Kansas City PM Characterization Study

Final Report

Appendix BB
Pilot Report

Assessment and Standards Division
Office of Transportation and Air Quality
U.S. Environmental Protection Agency

Sponsors:

National Renewable Energy Laboratory, U.S. Department of Energy
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Kansas City PM Characterization Study

Draft Pilot Testing Report

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KANSAS CITY PM CHARACTERIZATION STUDY
DRAFT PILOT TESTING REPORT

EPA Contract #GS 10F-0036K

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1.0 Introduction

The USEPA have established a contract with Eastern Research Group, Inc. to conduct a program in Kansas City to evaluate exhaust emissions from light-duty gasoline vehicles. The proposed program consists of measuring particulate matter (PM) and other components in exhaust emissions from 480 randomly selected light-duty gasoline vehicles in the Kansas City metropolitan area.

The study is being conducted in Kansas City in three parts:

Part 1: Pilot Study (May 2004)
Part 2: Phase I Testing (July-September 2004)
Part 3: Phase II Testing (January-March 2005)

This report summarizes the results of the Pilot Study conducted in Ann Arbor, MI and Kansas City, KS in April through May 2004.

1.1 Goals of the Pilot Testing

The primary goals of the Pilot Study were to:

1) Set up a testing facility in Kansas City that will be used for the entire study;

2) Finalize all testing methodologies, testing procedures, and data handling procedures; and

3) Test three vehicles in Ann Arbor and Kansas City to establish the relationship between the emission results from the two facilities.

2.0 Site Preparation

2.1 Site Selection for Protective Covering for the Equipment and Vehicles

Five potential test sites for the Kansas City vehicle emissions study were visited on Friday, March 26, 2004. Several additional sites were visited in April. Visits to all of the sites were arranged through Brian Staton of CBRE (Industrial site realtor) and John Dietel of ERG, both of whom visited the sites with ERG's technical staff. The listing realtors were also with ERG at their respective properties. ERG subsequently ranked the sites from most desired to least desired according to criteria important to the emissions study. The major ranking criteria are as follows:

1) Can be used to soak and test vehicles at outside, ambient temperatures.

2) Adequate ventilation to maintain suitable background levels and to insure safety of personnel.

3) Adequate size for test equipment, vehicle storage and movement.

4) Heated/Air Conditioned office space.

5) Other: Easy access to major driving arteries (interstate highways), Adequate power, restrooms, minimum sound amplification, adequate outdoor parking.

Another important factor was whether or not the property had an overhead water sprinkler system. The typical warehouses were all equipped water sprinkler systems and could not be used below ~34 F. Only two of the properties offered did not have water sprinkler systems, so these two properties became our primary choices, and are described below.

#1. 6636 Berger Avenue, Kansas City, KS

This property had about 7,000 sq ft total floor space, with about 1,000 sq ft office and 2 restrooms. With four 12' x 12' bay doors plus two wall vent fans, this site provided adequate ventilation and easy access. This was also one of two properties visited which did not have an overhead water sprinkler system, which meant it can be used at sub-freezing temperatures. Indoor space was adequate -- about 5,000 sq ft of main floor space for test area and vehicle soaking, with another 900 sq ft of area for working on and inspecting vehicles. The site also included three offices plus a common area. The front entrance and parking was ideal to greet vehicle owners. This was a stand-alone property, so we would not have to interact with other tenants. The site had ample outdoors parking and storage, and the building was ready to occupy after minor clean up.

This was the site ultimately chosen.

#2. 9601 Alden, Lenexa, KS.

This property had about 7,900 sq ft total floor space, with about 1,000 sq ft office and 2 restrooms. With seven 12' x 12' bay doors plus two ceiling vent fans, this facility was built with ventilation of exhaust fumes in mind. This was one of two properties visited, and did not have an overhead water sprinkler system, which meant it could be used at sub-freezing temperatures. Indoor space was adequate, with about 6,000 sq ft main floor space for test area and vehicle soaking, and another 900 sq ft of area for working on and inspecting vehicles. The site featured eight offices plus a common area. One office had window overlooking test area and has potential for housing auxiliary sampling equipment (PM samplers, etc). The front entrance and parking was ideal to greet vehicle owners. This was also a stand-alone property, so we would not have to interact with other tenants. The site had ample outdoors parking and storage, and was located in an industrial park with easy access to Interstates 35 and 435. The building was ready to occupy after minor clean up. The only negative feature of this property was that a sub-lease arrangement could not be worked out satisfactorily in the required time.

#3. 9870-9878 Pflumm Rd, Lenexa, KS.

This property was a huge warehouse, of which we would occupy half. A dividing wall, offices, and restrooms would have to be constructed. One drive in bay door and four dock high bay doors were located on one side of this space, with the other three sides enclosed, so ventilation was in question. A couple of roof vents could have been added to help with ventilation. The facility could not be operated below 35 F due to water sprinkler system. In addition, ERG would need to obtain permit to operate motor vehicles inside this space. This is the largest space we visited and had ample room. One office is presently in place. Additional offices, restrooms, and dividing firewall would have to be constructed. The site featured easy access to interstates.

#4. 6926 Martindale Road, Shawnee, KS

This site was a 6,000 sq ft warehouse, with unfinished construction. They were preparing (grading) the parking lot for paving when we were there. The site featured two drive in bay doors along one wall. Again, ventilation was a problem. The offices (once constructed) would split the test area into two halves. The site had a water sprinkler system, so building must be maintained above 35 F.

#5. 1530-64 E. Spruce St, Olatahe, KS

This was a warehouse space with adequate office space and a nice entrance facade for greeting vehicle owners. However, one drive in bay door and two dock high bay doors on one corner of space did not lend itself to adequate ventilation. Noise amplification was high in this space. The overhead water sprinkler system meant temperatures must be kept above 35 F.

#6. 6230-6244 Merriam Dr., Johnson Co.

This site was totally unacceptable, with one 8' high drive in bay door. ERG would not be able to get the testing equipment into the facility. Multiple dock high bay doors opposite wall could have provided ventilation, although minimal power was available. Three 3,000 sq ft spaces were separated by walls. This was a dirty warehouse space located in a very crowded, small parking area.

2.2 Transportation of Dynamometer and Analytical Trailer.

Final preparations for shipping the transportable dynamometer and analytical trailer were made the week of May 3, 2004. All necessary equipment was loaded onto either the open dynamometer trailer or the enclosed analytical trailer. Equipment was protected from the elements as appropriate and securely strapped.

Equipment was transported by Wilson Transport, SVC, and left the RTP-EPA facility on Monday, May 10, 2004, aboard two separate drop deck trucks. Delivery in Kansas City was scheduled for Wednesday, May 12.

The equipment arrived in Kansas City without incidence. BKI staff members also arrived in Kansas City on May 12 to off-load the equipment and begin set-up. The drop deck trucks arrived at the test site around 4:00 p.m. A wrecker was called and arrived shortly thereafter to off-load both the dynamometer and analytical trailer. The equipment was inspected and found to be in great shape, with no apparent mishaps in transit. Provisions were made to store the equipment in the secure, fenced yard at the test site, as the building itself had not yet been vacated by the previous tenant.

2.3 Transportation of Correlation Vehicles.

The three correlation vehicles were transported from Ann Arbor to the Kansas City site by M & R Transport. The vehicles were picked up in Ann Arbor on May 14 and arrived at the Kansas City test site on Monday, May 17. The vehicles appeared to have suffered no damage during transit. At the conclusion of the pilot study, two of the vehicles were shipped back to Ann Arbor via the same carrier. (The third vehicle is to remain at the KC test site for use during the summer and winter test phases). These two vehicles were picked up on May 28 and arrived in Ann Arbor on June 1.

2.4 Set-up of Dynamometer, Analytical Trailer, and Associated Sampling Equipment.

Set up of the dynamometer and associated equipment began on the afternoon of Saturday, May 15, immediately after the previous tenet completed moving out. The first order of business was to wash the bay floors, which were covered in mud and other debris. The dynamometer and analytical trailer were then towed into the building and positioned at the rear of the building, near electrical power sources and ventilation. The dynamometer trailer was set in place, leveled, and catwalks and ramping were installed. The following day, electrical power was connected, the dilution tunnel was assembled and set in place, and plumbing and electrical interfaces between the analytical trailer and dynamometer were established. Working gases for the analytical trailer were received and installed.

2.4.1 Setup of Associated Sampling Equipment

DRI installed and operated a suite of instruments to provide continuous PM analysis and to collect batch samples of particle and gaseous exhaust components for later analysis. These instruments collected sample air from the dynamometer dilution system via two isokinetic probes, provided by BKI, inserted prior to a 90-degree bend in the dilution tunnel. Figure 2-1 illustrates the sample train as it was installed for the pilot study. Heated conductive lines carried air from the probes to the continuous instruments. Insulated copper tubing was used to carry sample air to the time-integrated samplers. The following instruments were operated continuously during all tests.

Photoacoustic: Designed and built at DRI, this instrument continuously measures the concentration of light-absorbing carbonaceous material (black carbon) in the airstream by the photoacoustic principle, in which the absorption of modulated light by particles results in thermal-acoustic pulses that can be detected by a highly-sensitive transducer and phase-locked amplifier.

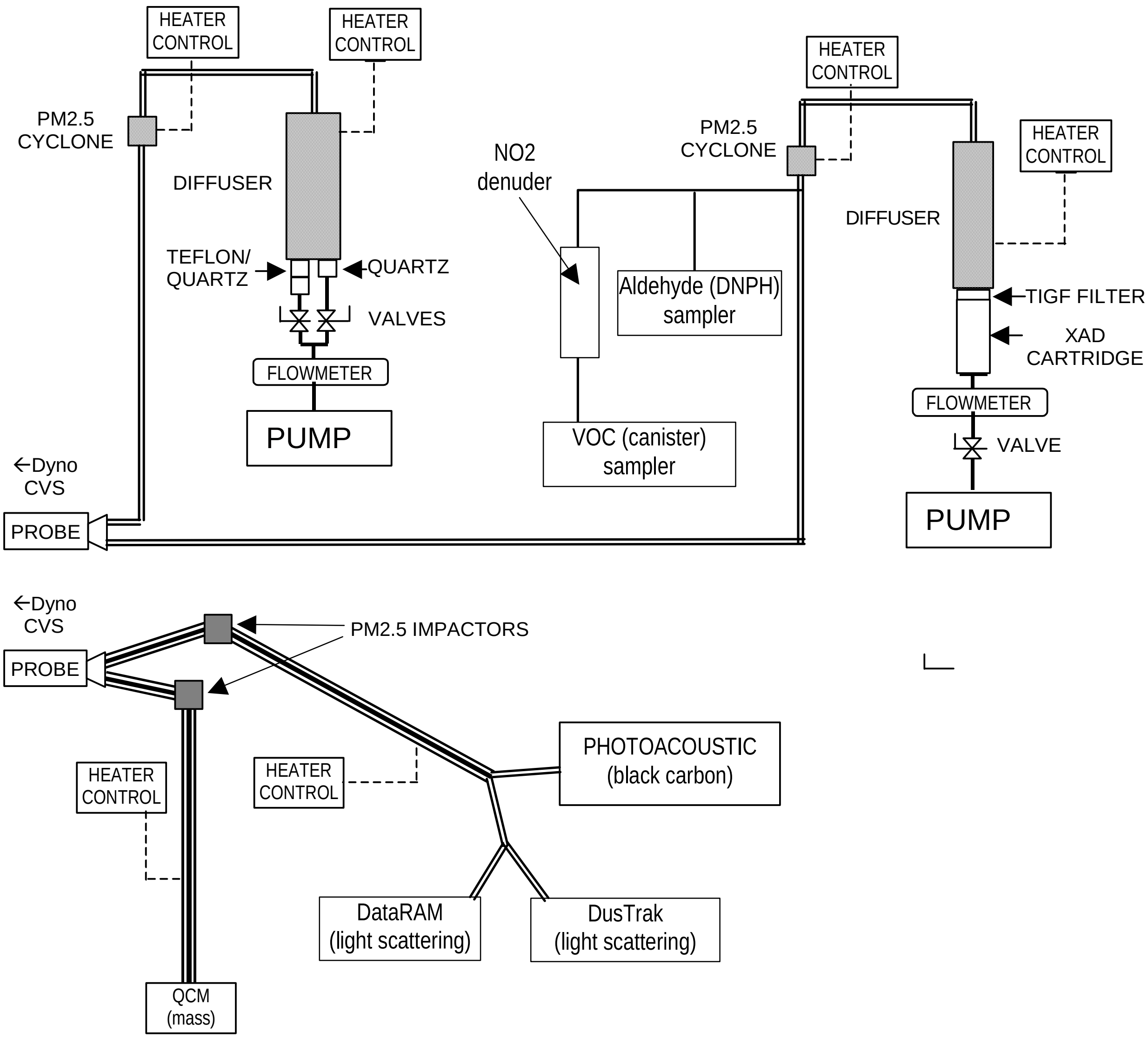


Figure 2-1. Sampling Train for the Pilot Study

QCM: Quartz crystal microbalance, manufactured by SEMTECH, monitors the accumulation of particles on a surface in real-time. A clean-air dilution system is used in conjunction with this instrument to reduce the dynamic range of the source aerosol concentration.

DustTrak: A commercially available portable monitor for particulate matter, the TSI DustTrak estimates the concentration of particulate mass by measuring the intensity of light scattered perpendicular to a laser beam directed through the airflow stream. Flow rate is 1.5 lpm.

DataRAM: Another commercially available portable monitor for particulate matter, which operates on the same principle but uses two wavelengths for more uniform response to varying particle sizes. Flow rate is 2 lpm.

