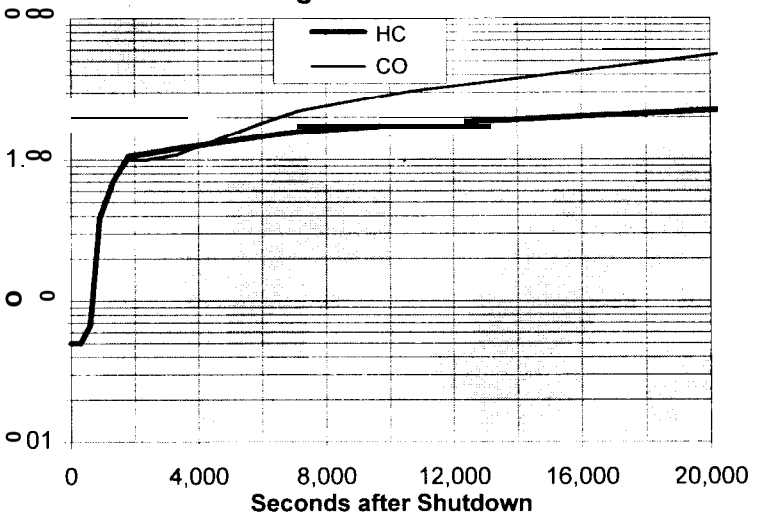
CO

/5/96 **Tailpipe Cold-to-Hot Ratios (Engine-out hot = 1.00)** **Engine: Normal** **Catalyst: EHC**

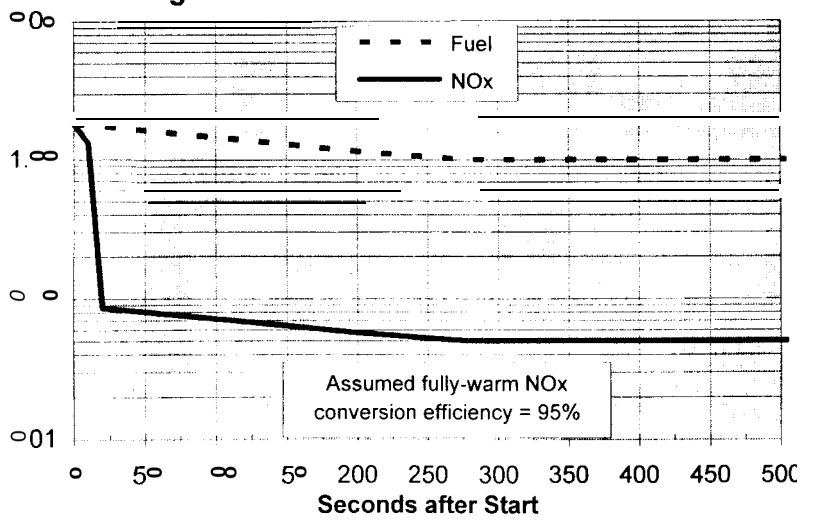
Warming from 24-hour Soak After Hot Shutoff



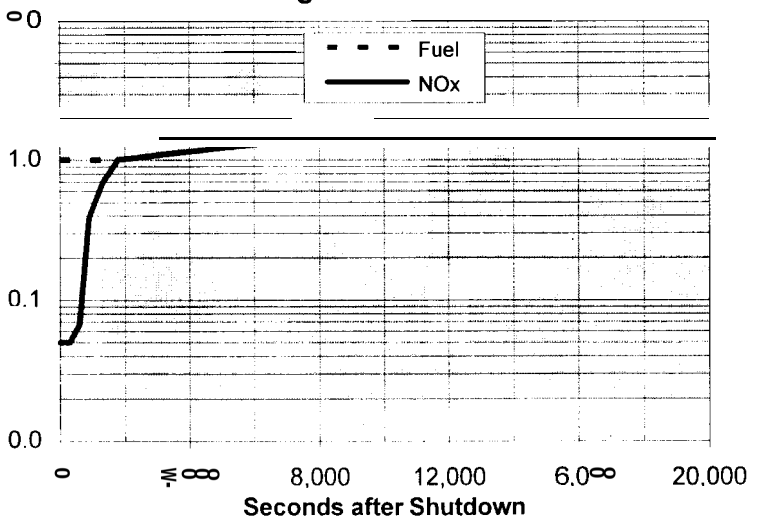
Cooling from Hot Shutoff



Warming from 24-hour Soak After Hot Shutoff

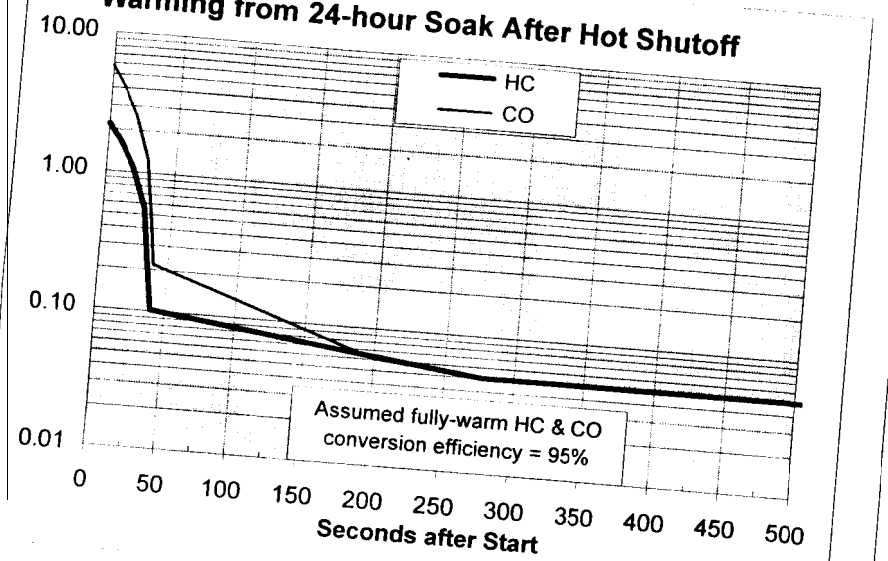


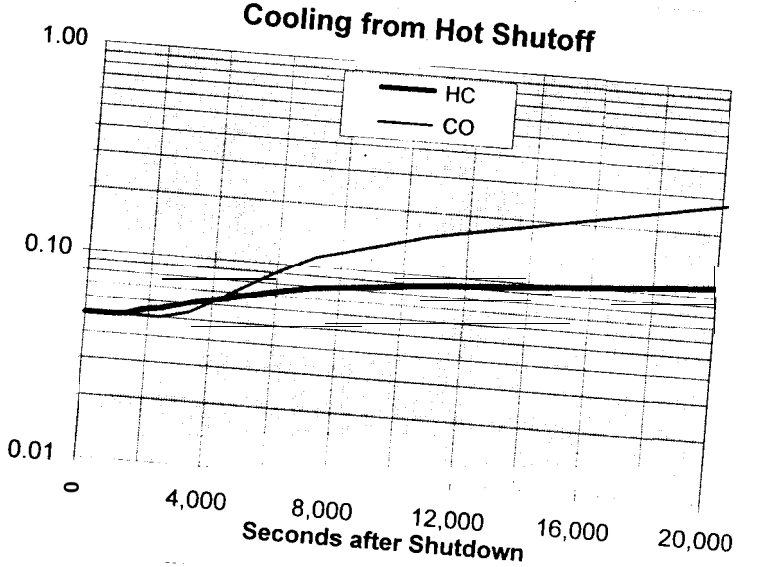
Cooling from Hot Shutoff

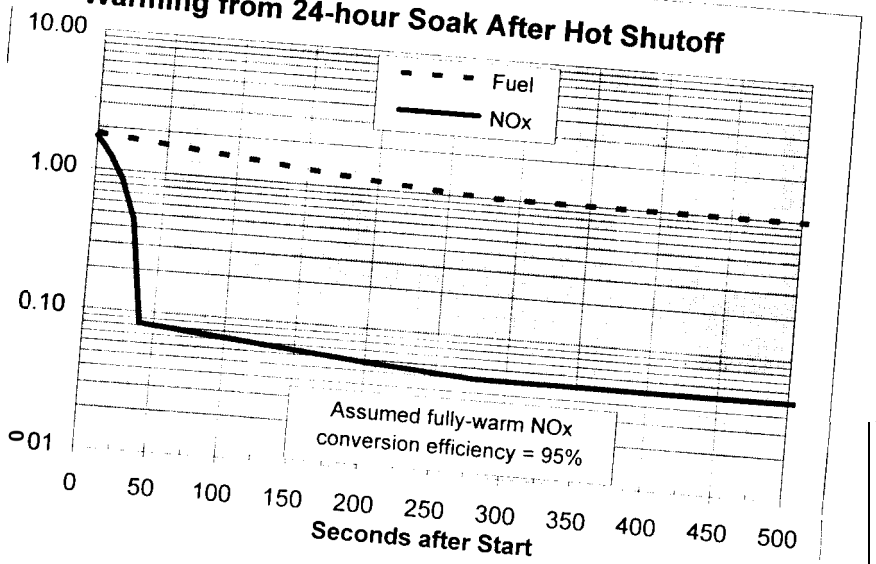


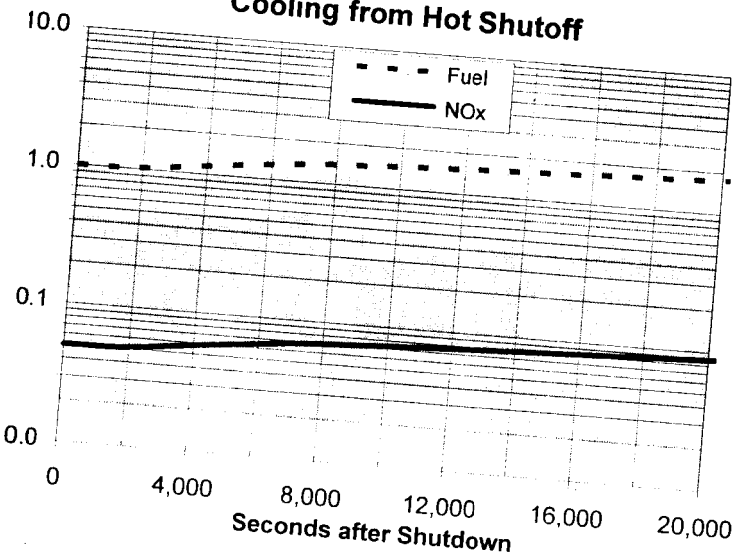
Tailpipe Cold-to-Hot Ratios (Engine-out hot = 1.00)

Engine: Normal **Catalyst: VCI**



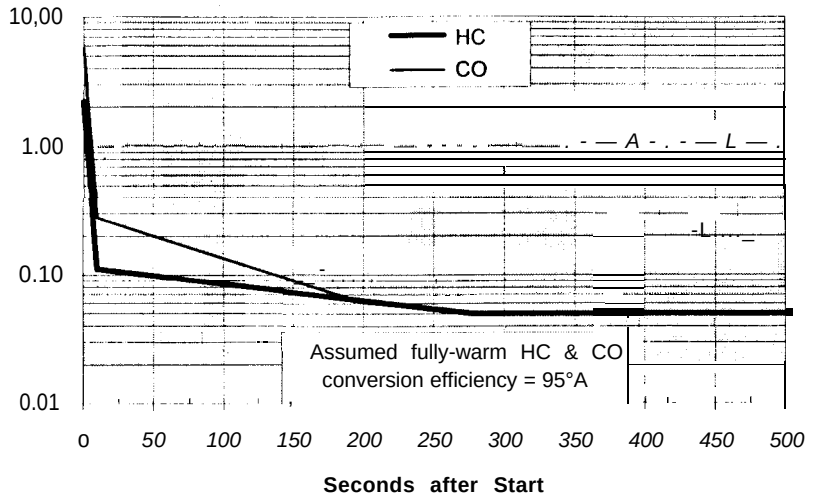




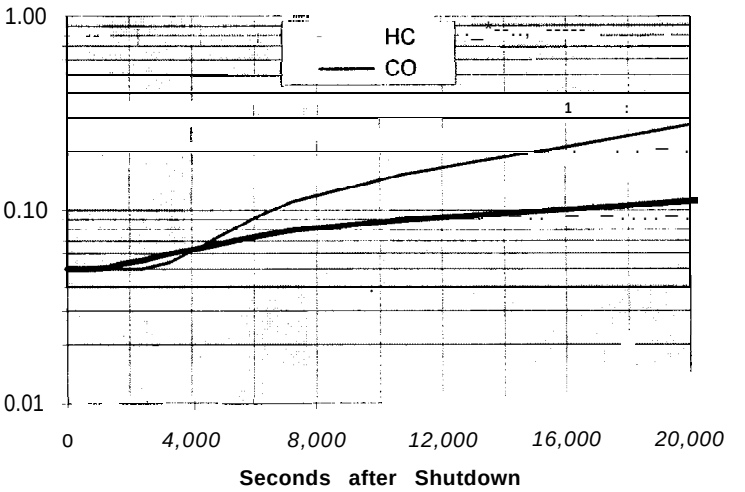


1/5/96 **Tailpipe Cold-to-Hot Ratios (Engine-out hot = 1.00)** **Engine: Normal** **Catalyst: EHC with VCI**

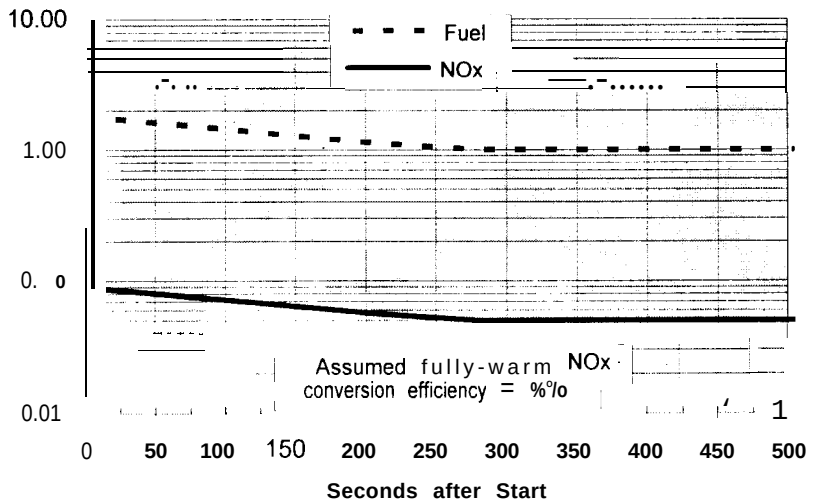
Warming from 24-hour Soak After Hot Shutoff



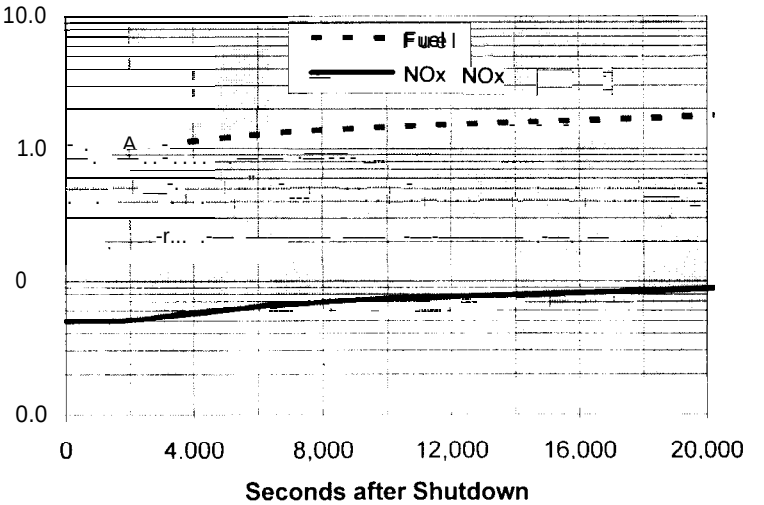
Cooling from Hot Shutoff



Warming from 24-hour Soak After Hot Shutoff



Cooling from Hot Shutoff



ICE Vehicle Simulations

The conventional powertrain runs used the same in-house generic 3. O-L hot engine map and hot catalyst efficiency map for both vehicles. The hybrid powertrain runs used the hot engine map and hot catalyst efficiency map of an early 1990s Geo (Suzuki) 1. O-L engine ruining in best-fuel strategy mode (21 hp), a 3.0 kWh ESS with 87% round trip efficiency, and 70% initial state of charge. All runs used the warmup routines discussed earlier and illustrated on pages 9-12.

The DSIM results are summarized in Table 2. Complete run reports appear in the Appendix. For the hybrid runs, two sets of emissions and MPG results are automatically generated: the first is for the driving cycle itself and the second includes the effect of running the engine after the cycle to restore ESS charge to its start-of-cycle value. For this recharge, the engine is assumed to restart immediately following Bag 4 with the C/H ratios in effect at that time.

Table 2 — Lumina and Taurus FTP Simulation Results

Vehicle	Drivetrain		Standard Catalyst	Quick-light Catalyst	Standard with VCI	Quick-light with VCI
Lumina	Conventional	HC gin/mile	0.146	0.102	0.105	0.098
	(with warming)	*CO* gin/mile	1.627	0.908	0.961	0.852
		NOX gin/mile	0.261	0.225	0.227	0.225
		MPG	19.6	19.6	19.6	19.6
	Series Hybrid	HC gin/mile	0.223	0.151	0.137	0.113
	(with warming/cooling)	*w/* charge restore	0.235	0.163	0.143	0.119
		CO gin/mile	2.522	1.456	1.019	0.505
		w/ charge restore	2.580	1.535	1,027	0.513
		NOX gin/mile	0.314	0.120	0.095	0.035
		w/ charge restore	0.331	0.138	0.095	0.035
		MPG	39.4	39.4	39.4	39.4
		w/ charge restore	37,2	37.2	37.2	37.2
			Standard Catalyst	**Quick-light Catalyst**	**Standard with VCI**	**Quick-light with VCI**
Taurus	Conventional	HC gin/mile	0.144	0.101	0.104	0.097
	(with warming)	*CO* gin/mile	1,341	0.649	0.698	0.592
		NOX gin/mile	0.241	0.209	0.211	0.209
		MPG	20.1	20.1	20.1	20.1
	Series Hybrid	HC gin/mile	0.219	0,146	0.132	0.109
	(with warming/cooling)	*w/* charge restore	0.230	0.158	0.138	0.114
		CO gin/mile	2.514	1.440	1.014	0.499
		w/ charge restore	2.573	1.520	1.022	0.507
		NOX gin/mile	0.315	0.119	0.095	0.035
		w/ charge restore	0.332	0,137	0.095	0.035
		MPG	41.1	41.1	41.1	41.1
		w/ charge restore	38.9	38.9	38.9	38.9

EMISSIONS

The main factors responsible for emissions differences between the conventional and hybrid cases come to light when examining the Bag 1 data, Table 3. For both the conventional and hybrid powertrains, that is where the first, by definition cold, start occurs (if the hybrid configuration is one that calls for engine start in Bag 1). The emissions results in the remaining bags are less significant. An item affecting all catalyst options is the difference between Bag 1 engine energy requirements for the hybrids vs. the conventional cases. Whereas the conventional engine responds straightforwardly to the traction demand in Bag 1, the engine in a series hybrid responds not to traction demand but to ESS recharge demand, which stems from traction but also relates to discharge efficiency in supplying traction energy *and* to the availability of regenerative braking energy *and* the use of it as influenced by charging efficiency *and* the charge rate limit if there is one. It so happens for the configurations studied that Bag 1 engine energy for the hybrids is less than that for the conventional cases.

Beyond this engine energy difference, the lightoff differences between the catalyst options produce results horizontally in the table that are generally similar for the conventional and the hybrids. Note that quick-light/no VCI comes out better than standard-light/VCI *in Bag 1* because the cooldown prevention of the VCI is of little help to Bag 1 emissions (note in Table 2, though, that over the whole cycle the VCI's cooldown mitigation effect does show.

Vertically in Table 3 (comparing conventional to hybrid), the emissions picture is more complex. For the conventional, for any catalyst option, each effective brake specific emission value is the composite of engine operation all over the engine map. For the hybrids, the BSemissions come from the engine's single operating statepoint, and it is the point of best BSFC, not necessarily best BSanyemission. As it turns out, the brake specific value for all emissions is usually worse for the hybrids. A major factor responsible for this is the fact that Bag 1 C/H ratios are better for the conventionals than the hybrids because of engine operating time. If the standard catalyst is lit by 80 seconds from start, the conventional engine enjoys 505-80 = 425 seconds of hot catalyst in Bag 1; in the hybrid, the engine only runs for some 225 seconds in Bag 1, so for the standard catalyst the engine sees only 145 seconds of hot catalyst effect. Other catalyst options see a similar effect.

Table 3 — Bag 1 Tailpipe Brake Specific Emissions, Lumina and Taurus

Vehicle	Drivetrain		Standard Catalyst	Quick-light Catalyst	Standard with VCI	Quick-light with VCI
Lumina	**Conventional**	HC gm/hp-hr	0.89	040	0.43	0.36
Bag 1 Engine hp-hr = 1.56		*CO* gm/hp-hr	12.89	4.91	5.50	4.28
		NOX gm/hp-hr	0.96	0.56	0,58	0.55
Lumina	Series Hybrid	HC gm/hp-hr	155	0.62	0.75	0.46
Bag 1 *Engine hp-hr = 1.41*		*CO* gm/hp-hr	25.58	8.41	10.99	4.65
		NOX gm/hp-hr	3.14	0.80	1.14	0.39
			Standard Catalyst	**Quick-light Catalyst**	**Standard with VCI**	**Quick-light with VCI**
Taurus	**Conventional**	HC gm/hp-hr	0.91	0.41	0.44	0.36
Bag 1 Engine hp-hr = 1.47		*CO* gm/hp-hr	11.85	3.71	4.29	3.05
		NOX gm/hp-hr	0.92	0.54	0.57	0.54
Taurus	Series Hybrid	HC gm/hp-hr	1.63	0.64	0.78	0.47
Bag 1 Engine hp-hr = 1.33		*CO* gm/hp-hr	26.99	8.83	11.57	4.89
		NOX gm/hp-hr	3.31	0.84	1.20	0.41

FUEL CONSUMPTION

Table 4 lists bag-by-bag particulars that explain the fuel consumption differences between the conventional powertrains and the hybrids. The primary difference is that, in all bags, engine BSFC and efficiency are better for the hybrid because the engine runs at best efficiency there whereas in the conventional case the engine runs all over the map.

The energy requirements in each bag were explained above and have a secondary effect that in most cases favors the hybrids.

For conventional powertrains the traction-derived energies demanded of the engine in Bags 1 and 3 are always the same, and ditto for Bags 2 and 4. Guaranteed. Always. (Neglecting minor changes in tire and drivetrain friction with warmup.) For hybrids, however, the energy requirements on the engine are by no means that simple or predictable. For the cases in Table 4, it turns out that engine energy values in Bags 1, 2, and 4 are less in the hybrids than in the conventional, but Murphy gets even in hybrid Bag 3. The equality of engine energy "for hybrid Bags 2 and 4 is a coincidence for this particular engine, engine strategy, and ESS configuration; it is quite possible to have engine operation in Bag 2 but none at all in Bag 4 (or v.v.) for other configurations.

Engine warmup is also at work here. Both conventional and hybrid engines take an efficiency hit in Bag 1 because of it, and the hybrid's hit is proportionately worse (compare Bag 1 and 3 efficiencies for the conventional and the hybrid cases).

Finally, end-of-cycle charge restoration affects fuel consumption in the hybrids but not in the conventional.

Table 4 — Fuel Consumption Specifics, Lumina and Taurus

		Bag 1	Bag 2	Bag 3	Bag 4	FTP	Chg reetore	Total
Lumina	Lbs fuel	1.13	1.31	0.97	1.31	2.35		2.35
Conventional	Gallons	0.183	0.212	0.157	0.212	0.381		0.381
	MPG	19.6	18.2	22.8	18.2	19.6		19.6
	Hp-hr	1.56	1,62	1.56	1,62	3.18		3,18
	Lb/hp-hr	0.73	0.81	0.62	0.81	0.74		0.74
	Efficiency	19%	17%	22%	17%	19%		19%
Lumina	Lbs fuel	0.82	0.46	0.64	0.45	1,17	0.07	1.24
Series Hybrid	Gallons	0.132	0.074	0.104	0.073	0.189	0.011	0.200
	MPG	27.1	52.3	34.6	53.1	39.4		37.2
	Hp-hr	1.41	1.09	1,56	1.09	2.59	0.157	2.74
	Lb/hp-hr	0.58	0.42	0.41	0.41	0.45	0.43	0.45
	Efficiency	24%	33%	34%	33%	30%	32%	31%
		Bag 1	**Bag 2**	**Bag 3**	**Bag 4**	**FTP**	**Chg restore**	**Total**
Taurus	Lbs fuel	1.08	1.30	0.93	1.30	2.29		2.29
Conventional	Gallons	0.175	0.210	0.150	0.210	0.370		0.370
	MPG	20.6	18.4	24.0	18.4	20.1		20.1
	Hp-hr	1.47	1.54	1.47	1,54	3.02		3.02
	Lb/hp-hr	0.73	0.84	0.63	0.84	0.76		0.76
	Efficiency	19%	16'%	22%	16%	18%		18%
Taurus	Lbs fuel	0.78	0.44	0.61	0.43	1.12	0.06	1.18
Series Hybrid	Gallons	0.127	0.072	0.098	0.070	0.181	0.010	0.192
	MPG	28.3	53.8	36.6	55.2	41.1		38.9
	Hp-hr	1.33	1.05	1.48	1.05	2.46	0.151	2.61
	Lb/hp-hr	0.59	0.42	0.41	0.41	0.45	0.43	0.45
	Efficiency	23%	33%	33%	33%	30%	32%	30%

Electric Vehicle Simulations

The two electric vehicles were simulated with a 4-bag FTP, charge and discharge efficiencies typical of Lead-Acid batteries on a pretty good day, regenerative braking, and no rate limits on charge or discharge. The calculated city ranges are based on FTP kWh/mile results and the withdrawal of 900/0 of an initial full charge at the selected discharge efficiency.

Emissions were estimated based on recharging 7.5 miles worth of kWh at the selected charge efficiency via the 92.5% efficient transmission of power from the utility plant. Given the SOW's requirement to estimate recharge emissions for EVS operating in the Los Angeles Basin and the fact that southern California imports much of its power from the mountain states (SoCal Edison's highest-capacity plant is a coal-burner in Utah last I heard), emissions associated with both the Mountain grid and the Pacific grid were estimated using their respective emission factors.

The resulting emissions values, Table 5, are either/or numbers with respect to the two grids: driving a GM Impact a mile generates 0.082 grams of NOX in the SCAB if all recharge power is locally produced, or generates 0.431 grams NOX in the mountain states if all its recharge power comes from there. If SoCalEd's power is 50% imported, that mile's recharge puts 0.041 grams NOX in SCAB air and 0.2155 grams in mountain air.

For comparison, Table 6 lists the 100,000-mile California standards for emitting HC, CO, and NOX into California air by ICE-powered passenger cars. There are no California standards for emissions into mountain states air as a result of operation of vehicles in California.

Table 5 — EV Recharge Emissions: Depends on the Source

	GM Impact 3		Chrysler TEVan	
Test Weight, Lbs	3,110		5,350	
Traction kWh/mile at ESS w/ regenerative braking	0.196		0.391	
ESS Capacity, kWh	16.8		23.6	
Charge Efficiency	81%		81%	
Discharge Efficiency	80%		80%	
Calculated City Range, miles	77		54	
Emissions per vehicle mile:	Mountain Grid	Pacific Grid	Mountain Grid	Pacific Grid
Gin/mile ROG	0.004	0.006	0.009	0.013
Gin/mile CO	0.032	0.035	0.064	0.070
Gin/mile NOX	0.431	0.082	0.859	0.163
Gin/mile SOX	0.710	0.072	1.416	0.144
Gin/mile PM_{10}	0.026	0.019	0.052	0.037

Table 6 — California Emission Standards, Grams/mile

	Fuel	HC	CO	NOX
Primary, 1995+	Gasoline	0.31	4.2	0.4
	Diesel	0.31	4.2	1.0
	Methanol	0.31	4.2	0.4
TLEV 1994-1996	Gasoline	0.31	4.2	0.6
	Clean	0.156	4.2	0.6
LEV 1997+	Gasoline	0.156	4.2	0.6
	Clean	0.09	3.4	0.4
ULEV 1997+	Gasoline	*0.09*	2.1	0.3
	Clean	0.055	2.1	0.3

Conclusions

California 100,000-mile ULEV sets the bar for emissions achievement. All conclusions apply only for the configurations analyzed — including the current production vintage gasoline-fueled piston engine maps. Note that the hybrid numbers are associated with an assumed 87% round trip efficiency, and tolerance for high charge and discharge rates – up to ballparks of over 4C average and 17C peak – for the energy storage system. Also note that the ESS capacity used in the hybrids, 3.0 kWh, has limited EV range and the engine statepoint used, 21 hp, has limited gradeability.

- The emissions (all 3) penalties for starting the hybrid engines after the FTP and restoring ESS initial state of charge are negligible.
- The emissions cost of cooldown and warmup in hybrid on/ off cycling range from minuscule to 15%, varying with catalyst option and pollutant.

HC

- Nothing on the ICE page (Table 2) meets ULEV HC, but conventional using quick-light catalysts and hybrids using quick-lights with VCI come close enough that a Schatz-type heat battery on the engine might lower engine-out emissions enough to pull them under.
- For all catalyst options, hybrids' HC emissions are higher than those of the conventional (50% higher for standard catalyst down to 12% higher for quick-light with VCI.
- EV HC emissions are dramatically lower than those of ICE vehicles for both power grids.

CO

- Everything on the ICE page meets ULEV CO except for the hybrids with standard catalyst.
- For all catalyst options except quick-light with VCI, hybrids' CO emissions are higher than those of the conventional.
- EV CO emissions are dramatically lower than those of ICE vehicles for both power grids.

NOX

- All ICE cases meet ULEV NOX except for the hybrids with standard catalysts.
- Hybrids with better-than-standard catalysts have lower NOX than the conventional.
- Everything on the ICE page (midsize cars) beats the EV NOX emissions (as small as GM Impact) for the Mountain grid. Unless Utah likes NOX and Colorado likes acid rain, they should keep an eye on EVS in southern California.
- The hybrids with quick-lights and VCI beat the Impact EV NOX level *for the Pacific grid*.
- The EVS exceed ULEV NOX (but the Impact meets LEV) with Mountain grid emissions.

FUEL

- Hybrids double City MPG.
- The fuel cost of cooldown and warmup is about 6%.

References

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Appendix

Simulation Reports

- Conventional Powertrains
- Hybrids
- EVS

DSIM FTP Simulation, Conventional Powertrain

Vehicle: '94 Ford Taurus GL 4D
Engine: Generic 3,0-L Push/2v
Transmission: L4
Axle: 3.37

Engine thermal: Normal
Catalyst thermal: Normal

FTP hp-hr/mile: 0.405
Avg. power, hp: 7.9
Avg. torque, **lb-ft:** 30.9
Avg. rpm: 1130

	Engine Out, Hot				Engine Out, with Warmup			
	Bag 1	**Bag** 2	**Bag** 3	FTP	Bag 1	Bag 2	Bag 3	FTP
HC grams:	**4.7**	**6.1**	**4.7**	**10.8**	6.1	6.1	4.7	11.4
CO grams:	**34.6**	**43.4**	**34.6**	**77.9**	56.4	43.4	34.6	87.3
NOX grams:	6.6	**5.1**	**6.6**	**11.6**	7.4	5.1	6.6	12.0
Fuel pounds:	**0.93**	**1.30**	**0,93**	**2.22**	1.08	1.30	0.93	2.29
HC gin/mile:	1.32	1.57	1.32	1.45	1.69	1.57	1.32	1.53
CO gin/mile:	9.62	11.24	9.62	10.46	15.70	11.24	9.62	11,72
NOX gin/mile:	1.83	1,32	1,83	1.56	2.06	1.32	1.83	1.61
Fuel economy, MPG:	24.0	18.4	24.0	20.7	20.6	18.4	24.0	20.1
HC **gm/hp-hr:**	3.2	3.9	3,2	3.6	4.1	3.9	3.2	3.8
CO **gm/hp-hr:**	23.4	28.1	23.4	25.8	38,3	28.1	23,4	29.0
NOX **gm/hp-hr:**	4.5	3.3	4,5	3.9	5.0	3.3	4.5	4.0
Fuel **lb/hp-hr:**	0.63	0.84	0.63	0.74	0.73	0.84	0.63	0.76
Engine efficiency:	21.9%	16.4%	21.9%	18.7%	18.8%	16.4%	21.9%	18.1%

	Exhaust w/ War-mup, Normal Catalyst				Exhaust w/ Warmup, Fast Catalyst			
	Bag 1	Bag 2	Bag 3	FTP	Bag 1	Bag 2	Bag 3	FTP
HC grams:	1.35	0.28	0.37	1.07	0.60	0.28	0.37	0.75
CO grams:	17.47	0.97	2.65	9.99	5.47	0.97	2.65	4.83
NOX grams:	1.35	0,82	0.69	1,80	0.80	0.82	0.69	1.56
HC **gin/mile:**	**0.38**	**0.07**	**0,10**	**0144**	**0,17**	**0.07**	**0.10**	**0.101**
CO gm/mile:	**4.87**	**0.25**	**0.74**	**1.341**	**1.52**	**0.25**	**0.74**	**0.649**
NOX gin/mile:	**0.38**	**0.21**	**0.19**	**0,241**	**0.22**	**0.21**	**0.19**	**0.209**
HC efficiency:	*78%*	*95%*	*92%*	*91%*	90%	95%	*92%*	*93%*
CO efficiency:	*69%*	*98%*	*92%*	*89%*	*90%*	*98%*	92%	94%
NOX efficiency:	82%	84%	90%	85%	89%	84%	*90%*	*87%*

DSIM FTP Simulation, Conventional Powertrain

Vehicle: '94 Ford Taurus GL 4D
Engine: Generic 3,0-L Push/2v
Transmission: L4
Axle: 3.37

Engine thermal: Normal
Catalyst thermal: VCI

FTP hp-hr/mile: 0.405
Avg. power, hp: 7.9
Avg. torque, lb-ft: 309
Avg. rpm: 1130

	Engine Out, Hot				Engine Out, with Warmup			
	Bag 1	**Bag** 2	Bag 3	FTP	**Bag 1**	**Bag** 2	Bag 3	FTP
HC grams:	4.7	6.1	4.7	10.8	6.1	6.1	*4 7*	*11.4*
CO grams:	34,6	43.4	34.6	77.9	*56.4*	*43.4*	*34.6*	*87.3*
NOX grams:	6.6	5.1	6.6	11,6	*7.4*	*5.1*	6.6	*12.0*
Fuel pounds:	0.93	1.30	0.93	2.22	*1.08*	*1.30*	*0.93*	*2.29*
HC gin/mile:	**1.32**	**1.57**	**1.32**	**1.45**	**1.69**	**1.57**	**1.32**	**1.53**
CO gin/mile:	9.62	**11.24**	**9,62**	**10.46**	15.70	**11.24**	**9.62**	**11,72**
NOX gin/mile:	**1.83**	**1.32**	**1.83**	**1.56**	**2.06**	**1.32**	**1.83**	**1.61**
Fuel economy, MPG:	**24.0**	18.4	**24.0**	**20.7**	**20.6**	**18.4**	**24,0**	**20.1**
HC gm/hp-hr:	**3.2**	**3.9**	**3.2**	3.6	4.1	**3.9**	**3.2**	**3.8**
CO gm/hp-hr:	**23.4**	**28.1**	**23,4**	**25.8**	**38.3**	**28.1**	**23.4**	**29.0**
NOX gm/hp-hr:	**4.5**	**3.3**	**4.5**	**3.9**	**5.0**	**3.3**	**4.5**	**4.0**
Fuel lb/hp-hr:	**0.63**	**0.84**	**0.63**	**074**	**0.73**	**0.84**	**0.63**	**0.76**
Engine efficiency:	21.9%	**16.4%**	**21 .9%**	**18.7%**	**18.8%**	**16.4%**	**21.9%**	**18. 1.%**

	Exhaust w/ Warmup, Normal Catalyst				Exhaust w/ Warmup, Fast Catalyst			
	Bag 1	**Bag** 2	Bag 3	FTP	Bag 1	Bag 2	Bag 3	FTP
HC grams:	0.66	0.28	0.37	0.77	0.53	0.28	037	0.72
CO grams:	6.33	0.97	2.65	5.20	4.50	0.97	2.65	4.41
NOX grams:	0.84	0.82	0.69	1.58	0.79	0.82	0.69	1.55
HC **gin/mile:**	**0.18**	**0.07**	**0.10**	**0.104**	**0.15**	*0.07*	*0.10*	*0.097*
CO **gin/mile:**	**1.76**	**0.25**	**0.74**	**0.698**	**1.25**	**0,25**	**074**	**0.592**
NOX gin/mile:	**0.23**	**0.21**	**0.19**	**0.211**	**0.22**	**0.21**	**0.19**	**0.209**
HC efficiency:	89%	95%	92%	93%	91%	95%	92%	94%
CO efficiency:	89%	98%	92%	94%	92%	98%	92%	95%
NOX efficiency:	89%	84%	90%	87%	89%	84%	90%	87%

DSIM FTP Simulation, Conventional Powertrain

Vehicle: '94 Chev. Lumina 4D
Engine: Generic 3. O-L Push/2v
Transmission: L4
Axle: 3.33

Engine thermal: Normal
Catalyst thermal: Normal

FTP hp-hr/mile: 0.427
Avg. power, hp: 8.3
Avg. torque, lb-ft: 31.8
Avg. rpm: 1146

	Engine Out, Hot				Engine Out, with Warmup			
	Bag 1	Bag 2	Bag 3	FTP	Bag 1	Bag 2	Bag 3	FTP
HC grams:	4.9	6.2	4.9	11.1	6.2	6.2	4.9	11.6
CO grams:	39.1	44.5	39.1	83.6	62.5	44.5	39.1	93.7
NOX grams:	7,0	5.5	7.0	12.5	7.9	5.5	*7,0*	*12.9*
Fuel pounds:	0.97	1.31	0.97	2,29	*1.13*	1.31	*0.97*	*2.35*
HC gin/mile:	1.35	1.61	1,35	1.48	1.73	1.61	1.35	1.56
CO gin/mile:	10.89	11.53	10,89	11.22	17.41	11.53	10.89	12.57
NOX gin/mile:	1.94	1.43	1.94	1,68	2.20	1.43	1.94	1,73
Fuel economy, MPG:	22.8	18.2	22.8	*20.1*	*19.6*	*18.2*	*22.8*	*19.6*
HC gm/hp-hr:	3.1	3.8	3.1	3.5	4.0	3.8	3.1	3.7
CO gm/hp-hr:	25.1	27.5	25.1	26.3	40.1	27.5	25.1	29,5
NOX gm/hp-hr:	4.5	3.4	4.5	3.9	5.1	3.4	4.5	4.1
Fuel lb/hp-hr:	0.62	0.81	0.62	0.72	0.73	0.81	0.62	0.74
Engine efficiency:	22.1%	17.0V0	22.1%	19,1%	19,0%	17.0%	22.1%	18.6%

	Exhaust w/ Warmup, Normal Catalyst				Exhaust w/ Warmup, Fast Catalyst			
	Bag 1	Bag 2	Bag 3	FTP	Bag 1	Bag 2	Bag 3	FTP
HC grams:	1.38	0.27	0,39	1,09	0.63	0.27	0.39	0.76
CO grams:	20.10	0.97	4.40	12,12	7.65	0.97	4.40	6.77
NOX grams:	1.49	0,88	0.75	1.94	0.87	0.88	0.75	1.68
HC gin/mile:	0.38	0.07	0.11	0.146	0.17	0,07	0.11	0.102
CO gin/mile:	5.60	0.25	1.22	1.627	2.13	0.25	1.22	0.908
NOX gin/mile:	0.41	0.23	0.21	0,261	0.24	0.23	0.21	0.225
HC efficiency:	78%	96%	92%	91%	90%	96%	92%	93%
CO efficiency:	68%	98%	89%	87%	88%	98%	89%	93%
NOX efficiency:	81%	84%	89%	85%	89%	84%	89%	87%

DSIM FTP Simulation, Conventional Powertrain

Vehicle: '94 Chev. Lumina 4D
Engine: Generic 3. O-L Push/2v
Transmission: L4
Axle: 3.33

Engine thermal: Normal
Catalyst thermal: VCI

FTP hp-hr/mile: 0.427
Avg. power, hp: 8.3
Avg. torque, lb-ft: 31.8
Avg. rpm: 1146

	Engine Out, Hot				Engine Out, with Warmup			
	Bag 1	Bag 2	Bag 3	FTP	Bag 1	Bag 2	Bag 3	FTP
HC grams:	4.9	6.2	4.9	11.1	6.2	6.2	4.9	11,6
CO grams:	39.1	44.5	39.1	83.6	62.5	44.5	391	93.7
NOX grams:	7,0	5.5	7.0	12.5	7.9	5.5	7.0	12.9
Fuel pounds:	0.97	1.31	0.97	2.29	1,13	1.31	0.97	2.35
HC gin/mile:	1.35	1.61	1.35	1.48	1.73	1.61	1.35	1.56
CO gin/mile:	10,89	11.53	10.89	11.22	17.41	11.53	10.89	12.57
NOX gin/mile:	1.94	1.43	1.94	1.68	2.20	1.43	1.94	173
Fuel economy, MPG:	22.8	18.2	22.8	20.1	19,6	18.2	22.8	19.6
HC gm/hp-hr:	3.1	3.8	3.1	3.5	4.0	3.8	3.1	37
CO gm/hp-hr:	25.1	27.5	25.1	26.3	40.1	27.5	25.1	29.5
NOX gm/hp-hr:	4.5	3.4	4.5	3.9	5.1	3 4	4,5	4.1
Fuel lb/hp-hr:	0.62	0.81	0,62	0.72	0.73	0.81	0.62	0.74
Engine efficiency:	22.1%	17.0%	22.1%	19.1%	19.0%	17.0%	22.1%	18.6!/0

	Exhaust w/ Warmup, Normal Catalyst				Exhaust w/ Warmup, Fast Catalyst			
	Bag 1	Bag 2	Bag 3	FTP	Bag 1	Bag 2	Bag 3	FTP
HC grams:	0.68	0.27	0.39	0.78	0.56	0.27	0.39	0.73
CO grams:	8.57	0.97	4.40	7.16	6.68	0.97	4.40	6.35
NOX grams:	0.91	0.88	0.75	1.69	0.86	0.88	0.75	1.67
HC gin/mile:	0.19	0,07	0.11	0.105	0.15	0.07	0.11	0.098
CO gin/mile:	2.39	0.25	1.22	0,961	1.86	0.25	1.22	0.852
NOX gin/mile:	0.25	0.23	0.21	0.227	0.24	0.23	0.21	0.225
HC efficiency:	89%	96%	92%	93%	*91%*	96%	*92%*	*94%*
CO efficiency:	86?40	98%	89%	92%	*89%*	*9 8*	*%89%*	93%
NOX efficiency:	88%	84%	89%	87%	*89%*	*84%*	*89%*	*87%*

DSIM FTP Simulation, Series Hybrid Powertrain

Vehicle : Ford Taurus GL 4D	ESS capacity, kWh : 3.00
Vehicle weight: 3304	ESS charge efficiency : 94%
Engine: Geo 1. O-L 2valv Metro	ESS disch efficiency : 93%
Engine strategy : Best Fuel	ESS initial SOC : 70%
Engine Hp : 21,0	Charge start SoC : 50%
Thermal - engine, catalyst: Normal, Normal	Charge stop SoC : 70%
Grade, 55 mph, Engine : 2.0%	Eng hp-hr, drive : 2.46
ESS minutes that grade: 10.7	ESS end-cycle SOC : 66%
Engine City Range, miles : 347	Eng hp-hr, restore initial SoC : 0.15
ESS City Range, miles : 11.7	Tot Eng hphr: 2.61
Engine duty, drive : 31%'.	#Engine starts : 3
Avg sec eng on, drive : 211	Eng see, restore ini SOC : 26

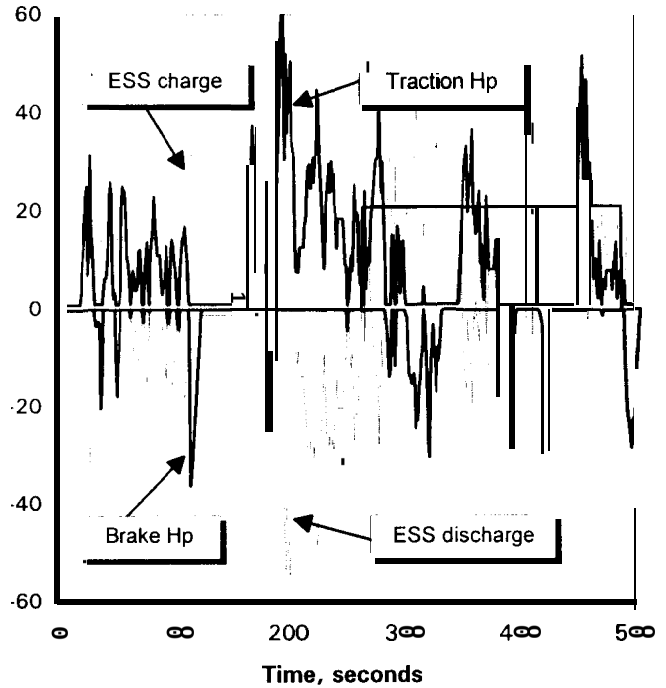
Engine, by Bag	Bag 1	Bag 2	Bag 3	Bag 4	FTP			
Grams HC starts	0.018	0.018	0.018	0.018	0.035	resto chg	Grams/mile HC	
drive, engine-out hot	3.41	2.70	3.79	2,70	6.32	0.09	0.85	hot eng-out
drive, cat effect hot	-3.06	-2.41	-3.39	-2,41	-5.66	grams	0,09	hot exhaust
cool/warm effect	1.79	0.09	0.14	0.09	0.93	1.63	0.22	cool exhaust
start effect% vs. drive hot	0.5%	0.6%	0.5%	0.6%	0.6%	resto chg	0.23	cool exh + resto
cool effect% vs. drive hot	52%	3%	4'%	3%	15%	5.2%		
Grams CO starts	0.163	0.163	0.163	0.163	0.325	resto chg	Grams/mile CO	
drive, engine-out hot	27.5	21.7	30.6	21.7	51.0	0.44	6.89	hot eng-out
drive, cat effect hot	-27.1	-21.4	-30.1	-21.4	-50.2	grams	0,15	hot exhaust
cool/warm effect	35.29	1.48	1.67	1,47	17.6	18.7	2.51	cool exhaust
start effect% vs. drive hot	0.6%	0.7%	0.5%	0,7%	0.6%	resto chg	2.57	cool exh + resto
cool effect% vs. drive hot	128%	7%	5%	7'%	35%	2.3%		
Grsms NOX starts	0.010	0.010	0.010	0.010	0.020	resto chg	Grams/mile NOX	
drive, engine-out hot	10.07	7.95	11.17	7.95	18.65	0.12	2.51	hot eng-out
drive, cat effect hot	-10.07	-7.95	-11.17	-7.95	-18.64	grams	0.003	hot exhaust
cool/warm effect	4.40	0.21	0,39	0.21	2.32	2.35	0.315	cool exhaust
start effect% vs. drive hot	0.1%	0,1%	0.1%	0.1%	0.1%	resto chg	0.332	cool exh + resto
cool effect% vs. drive hot	44%	3%	4%	3%	12?40	5.3%		
Lbs Fuel starts	0.003	0.003	0.003	0.003	0.005	resto chg		
drive, engine-out hot	0.54	0.43	0.60	0.43	1.01	0.065	City MPG	
drive, cat effect hot	0.00	0.00	0.00	0.00	0.00	pounds	45.5	hot
cool/warm effect	0.24	0.01	0.00	0,00	0.11	1.12	41.1	cool
start effect% vs. drive hot	0.5%	0.6%	0.4%	0.6%	0.5%	resto chg	38.9	cool + resto
cool effect% vs. drive hot	43%	3%	o%	o%	11%	5.8%		
Engine Hp-hr :	1,330	1.050	1.476	1.050	2,463		Highway MPG	
							48.6	hot
ESS, by Bag	Bag 1	Bag 2	Bag 3	Bag 4	FTP		48.6	cool
Driving cycle kWh :	1.099	1.150	1.099	1.150	2.249		47.2	cool + resto
Net kWh from/to (+/-) ESS :	-0.037	0.142	-0.140	0.142	0.046			
Maximum SOC :	71%	71%	71%	71%	71%			
Minimum SOC :	50%	50%	49%	50%	49%		Combined (CAFE) MPG	
Average charge C :	5.2	3.7	5.2	3.7	4.4		46,8	hot
Average discharge C :	-2.8	-1,7	-2.8	-1.7	-2.3		44.2	cool
Maximum charge C :	13	11	13	11	13		42.2	cool + resto
Maximum discharge C :	-16	-10	-16	-lo	-16			

Vehicle: 3304 lb
Ford Taurus GL 4D

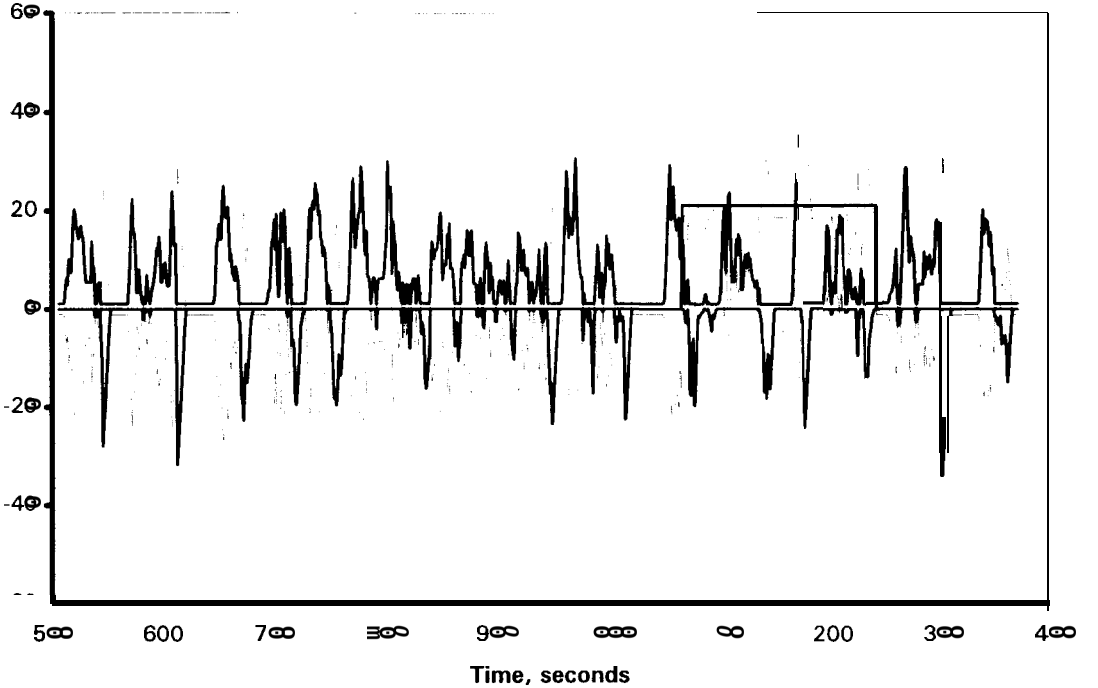
ESS: 3.0 kWh
87% RT Efficiency

Engine: 21 Hp
Strategy: Best Fuel

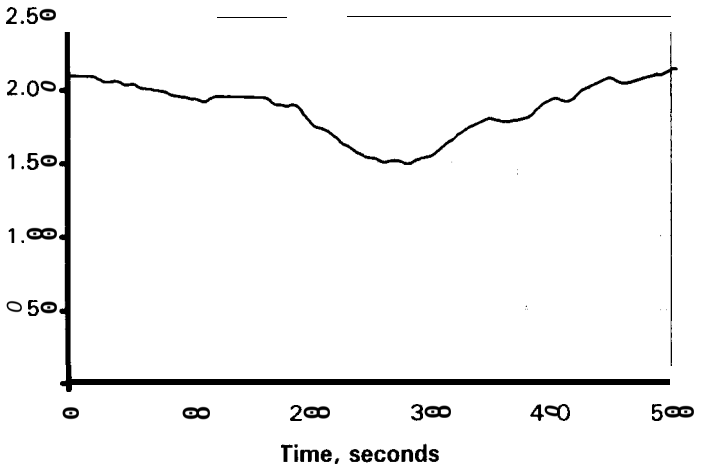
FTP Bag 1: Power Flow, Hp



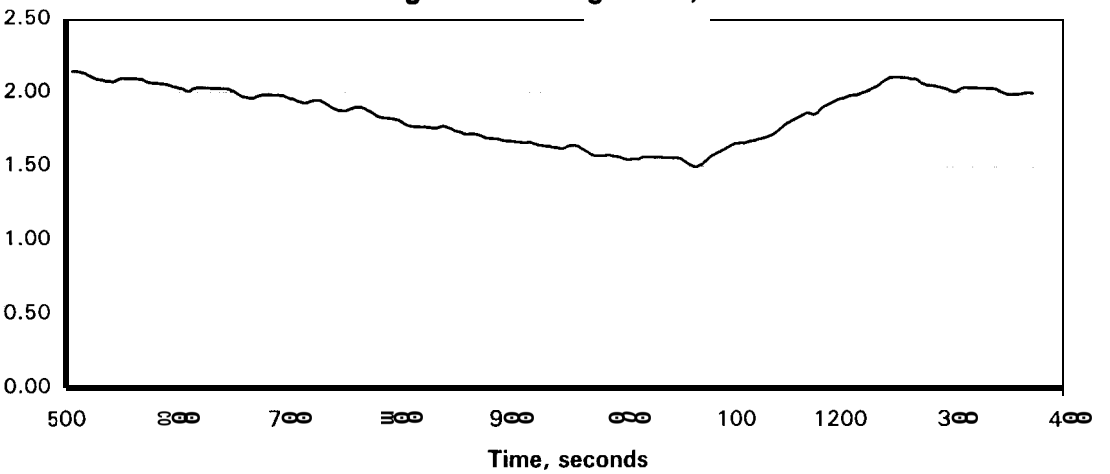
FTP Bag 2: Power Flow, Hp



FTP Bag 1: ESS Charge State, kWh



FTP Bag 2: ESS Charge State, kWh

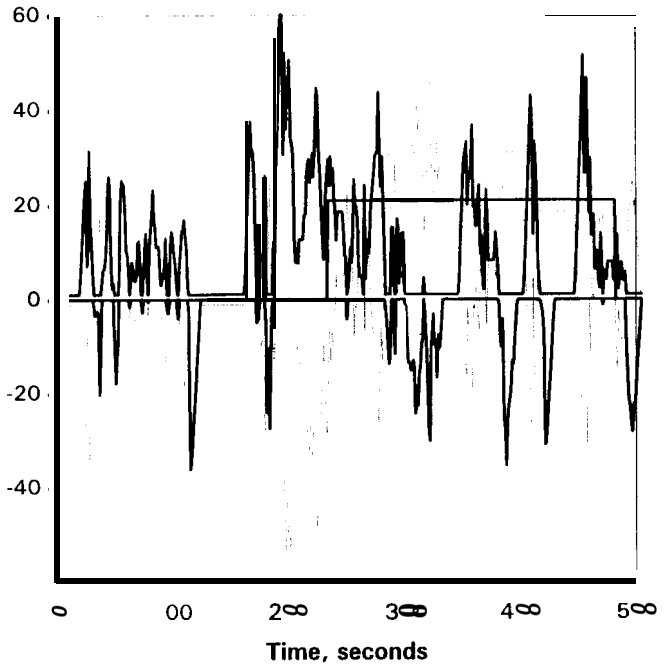


Vehicle: 3304 lb
Ford Taurus GL 4D

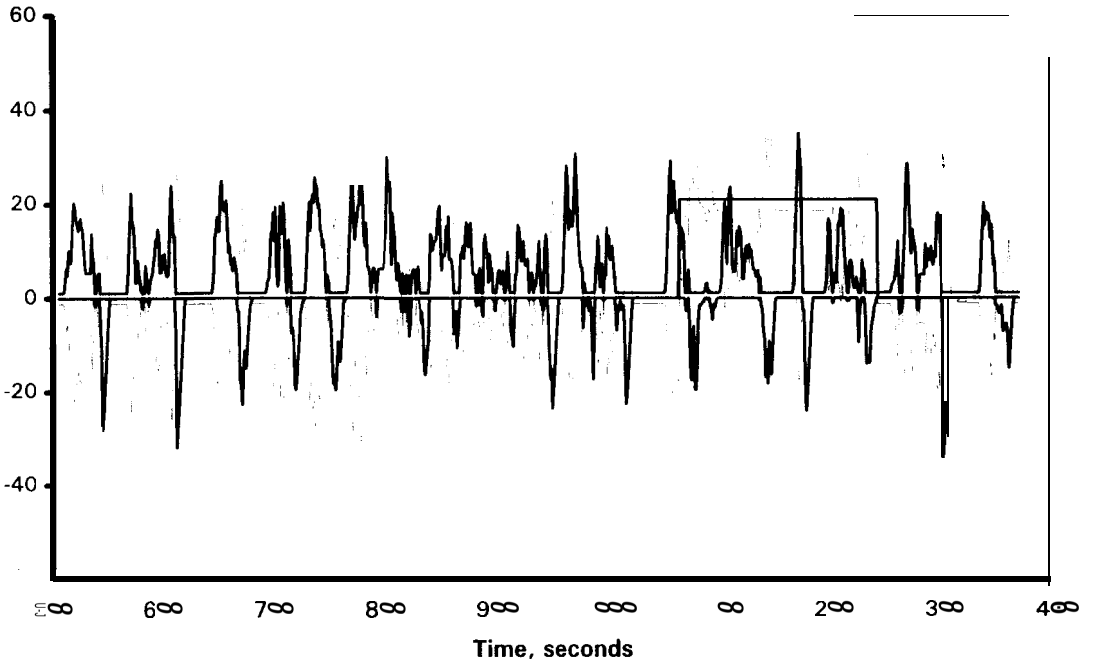
ESS: 3.0 kWh
87% RT Efficiency

Engine: 21 Hp
Strategy: Best Fuel

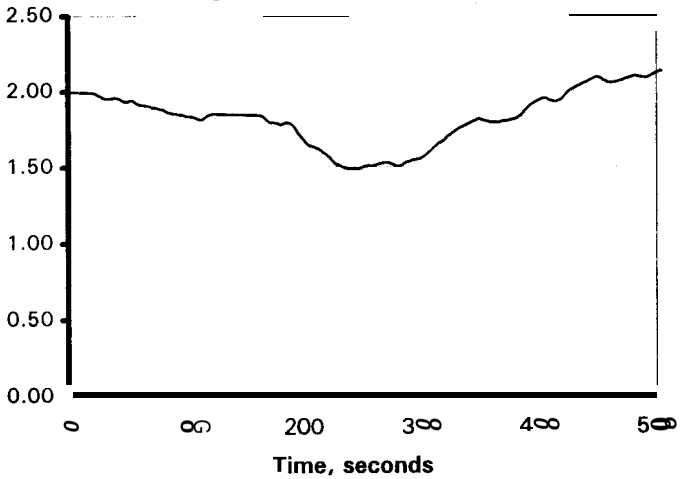
FTP Bag 3: Power Flow, Hp



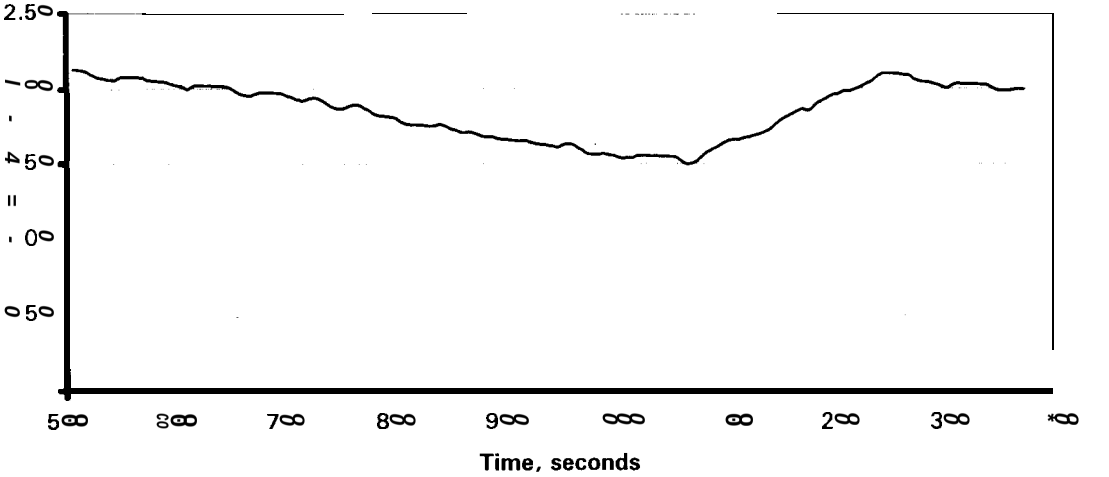
FTP Bag 4: Power Flow, Hp



FTP Bag 3: ESS Charge State, kWh



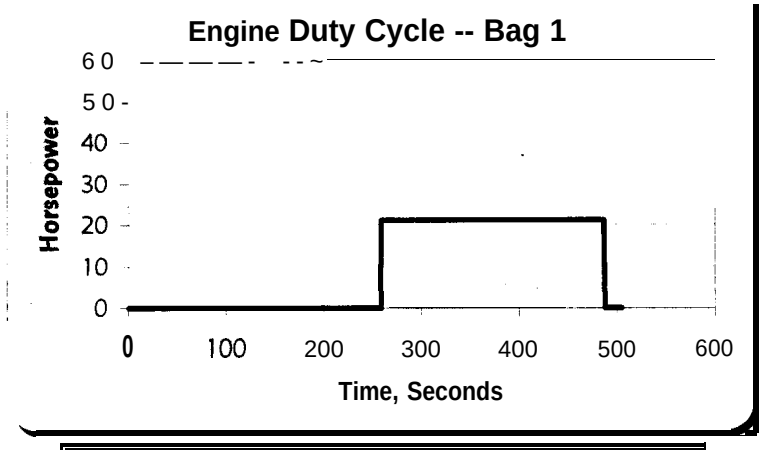
FTP Bag 4: ESS Charge State, kWh



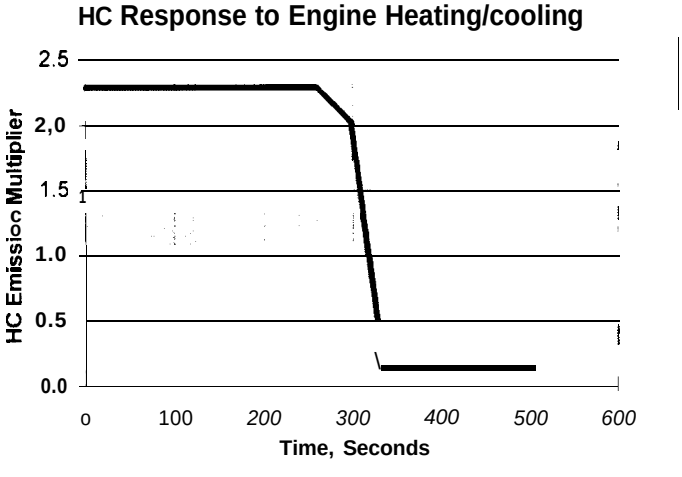
Vehicle: 3304 lb
Ford Taurus GL 4D
Engine Strategy: Best Fuel