Time-integrated samples for laboratory analysis were collected during each unified cycle test and a 60-minute tunnel blank each day as described below, using specially adapted samplers designed and constructed at DRI:

Filter samples: During each phase of the unified cycle tests a pair of filter cartridges collected particles to be analyzed for gravimetric mass and organic and elemental carbon concentrations. Pre-weighed 47mm Gelman Teflo filters were used for gravimetry. Pre-fired 47mm quartz fiber filters were collected for analysis of organic and elemental carbon by Thermal Optical Reflectance (TOR). Back-up quartz filters were also included behind the Teflo and will also be analyzed by TOR to investigate the effect of sampling temperature on volatilization of organic particles. For this sampler, air was drawn from the CVS via ½" insulated copper tubing to a small heated stainless steel chamber. The sample air exited via a $PM_{2.5}$ cyclone contained in the chamber to a heated diffusing chamber approximately 1m tall, containing a thermistor temperature probe. From this chamber, the sample air exited through the two filter cartridges. Flow rates for each filter were set to 56 lpm by adjustable valves to give a combined flow of approximately 113 lpm as required by the inlet cyclone. A single oil-less pump was used to draw air through the sampler.

Since the automated sequential sampler designed for this project was not completed in time for the Pilot Study, it was necessary to manually change filters between phases of each test. This was done as quickly as possible during the ~25 second idle period during the transition from phase 1 to phase 2. The operators were able to observe the vehicle on the dynamometer during this process and begin the process as soon as the vehicles wheels stopped turning to assure synchronization with the driving cycle.

Samples were collected by a separate sampler for determination of particulate and semi-volatile organic compounds on 100 mm Teflon-impregnated glass fiber (TIGF) filters followed by glass cartridges containing XAD adsorbent at a flow rate of 112 lpm. The material collected on these media will be removed by solvent extraction and analyzed at DRI by gas chromatography and mass spectrometry. A single filter and adsorbent pair were collected for each unified cycle, combining phases 1, 2 and 3. Sampling was suspended during the 10-minute soak period by turning off the pump. Sample air was drawn from the dynamometer CVS via ½" insulated copper tubing to a small heated stainless steel chamber. The sample air exited via a

$PM_{2.5}$ cyclone contained in the chamber to a heated diffusing chamber, containing a thermistor temperature probe, approximately 50cm tall. From this chamber, the sample air exited via the filter followed by the XAD cartridge. Flow rates were approximately 113 lpm as required by the inlet cyclone, and was monitored by an in-line TSI 4000 mass-flow meter. A single oil-less pump was used to draw air through the sampler.

Aldehydes: Sample air was drawn from the heated cyclone chamber via a ¼" diameter Teflon hose and passed through 2,4-dinitrophenylhydrazine (DNPH) cartridges using a 6-channel sampler with integrated pump and mass flow controller. Airflow was maintained at 500 cc/min. A single cartridge was exposed for the duration of the 3 phases of the unified cycle. Sampling was suspended during the 10-minute soak by switching to an unused channel.

VOC: Sample air was drawn from the heated cyclone chamber via a ¼" diameter Teflon hose and passed through a Teflo filter and a denuder coated with triethanolamine to remove NO_2 before being pumped into a Summa polished steel canister. Air flow was controlled by a needle valve to obtain the necessary flow rate to fill the canisters to approximately 15"Hg positive pressure over the duration of the complete unified cycle. Sampling was interrupted during the 10-minute soak by switching to a bypass channel. The sampler draws a total flow of 2 lpm, but only about 300 cc/min of that was pumped into the canisters.

[Heated tubing is shown as triple lines, insulated tubing as double lines.]

2.4.2 Equipment Provided

Table 2-1 lists equipment was either rented or purchased to support the sampling efforts.

Table 2-1: Sampling Support Equipment Rented or Purchased by ERG, On-Site.

Name	Purpose	Notes
Oil-less Air Compressor	To supply clean, dry dilution air to the micro-dilution system used with the QCM.	Purchased. Provides up to 5 SCFM at 100 psig. Has a 25 gal. tank. Water trap and filtration provided by EPA.
AC Electricity Generator	To supply power for the CVS dilution air heater.	Rented from United Rentals. Wacker model G-50. 50-kilowatt capacity. Diesel fueled. Power umbilical provided by BKI.
CVS Dilution Air Dryer	To reduce CVS dilution air humidity.	Rented from United Rentals. TempAir (Rupp Industries) model TD 400. Dries up to 400 CFM. Intentionally undersized for this application (since we don't require the usual 10% RH it is designed to deliver). Requires 230 V, 1 phase, 30 A, electric supply. Portable desiccant-type dehumidifier. Alumina silicate wheel continuously absorbs gas-phase water. Heated slip-stream of dried air re-directed back to used section of wheel to desorb water and regenerate the wheel.
Refrigerator	To store particulate filter media.	Purchased. 14 cubic feet, upright.
Freezer	To store fuel samples.	Purchased. 10 cubic feet, chest.

2.5 Maintenance and Calibration of Dynamometer, Analytical Trailer, and Associated Sampling Equipment.

Dynamometer Static Load (Dead Weight) and Speed Calibrations:

Initial, and thereafter, daily, load cell checks were made using the available calibration weights. Minor "zero" adjustments were periodically required. No span adjustments were made. Results, shown below in Table 2-2, were consistent with historic data.

Table 2-2. Static Load (Dead Weight) Checks

	Arbor + W1+W2	Arbor + W1	Arbor + W2	Arbor	Unloaded
Total Weight	50 lbs	40 lbs	15 lbs	5 lbs	0 lbs
Equivalent Hp @ 50 MPH	18.5	14.8	5.55	1.85	0.0
5/17/04 Reading	18.5	14.9	5.5	1.8	0.0
5/19/04 Reading	18.4	14.7	5.5	1.8	0.0
5/20/04 Reading	18.3	14.6	5.4	1.8	0.0
5/21/04 Reading	18.5	14.7	5.5	1.8	0.0
5/22/04 Reading	18.4	14.6	5.5	1.8	0.0
5/23/04 Reading	18.4	14.7	5.4	1.7	0.0
5/25/04 Reading	18.3	14.6	5.4	1.8	0.0
5/26/04 Reading	18.3	14.6	5.4	1.7	0.0

Initial, and thereafter, daily dynamometer roll speed checks were also made. Roll speed was checked using a phototachometer and compared to the driver's aid digital speed output. No adjustments were required. Results are shown in Table 2-3.

Table 2-3. Dynamometer Roll Speed Checks

Date	Roll RPM	*Equivalent Speed*	Driver's Aid Reading
5/17/04 Reading	1930	49.5 mph	49.7 mph
5/19/04 Reading	1938	49.9	50.0
5/20/04 Reading	1959	50.4	50.3
5/21/04 Reading	1955	50.3	50.3
5/22/04 Reading	1962	50.5	50.1
5/23/04 Reading	1944	50.0	49.8
5/24/04 Reading	1941	50.0	50.0
5/25/04 Reading	1941	50.0	49.9
5/26/04 Reading	1958	50.4	50.3

Dynamometer Coastdowns:

Daily dynamometer coastdowns were performed to verify overall dynamometer operation. Coastdowns were performed from 55 to 45 mph at an inertia setting of 3,500 lbs. and a load setting of 6.0 Hp (indicated) @ 50 MPH, after a 10-15 minute warmup at 50 mph. Coastdown times obtained are shown in Table 2-4, and indicated the dynamometer was operating within its normal specifications.

Table 2-4. Daily Coastdowns (Vehicle off Rolls) @ 3500 lbs and 6.0 Hp Indicated

Date	CD #1 time, seconds	CD #2 time, seconds	CD #3 time, seconds
5/17/04 Reading	22.84	23.17	23.35
5/20/04 Reading	24.18	24.49	-
5/21/04 Reading	23.72	23.28	-
5/22/04 Reading	23.84	24.26	-
5/23/04 Reading	23.46	23.88	23.96
5/24/04 Reading	23.31	24.07	23.54
5/25/04 Reading	22.66	22.86	22.90
5/26/04 Reading	23.31	22.77	23.05

Prior to vehicle testing, coastdowns were also performed with the three correlation vehicles on the rolls to determine appropriate load settings for each of the vehicles. Desired coastdown times for each of the vehicles was provided by EPA, Ann Arbor. Table 2-5 gives results of these initial vehicle coastdowns.

Table 2-5. Initial Correlation Vehicle Coastdowns

Vehicle	Test Inertia, pounds	Desired 55-45 mph Coastdown time, seconds	Actual 55-45 mph Coastdown time, seconds
2004 Stratus	3,500	17.86	17.90 ± 0.23
1988 Taurus	3,500	17.30	14.93 ± 0.16
1988 New Yorker	4,000	17.59	17.47 ± 0.19

Coastdown times obtained for the Stratus and New Yorker agreed very well with the desired coastdown times. Times for the Taurus could not be increased past ~ 15 seconds, as the dynamometer was fully unloaded at this point.

Vehicle coastdown times were checked on several additional days, immediately after the conclusion of the vehicle's emissions test, and again at the end of the study. For all three vehicles, the indicated load tended to be a little higher, and coastdown times a little shorter, immediately after the emissions test. This phenomena could be duplicated by motoring the vehicle above 60 mph for several seconds, but did not occur when motoring the vehicle below 60 mph. The apparent change in load is not clearly understood, but is thought to be due to mechanisms within the dynamometer's Power Absorption Unit, possibly as a result of leaks, cavitation, or aeration of the load fluid. Because this occurs apparently only after motoring at speeds above 60 mph, one would expect the LA92 driving cycle to be impacted most from the point in Phase 2 where maximum speeds are above 60 mph, and to extent into phase 3. That is, the vehicles would be operating under slightly higher loads than initially preset.

A major change in coastdown times occurred for the 1988 New Yorker during the course of testing. The initial coastdown time of 17.47 seconds had decreased to ~ 12 seconds when checked after the third day of testing. This could be due to brake “hang-up” (testing staff did exercise the breaks quite a bit on the first two days of the LA92) affecting the vehicle’s rolling resistance. After this change was detected, we readjusted the load setting (from 10.3 indicated to 5.0 indicated) to yield coastdown times within the 17 second time frame. It should be noted that warm start (phase 3) emissions exhibited no significant differences when using the two different load settings.

Additional, high speed coastdowns (65mph to 35 mph, and 65 mph to 45 mph) were also conducted on all three vehicles. It is assumed that the effect of dynamometer operation above 60 mph as described above would also affect these coastdowns.

Tables 2-6 through 2-8 below show results for the additional coastdown tests.

Table 2-6. Additional 2004 Stratus Coastdowns

Date	Speed Range, mph	Coastdown time, sec	Hp Indicated	Comment
5/22/04	55-45	12	6.0	Immediately after emission test
	55-45	12.49	6.0	Immediately after emission test
5/23/04	55-45	14.95	4.1	Immediately after emission test
	55-45	16.54	3.4	After test, reset to nominal value
	65-35	30.2	3.4	After test, reset to nominal value
5/26/04	55-45	17.05	3.4	After test, reset to nominal value
	55-45	16.99	3.4	After test, reset to nominal value
	55-45	17.09	3.4	After test, reset to nominal value
	65-35	49.4	3.4	After test, reset to nominal value
	65-35	50.7	3.4	After test, reset to nominal value
	65-35	51.62	3.4	After test, reset to nominal value

Table 2-7. Additional 1988 Taurus Coastdowns

Date	Speed Range, mph	Coastdown time, sec	Hp Indicated	Comment
5/22/04	55-45	14.6	3.5	Immediately after emission test
	65-45	26.63	3.5	Immediately after emission test
	55-45	15.58	3.0	After test, reset to nominal value
	65-45	29.25	3.0	After test, reset to nominal value
5/24/04	55-45	14.21	3.3	Immediately after emission test
	55-45	14.97	3.3	Immediately after emission test
	55-45	14.88	3.3	Immediately after emission test
	55-45	15.69	3.0	After test, reset to nominal value
	55-45	15.89	3.0	After test, reset to nominal value
	55-45	15.38	3.0	After test, reset to nominal value
5/26/04	55-45	11.74	6.3	Immediately after emission test
	55-45	11.88	6.3	Immediately after emission test
	55-45	12.02	6.3	Immediately after emission test
	65-35	37.16	6.3	Immediately after emission test
	65-35	38.86	6.3	Immediately after emission test
	65-35	38.79	6.3	Immediately after emission test
	55-45	15.27	3.0	After test, reset to nominal value
	55-45	15.63	3.0	After test, reset to nominal value
	55-45	15.52	3.0	After test, reset to nominal value
	65-35	47.2	3.0	After test, reset to nominal value
	65-35	47.16	3.0	After test, reset to nominal value
	65-35	47.3	3.0	After test, reset to nominal value

Table 2-8. Additional 1988 New Yorker Coastdowns

Date	Speed Range, mph	Coastdown time, sec	Hp Indicated	Comment
5/22/04	55-45	11.72	11.3	Immediately after emission test
	65-45	20.47	11.3	Immediately after emission test
5/23/04	55-45	12.5	10.3	After test, reset to nominal value
	55-45	17.38	5.0	Reset nominal from 10.3 to 5.0
	55-45	17.51	5.0	Nominal is now 5.0
	55-45	17.2	5.0	Nominal is now 5.0
5/24/04	55-45	15.78	5.5	Immediately after emission test
	55-45	17.7	5.5	After test, reset to nominal value
	55-45	16.56	5.0	After test, reset to nominal value
	55-45	16.65	5.0	After test, reset to nominal value
5/26/04	55-45	16.45	5.3	Immediately after emission test
	55-45	16.99	5.3	Immediately after emission test
	55-45	17.02	5.3	Immediately after emission test
	65-35	48.59	5.3	Immediately after emission test
	65-35	49.18	5.3	Immediately after emission test
	65-35	50.2	5.3	Immediately after emission test
	55-45	18.01	5.0	After test, reset to nominal value
	55-45	17.47	5.0	After test, reset to nominal value
	55-45	17.72	5.0	After test, reset to nominal value
	65-35	53.58	5.0	After test, reset to nominal value
	65-35	53.7	5.0	After test, reset to nominal value
	65-35	54.57	5.0	After test, reset to nominal value

It is not clear whether the increased load when motoring the dynamometer over 60 mph is due to a defective PAU or whether this response is an innate characteristic of the water brake system. Most other studies with this unit have involved lower speed cycles, so this issue has not been previously addressed.