ESS: 3.0 kWh
87% RT Efficiency
Cool Strategy: Engine = Normal; Catalyst = Normal

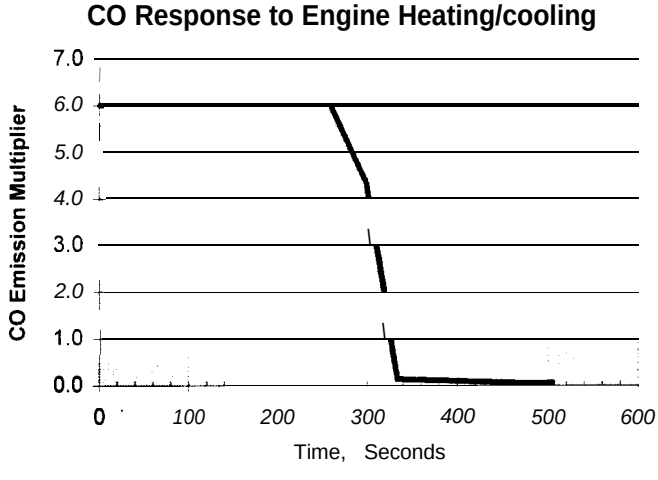
Engine: 21 Hp
Geo 1. O-L 2valv Metro



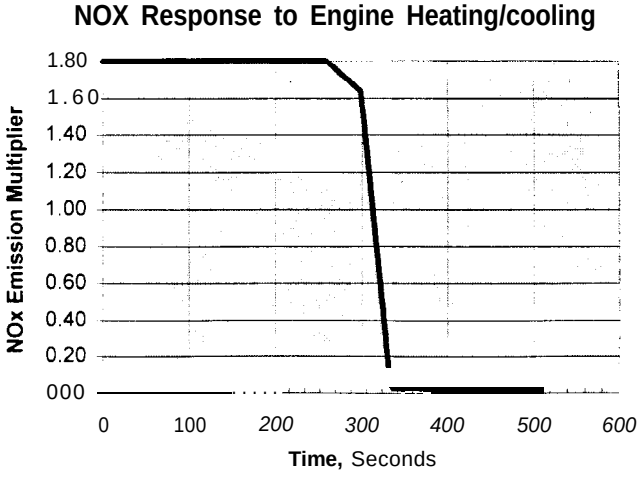
Bag 1 starts cold



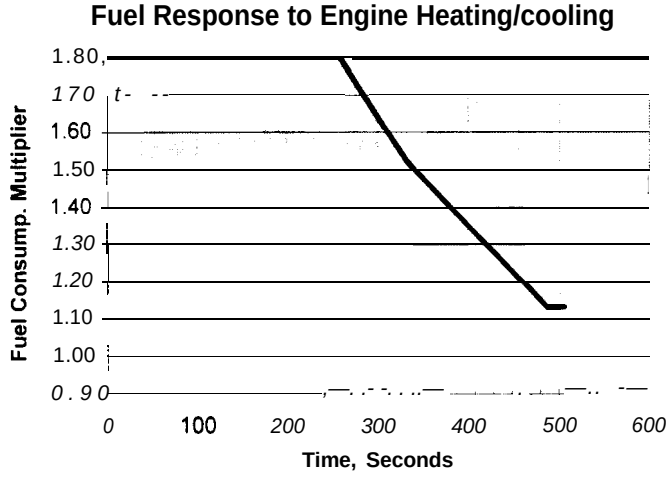
Avg. HC Multiplier: 0.628 while engine running



Avg. CO Multiplier: 1.297 while engine running



Avg. NOX** Multiplier: 0.437 **while engine running

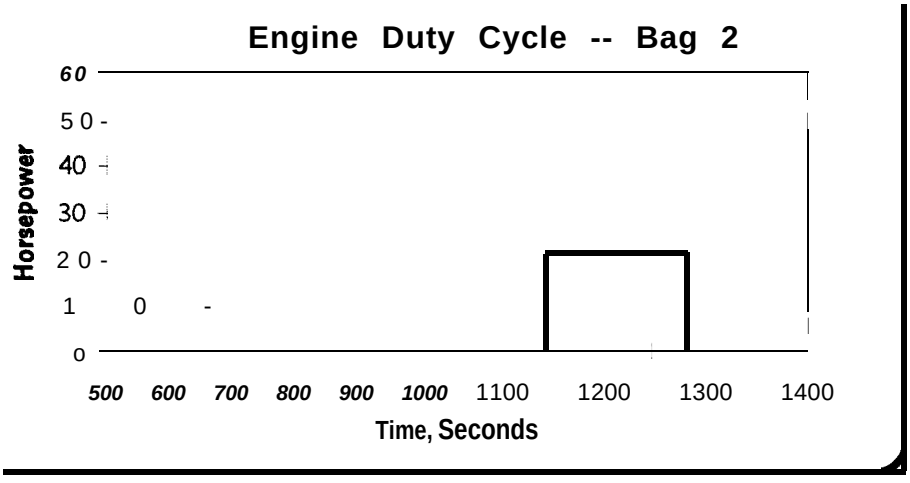


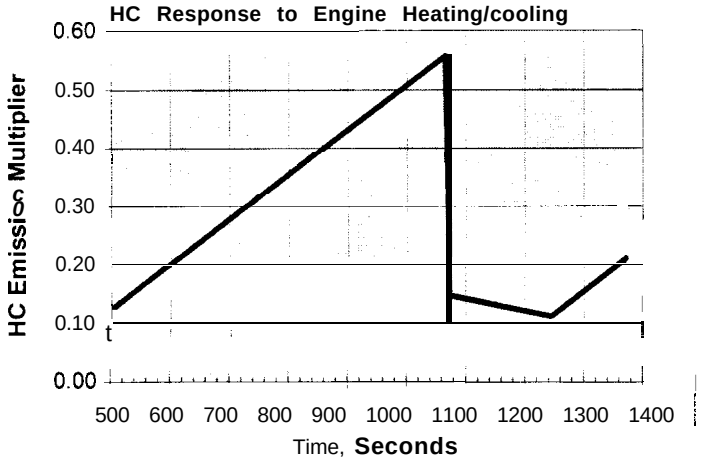
Avg. Fuel Multiplier:* 1.434 *while engine running

Vehicle: 3304 lb
Ford Taurus GL 4D
Engine Strategy: Best Fuel

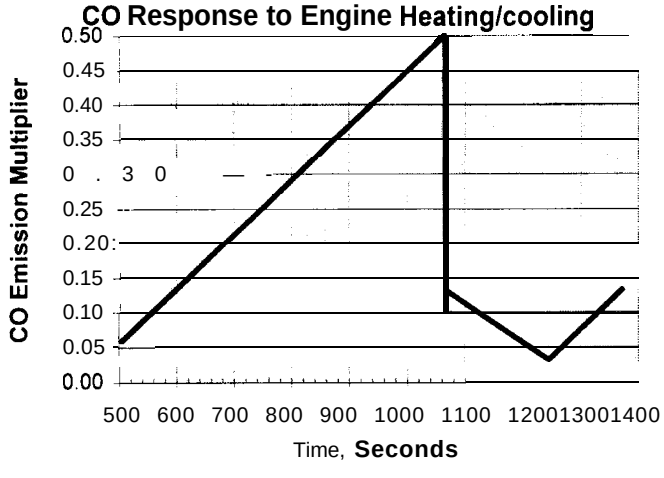
ESS: 3.0 kWh
87% RT Efficiency
Cool Strategy: Engine = Normal; Catalyst= Normal

Engine: 21 tip
Geo 10-L 2valv Metro

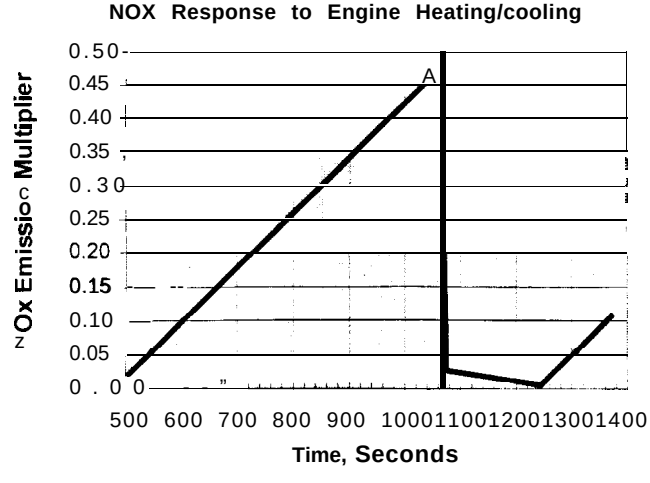




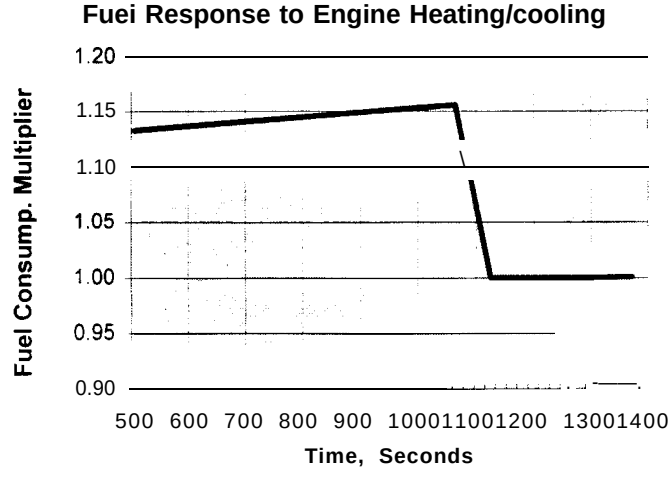
Avg. HC Multiplier: 0.138 while engine running



Avg. CO Multiplier: 0.084 while engine running



Avg. NOX Multiplier: 0.027 while engine running



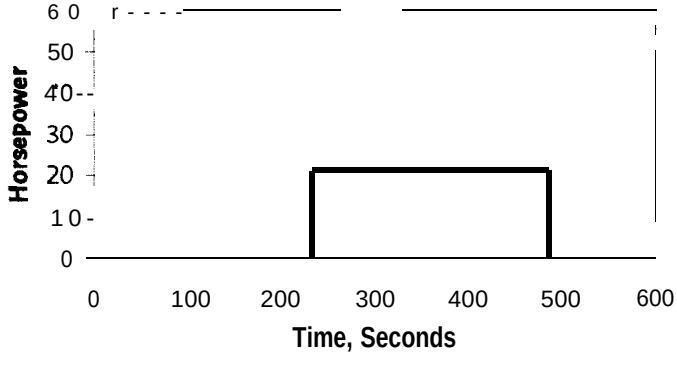
Avg. Fuel Multiplier: 1,026 while engine running

Vehicle: 3304 lb
Ford Taurus GL 4D
Engine Strategy: Best Fuel

ESS: 3.0 kWh
87% RT Efficiency
Cool Strategy: Engine = Normal; Catalyst = Normal

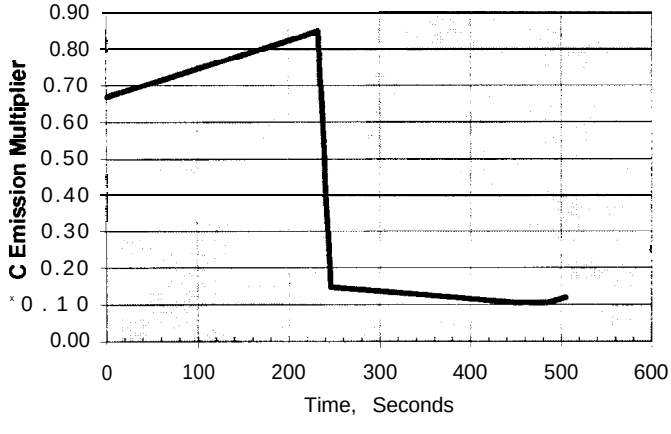
Engine: 21 Hp
Geo 1. O-L 2valv Metro

Engine Duty Cycle -- Bag 3



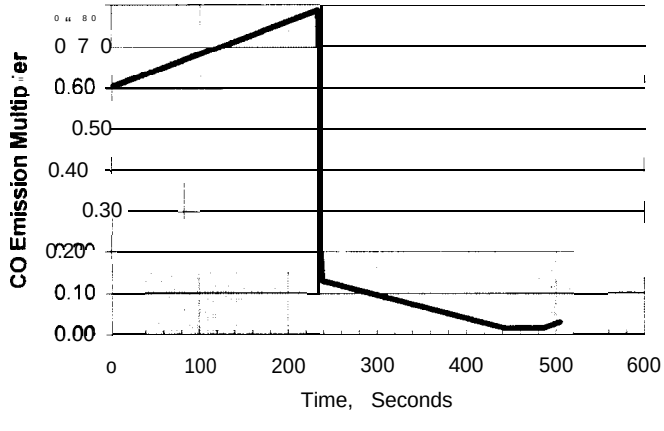
Bag 3 starts after ten minute cooldown

HC Response to Engine Heating/cooling



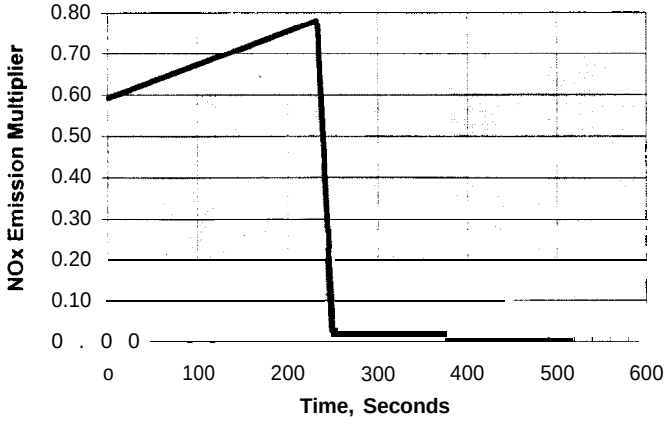
Avg. HC Multiplier: 0.141 while engine running

CO Response to Engine Heating/cooling



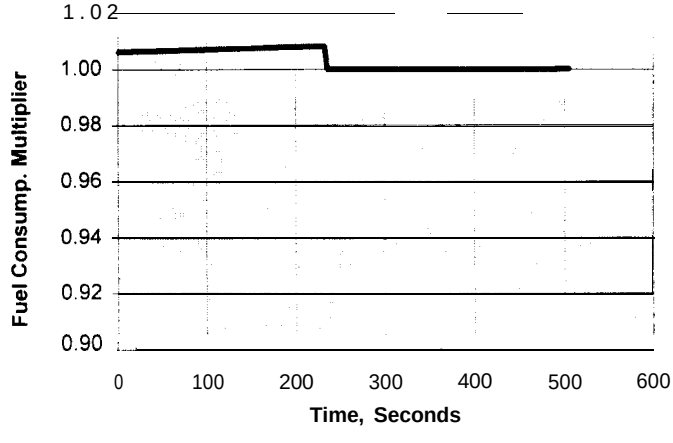
Avg. CO Multiplier: 0.070 while engine running

NOX Response to Engine Heating/cooling



Avg. NOX Multiplier: 0.035 while engine running

Fuel Response to Engine Heating/cooling

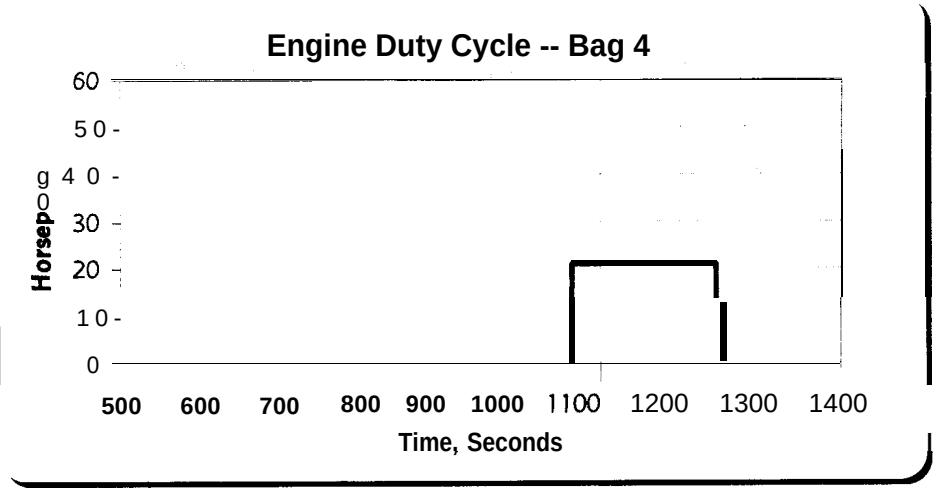


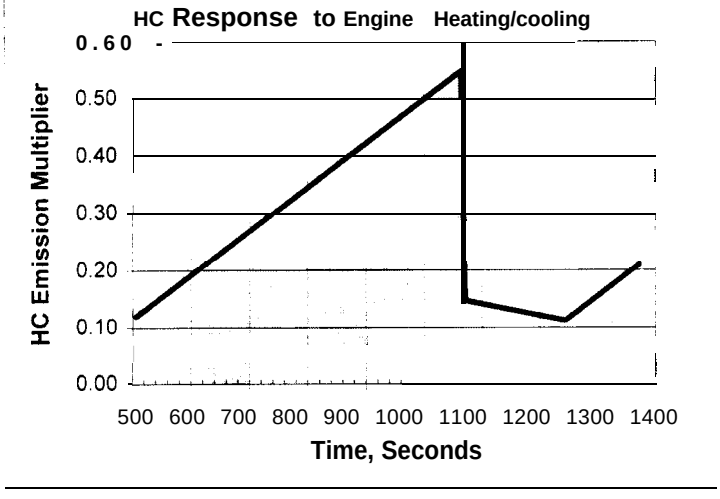
Avg. Fuel Multiplier: 1.000 while engine running

Vehicle: 3304 lb
Ford Taurus GL 4D
Engine Strategy: Best Fuel

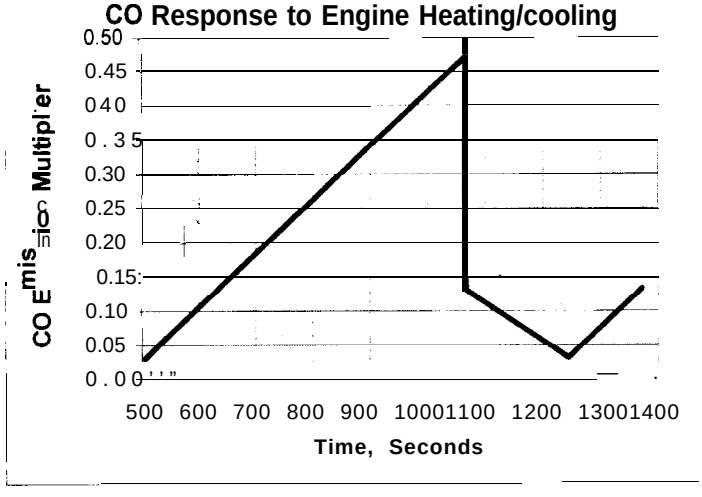
ESS: 3.0 kWh
87% RT Efficiency
Cool Strategy: Engine = Normal; Catalyst = Normal

Engine: 21 Hp
Geo 1. O-L 2valv Metro

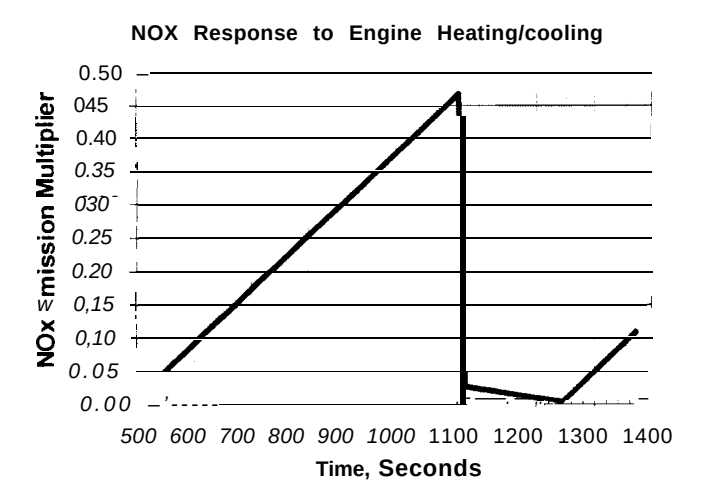




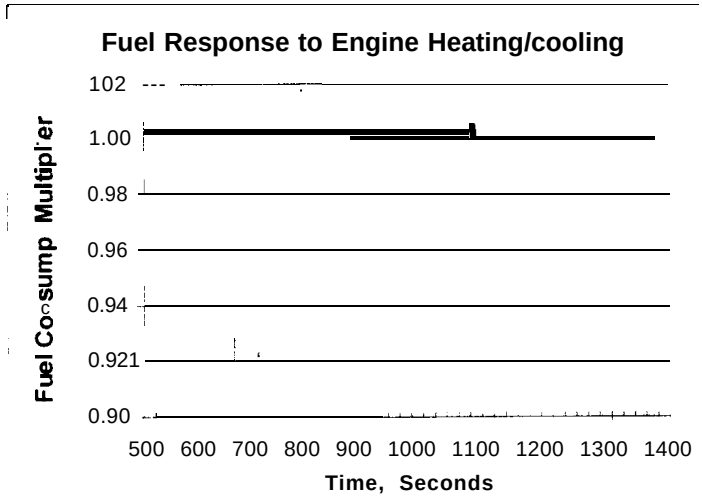
Avg. HC Multiplier: 0.137 while engine running



Avg. CO Multiplier: 0.083 while engine running



Avg. NOX Multiplier: 0.026 while engine running



Avg. Fuel Multiplier: 1.000 while engine running

DSIM FTP Simulation, Series Hybrid Powertrain

Vehicle : Ford Taurus GL 4D
Vehicle weight: 3304
Engine : Geo 1.0-L 2valv Metro
Engine strategy : Best Fuel
Engine Hp : 21.0
Thermal - engine, catalyst : Normal, EHC

ESS capacity, kWh : 3.00
ESS charge efficiency : 94%
ESS disch efficiency : 93%
ESS initial SOC : 70%
Charge start SOC : 50%
Charge stop SOC : 70%

Grade, 55 mph, Engine : 2.0%
ESS minutes that grade : 10.7
Engine City Range, miles : 347
ESS City Range, miles : 11.7
Engine duty, drive : 31%
Avg sec eng on, drive : 211

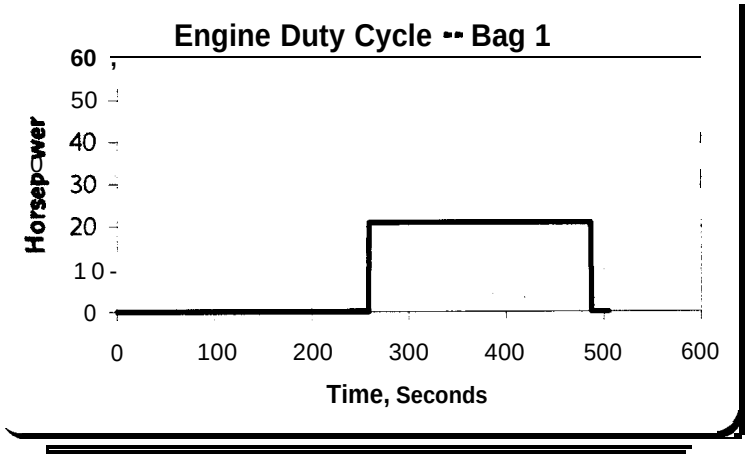
Eng hp-hr, drive : 2.46
ESS end-cycle SOC : 66%
Eng **hp-hr,** restore **initial SOC : 0.15**
Tot Eng hphr: 2,61
Engine starts : 3
Eng see, restore ini SOC : 26

Engine, by Bag	**Bag 1**	**Bag** 2	Bag 3	Bag 4	FTP			
Grams HC starts	0.018	0.018	0.018	0.018	*0.035*	resto chg	Grams/mile HC	
drive, engine-out hot	3.41	2.70	3.79	2.70	6.32	*0,09*	0.85	hot **eng-out**
drive, cat effect hot	-3.06	-2.41	-3.39	-2.41	-5.66	grams	0.09	hot exhaust
cool/warm effect	0.48	0,11	0.14	0.11	0.39	1.09	0.15	cool exhaust
start effect% vs. drive hot	0.5%	0.6%	*0.5%*	0.6%	0.6%	resto chg	0.16	cool exh + resto
cool effect% vs. drive hot	14%	4%	4%	4%	6%	8,2%		
Grams CO starts	0.163	0.163	*0.163*	0.163	0.325	resto chg	Grams/mile CO	
drive, engine-out hot	27,5	21.7	*30.6*	21.7	51.0	0.60	6.89	hot **eng-out**
drive, cat effect hot	-27.1	-21.4	*-30,1*	-21.4	-50.2	grams	0.15	hot exhaust
cool/warm effect	11.14	2.93	*3.29*	2.93	9.6	10.7	1.44	cool exhaust
start effect% vs. drive hot	0.6%	*0.7%*	0.5%	0.7%	0.6%	resto chg	1,52	COOl exh + resto
cool effect% vs. drive hot	40%	*13?40*	11%	1370	19%	5.5%		
Grams NOX starts	0.010	0.010	0,010	0.010	0.020	resto chg	Grams/mile NOX	
drive, engine-out hot	10.07	7.95	11.17	7,95	18.65	0.13	2.51	hot **eng-out**
drive, cat effect hot	-10,07	-7.95	-11,17	-7.95	-18.84	grams	0.003	hot exhaust
cool/warm effect	1.11	0,22	0,30	0.22	0.87	0.89	O.119	cool exhaust
start effect% vs. drive hot	0.1%	0.1%	0.1%	0.1%	0.1%	resto chg	0.137	cool exh + resto
cool effect % vs. drive hot	I1%	3%	3%	3%	5%	1 5.0%		
Lbs Fuel starts	0.003	0.003	0.003	0.003	0.005	resto chg		
drive, engine-out hot	0.54	0.43	0.60	0.43	1.01	0.065	City MPG	
drive, cat effect hot	0.00	0.00	0.00	0.00	0.00	pounds	45.5	hot
cool/warm effect	0.24	0.01	0.00	0,00	0.11	1.12	41.1	cool
start effect% vs. drive hot	0,5%	0.6%	0.4%	0.6%	0.5%	resto chg	38.9	cool + resto
cool effect% vs. drive hot	43%	3%	o%	o%	11?'0	5.8%		
Engine Hp-hr:	1.330	1.050	1.476	1.050	2.463		**Highway MPG**	
							48.6	hot
ESS, by Bag	Bag 1	Bag 2	Bag 3	Bag 4	FTP		48,6	cool
Driving cycle kWh :	1.099	1.150	1.099	1.150	2.249		47.2	cool + resto
Net kWh from/to (+/-) ESS :	-0.037	0.142	-0.140	0.142	0.046			
Maximum SOC :	71%	71%	7170	71%	71%			
Minimum SOC :	50%	50%	49%	50%	49%		Combined (CAFE) MPG	
Average charge C :	5.2	3.7	5.2	3.7	4.4		46.8	hot
Average discharge C :	-2,8	-1.7	-2.8	-1,7	-2.3		44.2	cool
Maximum charge C :	13	11	13	11	13		42.2	cool + resto
Maximum discharge C :	-16	-Io	-16	-Io	-16			

Vehicle: 3304 lb
Ford Taurus GL 4D
Engine Strategy: Best Fuel

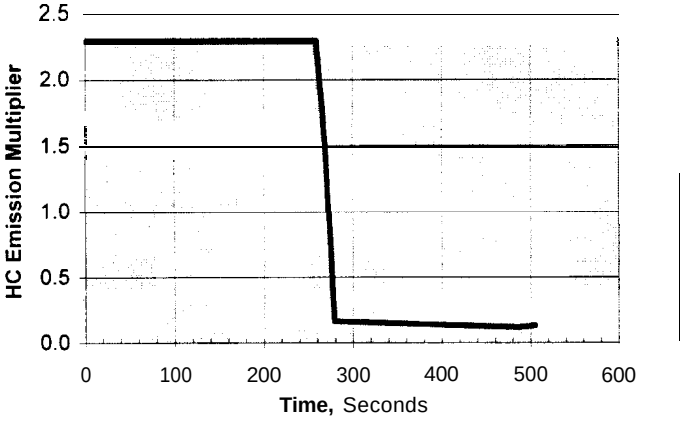
ESS: 3.0 kWh
87% RT Efficiency
Warm Scenario: Engine = Normal; Catalyst= EHC

Engine: 21 Hp
Geo 1. O-L 2valv Metro



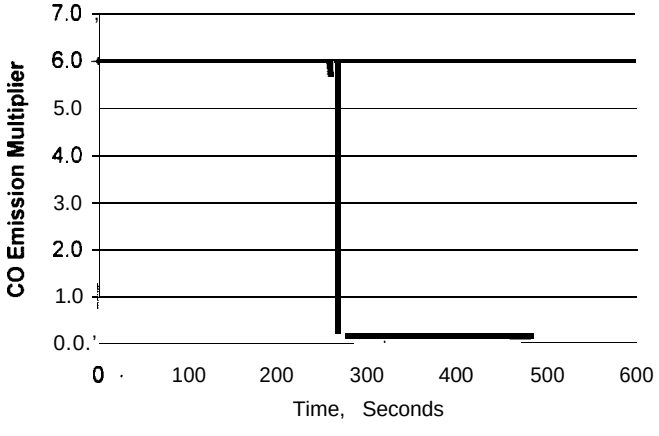
Bag 1 starts cold

HC Response to Engine Heating/cooling



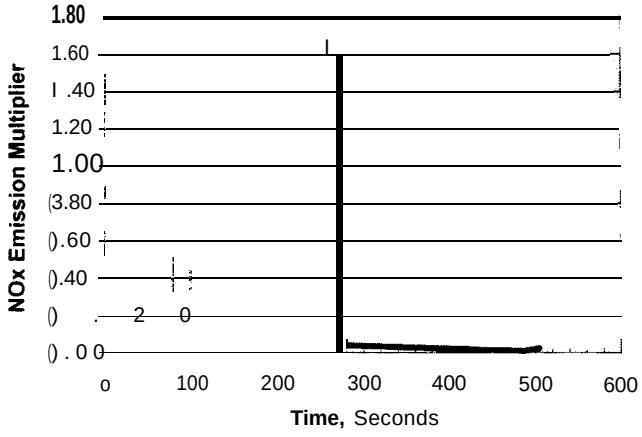
Avg. HC Multiplier: 0.245 while engine running

CO Response to Engine Heating/cooling



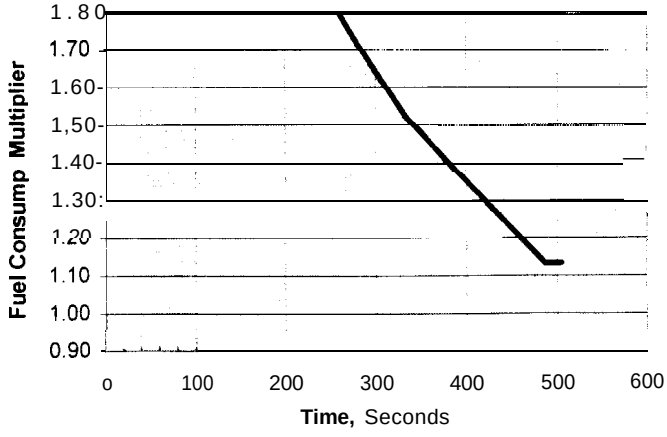
Avg. CO Multiplier: 0,420 while engine running