CVS and Analytical System:

Propane injections were conducted on two separate occasions to verify dilution tunnel flow. During the first set of injections, the dilution tunnel was heated to 47 C. During the second set of injections, the dilution tunnel was operated at ambient temperature (~ 25 C). Results of the injections are given in Table 2-9 and indicate the dilution tunnel flow was at normal levels.

Table 2-9. CVS Propane Injections

	1	2	3	4	5	6
Date	05/19/2004	05/19/2004	05/19/2004	05/24/2004	05/24/2004	05/24/2004
START MASS (GM)	860	849	838	827.2	819	811.2
FINISH MASS (GM)	849	838	827.6	819	811.2	803.5
TIME (MIN)	10	10	10	10	10	10
TEMP PDP, F	116.6	118.8	118.8	84	84	84
BARO PRES, (mmHg)	740.00	740.00	740.00	734.00	734.00	734
Pi, INCHES H20	11.00	11.00	11.00	11.00	11.00	11.00
CONC(B),PPM C	2.10	2.20	2.20	2.60	2.70	3.4
CONC(S),PPM C	136.90	137.10	132.00	98.30	96.60	93.9
COUNTS	17,700.00	17,700.00	17,700.00	17,700.00	17,700.00	17,700
VMIX	4,681.12	4,663.32	4,663.32	4,920.27	4,920.27	4,920.27
GMS PRO. CALC	10.92	10.88	10.47	8.15	7.99	7.70
GMS PRO. INJECTED	11.00	11.00	10.40	8.20	7.80	7.70
% Difference	-0.76	-1.06	0.69	-0.66	2.47	0.04
ACFM	543.98	545.66	536.16	543.43	526.83	539.62
Vo	0.307	0.308	0.303	0.307	0.298	0.305
	AVG	STD		AVG	STD	
ACFM	539.214	6.995		536.629	7.099	
Vo	0.305	0.004		0.303	0.004	
SCFM	471.56	471.21	463.01	495.14	480.02	491.67

Working gases (Zero air and FID fuel) were obtained locally from Kirk Gases. Span gases were also ordered from Kirk, but did not arrive in time for use in the Pilot Study. Alternately, span gases brought from RTP were used to span the gas analyzers. Pre-test spans for NO were conducted with an 89.2 ppm NO in N2 mixture. Pre-test spans for CO, CO2 and THC were conducted with a multi-component mixture containing 93.2 ppm C Propane, 90.1 ppm CO, and 0.900 % CO2. Concentrations of these gases were verified in RTP, with primary calibration gases, before being sent to KC. Additional calibration gases brought to KC included a 893 ppm CO in air and a 931 ppm C (propane) in air mixture. Multipoint calibrations were performed on each analyzer to verify linearity. Full Scale and downscale concentrations were generated using a capillary type ten-point gas divider. Full scale and down scale instrument readings and slope and correlation coefficient (r2) results from linear regression analysis are given in Table 2-10 for each analyzer.

Table 2-10. Gas Analyzer Linear Regression Analysis

	NO_x	Hi CO	Lo CO	CO2	HC1(sam)	HC2 (amb)
F.S.	90.0 ppm	893 ppm	90 ppm	0.892 %	93.2 ppm C	93.2 ppm C
90 % FS	80.7	806.4	79	0.798	83.7	83.2
80 % FS	71.7	722.6	71	0.714	74.6	73.8
70 % FS	62.7	634.8	62	0.615	64.5	63.8
60 % FS	54.0	545.0	54	0.533	55.8	55.3
50 % FS	44.7	462.2	45	0.446	46.5	46.1
40 % FS	35.7	371.8	36	0.352	37.1	36.4
30 % FS	27.0	273.8	27	0.265	27.8	27.2
20 % FS	18.0	177.3	19	0.176	18.6	17.9
10 % FS	9.0	84.2	11	0.086	9.2	8.5
Zero Air	0.0	5.8	0	0.002	0.0	0.0
Slope	0.9971	1.0105	0.9916	0.9955	0.0075	0.9898
R2	1.0000	0.9995	0.9990	0.9999	1.0000	0.9997

As a cross check, audit and span gases for the SEMTECH instruments were read on the dynamometer bench. These results are given in Table 2-11.

Table 2-11. Analysis of PEMS Audit and Span Gases

	NOx, ppm	CO, ppm	CO2, %	Propane, ppm
Audit Gas				
Dyno Bench	299	189	5.89	48.3
Vendor Analysis	305	198.8	6.045	49.6
Span Gas				
Dyno Bench	-	1,240	11.20	194
Vendor Analysis	1,485	1,203	12.02	200.6

2.5.1 Calibration and QC Testing of Associated Sampling Equipment

Prior to the start of the Pilot Study, all samplers were checked for leaks and the in-line flow meters were cross calibrated using reference flow measurement devices. Leak testing was performed by capping the inlet lines leading to each sampler and turning on the pumps. If the flow meter readings decreased to less than 10% of the nominal sampling flow rate in a reasonably short time, the system was passed. If not, the source of the leak was identified and fixed, then the test was repeated. With the exception of the Teflon/Quartz filter sampler all units achieved near-zero flow rates during the leak test. Due to the friable nature of the pre-fired quartz filters it is not possible to obtain a perfect seal in the filter holders without damaging the media, but the <10% criteria was still met for each filter individually and for the system as a whole. In addition to the vacuum test, the sum of flows through each of the two filter cartridges was compared to the total flow entering the inlet and found to agree within 5%.

All flowmeters were calibrated using either a Gillibrator electronic bubble meter or a rotameter that had been cross-calibrated with a Roots meter at DRI. Calibration flows were measured at the inlet point of each sampler (or outlet for the canister sampler) with appropriate sampling media installed. The resulting calibrations were used to determine the desired nominal flow rates, and these were marked on a label on each flowmeter so that the operator could observe any deviations during testing. Variations in nominal flow rate due to sampler problems were recorded in a logbook. The only significant flow problems occurred with the canister sampler, which was unable to provide adequate flow to pressurize the canister during 2 of the tunnel blank runs due to accumulated moisture in the internal tubing. Frequent draining of the accumulate moisture prevented additional data loss*, but this may represent a future problem unless the dilution air is dehumidified.*

For each integrated sample, the run number, start and stop time, elapsed time, initial and final flow rate, and any exceptional occurrences were recorded on log sheets which were kept with the media at all times. Bar coded stickers with unique media IDs were attached to all media and their corresponding log sheets for tracking. Immediately after the conclusion of each test cycle the media were repacked with the log sheets and stored in a refrigerator, except for the canisters, which were packed and shipped via 2-day express to DRI each day. At the conclusion of the Pilot Study all media were packed into coolers with ice packs and shipped overnight back to DRI where they were logged in and placed in cold storage until analysis.

Continuous data was backed up via the wireless network and processed at the end of each sampling day to determine phase-averaged values. Run number, date, time, and vehicle license plate number were attached to all files to identify the data.

2.6 QC Tests and Preparation of the Dilution Tunnel

Two issues regarding dilution tunnel operation, operating temperature and sample hang-up, were to be examined during the Pilot Study. Concerning operating temperature, it was desired to operate the dilution tunnel at $47 \pm 5\ ^{o}C$. For this purpose, an inlet air heater was installed to heat the dilution air entering the tunnel. The heater, requiring 480 VAC 3-phase power, was powered by a diesel-fueled generator placed outside of the building. Temperature of the diluted exhaust was monitored near the PM and regulated emissions sampling points (at the PDP entrance, some 30 feet downstream of the heater) using a type J thermocouple. This thermocouple also served as the feedback control for the heater. The dilution tunnel and sampling fittings were insulated to an R17 value using thin aluminum foiled bubble wrap insulating material. During vehicle testing, the second-by-second temperature of the diluted exhaust was recorded with the real time data acquisition system. Small adjustments were made to the temperature controller during the first two days of vehicle tests to fine-tune control. A plot of the diluted exhaust air temperatures obtained for all three vehicles on the final day of testing is given in Figure 2-2. Minimum observed temperatures were within the 47 ± 5 ^{o}C window for all three vehicles. Maximum observed temperatures exceeded the 47 ± 5 ^{o}C, most noticeably with the New Yorker. The higher than desired temperatures were due to heat being added from the vehicle's exhaust during high speed operation, and not due to heater malfunction. Figure 23-shows a plot of the distribution of diluted exhaust temperatures for the three vehicles. Temperature distributions for all three vehicles are slightly skewed toward the higher temperatures, again indicative of the heat added by the exhaust. As indicated in the distribution plots, the maximum desired temperature (52 C) was exceeded only a small percentage of the time (less than 1.5 % of the time) with the Taurus and Stratus, but almost ~ 12 % of the time with the New Yorker.

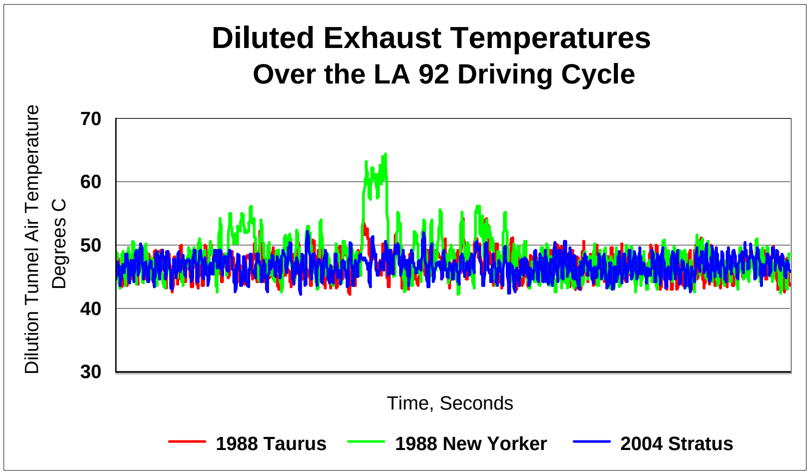


Figure 2-2. Diluted Exhaust Temperatures

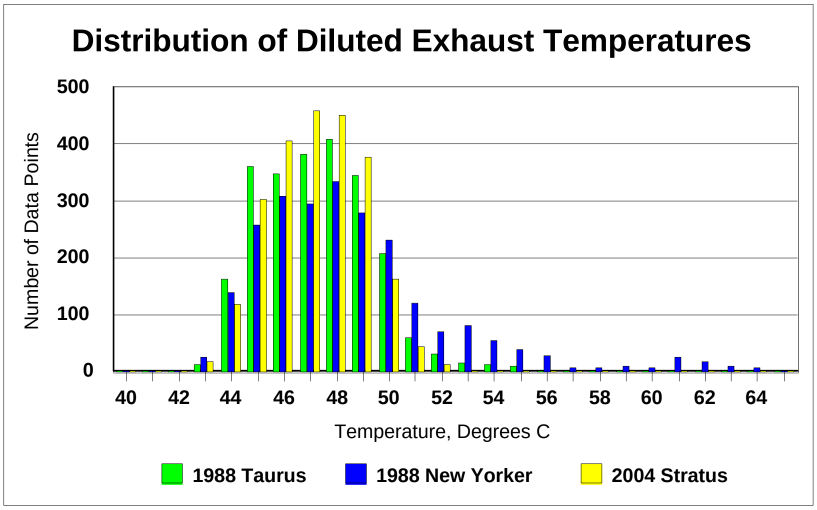


Figure 2-3. Diluted Exhaust Temperature Distribution

The second issue with regards to the dilution tunnel was to quantify any sample hang-up that may occur with THC and particulate matter, and to determine an appropriate tunnel purge time to minimize THC and particulate carry over to subsequent emissions tests. Tunnel THC emissions were measured during the 10 minute engine-off period of the LA92 cycle, and also on daily “blanks” conducted along with the Particulate Matter blanks. Very little THC sample hang-up was noted in the dilution tunnel. Figure 2-4 illustrates measured THC concentrations in the tunnel during the 10-minute engine off period during testing of the 1988 New Yorker, the highest emitter of the three correlation vehicles. Shown are concentrations measured at two locations. The Heated FID (HFID) Sample Port is located adjacent to the PDP and is the location normally used for sampling diluted exhaust. The background port is located upstream of the raw exhaust entry port and measures the treated dilution air. On three of the runs, THC was inadvertently sampled through a cold sample port and cold line. Data collected from the cold port on one of these tests is also included in the plot to contrast with the measurements collected through the normally used heated port and heated lines. As can be seen in the graph, THC levels at the HFID sample port quickly dropped from 10 ppm at the start of the soak, to background levels within 2 minutes. (The HFID trace appears to be much noisier because it was operated on the 0-1,000 ppmC range vs. the background, which was operated on the 0-100 ppmC range.). Conversely, the concentration of the THC sample collected through the cold sample line had not reached background levels at the conclusion of the 10-minute soak. This emphasizes the need to maintain heat to all sampling components when measuring THC.