NOX Response to Engine Heating/cooling



Avg. NOX Multiplier: 0.110 while engine running

Fuel Response to Engine Heating/cooling

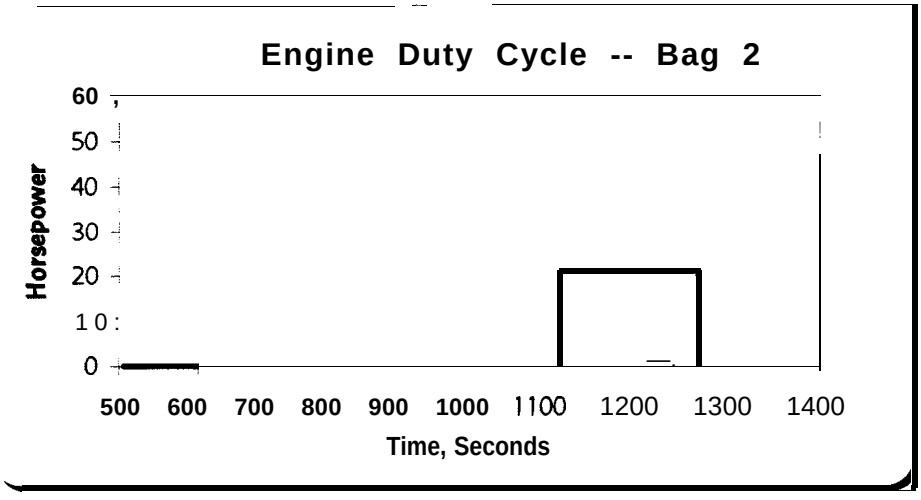


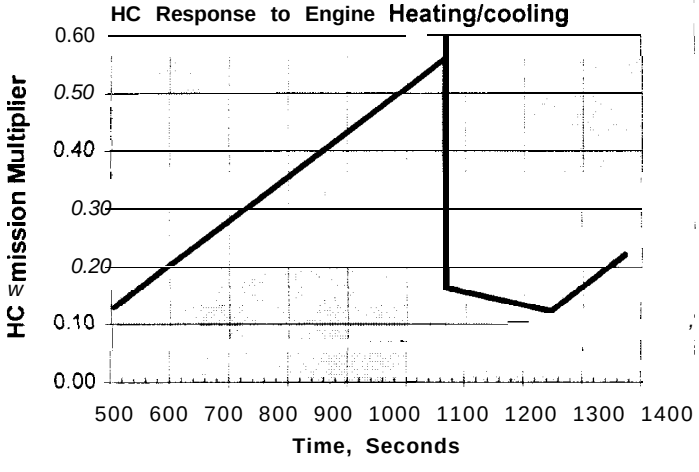
Avg. Fuel Multiplier: 1.434 *while engine running*

Vehicle: 3304 TD
Ford Taurus GL 4D
Engine Strategy: Best Fuel

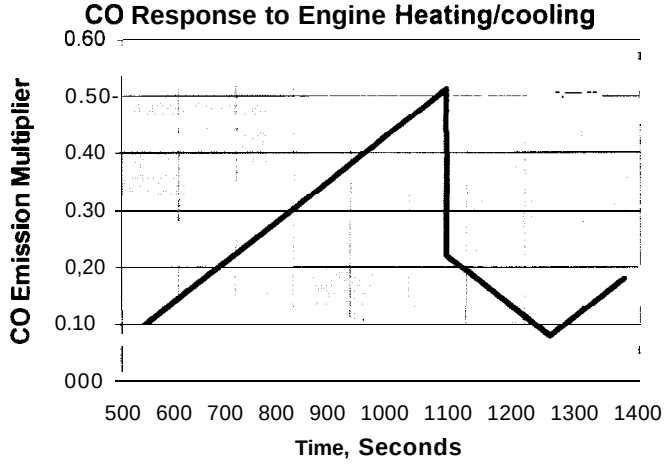
ESS 3.0 kWh
87% RT Efficiency
Warm Scenario: Engine = Normal; Catalyst= EHC

Engine: 21 Hp
Geo 1. O-L 2valv Metro

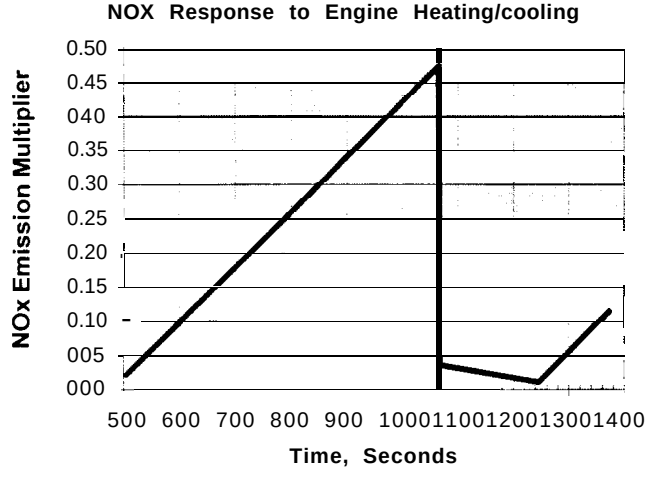




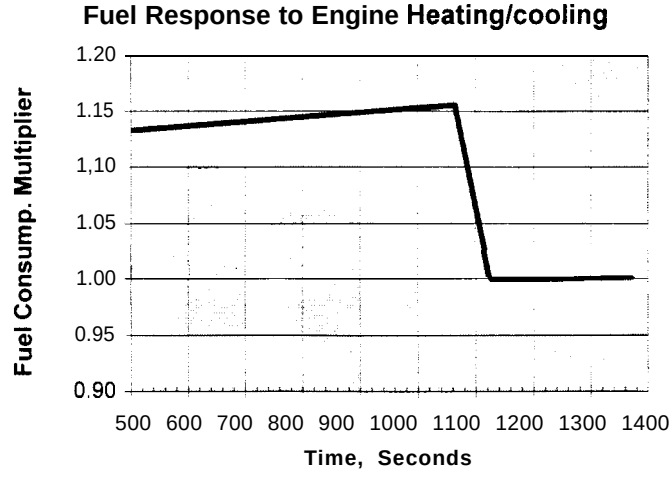
Avg. HC Multiplier: 0.145 while engine running



Avg. CO Multiplier: 0.151 while engine running



Avg. NOX Multiplier: 0.027 while engine running

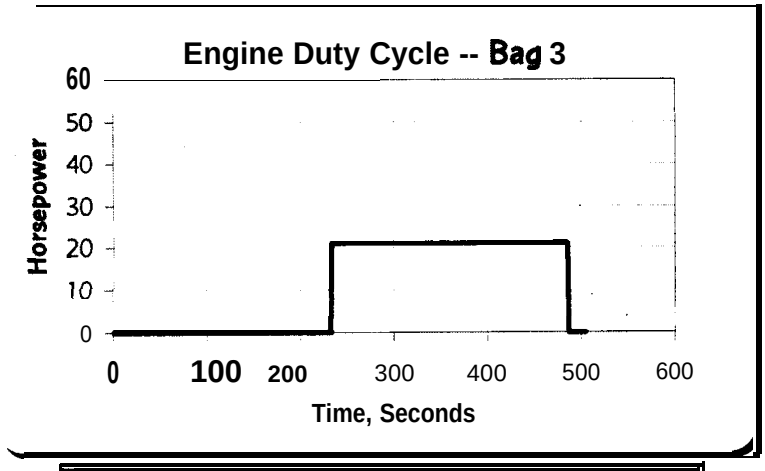


Avg. Fuel Multiplier 1.026 while engine running

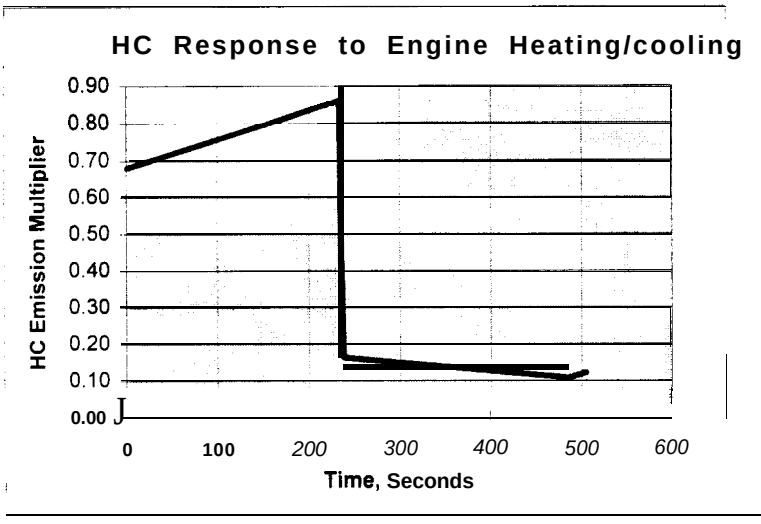
Vehicle: 3304 lb
Ford Taurus GL 4D
Engine Strategy: Best Fuel

ESS: 3.0 kWh
87% RT Efficiency
Warm Scenario: Engine = Normal; Catalyst= EHC

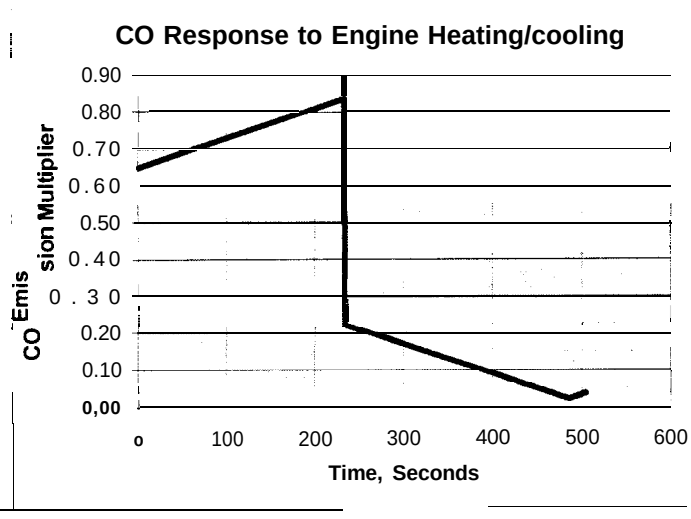
Engine: 21 Hp
Geo 1. O-L 2valv Metro



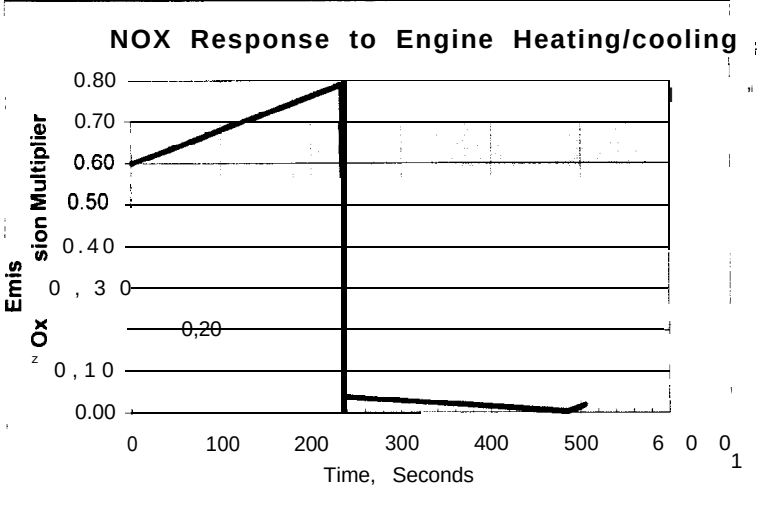
Bag 3 starts after ten minute cooldown



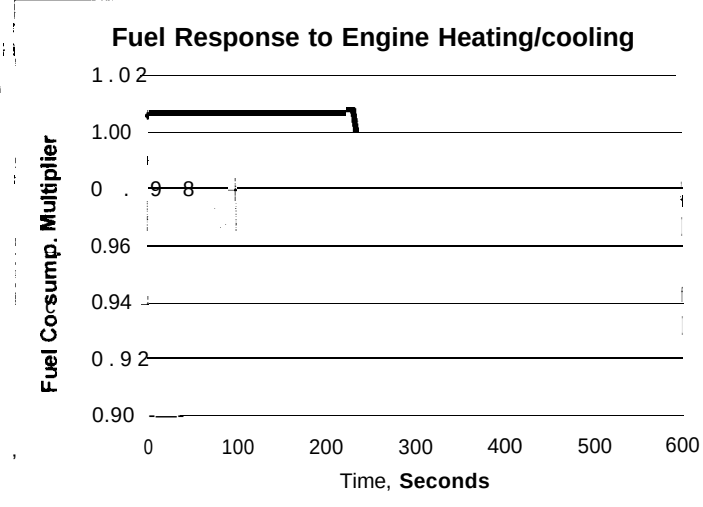
Avg. HC Multiplier: 0.141 while engine running



Avg. CO Multiplier: 0.123 while engine running



Avg. NOX Multiplier: 0.027 while engine running

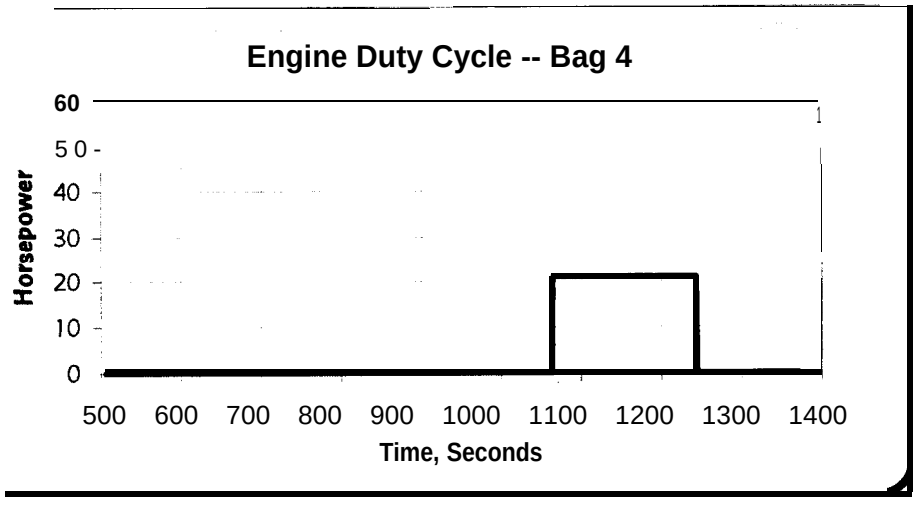


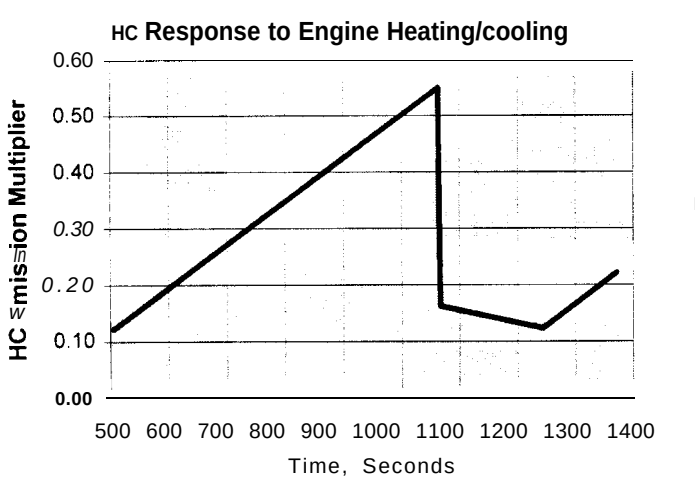
Avg. Fuel Multiplier: 1,000 while engine running

Vehicle: 3304 lb
Ford Taurus GL 4D
Engine Strategy: Best Fuel

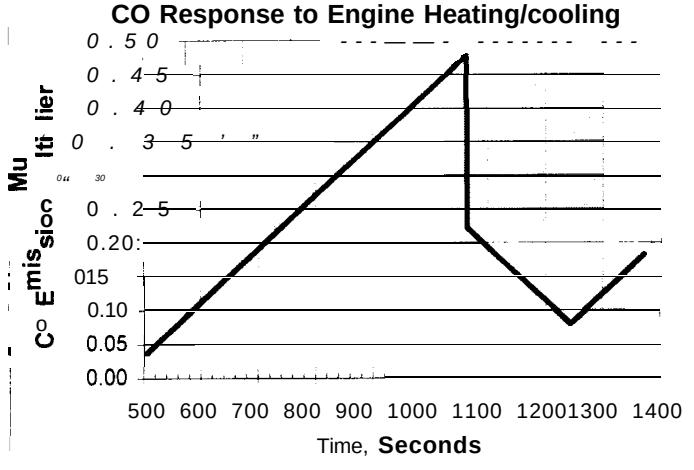
ESS: 3.0 kWh
87% RT Efficiency
Warm Scenario: Engine = Normal; Catalyst= EHC

Engine: 21 Hp
Geo 10-L 2valv Metro

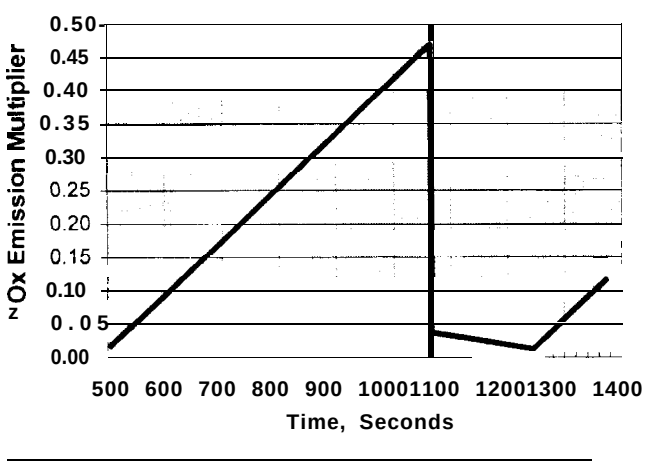




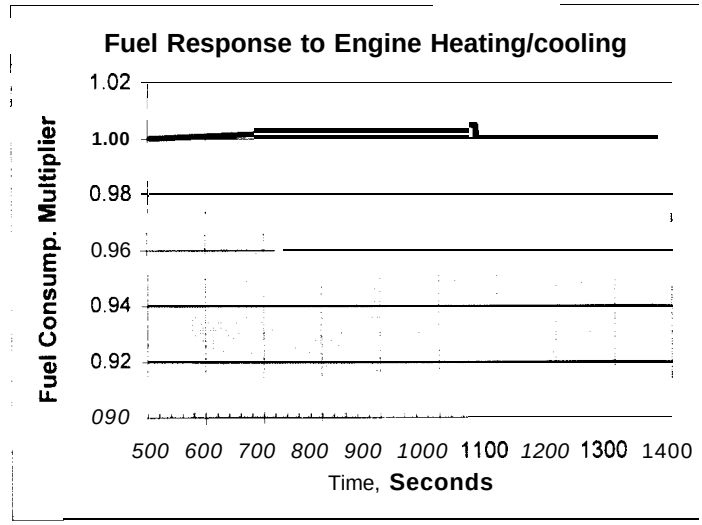
Avg. HC Multiplier: 0.145 while engine running



Avg. CO Multiplier: 0.151 while engine running



Avg. NOX Multiplier: 0.027 while engine running



Avg. Fuel Multiplier: 1.000 while engine running

DSIM FTP Simulation, Series Hybrid Powertrain

Vehicle :	Ford Taurus GL 4D	**ESS capacity, kWh :**	*3.00*
Vehicle weight:	3304	**ESS charge efficiency :**	*94%*
Engine :	Geo 1. O-L 2valv Metro	**ESS disch efficiency :**	93%
Engine strategy :	Best Fuel	**ESS initial SOC :**	70%
Engine Hp :	21.0	**Charge start SOC :**	50%
Thermal - engine, catalyst :	Normal, VCI	**Charge stop SOC :**	70%
Grade, 55 mph, Engine :	*2.0%*	**Eng hp-hr, drive :**	**2.46**
ESS minutes that grade :	*10.7*	**ESS end-cycle SOC :**	66%
Engine City Range, miles :	*347*	**Eng hp-hr, restore initial SOC :**	**0.15**
ESS City Range, miles :	*11.7*	**Tot Eng hphr:**	**2.61**
Engine duty, drive :	31%	**# Engine starta :**	**3**
Avg sec eng on, drive :	*211*	**Eng see, restore ini SOC :**	**26**

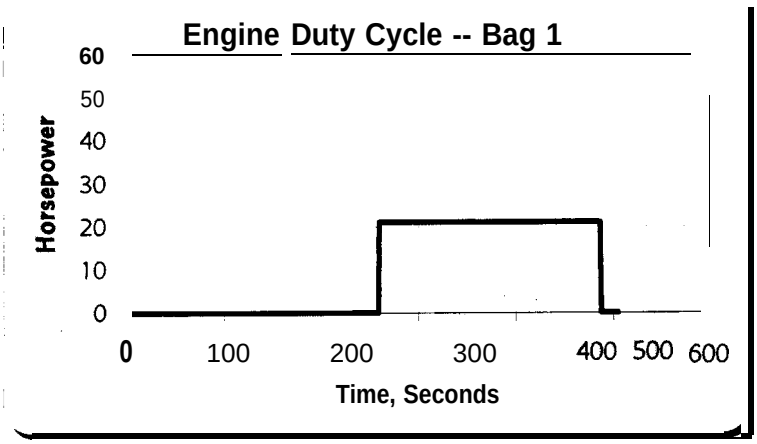
Engine, by Bag	Bag 1	Bag 2	Bag 3	Bag 4	FTP		
Grams HC starts	**0.018**	**0.018**	**0.018**	**0.018**	**0.035**	resto chg	**Grams/mile HC**
drive, engine-out hot	3.41	**2.70**	**3.79**	**2.70**	**6.32**	**0.04**	**0.85** hot eng-out
drive, cat effect hot	-3.06	**-2.41**	**-3.39**	**-2.41**	**-5.66**	grams	0.09 hot exhaust
cool/warm effect	0.66	**0.01**	**0.00**	**0.00**	**0.29**	**0.99**	0.13 cool exhaust
start effect% vs. drive hot	0.5%	0.6%	**0.5%**	**0.6%**	**0.6%**	resto chg	0.14 cool exh + resto
cool effect% vs. drive hot	19%	o%	o%	o%	5%	4.3%	
Grams CO starts	0.163	0.163	0.163	**0.163**	**0.325**	resto chg	**Grams/mile CO**
drive, engine-out hot	27.5	21.7	30,6	**21,7**	**51.0**	**0,06**	**6.89 hot eng-out**
drive, cat effect hot	-27.1	-21.4	-30.1	**-21.4**	**-50.2**	grams	**0.15 hot exhaust**
cool/warm effect	14.79	0.15	0.01	**0.00**	**6.4**	**7.6**	**1.01 cool exhaust**
start effect% vs. drive hot	0.6%	0.7%	0.5%	**0.7%**	**0.6%**	resto chg	**1.02 cool exh + resto**
cool effect% vs. drive hot	54%	1%	0%	o%	13%	0.7%	
Grams NOX starts	0.010	0.010	0.010	0.010	0.020	resto chg	**Grams/mile NOX**
drive, engine-out hot	10.07	7.95	11.17	**7.95**	18.65	**0.00**	**2.51 hot eng-out**
drive, cat effect hot	-10.07	-7.95	-11.17	**-7.95**	-18.64	grams	**0.003 hot exhaust**
cool/warm effect	1.58	0.01	0.00	**0.00**	0.69	0.71	**0.095 cool exhaust**
start effect% vs. drive hot	0,1%	0.1%	0.1%	**0.1%**	0.1%	resto chg	**0.095 cool exh + resto**
cool effect% vs. drive hot	16%	o%	o%	0%	4 %	0,1%	
Lbs Fuel starts	0.003	0.003	0,003	0.003	0.005	resto chg	
drive, engine-out hot	0.54	0.43	0.60	0.43	1.01	0.065	**City MPG**
drive, cat effect hot	0.00	0.00	0,00	0.00	0.00	pounds	**45.5 hot**
cool/warm effect	0.24	0.01	0.00	0.00	0.11	1.12	**41.1 cool**
start effect% vs. drive hot	0.5%	0.6%	0.4%	0,6%	0.5%	resto chg	**38.9 cool + resto**
cool effect% vs. drive hot	43%	3%	o%	o%	11%	5.8%	
Engine Hp-hr:	I .330	1.050	1.476	1.050	**2.463**		**Highway MPG**
							48.6 hot

ESS, by Bag	Bag 1	Bag 2	Bag 3	Bag 4	FTP	
Driving cycle kWh :	**1.099**	**1.150**	**1.099**	**1.150**	**2,249**	**48.6 cool**
Net kWh from/to (+/-) ESS :	-0.037	0.142	-0,140	0.142	0.046	**47.2 cool + resto**
Maximum SOC :	71%	71%	71%	71%	71%	
Minimum SOC :	50%	50%	49%	50%	49%	**Combined (CAFE) MPG**
Average charge C :	5.2	3.7	5.2	3.7	4.4	**46.8 hot**
Average discharge C :	-2.8	-1.7	-2.8	-1.7	-2.3	**44.2 cool**
Maximum charge C :	13	11	13	11	13	**42.2 cool + resto**
Maximum discharge C :	-16	-Io	-16	-10	-16	

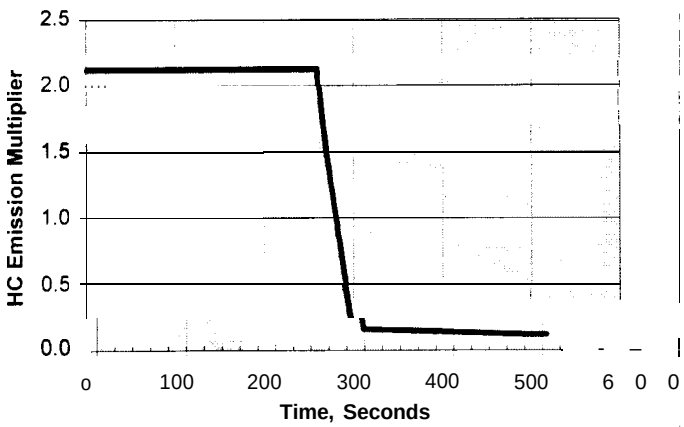
Vehicle: 33041b
Ford Taurus GL 4D
Engine Strategy: Best Fuel

ESS: **3.0 kWh**
87% RT Efficiency
Warm Scenario: Engine = Normal; Catalyst= VCI

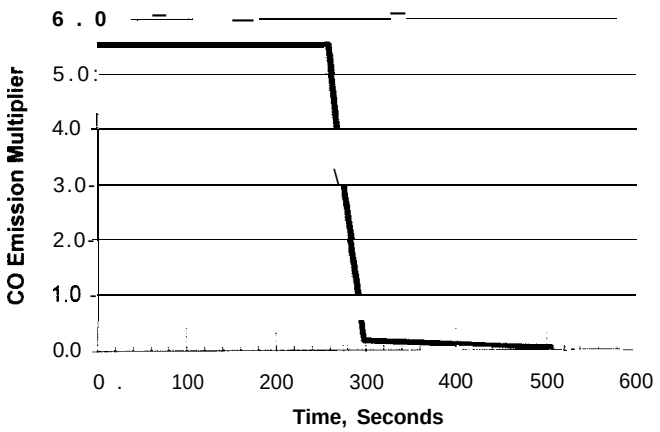
Engine: 21 Hp
Geo 1. O-L 2valv Metro



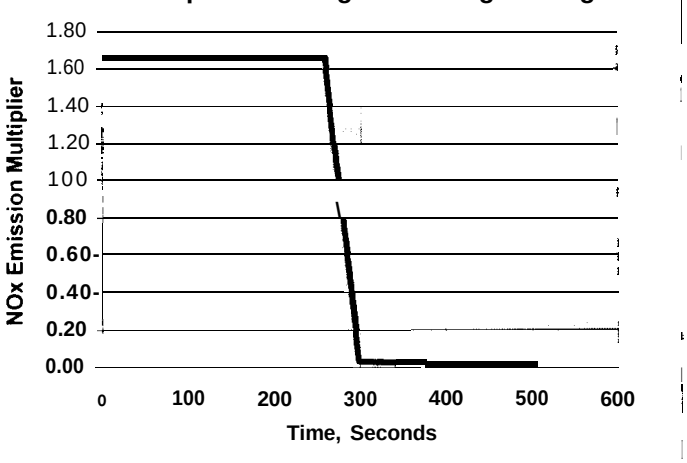
Bag 1 starts cold



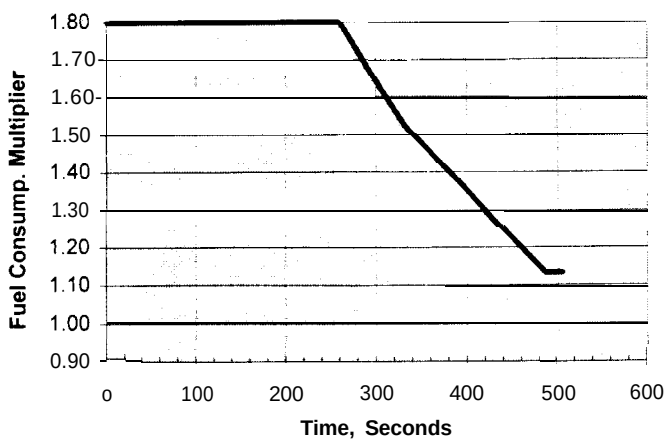
Avg. HC Multiplier: 0.299 while engine running



Avg. CO Multiplier: 0.553 while engine running

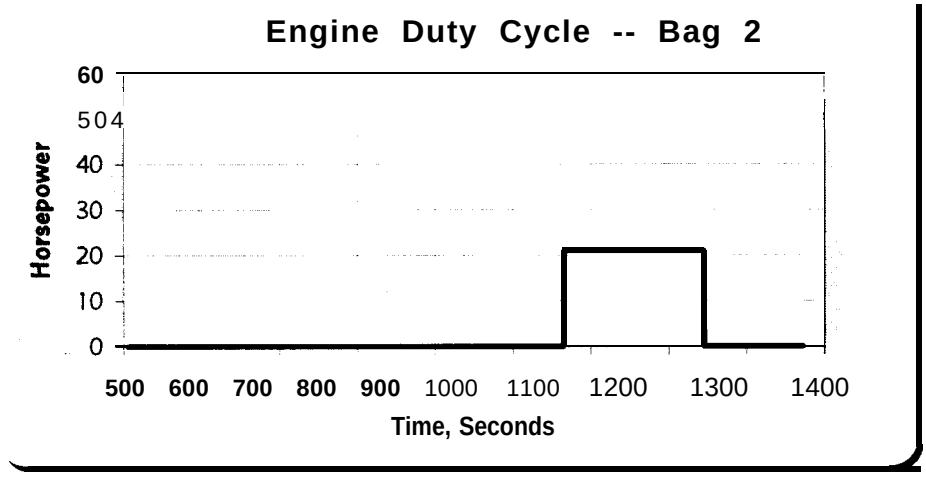


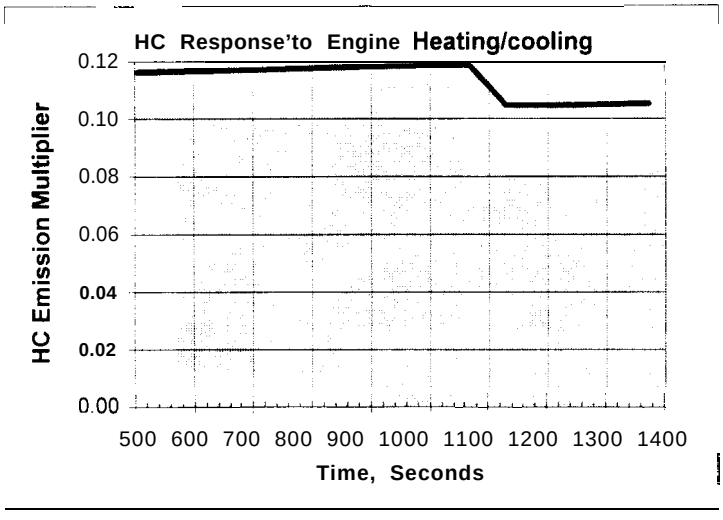
Avg. NOx Multiplier: 0. 57 while engine running



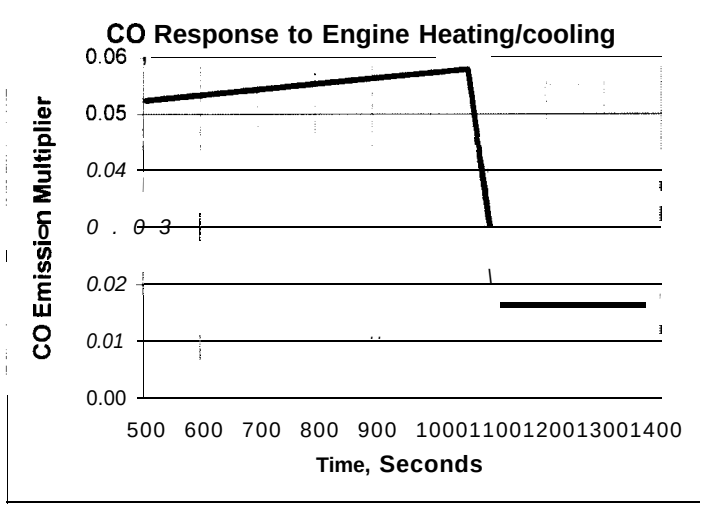
Avg. Fuel Multiplier: 1.434 while engine running

Vehicle: 3304 lb	ESS: 3.0 kWh	Engine: 21 Hp
Ford Taurus GL 4D	87% RT Efficiency	Geo 1. O-L 2valv Metro
Engine Strategy: Best Fuel	Warm Scenario: Engine = Normal; Catalyst= VCI	

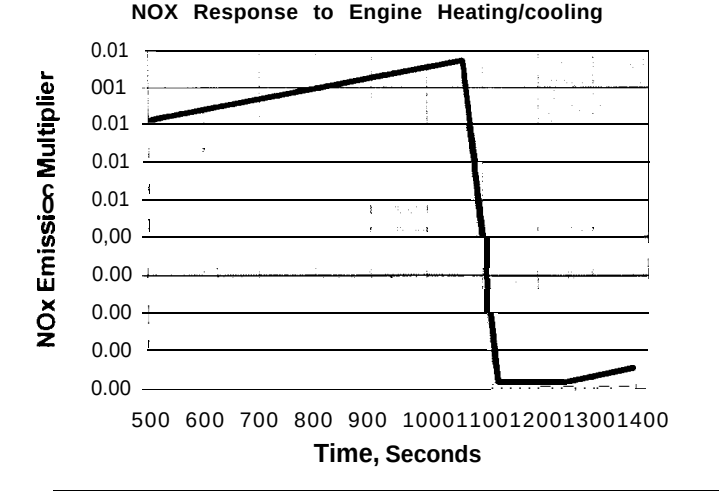




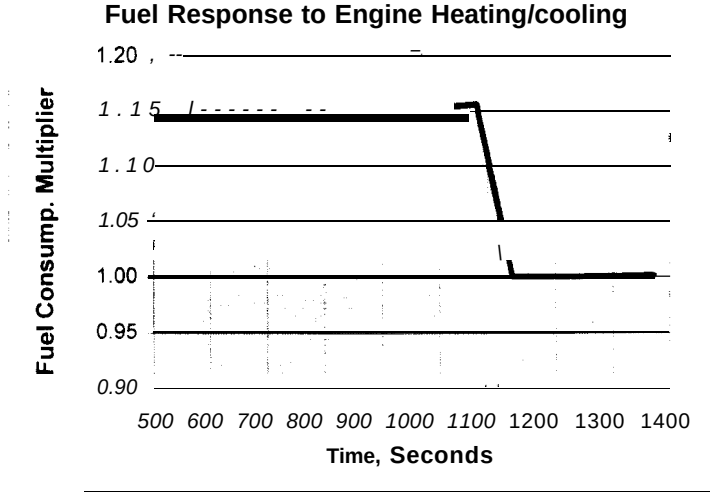
Avg. UC Multiplier: 0.107 while engine running



Avg. CO Multiplier: 0.023 while engine running



Avg. NOX Multiplier 0,002 while engine running

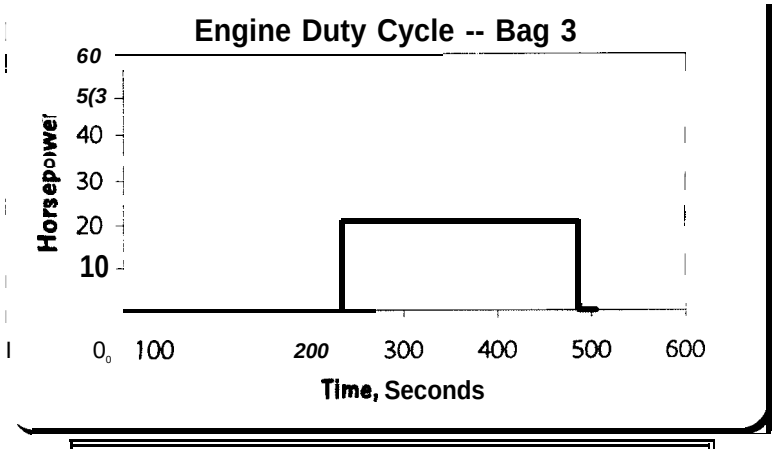


Avg. Fuel Multiplier' 1.026 while engine running

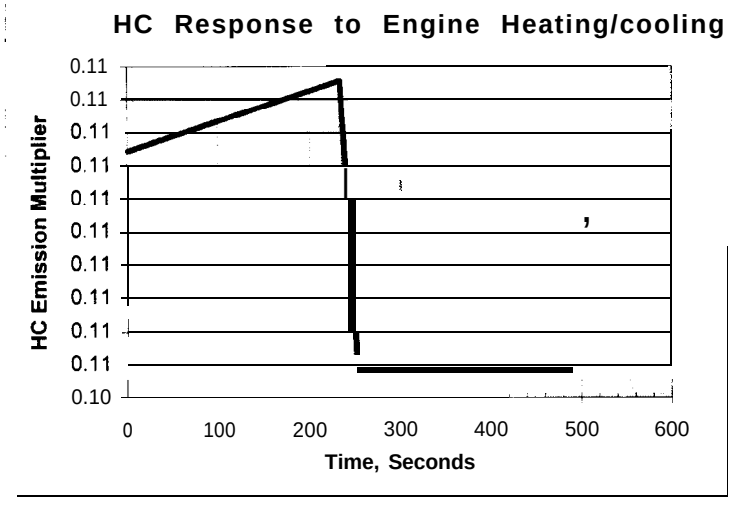
Vehicle: 3304 lb
Ford Taurus GL 4D
Engine Strategy: Best Fuel

ESS: 3.0 kWh
87% RT Efficiency
Warm Scenario: Engine = Normal; Catalyst= VCI

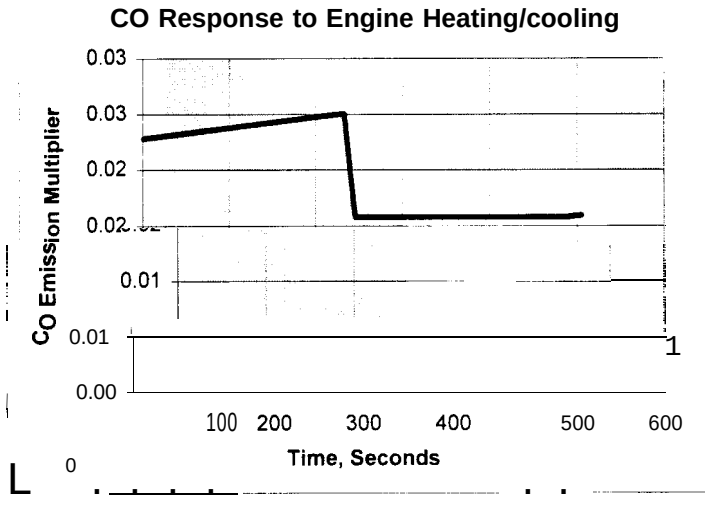
Engine: 21 Hp
Geo 10-L 2valv Metro



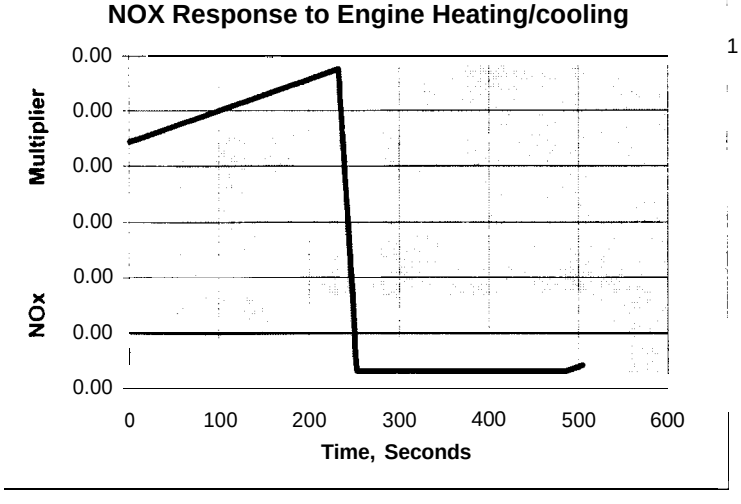
Bag 3 starts after ten minute cooldown



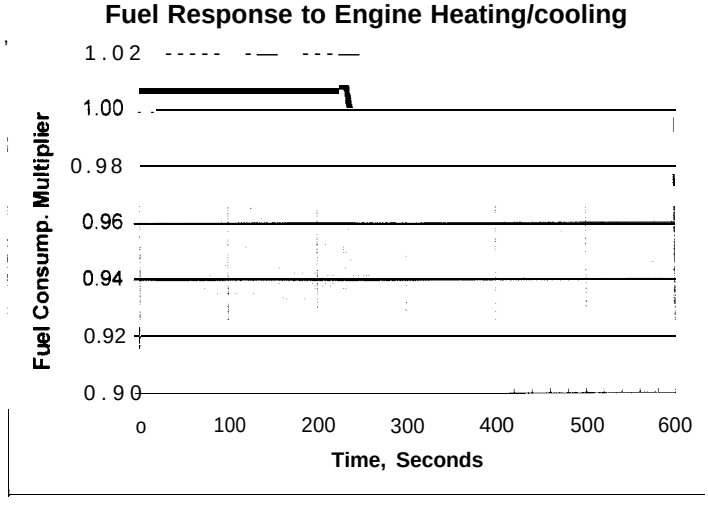
Avg. HC Multiplier: 0.105 while engine running



Avg. CO Multiplier: 0.016 while engine running



Avg. NOX Multiplier: 0.000 while engine running



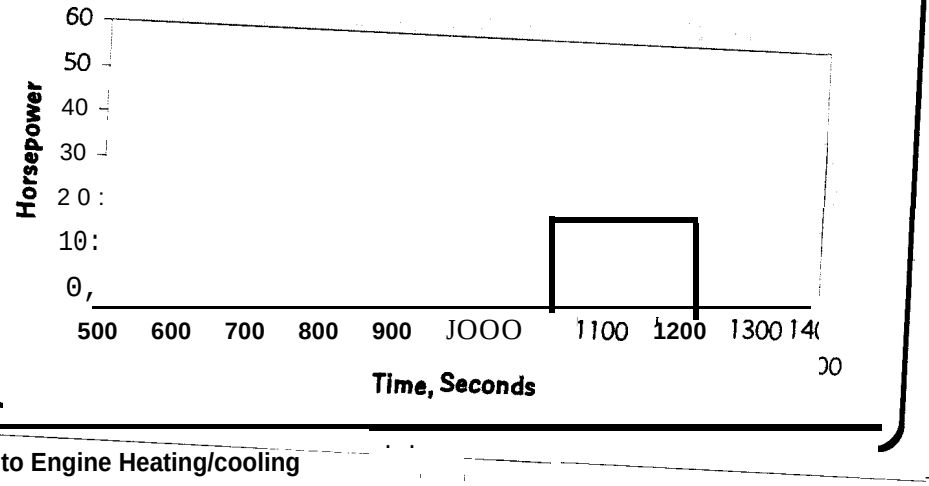
Avg. Fuel Multiplier: 1.000 while engine running

Vehicle: 3304 lb
Ford Taurus GL 4D
Engine Strategy: Best Fuel

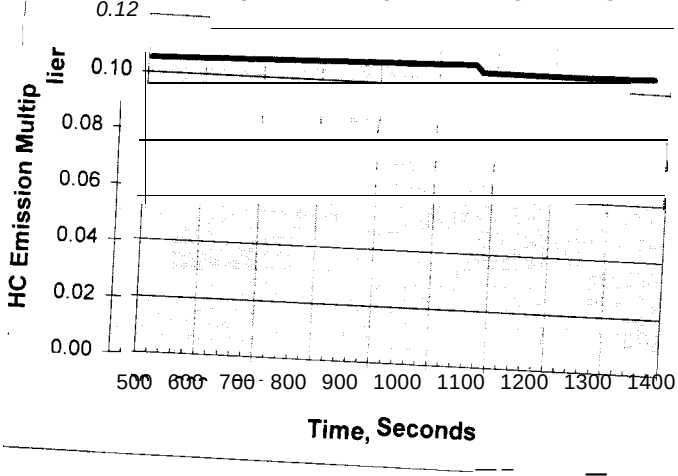
ESS: 3.o kWh
87% RT Efficiency

Engine: 21 H$_p$
Geo 1.0-L 2valv Metro
Warm Scenario: Engine = Normal, Catalyst= VCI

Engine Duty Cycle -- Bag 4

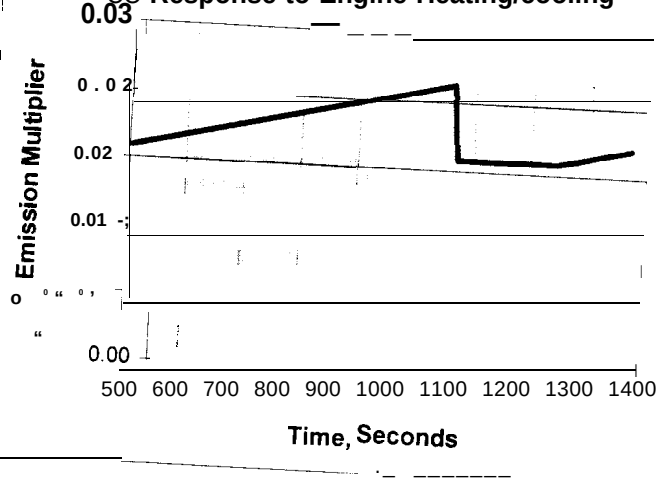


HC Response to Engine Heating/cooling



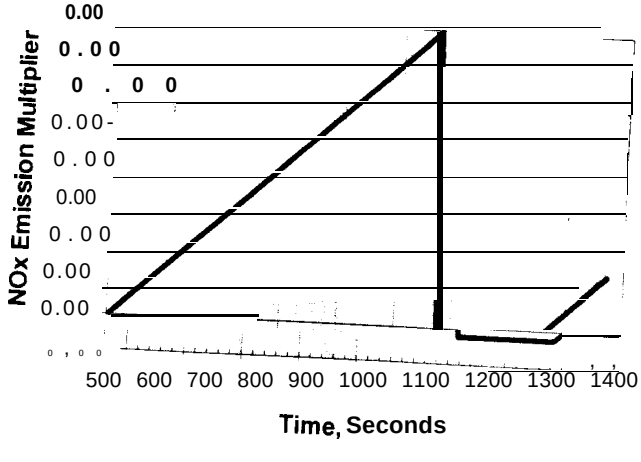
*Avg. HC Multiplie, **0.105 while engine running***

CO Response to Engine Heating/cooling



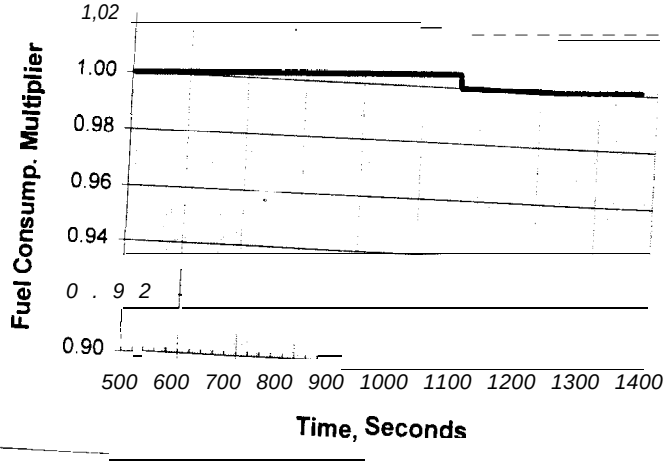
*Avg. CO Multipli$_{er}$ **O.016 while engine running***

NOX Response to Engine Heating/cooling



*Avg. NOx Mu/tip/i$_{er}$ **0.000 while engine running***

Fuel Response to Engine Heating/cooling



*Avg. Fuel Multiplier: **1.000 while engine running***

DSIM FTP Simulation, Series Hybrid Powertrain

Vehicle : Ford Taurus GL 4D
Vehicle weight: 3304
Engine : Geo 1.0-L 2valv Metro
Engine strategy : Best Fuel
Engine Hp : 21.0
Thermal - engine, catalyst : Normal, EHC+VCI

Grade, 55 mph, Engine : 2,0%
ESS minutes that grade : 10.7
Engine City Range, miles : 347
ESS City Range, miles : 11.7
Engine duty, drive : 31%
Avg sec eng on, drive : 211

ESS capacity, kWh : 3.oo
ESS charge efficiency : 94%
ESS disch efficiency : 93%
ESS initial SOC : 70%
Charge start SOC : 50%
Charge stop SOC : 70%

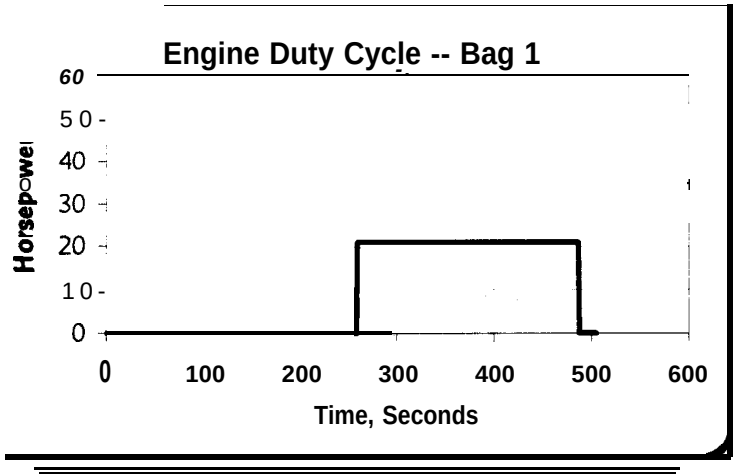
Eng hp-hr, drive : 2.46
ESS end-cycle SOC : 66%
Eng hp-hr, restore initial SOC : 0.15
Tot Eng hphr: 2.61
 # Engine starts : 3
Eng see, restore ini SOC : 26

Engine, by Bag		Bag 1	Bag 2	Bag 3	Bag 4	FTP			
Grams HC	**starts**	**0.018**	**0.018**	**0.018**	**0.018**	*0.035*	resto chg	**Grams/mile HC**	
	drive, engine-out hot	**3.41**	**2,70**	**3.79**	**2.70**	**6.32**	0.04	0.85	hot eng-out
	drive, cat effect hot	-3.06	-2.41	-3.39	-2.41	-5.66	grams	0.09	hot exhaust
	cool/warm effect	0.25	0.01	0.00	0.00	0.11	0.81	0.11	cool exhaust
	start **effect%** vs. drive hot	0.5?4	0.6%	0.5%	0.6%	0.6%	**resto chg**	0,11	cool exh + **resto**
	cool effect% vs. drive hot	7%	**0%**	o%	o%	2%	5.3%		
Grams CO	starts	0.163	0.163	0.163	0.163	0.325	**resto chg**	Grams/mile CO	
	drive, **engine-out hot**	27.5	21.7	30.6	21.7	51.0	0.06	6.89	hot **eng-out**
	drive, cat effect hot	-27.1	-21.4	-30.1	-21.4	-50.2	grams	0.15	hot exhaust
	cool/warm effect	5.90	0.05	0.04	0.01	2.6	3.7	0.50	cool exhaust
	start **effect%** vs. drive hot	0.6%	0.7%	0.5%	0.7%	0.6%	**resto chg**	0.51	cool exh + **resto**
	cool **effect%** vs. drive hot	21%	o%	o%	0%	5%	f 5%		
Grams NOX	**starts**	**0.010**	0.010	0.010	0.010	0.020	**resto chg**	**Grams/mile NOX**	
	drive, engine-out hot	10.07	7.95	11.17	7.95	**18.65**	**0.00**	**2.51**	**hot eng-out**
	drive, cat effect hot	-10.07	-7.95	-11.17	-7.95	**-18.64**	**grams**	**0.003**	**hot exhaust**
	cool/warm effect	0.53	0.01	0.00	0,00	**0.24**	**0.26**	**0.035**	**cool exhaust**
	start **effect%** vs. drive hot	0.1%	0.1%	0.1%	0.1%	**0.1%**	resto chg	**0.035**	**cool exh + resto**
	cool **effect%** vs. drive hot	5%	0%	o%	**0%**	1%	**0,2%**		
Lbs Fuel	starts	0.003	0.003	0.003	0.003	**0.005**	resto chg		
	drive, engine-out hot	0.54	0.43	0,60	0,43	1.01	**0.065**	**City MPG**	
	drive, cat effect hot	0.00	0.00	0.00	0.00	**0.00**	**pounds**	**45.5**	**hot**
	cool/warm effect	0.24	0.01	0.00	0.00	**0.11**	**1.12**	**41.1**	**cool**
	start **effect% vs**. drive hot	0,5%	0.6%	0.4%	0.6%	**0.5%**	resto chg	**38.9**	**coot + resto**
	cool **effect%** vs. drive hot	43%	3%	o%	0%	**I I%**	**5.8%**		
	Engine Hp-hr :	1.330	1.050	1.476	1.050	2.463		**Highway MPG**	
								48.6	**hot**
ESS, by Bag		Bag 1	Bag 2	Bag 3	Bag 4	FTP		**48.6**	**cool**
	Driving cycle kWh :	**1.099**	**1.150**	**1.099**	**1.150**	**2.249**		**47.2**	**cool + resto**
	Net kWh from/to **(+/-)** ESS :	-0.037	0.142	-0.140	0.142	0.046			
	Maximum SOC :	71%	**71%**	**71%**	71%	71%			
	Minimum SOC :	**50%**	50%	49%	50%	49%		**Combined (CAFE) MPG**	
	Average charge C :	5.2	3.7	5.2	3.7	4.4		**46.8**	**hot**
	Average discharge C :	-2,8	-1,7	-2.8	-1.7	-2.3		**44,2**	**cool**
	Maximum charge C :	13	11	13	11	13		**42.2**	**cool + resto**
	Maximum discharge C :	-16	-10	-16	-Io	-16			

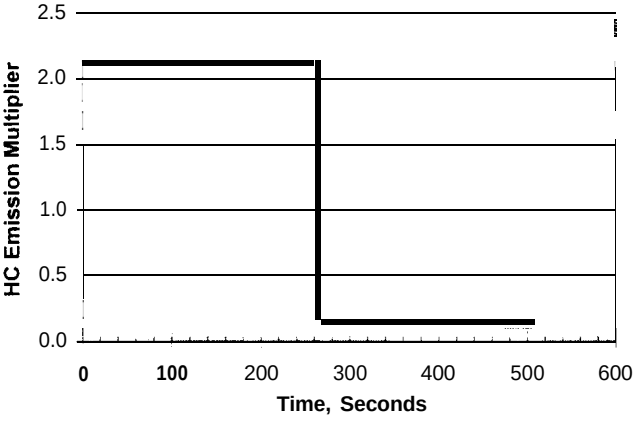
Vehicle: 3304 lb
Ford Taurus GL 4D
Engine Strategy: Best Fuel

ESS: 3.0 kWh
87% RT Efficiency
Warm Scenario: Engine = Normal; Catalyst= EHC+VCI

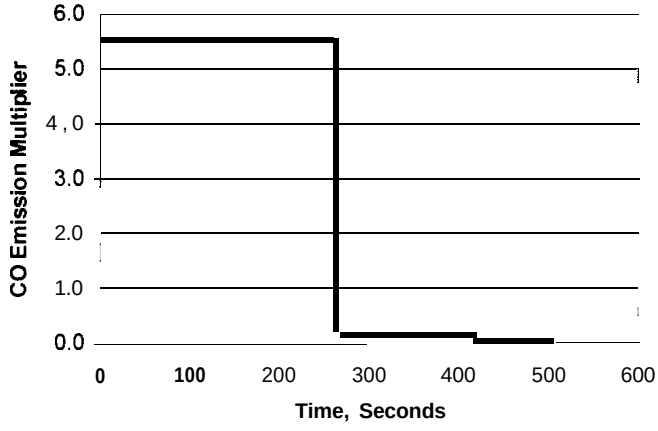
Engine: 21 Hp
Geo 1. O-L 2valv Metro



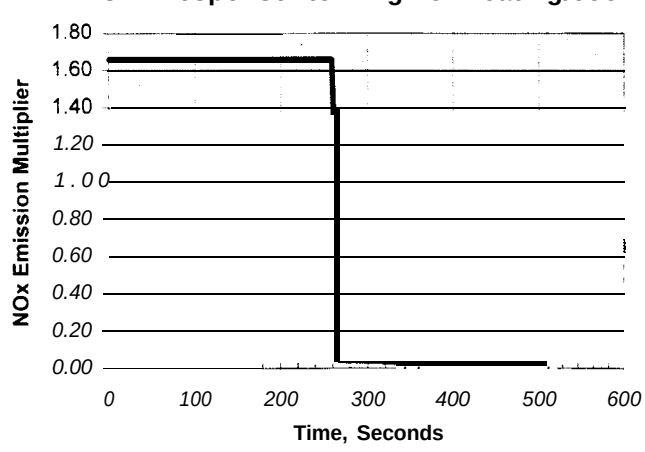
Bag 1 starts cold



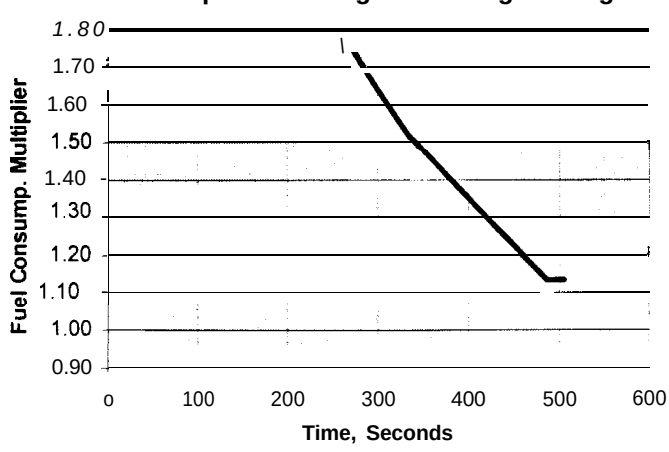
Avg. HC Multiplier: 0.178 while engine running



Avg. CO Multiplier: 0.230 while engine running



Avg. NOX Multiplier: 0.053 while engine running

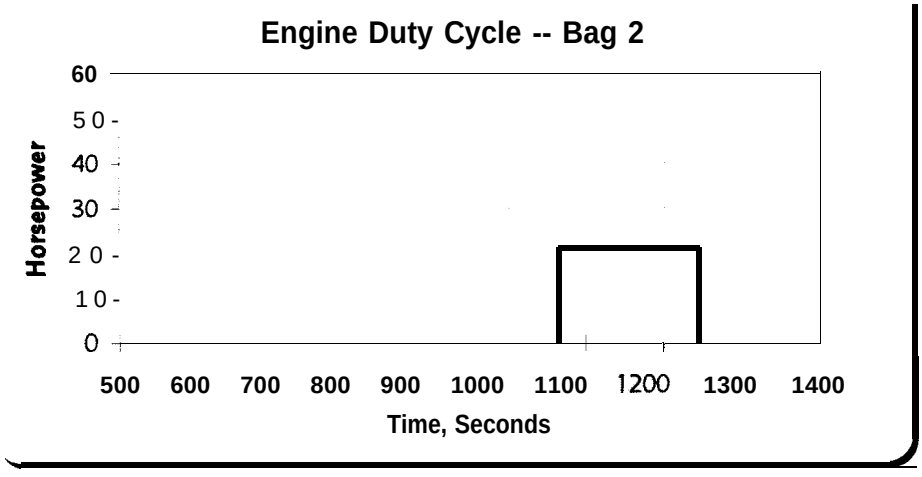


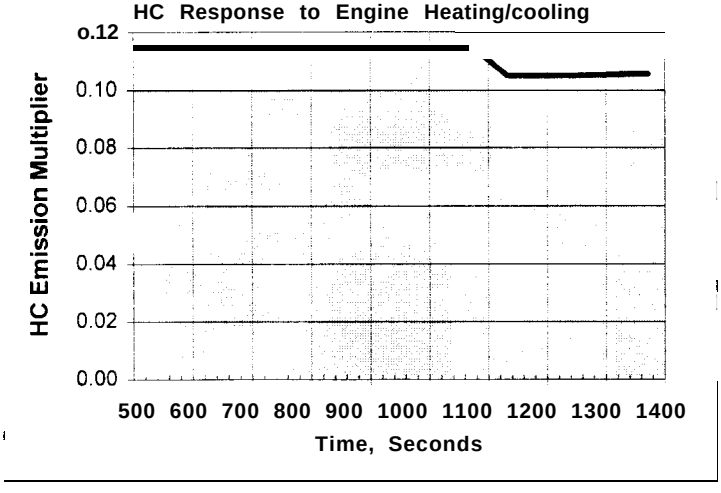
Avg. Fuel Multiplier." 1.434 while engine running

Vehicle: 3304 lb
Ford Taurus GL 4D
Engine Strategy: Best Fuel

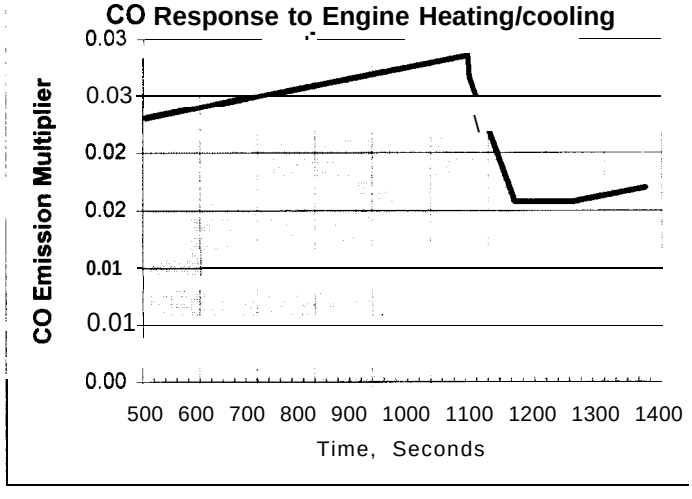
ESS: 3.0 kWh
87% RT Efficiency
Warm Scenario: Engine = Normal; Catalyst= EHC+VCI