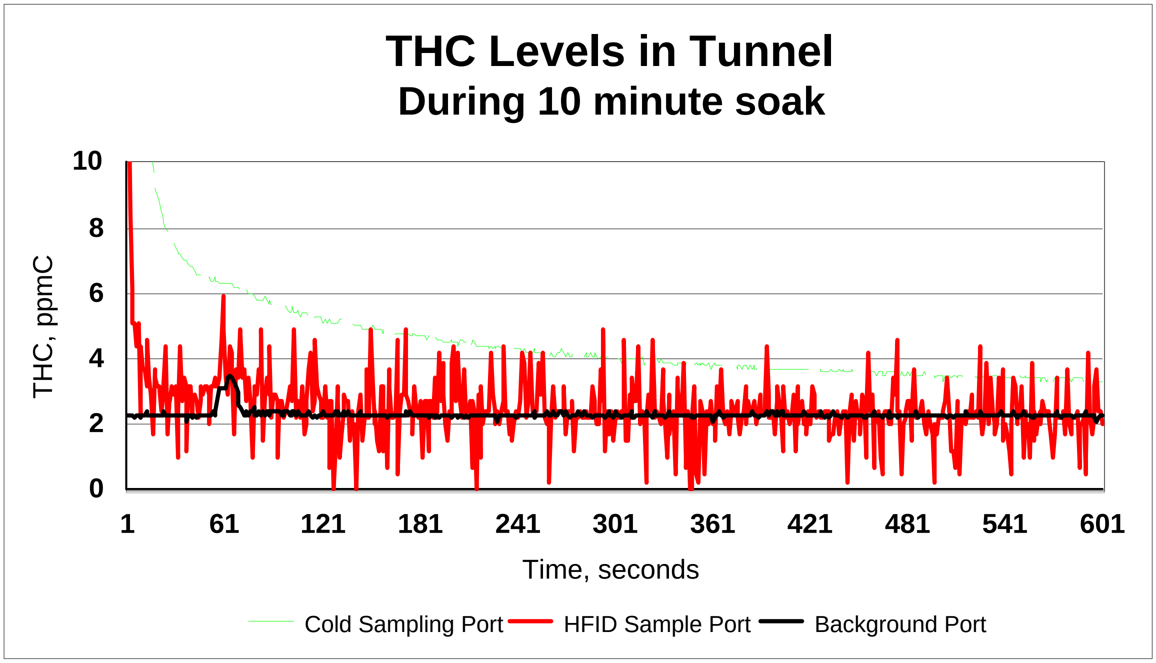


Figure 2-4. THC Levels in Dilution Tunnel.

2.7 SEMTECH Setup

2.7.1 General Pilot Study Issues

ERG and BKI staff prepared three SEMTECH units for service (units SG-01, SG-04 and SG-06). Units SG-01 and SG-04 were both used at different times for dynamometer testing, and unit SG-04 was used on all preconditioning drive testing.

In an effort to increase the accuracy of audit and calibration procedures, audits and calibrations were performed using the SEMTECH's sample port (rather than the zero and span ports). However, this change in procedure resulted in an inadvertent draining of the span and zero gasses (the sample port is not equipped with an auto shut-off solenoid as are the span and zero ports). Therefore, some testing conducted between the afternoon of Thursday, May 20, and the morning of Monday, May 24, was conducted using out of range SEMTECH equipment. To avoid this in the future, all zeros, audits, and spans will be performed using the zero and span ports on the SEMTECH, rather than drawing through the sample port. Additional information on testing conducted using out of range equipment is provided in Sections 2.8.2 and 2.8.3 below.

The flash cards used for SEMTECH memory and processing and appear to have been switched among the three SEMTECH units. Since these cards have unit-specific information, this switching appears to have created some SEMTECH initialization issues, primarily odd operation errors and communication issues between the host computers and the SEMTECH units. To prevent future problems, all SEMTECH firmware was updated (upon automatic prompting) in all three units, all out of date SEMTECH software was deleted from host computers, and current software (version 9.1) was reloaded onto all host computers. Sensors staff was helpful in diagnosing SEMTECH initialization and software problems.

Possibly due to the number of wireless networks in use at the test facility, some communication problems were identified between the SEMTECHs and their host computers. To resolve this problem, communication between the three SEMTECHs and their host computers were converted from wireless communication to a direct Ethernet cable connection (through resetting of the connection properties and reassignment of a fixed IP address). Ethernet communication is anticipated for future testing to help prevent problems associated with wireless communication.

The SEMTECH units do not record calibration or audit results (or gas concentrations used for audits/calibrations), so individual test files were created while performing all audits and calibrations during the Pilot Study. Individual test records will be used to record calibration and audit results during Phase 1 testing. This will ensure all audit and calibration results are captured and retained for future analysis. Future SEMTECH software is expected to record calibration and audit results

Despite multiple efforts, no vehicle interface (VI) communication was established with the 3 correlation vehicles or with other rental vehicles during the Pilot Study. We will be working with Sensors staff to resolve VI problems prior to the start of Phase 1 testing.

EPA comparison of vehicle exhaust flow rates as measured by the dynamometer with those measured by the SEMTECH flow meter revealed a possible bias in the SEMTECH's flow rate measurement. The EPA has been working with Sensors to correct this issue. Sensors has reportedly corrected the Pilot Study data and will revise the SEMTECH processing software to eliminate this problem.

Data collection and tracking procedures for SEMTECH test, audit and calibration files were developed to allow daily tracking of all SEMTECH data collected during the study. Since SEMTECHs don't currently record audit and span calibration results, all audits and span calibrations performed during the pilot were individually recorded as test files. Future SEMTECH software updates will apparently all the units to record audit and span calibration results.

2.7.2 SEMTECH Sampling during Preconditioning Runs

Prior to performing preconditioning runs, a preconditioning drive route believed to be equivalent to the LA92 drive trace was developed. Rental car drives along this route resulted in unacceptable speeds and delays, so this preliminary route was modified. Due to extensive on-going road construction near the test facility, future revisions of this route are possible. Speed, time, and acceleration information of the preconditioning run is presented in Section 4.

Preconditioning drives were performed on all three correlation vehicles using SEMTECH unit SG-04. The 1988 Ford Taurus (license number EPA975) and the 2004 Dodge Stratus (license number 52083) received preconditioning drives on 5/22/04. Review of the audit records performed prior to these two drives indicates possible CO bias. As shown in the dyne SEMTECH table below, (Table 2-12) this unit was also seen to have a CO bias in subsequent testing. During this time period (5/20 to 5/24), span calibration gas was not available to recalibrate the SEMTECH.

Table 2-12. Dynamometer SEMTECH Test Issues During Pilot

Date	Unit ID	Approx Start Time	Vehicle	Plate	Notes
5/20/04	SG-01	13:55	88 Taurus	EPA975	***Questionable HC readings for this test*** Test faults, and warnings indicated that the system had improper vacuum readings on drains 1 and 2 and improper sample flows. Also, test notes indicate HC calibration may not be within range (and span calibrations were not able to bring HC into range). Discussion with Sensors ruled out the possibility of the incorrect FID fuel pressure setting being the root cause.
5/20/04	N/A	N/A	N/A	N/A	Zero and span calibration gasses were inadvertently depleted in the early afternoon (after test of EPA975 but prior to 707WHY). Explanation provided in Section 2.8.1.
5/20/04	SG-01	15:10	88 New Yorker	707WHY	***Questionable HC readings for this test*** Test notes indicate pre-test audit failed for high HC. No span gas, could not recalibrate SEMTECH.
5/21/04	SG-01	N/A	All	All	Test notes do not indicate any pre-test audit issues.
5/22/04	SG-01	09:45	04 Stratus	52083	Test notes indicate SEMTECH passed all audit gasses
5/22/04	SG-01	11:05	88 Taurus	EPA975	***Questionable HC readings for this test*** SEMTECH failed HC audit, no span gas with which to recalibrate
5/22/04	SG-01	13:30	88 New Yorker	707WHY	***Questionable HC readings for this test*** SEMTECH failed HC audit, no span gas with which to recalibrate
5/23/04	SG-01	10:05	04 Stratus	52083	***Questionable HC readings for this test*** SEMTECH failed HC audit, no span gas with which to recalibrate
5/24/04	SG-04	10:50	88 Taurus	EPA975	***Questionable CO readings for this test*** SEMTECH SG-01 replaced with SG-04. SG-04 failed CO audit, no span gas with which to recalibrate.
5/24/04	N/A	N/A	N/A	N/A	Replacement span calibration gas arrived in late morning
5/24/04	SG-04	12:10	88 New Yorker	707WHY	SG-04 initially failed CO audit, recalibrated with CO span, and re-audit then passed.

2.7.3 SEMTECH Sampling during Dynamometer Testing

SEMTECH testing was performed concurrently with dynamometer testing (using Units SG-01 and SG-04). Specific differences between use of the SEMTECH for dynamometer testing vs. in-vehicle testing include:

- Rather than exhausting to the environment, the exhaust sample was drawn from the SEMTECH's sample port and flow meter tube into the transition tube feeding the dynamometer's CVS

- No GPS input was used

- An analog voltage signal proportional to dynamometer roller speed (ratio of 0.1 volt = 1 mph) was connected to external analog input 3.

- An external event marker switch was used to indicate the start of a run, and also to distinguish between test phases. However, for accuracy purposes, test-phase delineation will be based on test timing rather than manually inserted markers.

As mentioned in Section 2.7.1, some dynamometer testing was performed with "out of range" SEMTECHs. Details are presented in Table 2-12 below.

2.7.4 SEMTECH Testing during Customer Drive-Aways

No drive-away testing was performed during the Pilot Study, but some issues to consider for Round 1 testing were discussed. A primary concern for drive-away testing is motorist safety and installation integrity. In particular, the current method for installing the exhaust tube flow meter assembly requires hanging the tube off the license plate mount with extension rods and a suction-cup mounted support brace. In addition to being a potential burn hazard, this may not offer sufficient stability for long-term (i.e., one day) usage. Alternative mounting procedures are currently being considered. The objective is to develop an efficient method of mounting this assembly under the rear bumper without the need to weld or drill. As an alternative for some 1996 or newer vehicles (for which a VI is established), exhaust flow information may be gathered from the OBDII data stream collected by the SEMTECH units. With EPA approval, this OBDII information may be used in place of actual flow meter data, in installations where installation of the long flow meter tube poses a safety risk. In addition, Sensors has designed an alternative flow meter which is much shorter than the current design requirements (pressure differential vs. hot-wire anemometer). Testing is currently underway, and if this new flowmeter is found to have sufficient precision and accuracy, use of it may facilitate drive-away installations. Comparison testing between both flow meter designs is planned for Round 1 dyne/SEMTECH testing.

The SEMTECH and one or two large batteries placed in the trunk may also pose a potential safety risk (projectile, spark/flame, and acid burn hazard in the event of an accident). To minimize these risks, an attempt will be made to strap the battery (or batteries) to the SEMTECH unit, and also to tether the SEMTECH to a frame or latch section of the trunk.

Velcro will be used on the bottom of the SEMTECH units to reduce slippage and movement during everyday driving.

3.0 Testing of EPA Correlation Vehicles (Testing Schedule):

Each of the three correlation vehicles was tested over the three-phase, cold start LA92 test cycle according to the table below. All three vehicles were tested in triplicate with the dilution tunnel heater engaged (~ 47 C.). Both the Taurus and New Yorker were also tested in triplicate with the dilution tunnel at ambient temperature. One LA92 on the Stratus (Run #84011) was voided because the vehicle was tested using the wrong dynamometer settings. An additional LA92 was conducted on this vehicle to produce 3 valid tests.

Figure 3-1 describes the LA92 cycle graphically. Figure 3-2 shows the speed/acceleration contour plot for the cycle and Table 3-1 displays the speed acceleration profile in tabular form.

Collection of daily blanks were also assigned run numbers. The blanks were collected from the dilution tunnel with the raw exhaust transfer tube sealed, i.e. with only treated dilution air entering the dilution tunnel. Table 3-2 lists in numerical order the tests conducted and provides a brief description of conditions for each test. Table 3-3 groups the vehicle tests into groups by vehicle and indicated Hp.