Engine: 21 Hp
Geo 1. O-L 2valv Metro

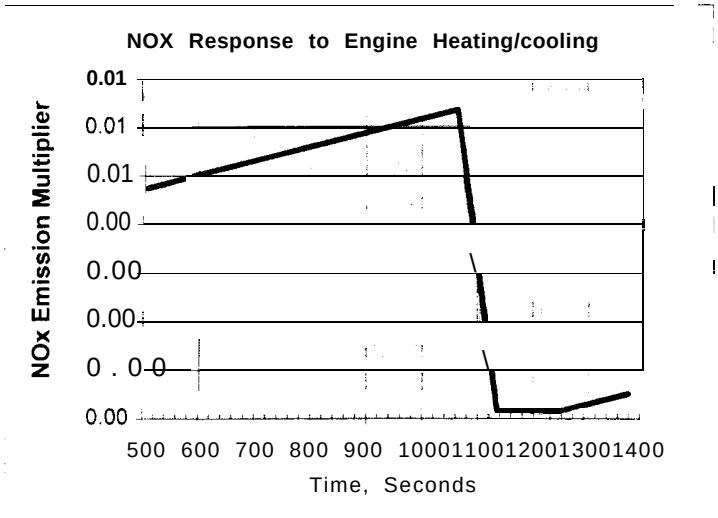




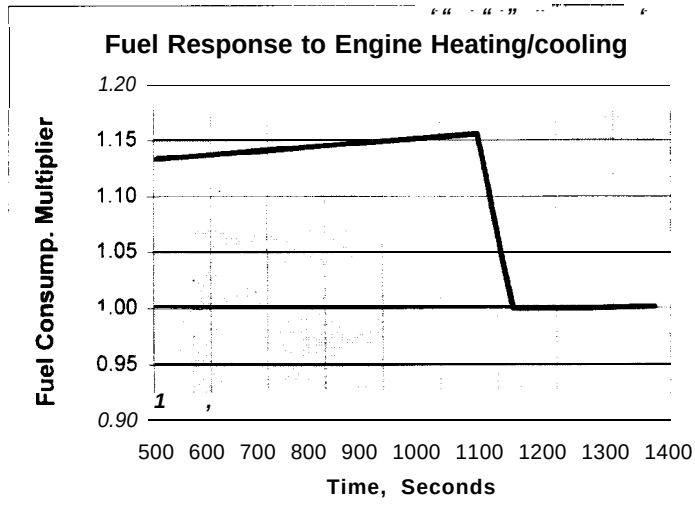
Avg. HC Multiplier: 0.107 while engine running



Avg. CO Multiplier: 0.018 while engine running



Avg. NOX Multiplier: 0.001 while engine running



Avg. Fuel Multiplier: 1.026 while engine running

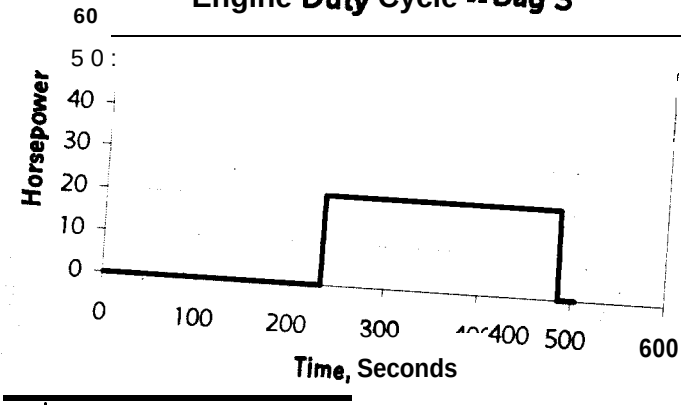
Vehicle: 3304 lb
Ford Taurus GL 4D
Engine Strategy: Best Fuel

ESS: 3.0 kWh
87% RT Efficiency

Engine: 21 Hp
Geo 1. O-L 2valv Metro

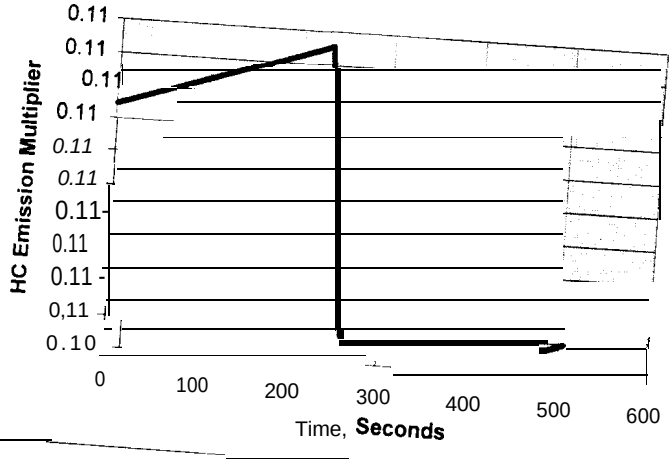
Warm Scenario: Engine = Normal; Catalyst= EHC+VCI

Engine Duty Cycle -- Bag 3



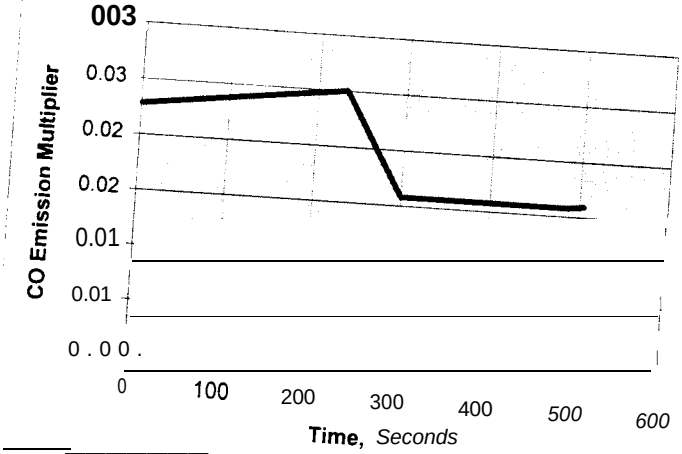
Bag 3 starts after ten minute cooldown

HC Response to Engine Heating/cooling



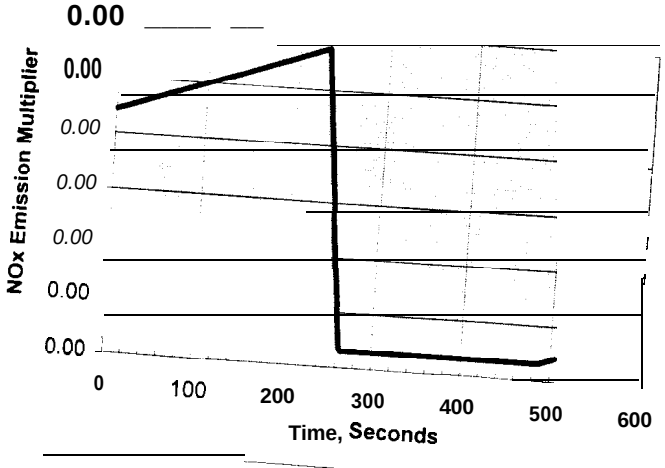
Avg. HC Multiplier: 0.105 while engine running

CO Response to Engine Heating/cooling



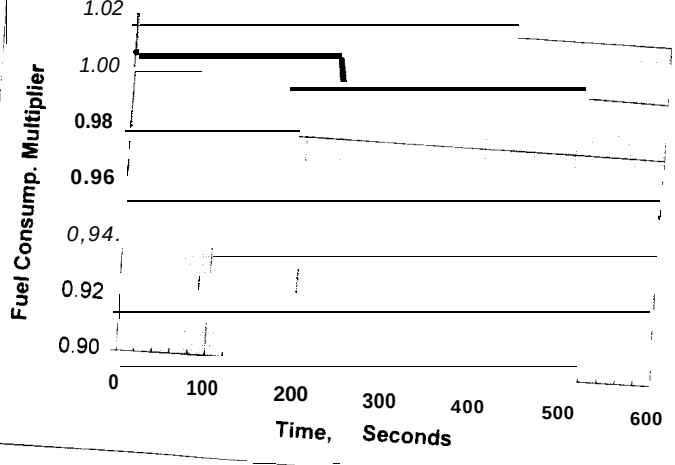
Avg. CO Multiplied 0.017 while engine running

NOX Response to Engine Heating/cooling



Avg. NOx Mu/tip/lec 0,000 while engine running

Fuel Response to Engine Heating/cooling



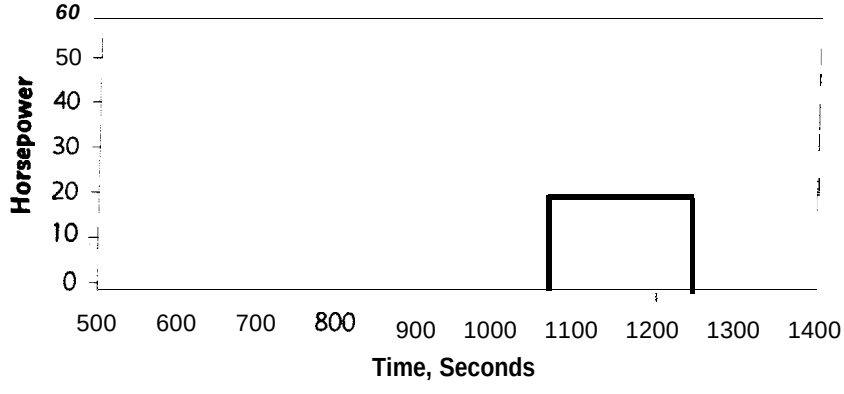
Avg. Fuel Multiplier: 1.000 while engine running

Vehicle: 3304 lb
Ford Taurus GL 4D
Engine Strategy: Best Fuel

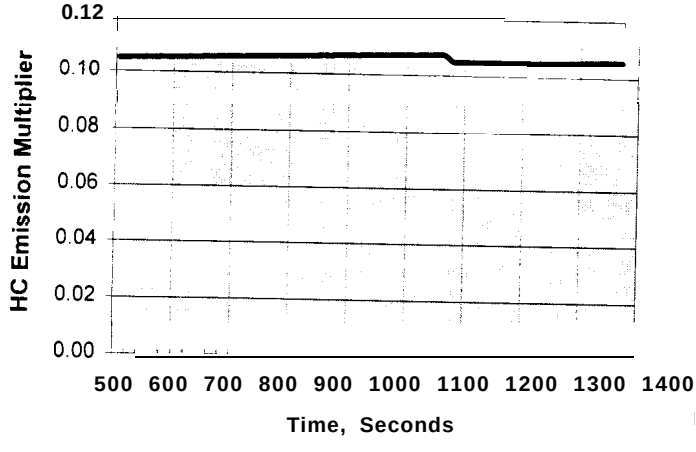
ESS: 3,0 kWh
87% RT Efficiency
Warm Scenario: Engine = Normal; Catalyst= EHC+VCI

Engine: 21 Hp
Geo 1. O-L2valvMetro

Engine Duty Cycle -- Bag 4

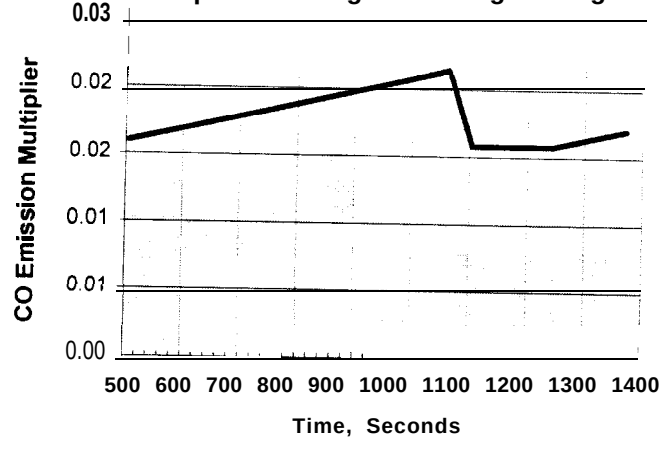


HC Response to Engine Heating/cooling



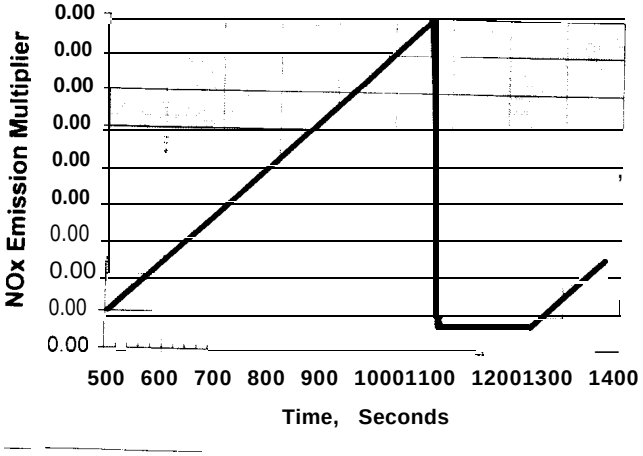
Avg. HC Multiplier: 0.105 while engine running

CO Response to Engine Heating/cooling



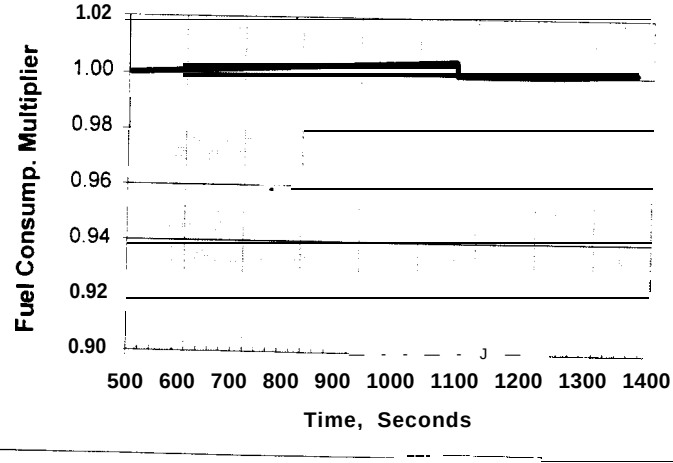
Avg. CO Multiplier: O.016 while engine running

NOX Response to Engine Heating/cooling



Avg. NOX Multiplier: 0.000 while engine running

Fuel Response to Engine Heating/cooling



Avg. Fuel Multiplier: 1.000 while engine running

DSIM FTP Simulation, Series Hybrid Powertrain

Vehicle : Chev. Lumina 4D
Vehicle weight : 3520
Engine: Geo 1.0-L 2valv Metro
Engine strategy : Best Fuel
Engine Hp : 21.0
Thermal - engine, catalyst : Normal, Normal

ESS capacity, kWh : 3.00
ESS charge **efficiency : 94%**
ESS disch efficiency : 93%
ESS initial SOC : 70%
Charge start SOC : 50%
Charge stop SoC : 70%

Grade, 55 mph, Engine: 1,8%
ESS minutes that grade : 10.7
Engine City Range, miles : 33o
ESS City Range, miles : 11,1
Engine duty, drive : 32%
Avg sec eng on, drive : 222

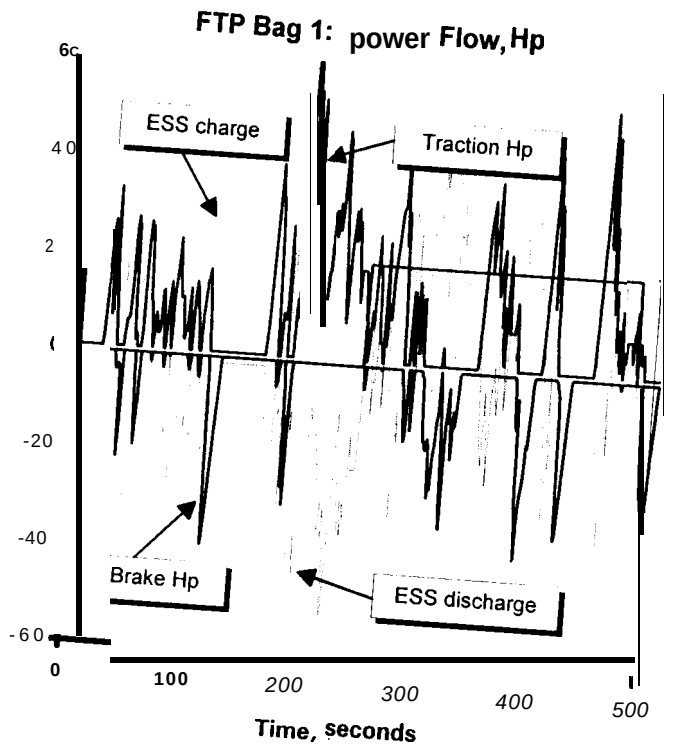
Eng hp-hr, drive : 2.59
ESS end-cycle SOC : 66%
Eng hp-hr, restore initial SoC : 0.16
Tot Eng hphr: 2.74
 # Engine starts : 3
Eng sec, restore ini SOC : 27

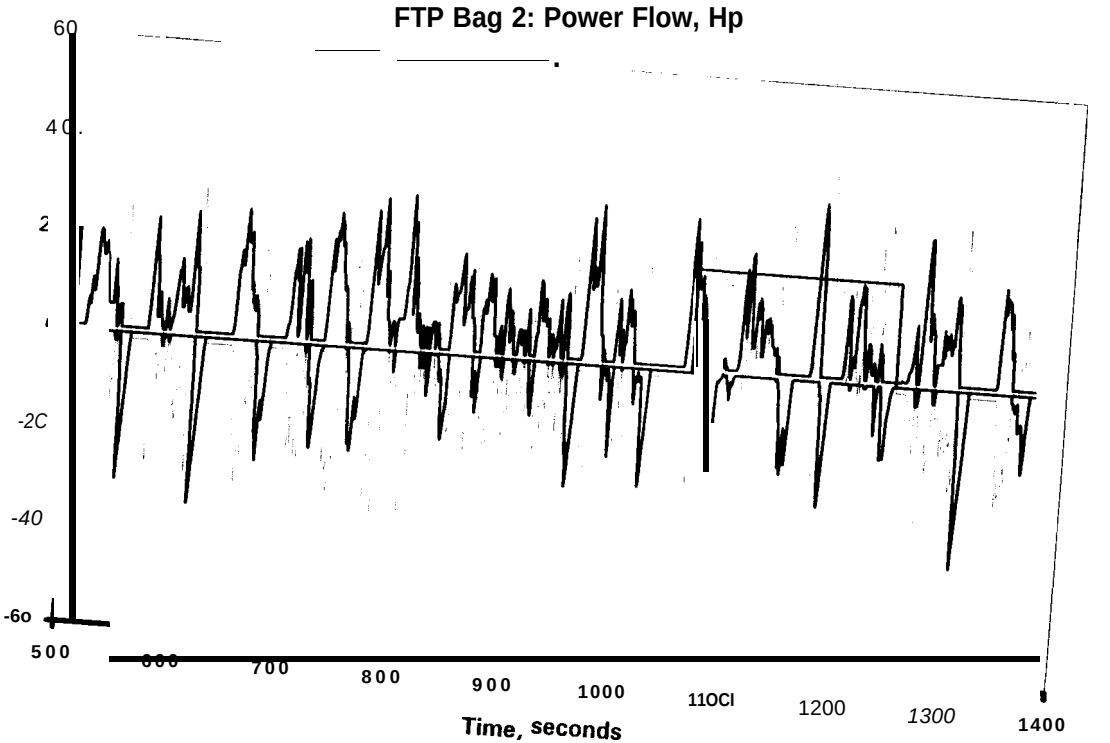
Engine, by Bag	Bag 1	Bag 2	Bag 3	Bag 4	FTP		Grams/mile HC	
Grams HC starts	**0,018**	**0.018**	**0.018**	**0.018**	*0.035*	resto chg		
drive, engine-out hot	**3.61**	**2.80**	**4.01**	**2.80**	**6,64**	**0.09**	**0.90**	**hot eng-out**
drive, cat effect hot	**-3.23**	**-2.51**	**-3.59**	**-2.51**	**-5.94**	grams	0.10	hot exhaust
cool/warm effect	**1.79**	**0.09**	**0,13**	0.09	0.93	'1 .66	0.22	cool exhaust
start effect% vs. drive hot	*0.5%*	**0,6%**	*0.4%*	0.6%	0.5%	resto chg	0.23	cool exh + resto
cool effect% vs. drive hot	50%	**3%**	**3%**	3%	**14%**	5.2%		
Grams CO starts	0.163	**0.163**	**0.163**	**0.163**	**0.325**	resto chg	**Grams/mile CO**	
drive, engine-out hot	**29.1**	**22.6**	**32.4**	**22,6**	**53.6**	**0.43**	**7.23**	hot eng-out
drive, cat effect hot	**-28.7**	**-22.2**	**-31.9**	**-22.2**	**-52,7**	**grams**	**0.16**	**hot exhaust**
cool/warm effect	**35.33**	**1.49**	**1.66**	**1.48**	**17.6**	**18.8**	**2.52**	**cool exhaust**
start effect% vs. drive hot	**0.6%**	**0.7%**	**0.5%**	**0.7%**	**0.6%**	resto chg	**2.58**	**cool exh + resto**
cool effect% vs. drive hot	**121%**	**7%**	**5%**	**7%**	**33%**	**2.3%**		
Grams NOX starts	**0.010**	**0.010**	**0.010**	**0.010**	**0.020**	resto chg	**Grams/mile NOX**	
drive, engine-out hot	10.64	**8.26**	*11.83*	**8.26**	**19.58**	**0.13**	**2.63**	hot eng-out
drive, cat effect hot	-10.64	**-8.26**	*-11.83*	**-8.26**	**-19.58**	**grams**	0.003	hot exhaust
cool/warm effect	4.40	*0.21*	*0.39*	**0.21**	**2.32**	**2.34**	0.314	cool exhaust
start effect% vs. drive hot	0,1%	**0.1%**	*0.1%*	**0.1%**	**0.1%**	resto chg	0.331	cool exh + resto
cool effect% vs. drive hot	41?40	3%	3%	**2%**	120/o	**5.3%**		
Lbs Fuel starts	0.003	0.003	0.003	**0.003**	**0.005**	resto chg		
drive, engine-out hot	0.58	0.45	0.64	**0.45**	**1.06**	**0.067**	**City MPG**	
drive, cat effect hot	0.00	0.00	0.00	**0.00**	**0.00**	pounds	**43.3**	**hot**
cool/warm effect	0.24	0.01	0.00	0.00	0.11	1.17	**39.4**	**cool**
start effect% vs. drive hot	0.5%	**0.6%**	0.4%	0.6%	0.5%	resto chg	**37.2**	cool + resto
cool effect% vs. drive hot	42%	2%	o%	o%	1o%	5.7%		
Engine Hp-hr :	1.406	1.091	1.563	1.091	2 . 5 8 6		**Highway MPG**	
							47.5	**hot**
ESS, by Bag	**Bag 1**	**Bag 2**	**Bag 3**	**Bag 4**	**FTP**		**47.5**	**cool**
Driving cycle kWh :	**1.162**	**1.208**	**1,162**	**1.208**	**2,371**		**44.9**	COOI + resto
Net kWh from/to (+/-) ESS :	**-0.042**	**0.152**	**-0. f 52**	0.152	**0.047**			
Maximum SoC :	**71%**	**71%**	**71%**	**71%**	**71%**			
Minimum SoC :	50%	50%	49%	50%	**49%**		**Combined (CAFE) MPG**	
Average charge C :	5.3	**3.8**	**5.3**	3.8	4,5		**45.1**	**hot**
Average discharge C :	-3.0	-1.8	-3.0	-1.8	-2.4		**42.7**	**cool**
Maximum charge C :	14	11	14	11	14		**40.3**	**cool + resto**
Maximum discharge C :	-17	-Io	-17	-Io	**-17**			

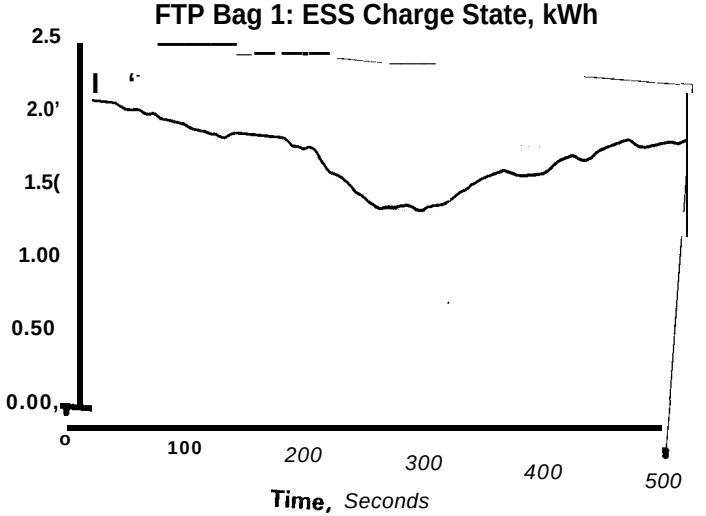
Vehicle 352o lb
Chev. Lumina 4D

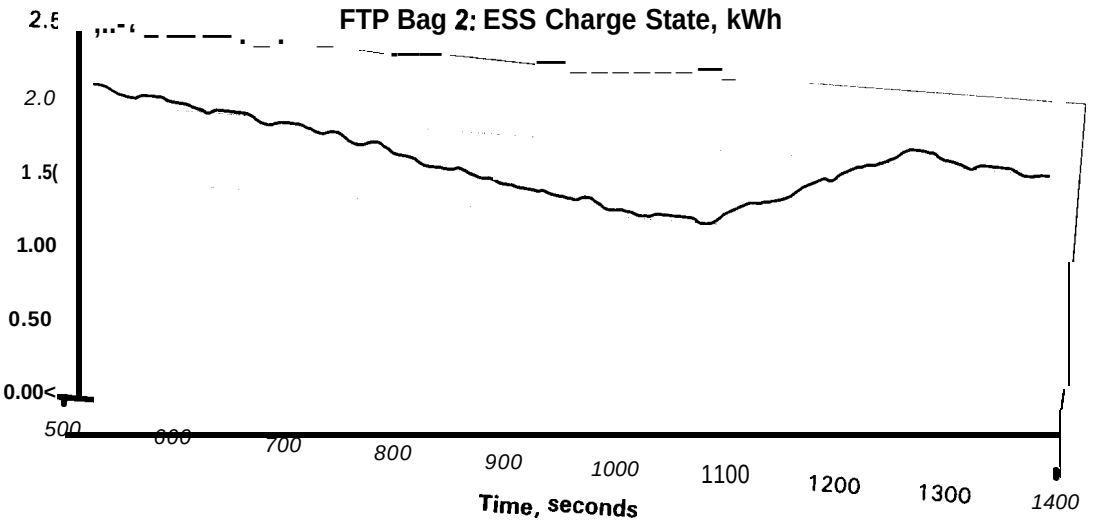
ESS: 3.o kWh
87% RT Efficiency

Engine: 21 Hp
Strategy: Best Fuel







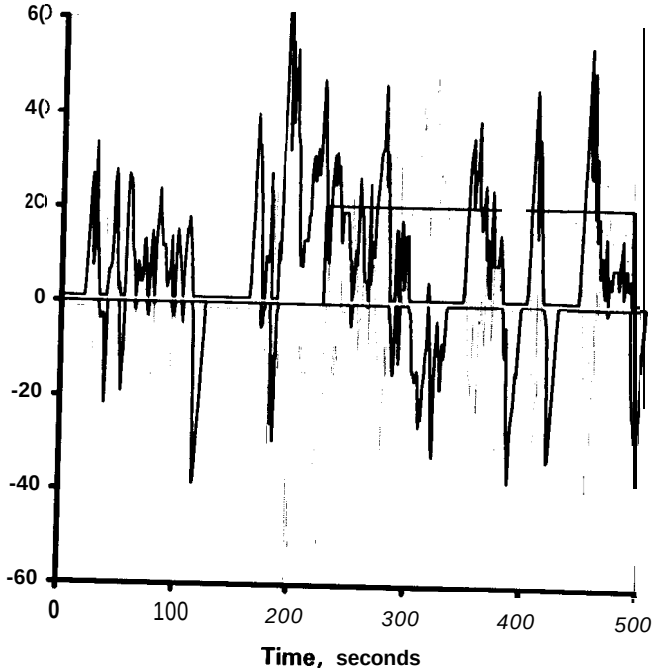


Vehicle: 3520 lb
Chev.Lumina 4D

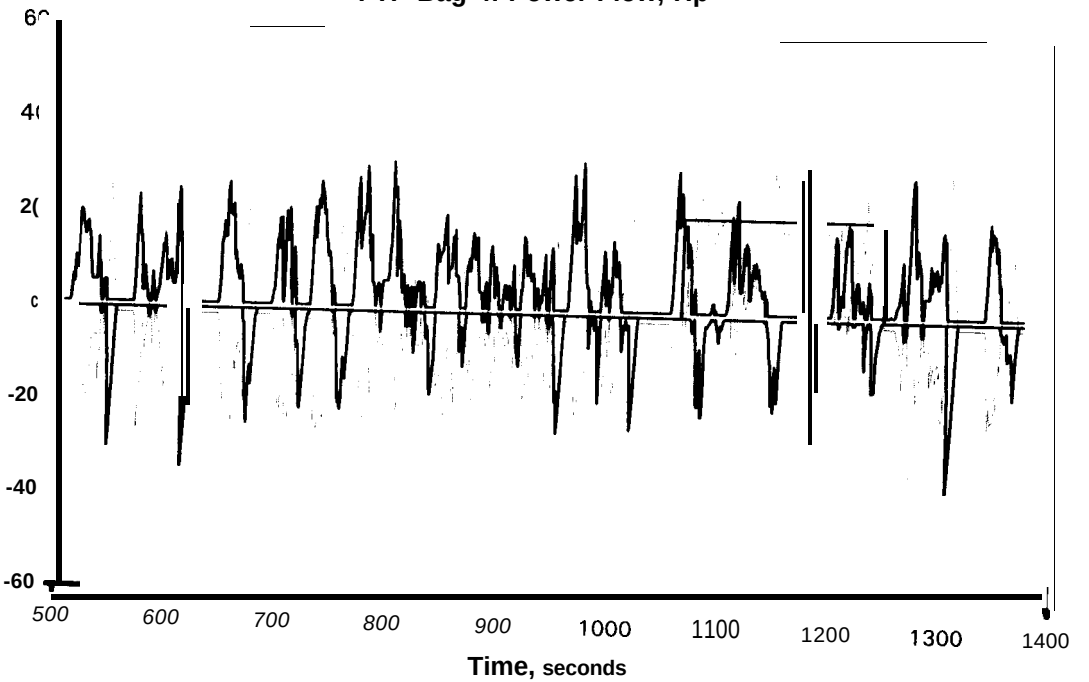
ESS: 3.0 k W h
87% RT Efficiency

Engine: 21 Hp
Strategy: Best Fuel

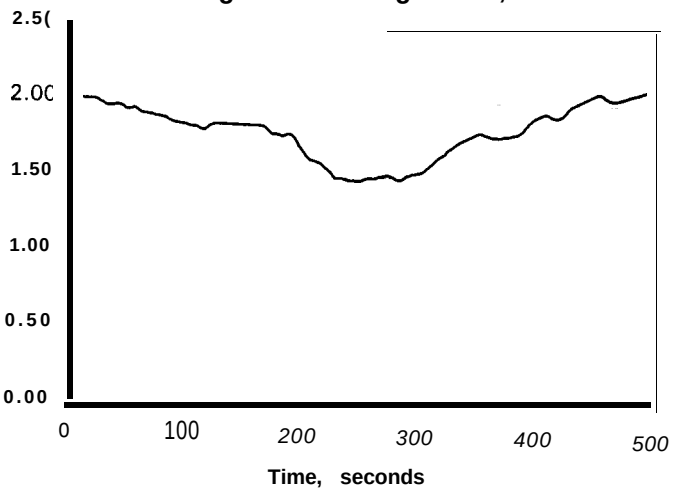
FTP Bag 3: Power Flow, Hp



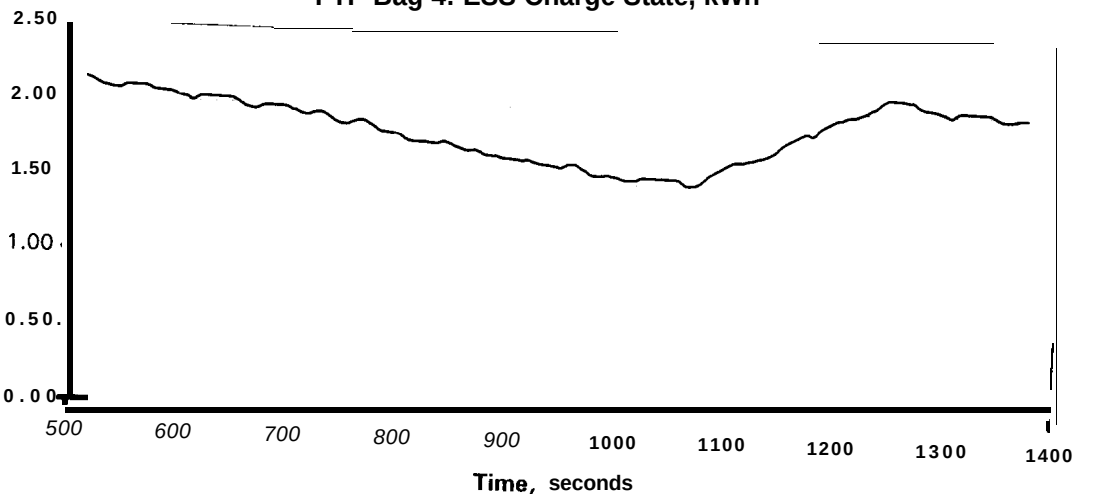
FTP Bag 4: Power Flow, Hp



FTP Bag 3: ESS Charge State, kWh



FTP Bag 4: ESS Charge State, kWh

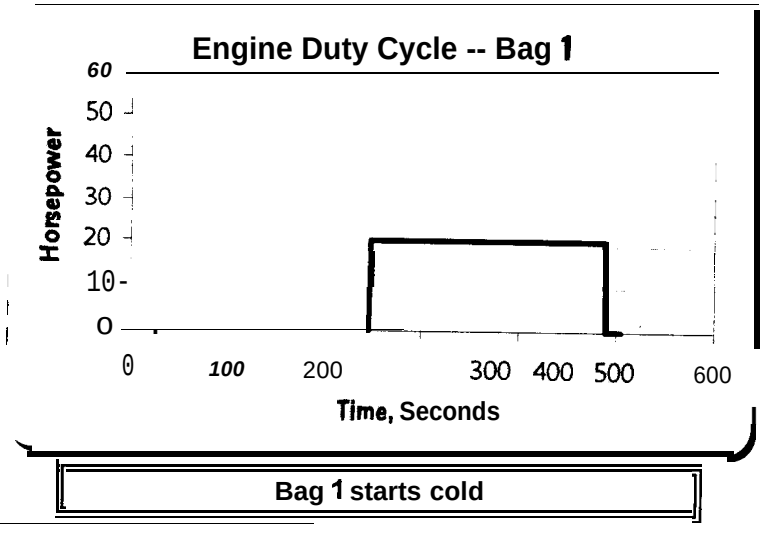


Vehicle: 3520 lb
Chev. Lumina 4D
Engine Strategy: Best Fuel

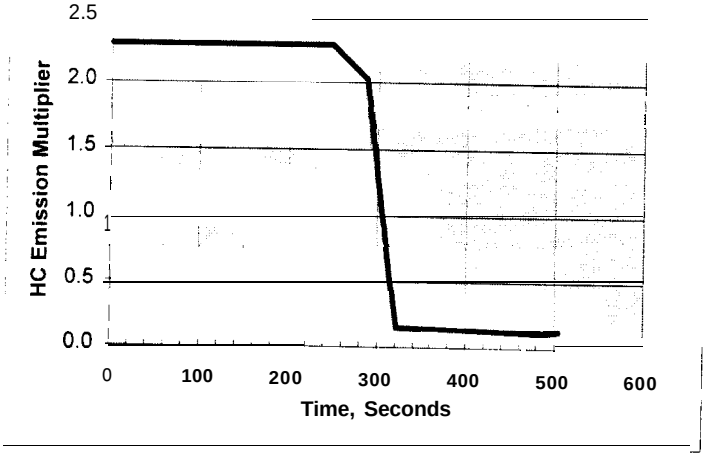
ESS: 3.0 kWh
87% RT Efficiency

Engine: 21 Hp
Geo 1.0-L 2valv Metro

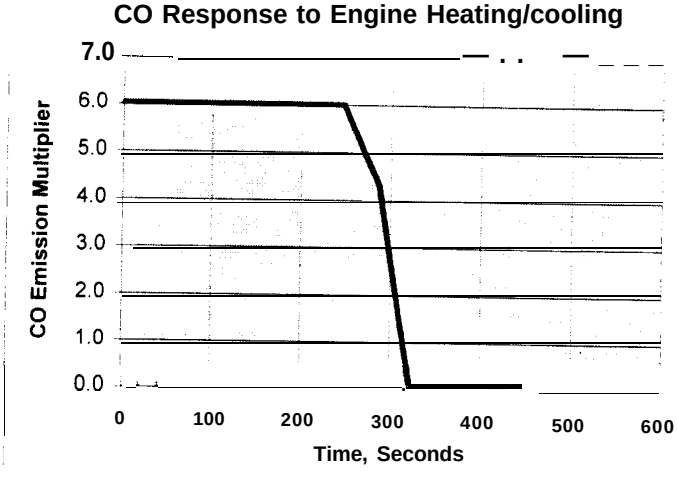
Warm Scenario: Engine = Normal; Catalyst = Normal