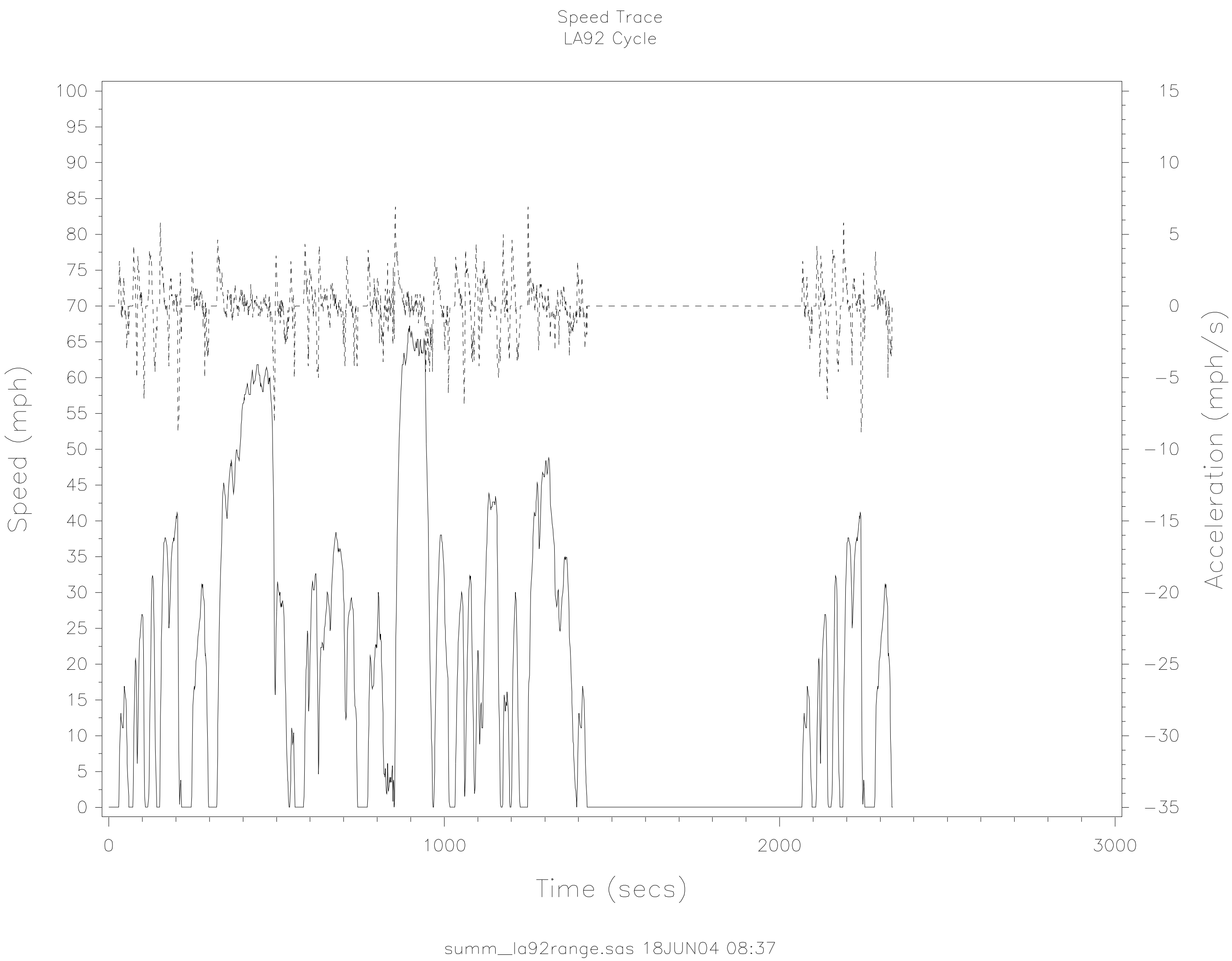


Figure 3-1. Contour Plot Showing the Speed/Acceleration Distribution of the LA92

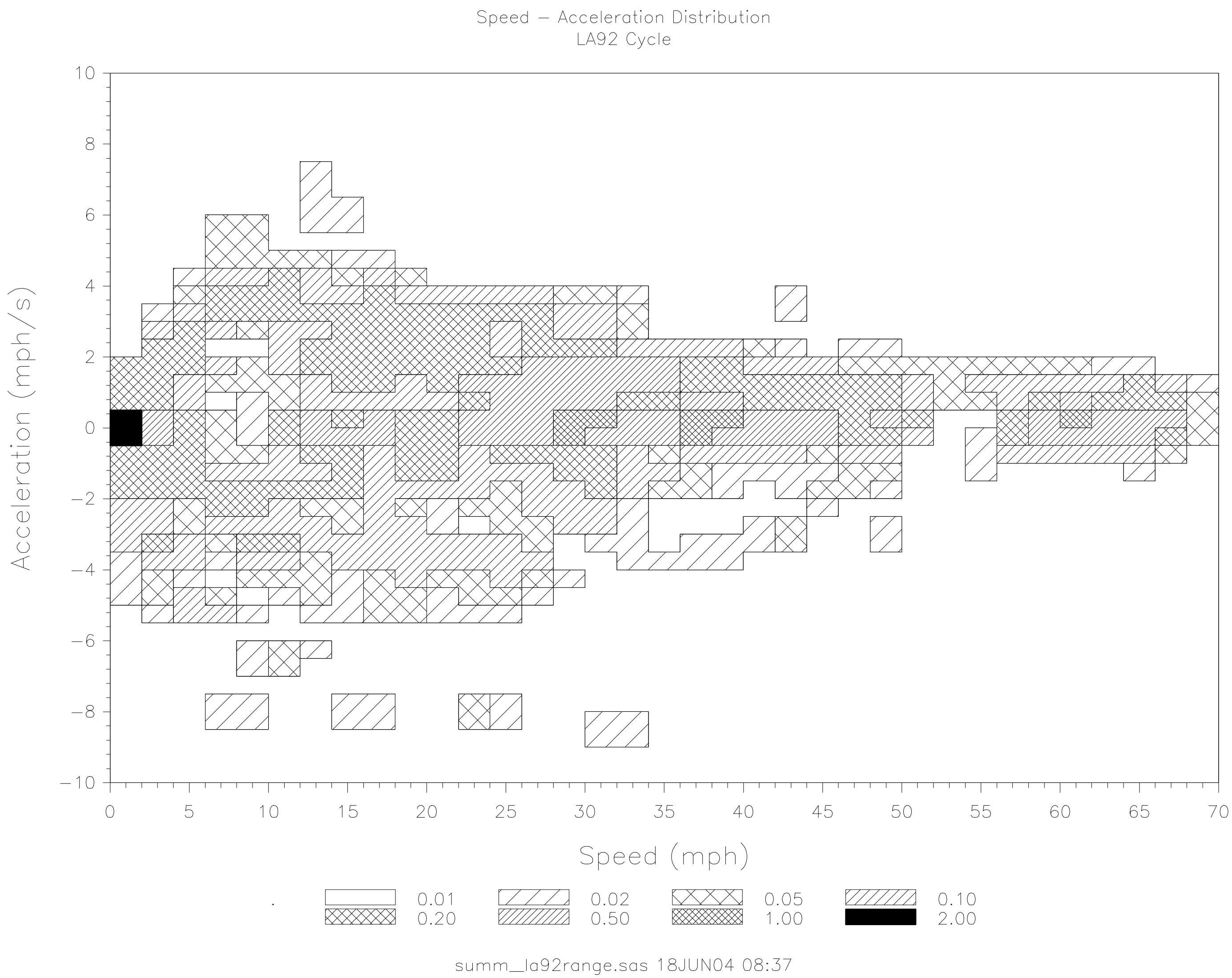


Figure 3-2. LA92 Speed Trace

Table 3-1. Speed-Acceleration for the LA92 Cycle

Speed - Acceleration Distribution 08:37 Friday, June 18, 2004 3
LA92 Cycle

Speed (mph)	Acceleration (mph/s)																	
	>-9 <=-8	>-8 <=-7	>-7 <=-6	>-6 <=-5	>-5 <=-4	>-4 <=-3	>-3 <=-2	>-2 <=-1	>-1 <0	=0	>0 <=1	>1 <=2	>2 <=3	>3 <=4	>4 <=5	>5 <=6	>6 <=7	All
	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)
=0	.	.	.	.	.	.	0.06	0.63	0.52	17.61	.	.	.	.	.	.	.	18.81
>0 <=5	.	.	.	0.29	0.23	0.81	0.75	1.27	0.98	0.81	1.09	1.44	0.69	0.23	.	.	.	8.57
>5 <=10	0.12	.	0.12	0.17	0.17	0.69	0.92	0.35	0.12	.	0.12	0.35	0.23	0.98	0.29	0.17	.	4.78
>10 <=15	.	.	0.12	0.12	0.23	0.58	0.35	0.81	1.21	1.15	0.46	0.98	0.81	0.69	0.29	0.12	0.12	8.00
>15 <=20	0.12	.	.	0.29	0.35	0.52	0.35	0.86	0.86	0.69	0.52	1.21	1.27	0.63	0.12	.	.	7.77
>20 <=25	0.17	.	.	0.12	0.35	0.63	0.29	0.63	0.98	0.98	1.78	1.55	0.81	0.63	0.06	.	.	8.98
>25 <=30	.	0.06	.	.	0.12	0.12	0.46	0.81	1.96	1.61	2.36	2.01	0.75	0.17	.	.	.	10.41
>30 <=35	0.12	.	.	.	0.06	0.12	0.12	0.75	1.27	0.75	1.50	2.13	0.23	0.12	.	.	.	7.13
>35 <=40	.	.	.	0.06	.	0.12	0.06	0.12	1.55	1.38	2.07	0.86	0.06	0.06	.	.	.	6.33
>40 <=45	.	.	.	.	.	0.17	0.12	0.17	1.78	0.75	1.44	0.69	.	0.12	.	.	.	5.24
>45 <=50	.	.	.	.	.	0.12	.	0.29	0.81	0.75	1.38	0.29	0.06	.	.	.	.	3.68
>50 <=55	.	.	.	.	0.06	.	.	0.12	.	.	0.29	0.23	.	.	.	.	.	0.69
>55 <=60	.	.	.	.	0.06	0.06	.	0.06	1.15	1.32	1.09	0.35	.	.	.	.	.	4.09
>60 <=65	.	.	.	.	.	.	.	0.12	1.27	1.32	1.50	0.12	.	.	.	.	.	4.32
>65 <=70	.	.	.	.	.	.	.	.	0.40	0.35	0.40	0.06	.	.	.	.	.	1.21
All	0.52	0.06	0.23	1.04	1.61	3.91	3.45	6.96	14.84	29.46	16.00	12.26	4.89	3.62	0.75	0.29	0.12	100.0

Table 3-2. Schedule and Description of Pilot Study Emissions Tests.

Date	Time	License Number	BKI Run Number	Notes	DOW	Vehicle	Desired Dil Tun Temp	Actual Dil Tun Temp, C	Test Temp F	% Rel Hum
05/20/2004	10:30 AM	52083	84003		T	Stratus	47	48.5	81.2	76.5
05/20/2004	"Lunch"	Blank	84004	Test blank	T		47			
05/20/2004	"PM"	EPA975	84005		T	Taurus	47	47.3	86.9	68.5
05/20/2004	"PM"	707WHY	84006		T	New Yorker	47	48.1	88.2	63.9
05/21/2004	9:30 AM	52083	84007		F	Stratus	47	46.8	82.6	73.9
05/21/2004	11:00 AM	EPA975	84008		F	Taurus	47	46.8	84.8	70.3
05/21/2004	2:00 PM	707WHY	84009		F	New Yorker	47	48	87.6	58.0
05/21/2004	3:00 PM	Blank	84010	Test blank	F		47			
05/22/2004	9:00 AM	52083	84011	Test Aborted: Wrong test inertia was used	S	Stratus	47		81.1	73.5
05/22/2004	10:30 AM	EPA975	84012		S	Taurus	47	46.9	83.8	68.8
05/22/2004	1:00 PM	707WHY	84013		S	New Yorker	47	48.1	85.1	68.1
05/22/2004	2:30 PM	Blank	84014	Test blank	S		47			
05/23/2004	9:00 AM	52083	84015		Su	Stratus	47	46.8	78.6	72.9
05/24/2004	9:00 AM	EPA975	84016		M	Taurus	25	29	78.8	81.3
05/24/2004	10:30 AM	707WHY	84017		M	New Yorker	25	33	82.1	76.3
05/24/2004	11:30 AM	Blank	84018	Test blank	M		25			
05/25/2004	9:00 AM	EPA975	84019		T	Taurus	25	22.4	67.5	82.5
05/25/2004	10:30 AM	707WHY	84020		T	New Yorker	25	25	67.9	72.2
05/25/2004	12:00 PM	Blank	84021	Test blank	T		25			
05/26/2004	9:00 AM	EPA975	84022		W	Taurus	25	23.5	67.2	69.6
05/26/2004	10:30 AM	707WHY	84023		W	New Yorker	25	26.6	70.5	65.1
05/26/2004	12:00 PM	Blank	84024	Test blank	W		25			

Table 3-3. Description of Correlation Tests.

	Run #'s	Dilution Tunnel Temp.	Ambient Temp.	Inertia, lbs.	Hp Indicated
Stratus	84003	48.5 ± 2.9 C	81.2 F	3,500	3.4
	84007	46.8 ± 1.9 C	82.6 F	3,500	3.4
	84015	46.8 ± 1.7 C	82.9 F	3,500	3.4
Taurus	84005	47.3 ± 3.4 C	86.9 F	3,500	3.0
	84008	46.8 ± 2.0 C	84.8 F	3,500	3.0
	84012	46.9 ± 2.1 C	83.4 F	3,500	3.0
Taurus	84016	29.0 ± 3.3 C	78.8 F	3,500	3.0
	84019	22.4 ± 3.8 C	67.5 F	3,500	3.0
	84022	23.5 ± 3.7 C	67.2 F	3,500	3.0
New Yorker	84006	48.1 ± 4.1 C	88.2 F	4,000	10.3
	84009	48.0 ± 3.6 C	87.6 F	4,000	10.3
	84013	48.1 ± 3.6 C	85.1	4,000	10.3
New Yorker	84017	33.0 ± 5.5 C	82.1 F	4,000	5.0
	84020	25.0 ± 5.1 C	67.9 F	4,000	5.0
	84023	26.6 ± 5.4 C	70.5 F	4,000	5.0

4.0 Pilot Study Emission Results

4.1 Ann Arbor Emissions Testing

Vehicles

Three vehicles were selected for correlation testing at the EPA test facility in Ann Arbor, Michigan and at the Kansas City test site based on their particulate mater (PM) emissions. The goal was to select one vehicle that had low PM emissions, another with moderate PM emissions, and one with high PM emissions. It is believed that this approach would best describe the precision of the project's data. This approach also allows the project to utilize EPA's current correlation data between EPA test sites and those of the automotive manufacturers, thereby adding further value to the project's measurements. EPA currently has such correlation measurements for spark ignition vehicles for total hydrocarbon (THC), oxides of nitrogen (NO_x), carbon dioxide (CO_2), carbon monoxide (CO), methane (CH_4), and fuel consumption.

The low emission vehicle selected was a 2004 Dodge Stratus, the moderate emission vehicle a 1988 Ford Taurus, and the high emitter a 1988 Chrysler New Yorker. Initially, the Taurus was to be the high emitting vehicle. Its catalyst was hollowed out and made ineffective. However, the vehicle had only 12,000 miles on the odometer and the PM emissions were judged to be to relatively low. The Chrysler New Yorker proved to be a better choice, producing visible smoke from the exhaust and higher emissions than the Taurus. Except for disabling the catalyst on the Ford Taurus and a fuel exchange to the test fuel, vehicles were tested as they were received. The following table summarized the vehicles used in the test program.

Vehicle	Plate ID	Model Year	Emission Standard	Engine	Odometer
Stratus	G1252083	2004	Tier 2	2.7 L V6	8,993
Taurus	EPA975	1988	Tier 0	3.0 L V6	12,709
New Yorker	707WHY	1988	Tier 0	3.0 L V6	203,435

Test and Measurement Conditions

Ambient conditions were standard for the Federal Test Procedure (FTP), nominally 75 degrees Fahrenheit and 50 grains per pound of dry air at 60 degrees Fahrenheit. The sampling procedure and condition for all vehicles featured tail pipe emissions measured dilute with room temperature air (approximately 25 degrees Centigrade) at a bulk stream flow rate of 350 scfm. THC and NOx were measured continuously. THC, NOx, CO, CO2, PM were mechanically integrated at the phase level using Tedlar bags and filters. The PM testing used 47mm diameter

2.0-Micron Teflon filters manufactured by Pall. The flow rates for the filters were nominally 0.88 scfm. The dilution tunnel was 10-inch diameter insulated with fiberglass insulation.

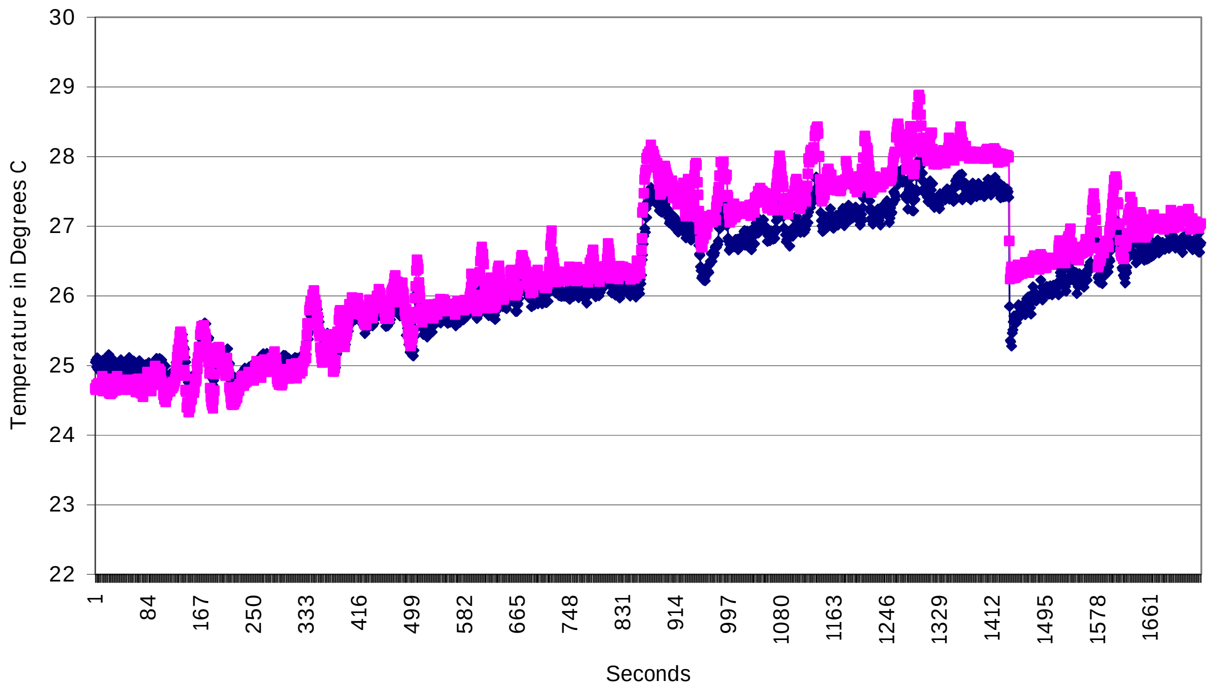
The filters were conditioned and weighted as specified under 40 CFR Part 86 for model year 2007 heavy duty engine testing. The balance has seven-place precision (10^{th} of microgram) and was mounted on a table supported by compressed air.

The vehicles were tested on a single roll 48" electric dynamometer. The dynamometer settings were similar to those used each vehicle's emission certification. However, the Taurus and the New Yorker were certified on a twin-roll water break dynamometer. Furthermore, the Taurus was tested at 150 pounds less, and the New Yorker at 450 pounds greater, than their certification test weights. The alternate weights were chosen out of necessity to match the resolution of the Kansas City dynamometer and the desire to increase emissions in the New Yorker. The following table summarizes each vehicle's dynamometer settings.

Vehicle	Test Weight (lbs.)	a Dyno coef (lbs.)	b Dyno coef (lbs./MPH)	c Dyno coef (lbs/MPH^2)	Average 55-45 mph coast (seconds)
Stratus	3500	15.47	-0.3290	0.02240	17.86
Taurus	3500	5.66	0.0355	0.02111	17.30
New Yorker	4000	4.84	0.0426	0.02498	17.59

The PM sample zone temperature for the Ann Arbor tests was uncontrolled. This was in variance to what was called for in the statement of work (47 degrees C). Though uncontrolled, all tests had sample zone temperatures between 23 and 29 degrees C. The sample zone temperature tended to rise from ambient after vehicle start to the end of the first phase, decline during the vehicle soak, and increase during the third phase. A typical temperature profile is provided in Figure 1.

Figure 1



Test Fuel

The test fuel used for all correlation testing was Federal Test Procedure Certification Fuel having the following properties.

Item		Method	Units	Target	VALUES
Vapor Pressure		Grabner	psi	8.7-9.2	8.91
Distillation		ASTM D 86			
initial boiling point			◦ F	75-95	92
10% evaporated			◦ F	120-135	124
50% evaporated			◦ F	200-230	221
90% evaporated			◦ F	300-325	311
end point			◦ F	415 MAX.	395
Sulfur		ASTM D 2622	PPM	0.003 - .0045	0.0035
Lead		ASTM D 3237	g/gal	0.01 MAX.	0.0
Phosphorous		ASTM D 3231	g/gal	0.005 MAX.	0.0001
Hydrocarbon Composition		ASTM D 1319			
olefins			Vol %	10 MAX.	2.6
aromatics			Vol %	35 MAX.	30.9
saturates			Vol %	REMAINDER	66.5
Research octane number		ASTM D 2699		96.0 MIN.	96.6
Motor octane number		ASTM D 2700		_	87.4
Antiknock index		ASTM D 439		_	92.0
Sensitivity		RON-MON		7.5 MIN.	9.2

Weight fraction carbon		ASTM D 3343		_	0.8667219
Net heat of combustion		ASTM D 3338	BTU/LB	_	18436.899
API Gravity		ASTM D 4052	◦ API	_	58.9
Specific gravity (60 F/60 F)				_	0.7431723
Fuel economy numerator (g carbon/gal)				2401-2441	2433

Preconditioning

The vehicle fuel tanks were drained of any residual gasoline and filled with the test fuel. The vehicles were then preconditioned before the first test with the dynamometer coefficient derivation procedure and a single LA92. All following tests used the previous test as preconditioning. In all instances the vehicles were tested several times before obtaining the results reported here. (The earlier tests were conducted at inertia weights that were not consistent with the Kansas City dynamometer.)

Test Data

The emission results from the Ann Arbor testing are found in Table 4-1.

Post-Test Preparation for Kansas City

An inspection of vehicle fluids was performed after testing. However, only test fuel was added to each vehicle.

Table 4-1. Summary of Ann Arbor Results

License Plate	Test Date	Bag #	Miles per gallon	CH4 (gpm)	CO (gpm)	CO2 (gpm)	THC (gpm)	NOx (gpm)	PM (micro gpm)
707WHY	04/20/2004	1	12.402	0.188	25.414	667.634	3.202	1.16	35.407
707WHY	04/21/2004	1	12.538	0.183	24.1	661.936	3.188	1.262	35.516
707WHY	04/22/2004	1	12.286	0.194	26.396	672.623	3.276	1.401	82.194
707WHY	04/27/2004	1	12.226	0.191	23.761	680.805	3.127	1.349	55.49
707WHY	04/28/2004	1	12.138	0.193	26.286	681.961	3.18	1.415	50.244
707WHY	04/20/2004	2	20.325	0.08	8.039	423.09	0.697	1.096	33.007
707WHY	04/21/2004	2	20.581	0.074	7.826	418.133	0.649	1.058	19.404
707WHY	04/22/2004	2	20.024	0.076	6.928	431.629	0.634	1.206	31.789
707WHY	04/27/2004	2	20.111	0.076	7.157	429.27	0.656	1.163	20.523
707WHY	04/28/2004	2	20.052	0.069	5.89	432.803	0.58	1.16	25.919
707WHY	04/20/2004	3	15.072	0.111	14.086	563.607	1.519	1.347	13.94
707WHY	04/21/2004	3	15.154	0.117	14.135	559.748	1.713	1.647	16.952
707WHY	04/22/2004	3	14.775	0.12	17.3	569.687	1.75	1.715	15.452
707WHY	04/27/2004	3	14.811	0.137	16.242	569.721	1.806	1.713	17.765
707WHY	04/28/2004	3	14.872	0.11	14.464	570.683	1.607	1.676	15.935
EPA975	04/20/2004	1	13.267	0.148	25.897	617.341	4.058	5.875	32.016
EPA975	04/21/2004	1	13.088	0.151	28.92	622.316	3.881	6.191	11.46
EPA975	04/22/2004	1	13.456	0.161	29.673	602.62	3.853	5.782	11.964
EPA975	04/27/2004	1	13.104	0.2	29.92	619.329	4.07	5.722	22.228
EPA975	04/28/2004	1	13.303	0.196	29.82	609.913	3.887	5.896	13.908
EPA975	04/20/2004	2	22.361	0.065	13.328	370.998	1.93	3.947	10.093
EPA975	04/21/2004	2	22.41	0.063	13.73	369.915	1.799	3.927	6.39
EPA975	04/22/2004	2	22.73	0.063	13.126	365.109	1.847	3.83	8.815
EPA975	04/27/2004	2	22.601	0.063	13.004	367.479	1.867	3.65	5.846
EPA975	04/28/2004	2	22.688	0.064	13.153	365.632	1.897	3.7	4.814

License Plate	Test Date	Bag #	Miles per gallon	CH4 (gpm)	CO (gpm)	CO2 (gpm)	THC (gpm)	NOx (gpm)	PM (micro gpm)
EPA975	04/20/2004	3	15.643	0.127	20.455	527.129	3.076	6.1	5.219
EPA975	04/21/2004	3	15.645	0.119	21.487	525.609	3.015	5.994	6.164
EPA975	04/22/2004	3	15.742	0.127	20.811	523.356	2.952	6.198	6.434
EPA975	04/27/2004	3	15.654	0.123	22.147	524.237	3.015	5.602	4.193
EPA975	04/28/2004	3	15.751	0.128	21.39	522.037	2.982	5.605	6.354
G1252083	04/21/2004	1	14.506	0.025	3.785	606.135	0.487	0.464	1.05
G1252083	04/22/2004	1	14.487	0.026	3.677	607.069	0.496	0.524	2.428
G1252083	04/27/2004	1	14.112	0.027	4.309	622.154	0.572	0.433	1.958
G1252083	04/28/2004	1	14.161	0.028	4.177	620.365	0.513	0.45	1.89
G1252083	04/21/2004	2	25.17	0.006	0.321	353.06	0.022	0.116	0.636
G1252083	04/22/2004	2	25.246	0.006	0.361	351.919	0.027	0.117	0.5
G1252083	04/27/2004	2	24.944	0.006	0.361	356.181	0.029	0.103	0.412
G1252083	04/28/2004	2	24.827	0.004	0.29	358.016	0.017	0.112	0.449
G1252083	04/21/2004	3	17.942	0.017	0.672	494.927	0.038	0.073	2.883
G1252083	04/22/2004	3	17.823	0.017	0.792	497.985	0.062	0.099	0.702
G1252083	04/27/2004	3	17.826	0.009	0.44	498.582	0.018	0.072	0.123
G1252083	04/28/2004	3	17.692	0.008	0.263	502.671	0.012	0.097	1.058

4.2 Regulated Emission Results

Regulated emission rates were calculated using modal (second-by-second) data. Table 4-2 gives individual phase emission rates for each run as well as average emission results and standard deviations. Two sets of tests were conducted on the Taurus and New Yorker, one set with the dilution tunnel temperature of ~ 47 C, the other set with an unheated tunnel temperature at about 25 C. Ambient temperatures were also a bit cooler while the second set of tests were being conducted. The effect of ambient temperature can be seen with Phase 1, and to a lesser degree, Phase 2 emissions being higher for tests conducted at the lower ambient temperature. Phase 3 emissions were not much affected by differences in ambient temperature.