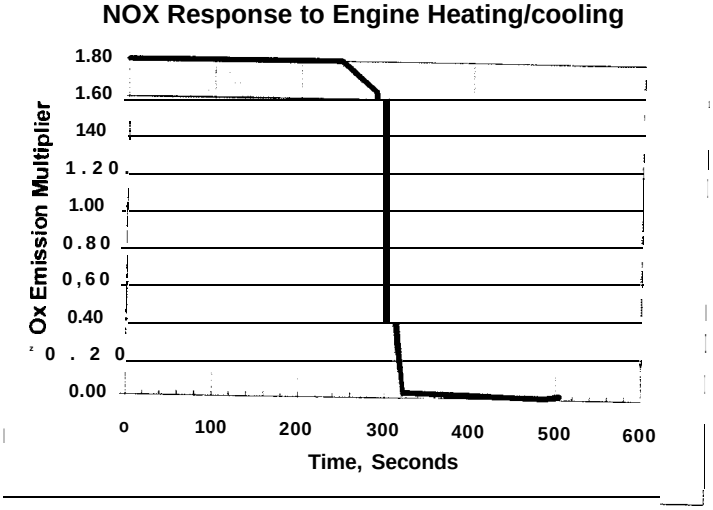
Bag 1 starts cold



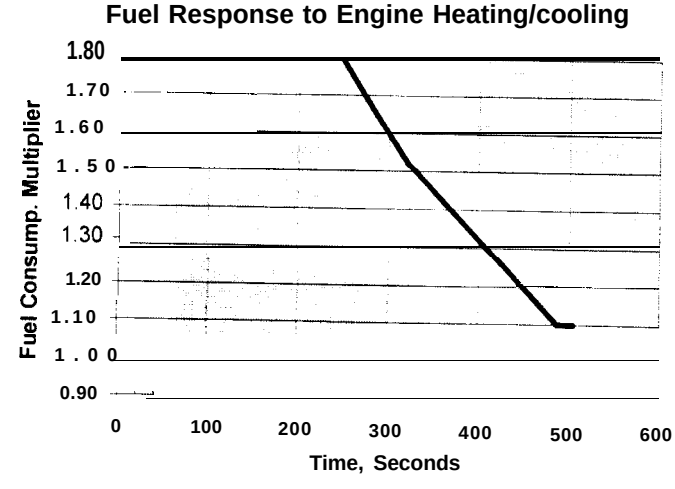
Avg. HC Multiplier: 0.601 while engine running



Avg. CO *Multiplier:* *1.229 while engine running*



Avg. NOX ***Multiplier: O.414 while engine running***



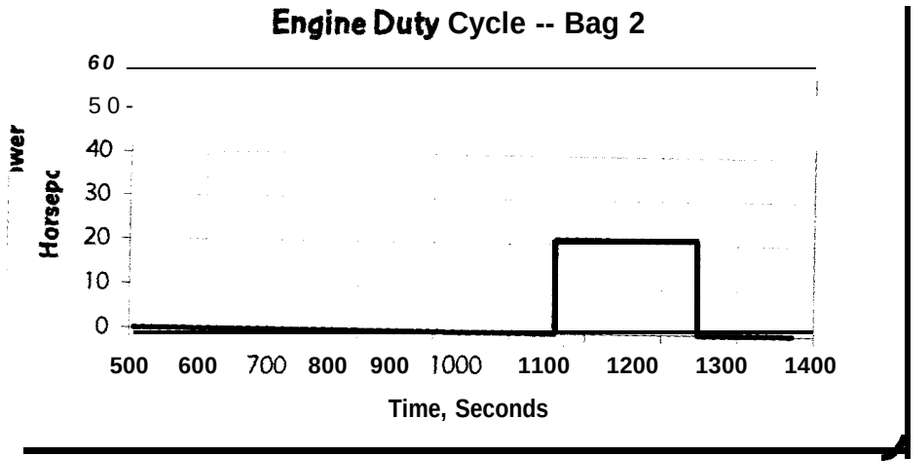
Avg. Fuel Multiplier. 1.417 while engine running

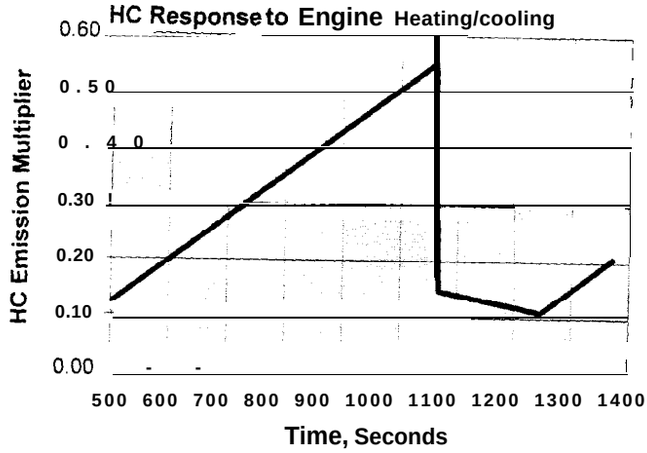
Vehicle: 3520 lb
Chev. Lumina 4D
Engine Strategy: Best Fuel

ESS: 3.0 kWh
87% RT Efficiency

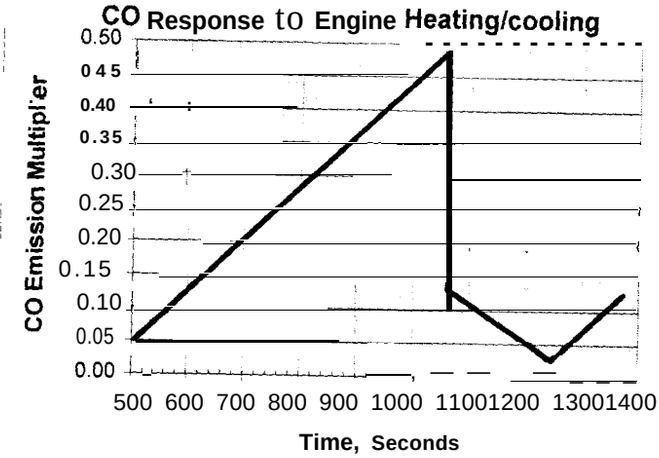
Engine 21 Hp
Geo 1. O-L 2valv Metro

Warm Scenario: Engine = Normal; Catalyst = Normal

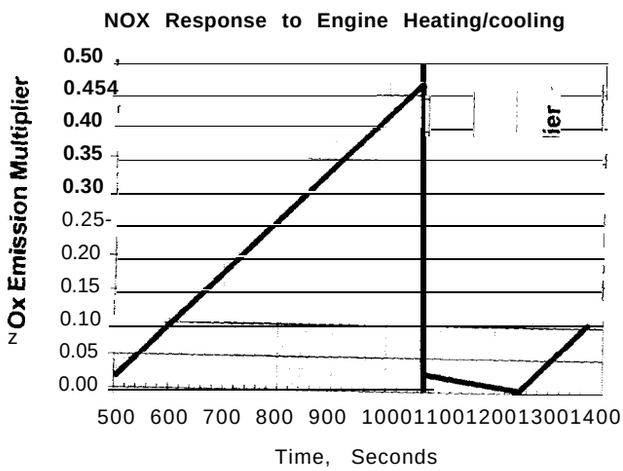




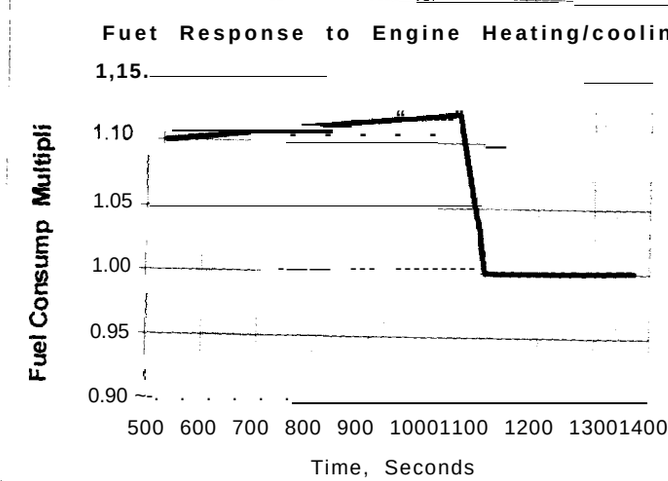
Avg. HC Multiplier: 0.136 while engine running



Avg. CO Multiplier: 0.082 while engine running



Avg. NOx Multiplier: 0.026 while engine running



Avg. Fuel Multiplier: 1.015 while engine running

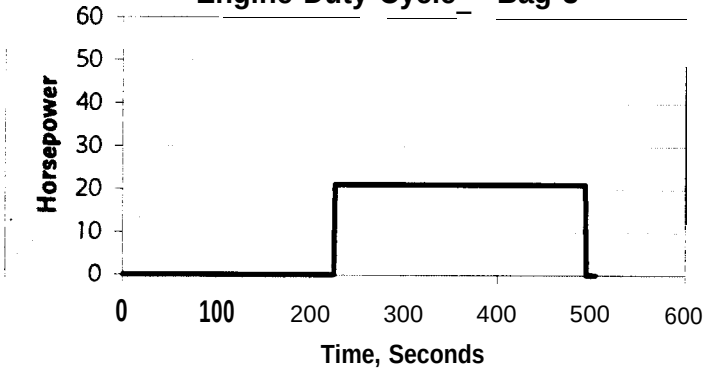
Vehicle: 3520 lb
Chev. Lumina 4D
Engine Strategy: Best Fuel

ESS: 3.0 kWh
87% RT Efficiency

Engine: 21 Hp
Geo 1. O-L 2valv Metro

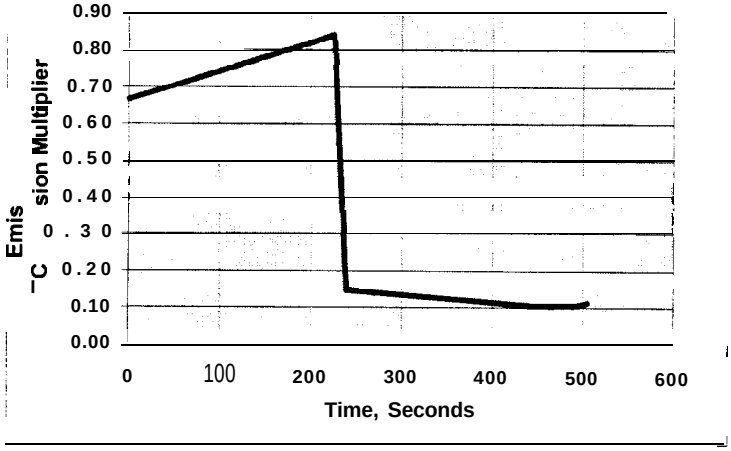
Warm Scenario: Engine = Normal; Catalyst = Normal

Engine Duty Cycle -- Bag 3



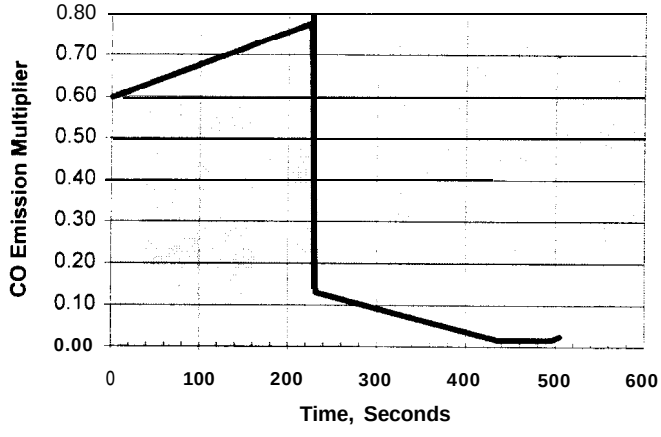
Bag 3 starts after ten minute cooldown

HC Response to Engine Heating/cooling



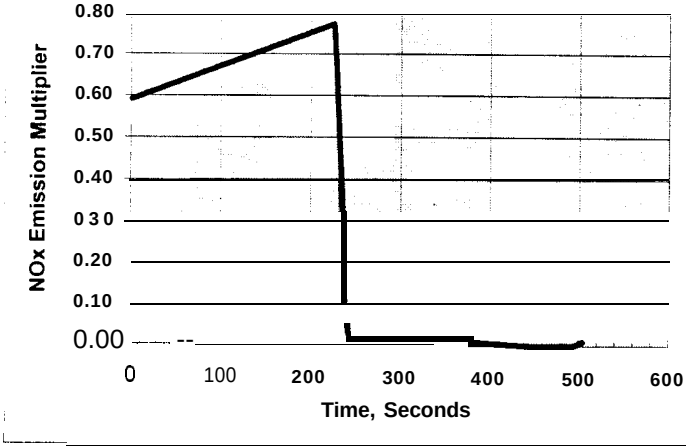
Avg. HC Multiplier: 0.138 while engine running

CO Response to Engine Heating/cooling



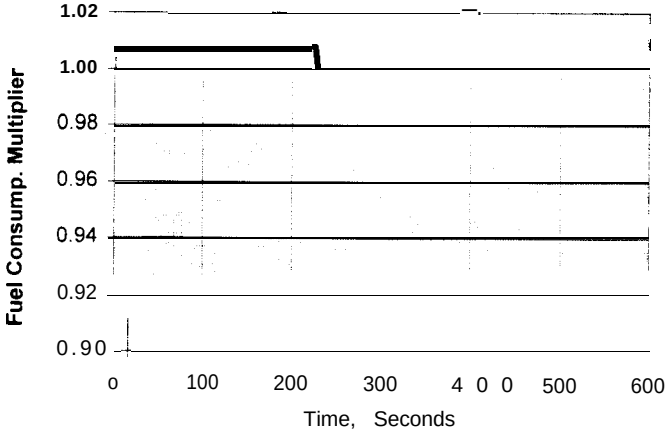
Avg. CO Multiplier: 0.067 while engine running

NOX Response to Engine Heating/cooling



Avg. *NOx* *Multiplier: 0.033 while engine running*

Fuel Response to Engine Heating/cooling



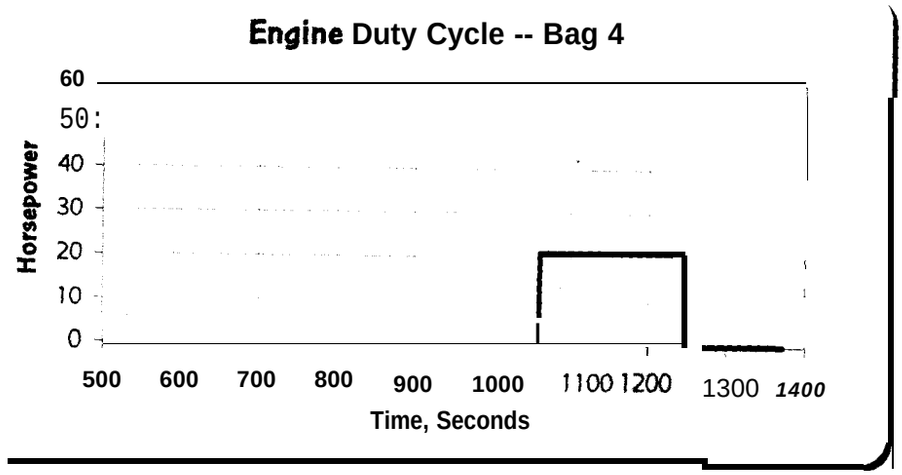
Avg. Fuel Multiplier: 1.000 while engine running

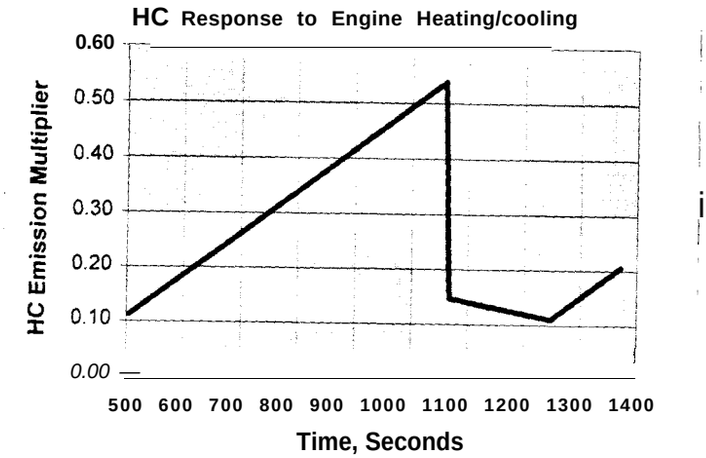
Vehicle: 3520 lb
Chev.Lumina 4D
Engine Strategy: Best Fuel

ESS: 3.0 kWh
87% RT Efficiency

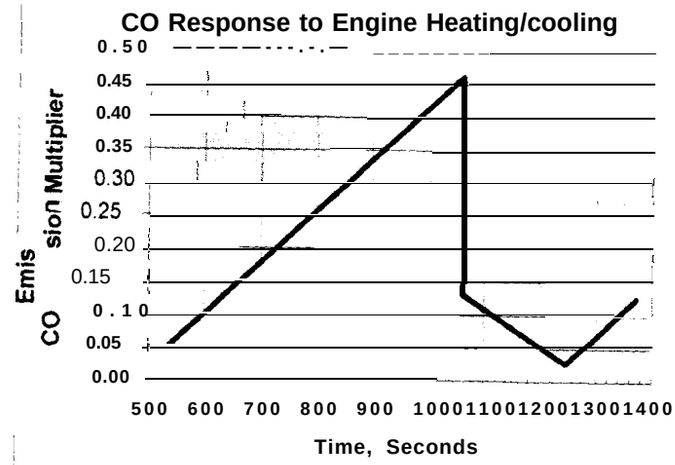
Engine: 21 Hp
Geo 1.0-L 2valv Metro

Warm Scenario: Engine = Normal; Catalyst = Normal

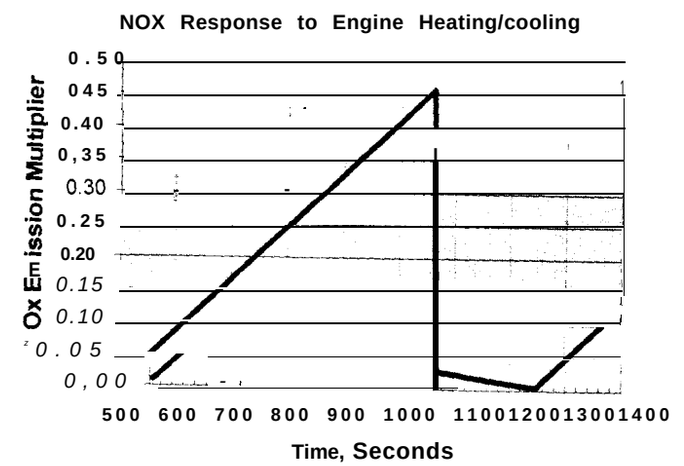




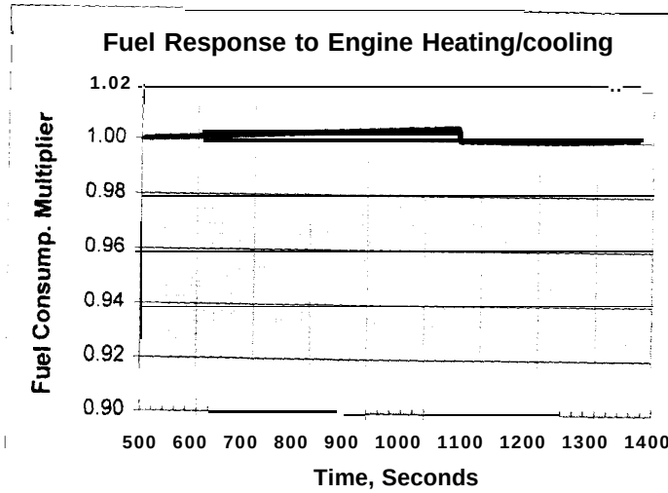
Avg. UC Multiplier: 0.136 while engine running



Avg. CO Multiplier. 0.081 while engine running



Avg. NOX Multiplier: 0.025 while engine running



Avg. Fuel Multiplier: 1.000 while engine running

DSIM FTP Simulation, Series Hybrid Powertrain

Vehicle :	Chev.Lumina 4D	**ESS capacity, kWh :**	3.00
Vehicle weight:	3520	**ESS charge efficiency :**	94%
Engine :	Geo 1.0-L 2valv Metro	**ESS disch efficiency :**	93°A
Engine strategy :	Best Fuel	**ESS initial SoC :**	70%
Engine Hp :	21.0	**Charge start SOC :**	50%
Thermal - engine, catalyst:	Normal, EHC	**Charge stop SoC :**	70%
Grade, 55 mph, Engine :	1.8%	**Eng hp-hr, drive :**	2.59
ESS minutes that grade :	*10.7*	**ESS end-cycle SOC :**	66%
Engine City Range, miles :	*330*	**Eng hp-hr, restore initial SoC :**	0.16
ESS City Range, miles :	11.1	**Tot Eng hphr:**	2.74
Engine duty, drive :	3276	**# Engine starts :**	3
Avg sec eng on, drive :	222	**Eng see, restore ini SoC :**	27

Engine, by Bag		Bag 1	Bag 2	Bag 3	Baa 4	FTP		
Grams HC	**starts**	**0.018**	0.018	**0.018**	**0.018**	**0.035**	resto chg	**Grams/mile HC**
	drive, engine-out hot	3.61	2.80	4.01	2.80	**6.64**	**0.09**	**0.90 hot eng-out**
	drive, cat effect hot	-3.23	-2.51	-3.59	-2.51	**-5.94**	**grams**	**0.10 hot exhaust**
	cool/warm effect	0.48	0.11	0.14	**0.11**	**0.39**	**1.13**	**0.15 cool exhaust**
	start effect% vs. drive hot	0.5%	0.6%	0,4%	0.6%	**0.5%**	resto chg	**0,16 cool exh + resto**
	cool **effect%** vs. drive hot	13%	4%	3%	4%	**6%**	**8.1%**	
Grams CO	**starts**	**0.163**	**0.163**	**0.163**	**0.163**	**0.325**	resto chg	**Grams/mile CO**
	drive, engine-out hot	29.1	22.6	32.4	22.6	**53.6**	*0.59*	**7,23 hot eng-out**
	drive, cat effect hot	-28.7	-22.2	-31.9	-22.2	**-52.7**	grams	**0.16 hot exhaust**
	cool/warm effect	11.20	2.98	3.29	2.98	**9.7**	10.8	**1.46 cool exhaust**
	start **effect% vs.** drive hot	0.6%	0.7%	0.5%	0.7%	**0.6%**	**resto chg**	**1.53 cool exh + resto**
	cool **effect%** vs. drive hot	***38%***	13%	10%	13%	**180/6**	5.4%	
Grams NOX	starts	0.010	0.010	0.010	0.010	**0.020**	resto chg	**Grams/mile NOX**
	drive, engine-out hot	10.64	8.26	11.83	8.26	**19.58**	0.13	**2.63 hot eng-out**
	drive, cat effect hot	-10.64	-8.26	-11.83	-8.26	**-19.58**	grams	**0.003 hot exhaust**
	cool/warm effect	1.11	0.22	0.30	0.22	**0.87**	0.89	**0.120 cool exhaust**
	start **effect%** vs. drive hot	0.1%	0.1%	0.1%	0.1%	**0.1%**	**resto chg**	**0.138 cool exh + resto**
	cool effect% vs. drive hot	1o%	3%	3%	3%	**4%**	15.0%	
Lbs Fuel	starts	**0.003**	**0.003**	**0.003**	**0.003**	**0.005**	**resto chg**	
	drive, engine-out hot	**0.58**	**0.45**	**0.64**	**0.45**	**1.06**	**0.067**	**City MPG**
	drive, cat effect hot	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**pounds**	**43.3 hot**
	cool/warm effect	**0.24**	**0.01**	**0.00**	**0.00**	**0.11**	**1.17**	**39.4 cool**
	start **effect%** vs. drive hot	**0.5%**	**0.6%**	**0.4%**	**0.6%**	**0.5%**	**resto chg**	**37.2 cool + resto**
	cool **effect%** vs. drive hot	**42%**	**2%**	**o%**	**o%**	**1 o%**	**5.7?4**	
	Engine **Hp-hr** :	1.406	1.091	1.563	1.091	2.586		**Highway MPG**
								47.5 hot
ESS, by Bag		**Bag 1**	Bag 2	Bag 3	Bag 4	FTP		**47,5 cool**
	Driving cycle kWh :	1.162	1.208	1.162	1.208	2.371		**44.9 cool + resto**
	Net kWh from/to (+/-) ESS :	-0,042	0.152	-0.152	0.152	0.047		
	Maximum SOC :	**71%**	**71%**	**71%**	71%	**71%**		
	Minimum SOC :	50%	50%	49%	50%	49%		**Combined (CAFE) MPG**
	Average charge C :	5.3	3.8	5.3	3.8	4.5		**45.1 hot**
	Average discharge C :	-3.0	-1,8	-3.0	-1,8	-2.4		**42.7 cool**
	Maximum charge C :	14	11	14	11	**14**		**40,3 cool + resto**
	Maximum discharge C :	-17	-1o	-17	-1o	-17		

DSIM FTP Simulation, Series Hybrid Powertrain

Vehicle : Chev. Lumina 4D
Vehicle weight: 3520
Engine: Geo 1. O-L2valv Metro
Engine strategy : Best Fuel
Engine Hp : 21.0
Thermal - engine, catalyst: Normal, VCI

ESS capacity, **kWh** : 3.00
ESS charge efficiency : 94%
ESS **disch efficiency : 93%**
ESS initial SOC : 70%
Charge start SoC : 50%
Charge stop SoC : 70%

Grade, 55 mph, Engine : 1,8%
ESS minutes that grade : 10,7
Engine City Range, miles : 330
ESS City Range, miles : 11,1
Engine duty, drive : 32%
Avg sec eng on, drive : 222

Eng hp-hr, drive : 2,59
ESS end-cycle SoC : 66%
Eng hp-hr, restore initial SOC : 0.16
Tot Eng hphr : 2,74
 # Engine starts : 3
Eng see, restore ini SOC : 27

Engine, by Bag	Bag 1	Bag 2	Bag 3	Bag 4	FTP		
Grams HC starts	**0.018**	**0.018**	**0.018**	**0.018**	**0.035**	**resto chg**	**Grams/mile HC**
drive, engine-out hot	3.61	**2.80**	*4.01*	**2.80**	**6.64**	**0.04**	**0.90 hot eng-out**
drive, cat effect hot	-3.23	**-2.51**	*-3.59*	**-2.51**	**-5.94**	**grams**	**0.10 hot exhaust**
cool/warm effect	0.66	**0.00**	*0.00*	**0.00**	**0.29**	**1.02**	**0.14 cool exhaust**
start **effect%** vs. drive hot	0.5%	**0.6%**	0.4%	**0.6%**	0.5%	**resto chg**	**0.14 cool exh + resto**
cool **effect% vs**. drive hot	18%	**o%**	*o%*	**0%**	**4%**	**4.3%**	
Grams CO starts	0.163	0.163	*0.163*	0.163	**0.325**	**resto chg**	**Grams/mile CO**
drive, engine-out hot	29.1	22.6	*32.4*	22.6	**53.6**	**0.06**	**7.23** hot eng-out
drive, cat effect hot	-28.7	-22.2	*-31.9*	-22.2	**-52.7**	**grams**	0.16 hot exhaust
cool/warm effect	14.83	0.09	*0.01*	0,00	**6.4**	**7.6**	1.02 cool exhaust
start **effect%** vs. drive hot	0.6%	**0.7%**	*0.5%*	0.7%	**0.6%**	**resto chg**	1.03 cool exh + resto
cool **effect%** vs. drive hot	51%	o%	*o%*	**0%**	**12%**	**0.8%**	
Grams NOX starts	0.010	0.010	0.010	0.010	**0.020**	**resto chg**	**Grams/mile NOX**
drive, engine-out hot	10.64	**8.26**	*11.83*	*8.26*	*19.58*	*0.00*	*2.63* hot eng-out
drive, cat effect hot	**-10.64**	**-8.26**	-11,83	-8,26	-19.58	grams	0.003 hot exhaust
cool/warm effect	**1.59**	0.01	0.00	0.00	0.69	0.71	0.095 cool exhaust
start **effect%** vs. drive hot	0.1%	0.1%	0.1%	0.l%	0.1%	resto **chg**	0.095 cool exh + resto
cool effect% vs. drive hot	15%	**o%**	**0%**	**0%**	**4%**	0.l%	
Lbs Fuel starts	**0.003**	**0.003**	**0.003**	**0.003**	**0.005**	**resto chg**	
drive, engine-out hot	**0.58**	**0.45**	**0,64**	**0,45**	**1.06**	**0.067**	**City MPG**
drive, cat effect hot	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**pounds**	**43.3 hot**
cool/warm effect	**0.24**	**0.01**	**0.00**	**0.00**	**0.11**	**1.17**	**39.4 cool**
start effect% vs. drive hot	**0.5%**	**0.6%**	**0,4%**	**0.6%**	**0.5%**	**resto chg**	**37.2 coot + resto**
cool **effect%** vs. drive hot	**42%**	**2%**	**0%**	**0%**	**10?40**	**5.7%**	
Engine **Hp-hr** :	1.406	1.091	**1.563**	**1.091**	**2.586**		**Highway MPG**
							47.5 hot

ESS, by Bag	Bag 1	Bag2	Baa 3	Bag 4	FTP		**47.5 cool**
Driving cycle kWh :	1.162	1.208	1,162	1.208	2.371		**44.9 cool + resto**
Net kWh from/to **(+/-)** ESS :	-0.042	0.152	-0.152	0.152	0.047		
Maximum SOC :	**71%**	71%	**71%**	71%	71%		
Minimum SOC :	50%	50%	49%	50%	**49%**		**Combined (CAFE) MPG**
Average charge C :	5.3	3.8	5.3	3.8	4,5		**45.1 hot**
Average discharge C :	-3.0	-1.8	-3.0	-1.8	-2.4		**42.7 cool**
Maximum charge C :	14	11	14	11	14		**40.3 cool + resto**
Maximum discharge C :	-17	-lo	-17	-lo	-17		

DSIM FTP Simulation, Series Hybrid Powertrain

Vehicle :	**Chev. Lumina 4D**	**ESS capacity, kWh :**	*3.00*
Vehicle weight:	**3520**	**ESS charge efficiency :**	*94%*
Engine :	**Geo 1.0-L 2valv Metro**	**ESS dischefficiency :**	*93%*
Engine strategy :	**Best Fuel**	**ESS initial SOC :**	**70?40**
Engine Hp :	**21.0**	**Charge start SOC :**	*50%*
Thermal - engine, catalyst:	**Normal, EHC+VCI**	**Charge stop SOC :**	**70%**
Grade, 55 mph, Engine :	**1.8%**	**Eng hp-hr, drive :**	**2.59**
ESS minutes that grade :	**10.7**	**ESS end-cycle SOC :**	**66%**
Engine City Range, miles :	**330**	**Eng hp-hr, restore initial SOC :**	**0.16**
ESS City Range, miles :	**11.1**	**Tot Eng hphr:**	**2.74**
Engine duty, drive :	**32%**	**# Engine starts :**	**3**
Avg sec eng on, drive :	**222**	**Eng see, restore ini SOC :**	**27**

Engine, by Bag		**Bag 1**	**Bag 2**	**Bag 3**	**Bag 4**	**FTP**		
Grams HC	starts	0.018	0.018	0.018	0.018	*0.035*	resto chg	**Grams/mile HC**
	drive, engine-out hot	3.61	2.80	4.01	2.80	*6.64*	**0.04**	*0.90* hot eng-out
	drive, cat effect hot	-3.23	-2.51	-3.59	-2.51	*-5.94*	**grams**	**0.10** hot exhaust
	cool/warm effect	0.25	0,00	0.00	0.00	0.11	**0.64**	0.11 **cool exhaust**
	start **effect%** vs. drive hot	0.5%	0.6%	0.4%	0.6%	0.5'%	**resto chg**	**0.12 cool exh + resto**
	cool **effect%** vs. drive hot	7%	o%	o%	o%	**2%**	**5.3%**	
Grams CO	**starts**	0.163	0.163	0.163	0.163	**0.325**	resto chg	**Grams/mile CO**
	drive, engine-out hot	29.1	22.6	32.4	22.6	**53.6**	**0.06**	**7.23** hot **eng-out**
	drive, cat effect hot	-28.7	-22.2	-31.9	-22.2	**-52.7**	**grams**	0.16 hot exhaust
	cool/warm effect	5.91	0.05	0.04	0.01	**2.6**	**3.8**	0.50 cool exhaust
	start **effect%** vs. drive hot	0.6%	0.7%	0.5%	0.7%	**0.6%**	**resto chg**	0.51 cool exh + **resto**
	cool **effect%** vs. drive hot	20%	o%	o%	0%	**5%**	**1.5%**	
Grams NOX	starts	**'0.010**	**0.010**	**0.010**	0.010	*0.020*	**resto chg**	**Grams/mile NOX**
	drive, engine-out hot	**10.64**	**8.26**	**11.83**	**8.26**	**19.58**	**0.00**	**2.63 hot eng-out**
	drive, cat effect hot	**-10.64**	**-8.26**	**-11.83**	**-8.26**	**-19.58**	**grams**	**0.003 hot exhaust**
	cool/warm effect	**0.54**	**0.01**	**0.00**	**0.00**	**0.23**	**0.26**	**0.035 cool exhaust**
	start **effect%** vs. drive hot	**0.1%**	**0.1%**	**0.1%**	**0.1%**	**0.1%**	**resto chg**	**0,035 cool exh + resto**
	cool **effect%** vs. drive hot	**5%**	**o%**	**o%**	**o%**	**1%**	0.2%	
Lbs Fuel	starts	0.003	0.003	0,003	0.003	0.005	**resto chg**	
	drive, engine-out hot	**0.58**	**0.45**	**0.64**	**0.45**	**1.06**	**0.067**	**City MPG**
	drive, cat effect hot	**0.00**	**0.00**	**0.00**	**0,00**	**0.00**	pounds	43.3 hot
	cool/warm effect	0.24	0.01	0.00	0.00	0.11	1.17	39.4 cool
	start **effect%** vs. drive hot	0.5%	0.6%	0.4%	0.6%	0.5%	resto chg	37.2 cool + resto
	cool effect% vs. drive hot	42%	**2%**	**0%**	o%	10%	5.7%	
	Engine Hp-hr:	1.406	1.091	1.563	1.091	2.586		Highway MPG
								47.5 hot
ESS, by Bag		**Bag 1**	**Bag 2**	**Bag 3**	**Bag 4**	**FTP**		**47.5 cool**
	Driving cycle kWh :	**1.162**	**1.208**	**1.162**	**1.208**	**2.371**		**44.9 cool + resto**
	Net kWh from/to **(+/-)** ESS :	-0.042	0.152	-0.152	0.152	0,047		
	Maximum SOC :	**71%**	**71%**	**71%**	**71%**	71%		
	Minimum SOC :	50%	50%	49%	50%	49%		Combined (CAFE) MPG
	Average charge C :	5.3	**3.8**	**5.3**	3.8	4.5		45.1 hot
	Average discharge C :	-3.0	-1.8	-3.0	-1.8	-2.4		42,7 cool
	Maximum charge C :	14	11	14	11	14		40.3 cool + resto
	Maximum discharge C :	-17	-Io	-17	-Io	-17		

DSIM Electric Vehicle FTP Simulation

Vehicle : GM Impact 3 EV
Vehicle weight: 3110 lbs
ESS charge efficiency : 81%
ESS disch efficiency : 80%

ESS capacity, kWh : 16.8
ESS initial SOC : 70°A
ESS SOC after 2 FTPs : 53%
ESS City kWh/mile : 0.196
ESS City Range, miles : 77.1

ESS, by Bag	Bag 1	Bag 2	Bag 3	Bag 4	2 FTPs
Driving cycle kWh :	0.802	0.837	0.802	0.837	3.279
Net kWh from/to (+/-) ESS :	0,737	0.724	0.737	0,724	2.922
Maximum SOC :	70%	66%	61%	57%	70%
Minimum SOC :	65%	61%	57%	53%	53%
Average charge C :	0.4	0.3	0.4	0.3	0.3
Average discharge C :	-0,4	-0.3	-0.4	-0.3	-0.3
Maximum charge C :	1,3	1.2	1.3	1.2	1.3
Maximum discharge C :	-3.0	-1.7	-3.0	-1.7	-3.0

Utility Gm/veh.mile	ROG	CO	NOX	Sox	PM1O
Pacific	0,006	0.035	0.062	0.072	0.019
Mountain	0.004	0.032	0.431	0.710	0.026

DSIM Electric Vehicle FTP Simulation

Vehicle: Chrysler TEVan
Vehicle weight: 5350 lbs
ESS charge **efficiency : 81%**
ESS disch efficiency : 80%

ESS capacity, **kWh:** 23.6
ESS initial SOC : 70'%
ESS SoC after 2 FTPs : 45%
ESS City kWh/mile : 0.391
ESS City Range, miles : 54,3

ESS, by Bag	Bag 1	Bag 2	Bag 3	Bag 4	2 FTPs
Driving cycle kWh :	1,535	1.534	1.535	*1.534*	6.138
Net kWh from/to (+/-) ESS :	1.507	1,406	1.507	*1,406*	5.826
Maximum SOC :	*70%*	64%	58%	*51%*	70%
Minimum SOC :	*63%*	58%	51%	45%	45%
Average charge C :	*0.5*	*0.3*	0.5	0.3	0.4
Average discharge C :	*-0,6*	*-0.3*	-0.6	*-0.3*	-0.5
Maximum charge C :	*1.5*	*1.4*	1.5	1.4	1.5
Maximum discharge C :	*-3.7*	*-2.1*	-3.7	-2.1	-3.7

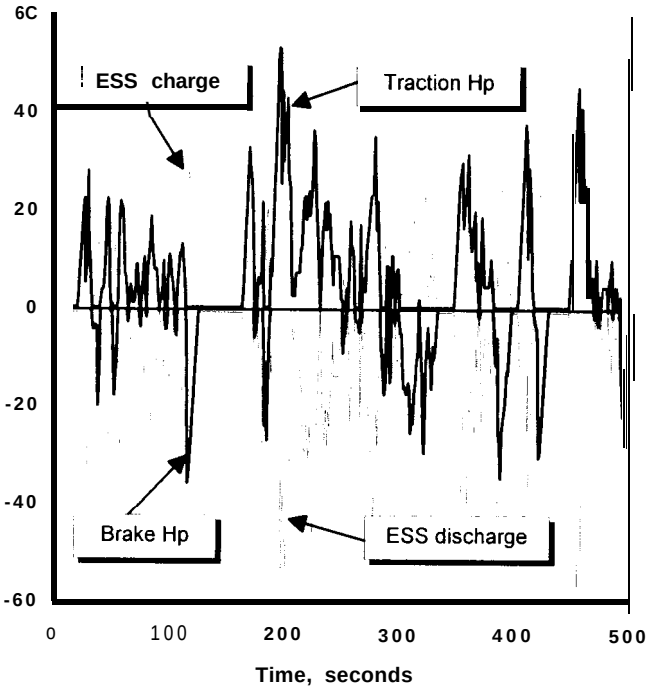
Utility Gm/veh.mile	ROG	c o	NOX	SOx	PM1O
Pacific	*0.013*	*0.070*	*0.163*	*0.144*	*0.037*
Mountain	*0.009*	*0.064*	*0,859*	*1.416*	*0.052*

Vehicle: 3110 lb
GM Impact 3 EV

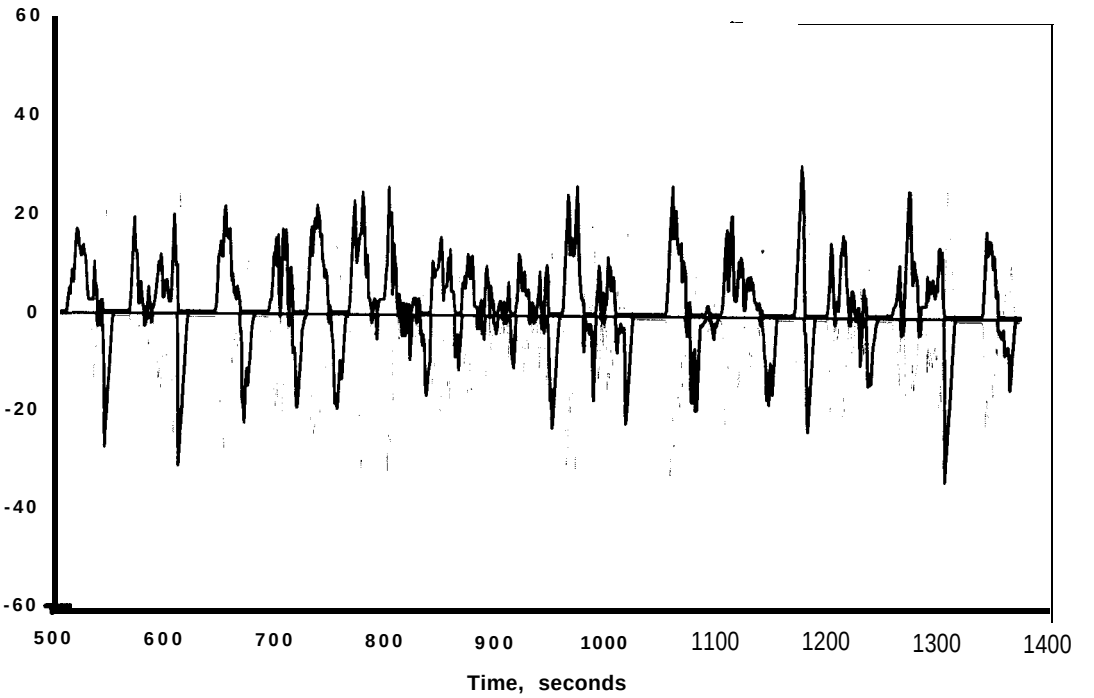
ESS: *16.8* kWh
65% RT Efficiency

Engine: 21 Hp
Strategy: Best Fuel

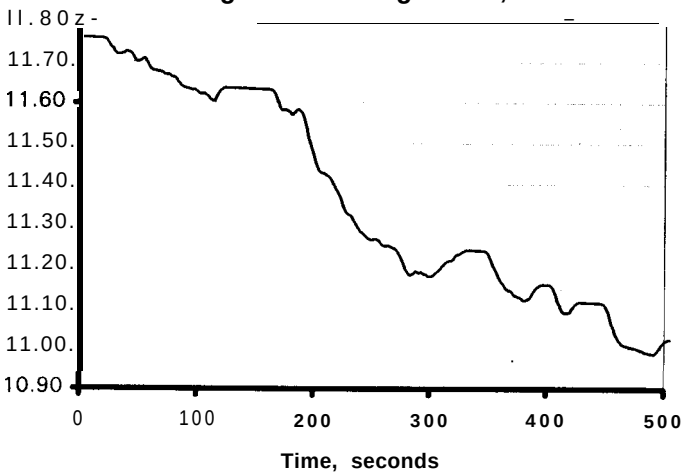
FTP Bag 1: Power Flow, Hp



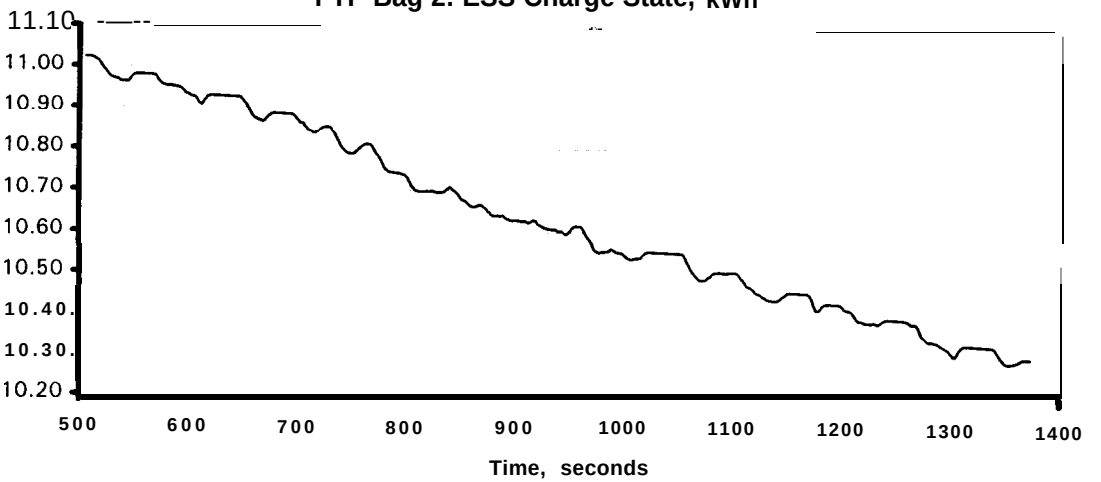
FTP Bag 2: Power Flow, Hp



FTP Bag 1: ESS Charge State, kWh



FTP Bag 2: ESS Charge State, kWh



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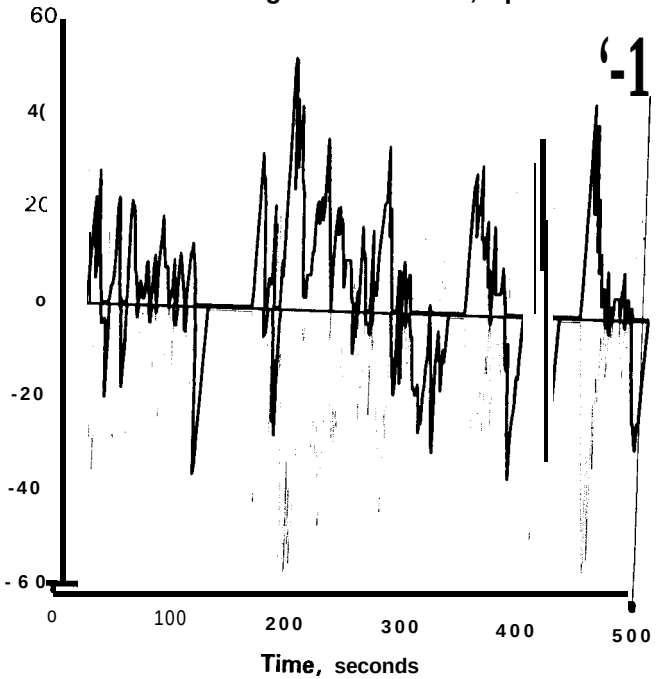
GM Impact 3 EV

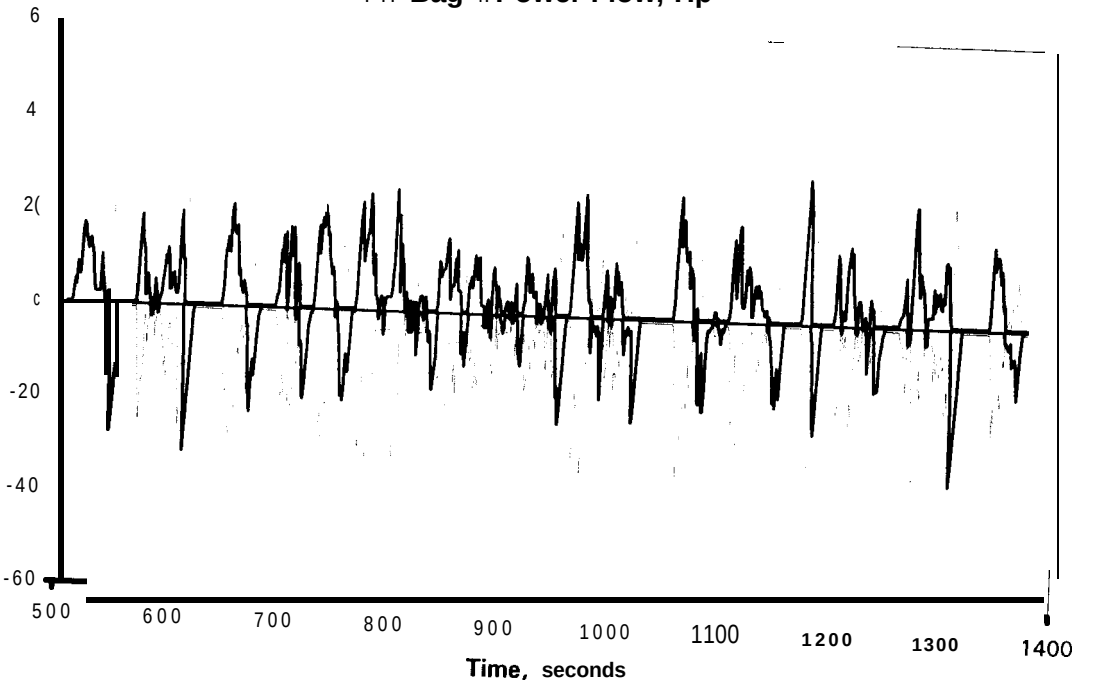
ESS: *16.8* kWh
65% RT Efficiency

Engine: 21 Hp
Strategy: Best Fuel

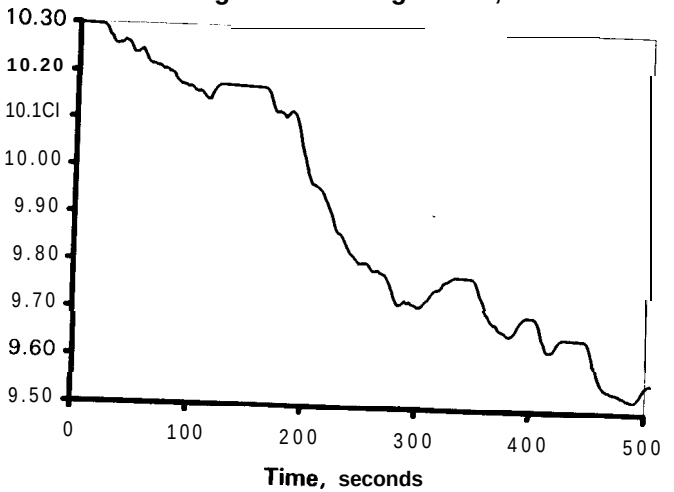
FTP Bag 3: Power Flow, Hp



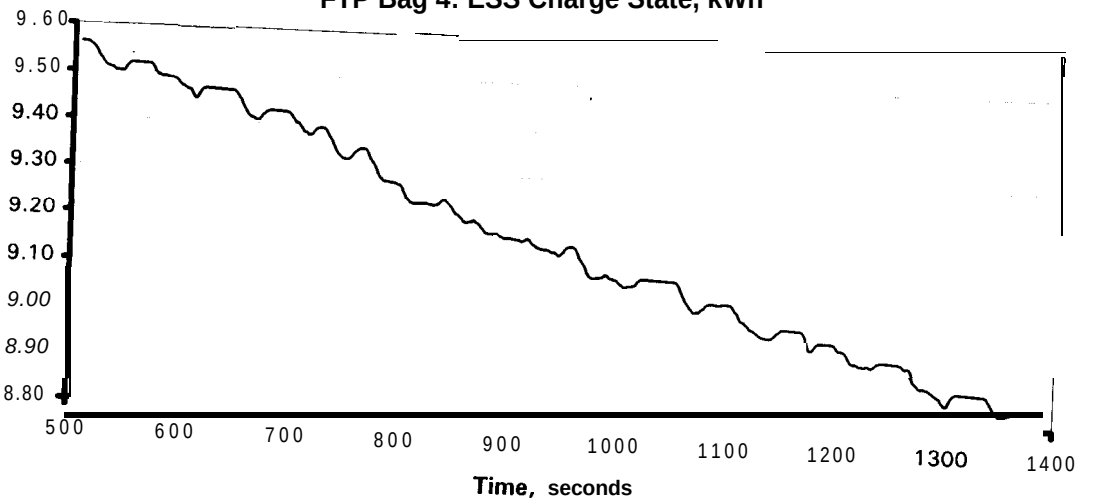
FTP Bag 4: Power Flow, Hp



FTP Bag 3: ESS Charge State, kWh



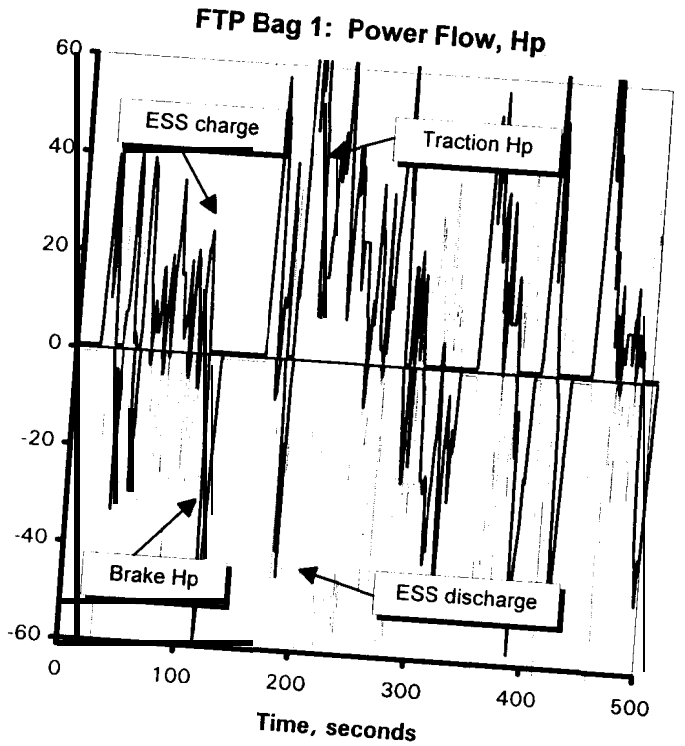
FTP Bag 4: ESS Charge State, kWh

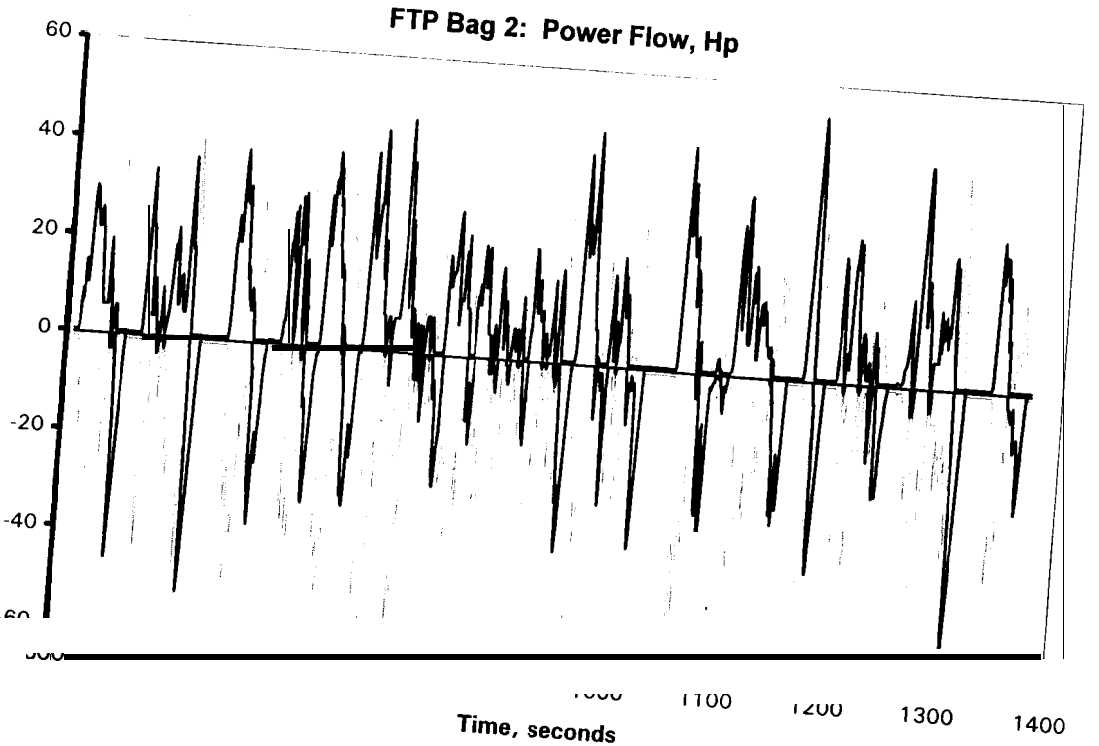


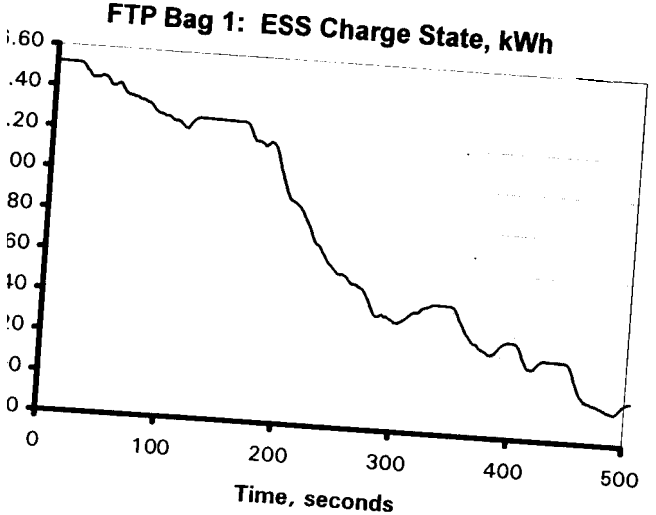
Vehicle: 5350 lb
Chrysler TEVan

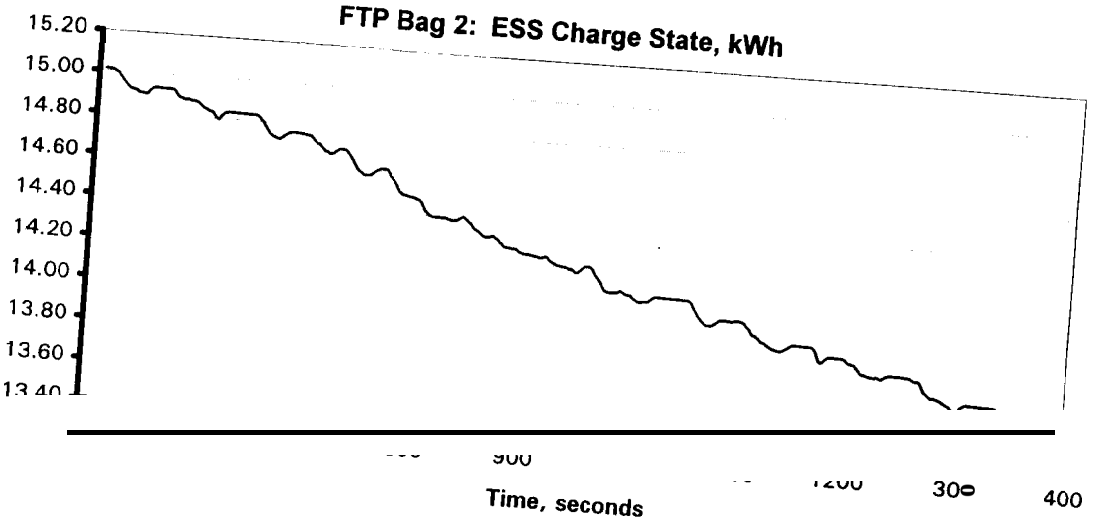
ESS: 23.6 kWh
65% RT Efficiency

Engine: 21 Hp
Strategy: Best Fuel









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Chrysler TEVan

ESS: 23.6 kWh
65% RT Efficiency

Engine: 21 Hp
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