Table 4-2 Regulated Emission Results

Stratus					
	Run #	**HC gm/mi**	**CO gm/mi**	**CO2 gm/mi**	**NOx gm/mi**
Phase 1	84003	0.583	3.104	645.718	0.501
	84007	0.546	3.188	655.967	0.602
	84015	0.625	3.276	637.369	0.439
	Avg	**0.585**	**3.190**	**646.352**	**0.514**
	Std Dev	**0.032**	**0.070**	**7.606**	**0.067**
Phase 2	84003	0.054	0.353	381.530	0.090
	84007	0.027	0.310	394.385	0.116
	84015	0.032	0.341	385.275	0.091
	Avg	**0.038**	**0.335**	**387.063**	**0.099**
	Std Dev	**0.012**	**0.018**	**5.398**	**0.012**
Phase 3	84003	0.056	0.181	519.757	0.163
	84007	0.013	0.339	544.240	0.181
	84015	0.042	0.421	509.885	0.142
	Avg	**0.037**	**0.313**	**524.627**	**0.162**
	Std Dev	**0.018**	**0.100**	**14.442**	**0.016**
Taurus, Set 1					
	Run #	HC gm/mi	CO gm/mi	CO2 gm/mi	NOx gm/mi
Phase 1	84005	5.331	35.355	674.961	10.419
	84008	5.038	32.677	664.854	10.300
	84012	5.525	34.414	673.240	9.987
	Avg	**5.298**	**34.149**	**671.018**	**10.236**
	Std Dev	**0.200**	**1.109**	**4.415**	**0.182**
Phase 2	84005	2.327	18.269	421.760	8.754
	84008	2.280	17.460	414.705	8.608
	84012	2.285	17.879	414.843	8.186
	Avg	**2.297**	**17.869**	**417.103**	**8.516**
	Std Dev	**0.021**	**0.330**	**3.294**	**0.241**
Phase 3	84005	3.814	25.318	575.042	10.761
	84008	3.569	22.886	569.298	10.790
	84012	3.822	22.086	569.178	10.476
	Avg	**3.735**	**23.430**	**571.173**	**10.676**
	Std Dev	**0.117**	**1.374**	**2.736**	**0.142**
Taurus, Set 2					

	Run #	HC gm/mi	CO gm/mi	CO2 gm/mi	NOx gm/mi
Phase 1	84016	5.936	39.941	685.902	10.080
	84019	6.582	45.075	683.585	8.725
	84022	6.244	43.291	674.279	8.569
	Avg	**6.254**	**42.769**	**681.255**	**9.124**
	Std Dev	**0.264**	**2.128**	**5.023**	**0.678**
Phase 2	84016	2.370	19.429	425.062	8.348
	84019	2.417	20.351	437.324	7.556
	84022	2.451	20.860	440.050	7.327
	Avg	**2.413**	**20.213**	**434.146**	**7.744**
	Std Dev	**0.033**	**0.592**	**6.519**	**0.437**
Phase 3	84016	3.926	22.678	577.758	10.601
	84019	3.770	24.220	568.340	9.199
	84022	3.871	24.729	572.297	8.646
	Avg	**3.856**	**23.876**	**572.798**	**9.482**
	Std Dev	**0.064**	**0.872**	**3.861**	**0.823**
New Yorker, Set 1					
	Run #	HC gm/mi	CO gm/mi	CO2 gm/mi	NOx gm/mi
Phase 1	84006	5.662	32.782	693.806	2.413
	84009	5.435	29.070	685.725	2.326
	84013	3.297	26.859	707.918	2.167
	Avg	**4.798**	**29.570**	**695.816**	**2.302**
	Std Dev	**1.065**	**2.444**	**9.171**	**0.102**
Phase 2	84006	1.012	10.972	496.552	2.210
	84009	1.018	12.077	479.766	2.184
	84013	0.403	14.804	481.561	2.338
	Avg	**0.811**	**12.618**	**485.960**	**2.244**
	Std Dev	**0.289**	**1.610**	**7.526**	**0.067**
Phase 3	84006	2.085	17.026	611.411	2.304
	84009	2.331	26.558	593.735	2.195
	84013	2.119	19.142	596.187	2.662
	Avg	**2.178**	**20.909**	**600.444**	**2.387**
	Std Dev	**0.109**	**4.087**	**7.819**	**0.200**
New Yorker, Set 2					
	Run #	HC gm/mi	CO gm/mi	CO2 gm/mi	NOx gm/mi
Phase 1	84017	5.947	31.166	718.395	2.350
	84020	7.355	26.316	725.995	1.965
	84023	6.866	27.266	737.880	2.189
	Avg	**6.723**	**28.250**	**727.423**	**2.168**
	Std Dev	**0.584**	**2.098**	**8.018**	**0.158**
Phase 2	84017	1.303	10.445	465.075	1.997
	84020	1.205	8.681	448.938	1.675
	84023	1.344	8.933	454.931	1.752
	Avg	**1.284**	**9.353**	**456.314**	**1.808**
	Std Dev	**0.058**	**0.779**	**6.660**	**0.137**
Phase 3	84017	2.321	20.433	609.247	2.550
	84020	2.244	18.255	591.832	2.103
	84023	1.930	17.664	598.233	2.390
	Avg	**2.165**	**18.784**	**599.771**	**2.348**
	Std Dev	**0.169**	**1.190**	**7.193**	**0.185**

Percent standard deviations for each set of triplicate tests were calculated as a measure of precision, and are presented in Table 4-3. A good level of precision was found for the regulated emissions. Percent standard deviations (%SD) were less than 2 % for CO2 for all three correlation vehicles, except Phase 3 Stratus CO2 emissions, which had a %SD of 2.8 %. In general, HC, CO, and NOx % SDs were within 5 %- 10 %. Higher %SDs were seen in the case of extremely low emissions, for instance Phase 2 and 3 HC emissions and Phase 1 and 2 NOx emissions for the Stratus. Higher %SDs were also noted for HC and CO emissions for the first set of New Yorker tests. The high HC %SD is the result of low Phase 1 and 2 HC emissions on the last test of the set. This is probably due to the HC sampling valve inadvertently being placed in the "cold" sampling position (see discussion below).

Table 4-3. Percent Standard Deviation (%SD) for the Regulated Emissions.

	HC,% SD	CO, % SD	CO2,% SD	NOx, %SD
Phase 1				
Stratus	5.48	2.20	1.18	13.08
Taurus Set 1	3.78	3.25	0.66	1.78
Taurus Set 2	4.21	4.98	0.74	7.43
New Yorker Set 1	22.21	8.26	1.32	4.42
New Yorker Set 2	8.68	7.43	1.10	7.29
Phase 2				
Stratus	31.52	5.38	1.39	11.86
Taurus Set 1	0.93	1.85	0.79	2.83
Taurus Set 2	1.39	2.93	1.50	5.65
New Yorker Set 1	35.59	12.76	1.55	2.99
New Yorker Set 2	4.55	8.33	1.46	7.58
Phase 3				
Stratus	49.09	31.77	2.75	9.82
Taurus Set 1	3.14	5.87	0.48	1.33
Taurus Set 2	1.67	3.65	0.67	8.68
New Yorker Set 1	4.99	19.55	1.30	8.37
New Yorker Set 2	7.82	6.34	1.20	7.88

During the course of the Pilot Study, several changes were made to the sampling schemes, which had a minor impact on the real-time regulated emissions data. These changes are listed below:

1) Starting with run # 84020, time and date columns were added to the real-time data files. These will become a permanent fixture of the real-time files.

2) On three runs, #84008, #84013, and #84023, both the sample and the background FIDs measured diluted exhaust through a "cold" sample train due to sampling valves inadvertently left open.

3) On runs #84016 through #84022, the HC background line was disconnected from the dilution tunnel in order to sample untreated room air during testing.

4) On run # 84015, the NOx span bottle was inadvertently sampled for the first 76 seconds of the test.

4.3 Continuous and Time-Integrated Gravimetric Mass Measurements

Chemical analysis of the time-integrated samples is currently in progress. Only data for gravimetric mass are available at this time, reported here and compared to the continuous PM mass measurements. The TOR organic and elemental carbon data will be available in mid-June and organic speciation will be available in July 2004. Table 4-4 shows the $PM_{2.5}$ gravimetric mass analysis of the Teflon filters for all tests by UDC phase along with the corresponding phase-averaged continuous mass concentrations.

Figure 4-1 shows the gravimetric mass concentrations for all tests for each of the three vehicles (Stratus, Taurus and New Yorker) in chronological order. Tests prior to May 24 were performed with the dilution air to the CVS heated to 47C and the sample train also maintained at 47±5C. Tests from May 24 –26 were performed with dilution air at ambient temperature and without temperature control of the sampling train. No substantial difference due to temperature is evident. Phase 1 consistently yields higher average mass concentrations than either Phases 2 or 3. Phase 3 shows the most variability, probably due to the smaller amounts of mass collected. Figure 4-2 shows the gravimetric filter mass loading for the daily tunnel blanks relative to the combined total mass loadings for each test. Mass data for the tunnel blanks are adjusted for the longer run time. Tunnel blanks are consistently small relative to Phase 1 and 2 concentrations. There is an apparent decrease in the tunnel blanks for the lower temperature tests, and total mass loadings are somewhat more consistent for the lower temperature tests.

Figures 4-3 through 4-5 compare the continuous mass data for the DustTrak versus the DataRam nephelometer for the Dodge Stratus, Ford Taurus and the Chrysler New Yorker, respectively. Figure 4-6 compares the average continuous mass and black carbon to the corresponding filter mass concentrations. The photoacoustic black carbon data are also shown. Nephelometer mass is much higher in the ambient temperature measurements (probably closer to

Table 4-4. Gravimetric Mass and Averaged Continuous Data for All Tests, by Phase

[Note: gravimetric mass has been corrected by media blank subtraction.]

Date	Run#	plate	vehicle	PHASE	T (C)	ug/filter	unc.	mass conc (ug/m3)	uncer. (ug/m3)	DustTrakMass _(ug/m3)	DataRamMass _(ug/m3)	BlackCarbon _(ug/m3)
5/20	84003	52083	Stratus	1	47	49	6	119	29	22	13	2
5/20	84003	52083	Stratus	2	47	102	6	88	12	15	9	0
5/20	84003	52083	Stratus	3	47	49	6	118	29	11	4	2
5/20	84004	blank		blank	47	70	5	16	3	5	2	0
5/20	84005	EPA975	Taurus	1	47	103	6	309	43	118	34	40
5/20	84005	EPA975	Taurus	2	47	73	6	53	9	38	20	9
5/20	84005	EPA975	Taurus	3	47	35	6	70	26	25	11	12
5/20	84006	707why	Yorker	1	47	305	6	1118	120	246	116	40
5/20	84006	707why	Yorker	2	47	481	6	432	45	141	238	43
5/20	84006	707why	Yorker	3	47	325	6	1067	114	56	28	5
5/21	84007	52083	Stratus	1	47	41	5	95	25	19	10	3
5/21	84007	52083	Stratus	2	47	87	5	72	10	11	7	1
5/21	84007	52083	Stratus	3	47	74	5	181	28	15	8	1
5/21	84008	epa975	Taurus	1	47	151	5	482	57	146	45	52
5/21	84008	epa975	Taurus	2	47	80	5	60	9	45	21	4
5/21	84008	epa975	Taurus	3	47	43	5	96	24	31	13	15
5/21	84009	707WHY	Yorker	1	47	157	5	508	59	208	94	43
5/21	84009	707WHY	Yorker	2	47	403	5	365	38	305	171	25
5/21	84009	707WHY	Yorker	3	47	112	5	344	44	94	45	12
5/21	84010	blank		blank	47	126	6	36	5	4	2	1
5/22	84012	EPA975	Taurus	1	47	105	5	424	56	114	204	55
5/22	84012	EPA975	Taurus	2	47	89	5	85	12	32	21	5
5/22	84012	EPA975	Taurus	3	47	139	5	573	69	42	25	21
5/22	84013	707WHY	Yorker	1	47	298	5	1003	107	456	908	60
5/22	84013	707WHY	Yorker	2	47	474	5	429	45	336	249	25
5/22	84013	707WHY	Yorker	3	47	72	5	201	32	106	91	8
5/22	84014	blank		blank	47	153	5	41	5	#N/A	#N/A	#N/A
5/23	84015	52083	Stratus	1	47	41	5	92	24	21	18	6
5/23	84015	52083	Stratus	2	47	66	5	48	8	6	4	0
5/23	84015	52083	Stratus	3	47	15	5	-2	19	5	3	1
5/24	84016	EPA975	Taurus	1	25	172	5	556	64	165	282	80
5/24	84016	EPA975	Taurus	2	25	107	5	84	11	25	20	5
5/24	84016	EPA975	Taurus	3	25	19	5	11	19	43	46	18
5/24	84017	707WHY	Yorker	1	25	229	5	758	83	360	639	59
5/24	84017	707WHY	Yorker	2	25	387	5	347	37	82	68	9
5/24	84017	707WHY	Yorker	3	25	73	5	205	32	62	73	6
5/24	84018	blank		blank	25	42	5	8	2	#N/A	#N/A	#N/A
5/25	84019	EPA975	Taurus	1	25	115	5	357	45	372	898	135
5/25	84019	EPA975	Taurus	2	25	170	5	149	17	31	100	7
5/25	84019	EPA975	Taurus	3	25	11	5	-18	19	83	78	26
5/25	84020	707WHY	Yorker	1	25	200	5	654	73	487	2178	75
5/25	84020	707WHY	Yorker	2	25	358	5	320	34	97	112	9
5/25	84020	707WHY	Yorker	3	25	95	5	283	39	86	97	9
5/25	84021	blank		blank	25	80	5	19	3	7	11	1
5/26	84022	EPA975	Taurus	1	25	155	3	490	56	390	1335	130
5/26	84022	EPA975	Taurus	2	25	237	3	207	22	37	37	8
5/26	84022	EPA975	Taurus	3	25	42	3	92	19	29	61	27
5/26	84023	707WHY	Yorker	1	25	279	3	936	100	830	3187	80
5/26	84023	707WHY	Yorker	2	25	485	3	439	45	280	258	14
5/26	84023	707WHY	Yorker	3	25	53	3	166	28	110	88	6
5/26	84024	blank		blank	25	26	3	3	1	1	0	0

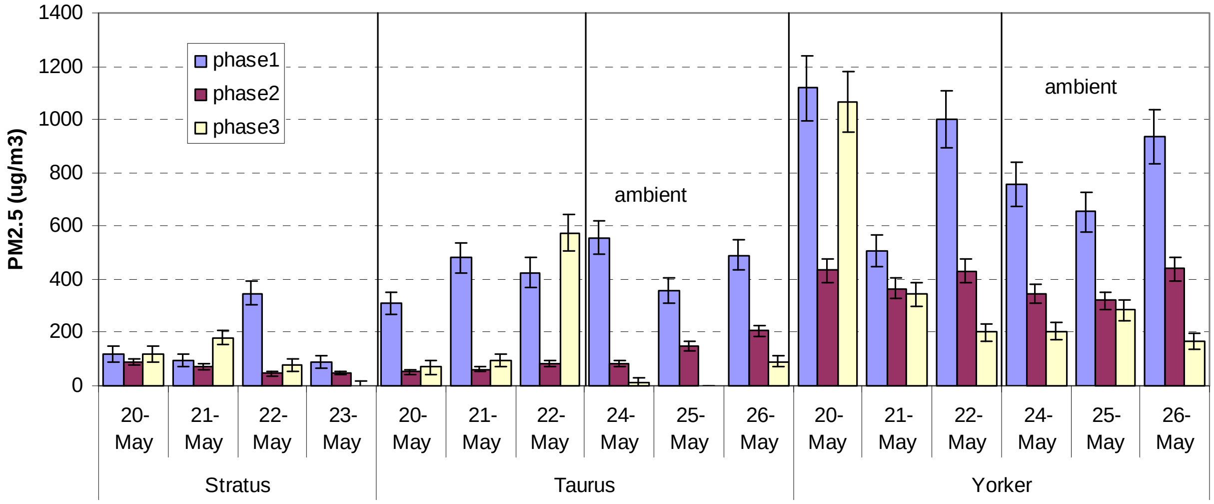


Figure 4-1. Mass Concentration as Determined by Gravimetric Analysis of Teflon Filters for All Tests by Cycle Phase.

[Uncertainties are indicated by error bars. Tests prior to May 24 were performed with the sample train maintained at 47C. Tests from May 24 –26 were performed w/out temperature control.]

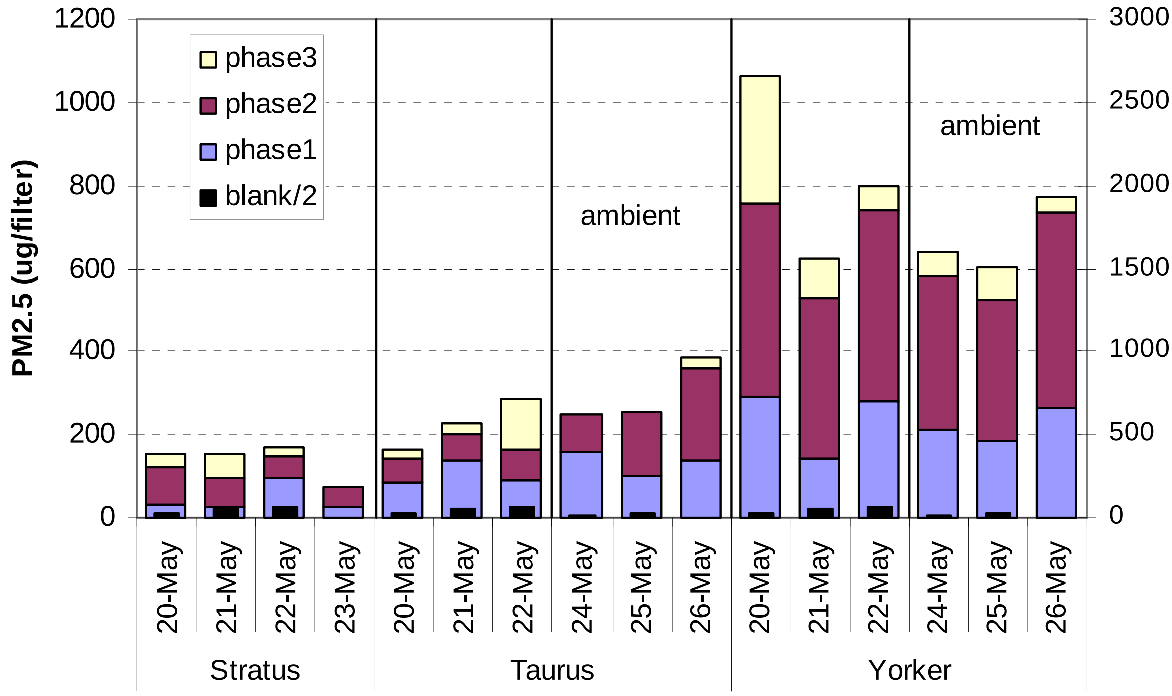


Figure 4-2. PM2.5 Gravimetric Filter Mass for All Tests

[Daily tunnel blanks are indicated also, and have been adjusted for the longer run time.]

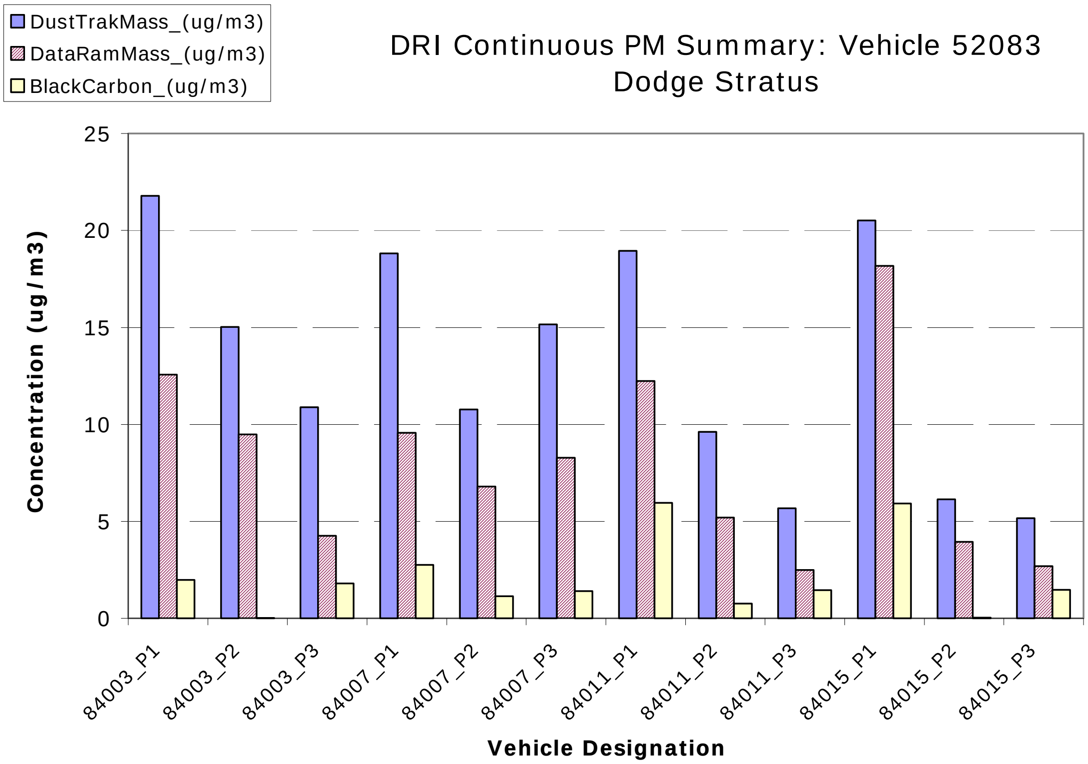


Figure 4-3. Continuous PM Mass Measurements, Dodge Stratus

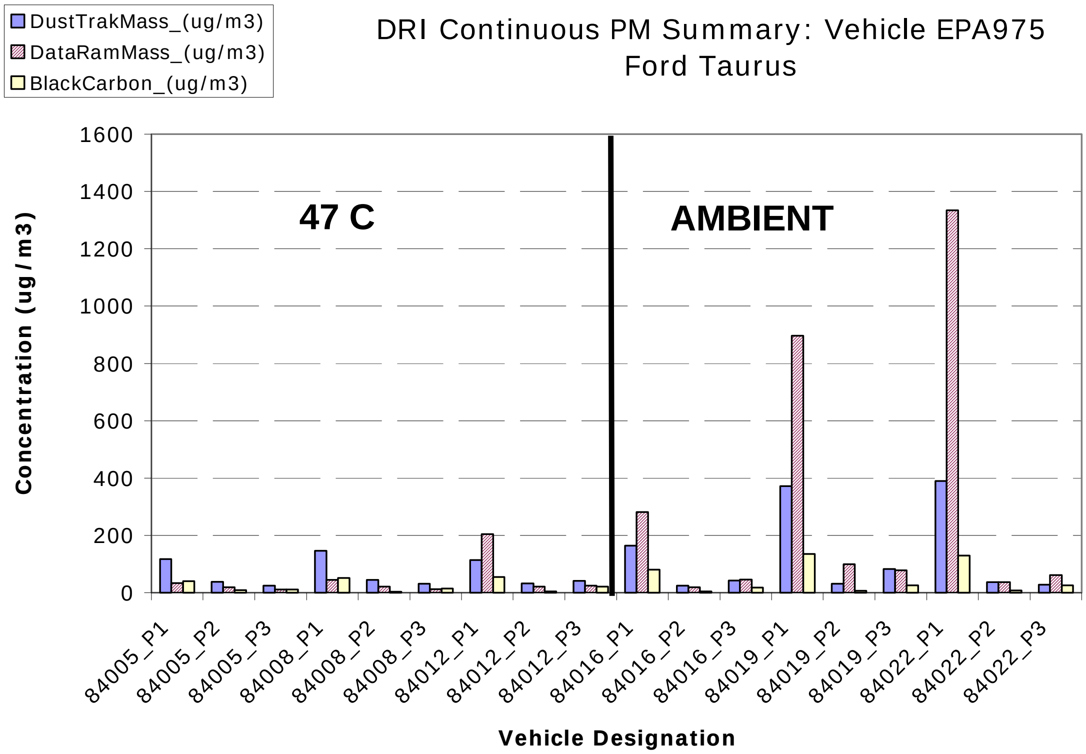


Figure 4-4. Continuous PM Mass Measurements, Ford Taurus

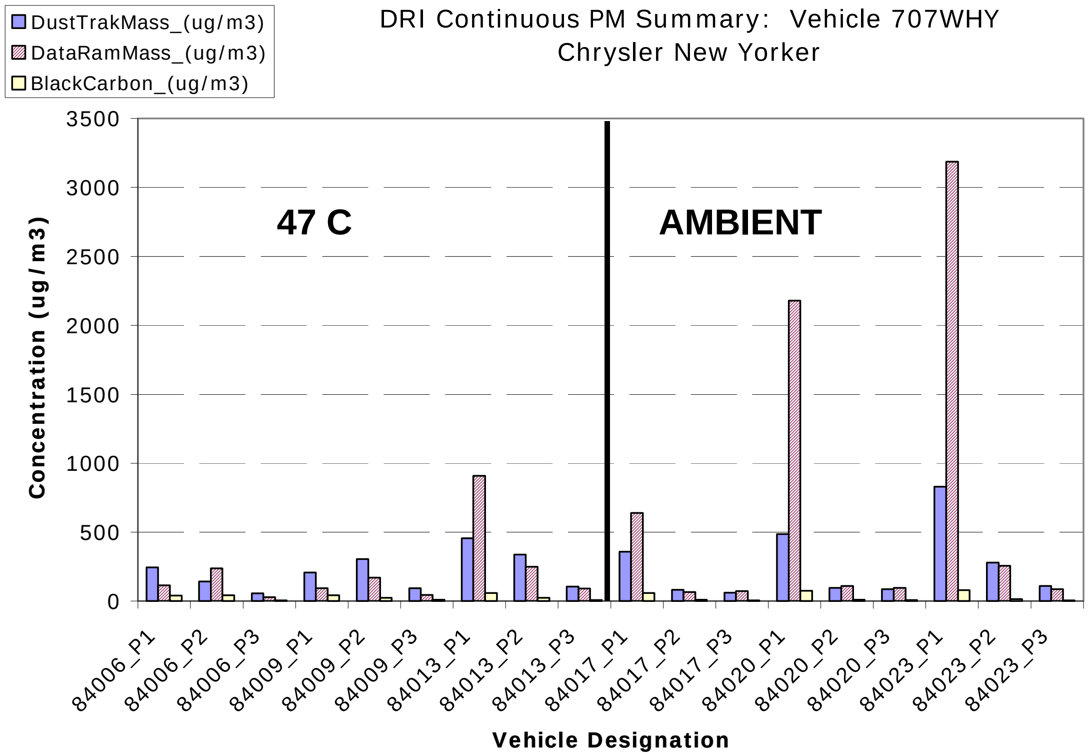


Figure 4-5. Continuous PM Mass Measurements, Chrysler New Yorker

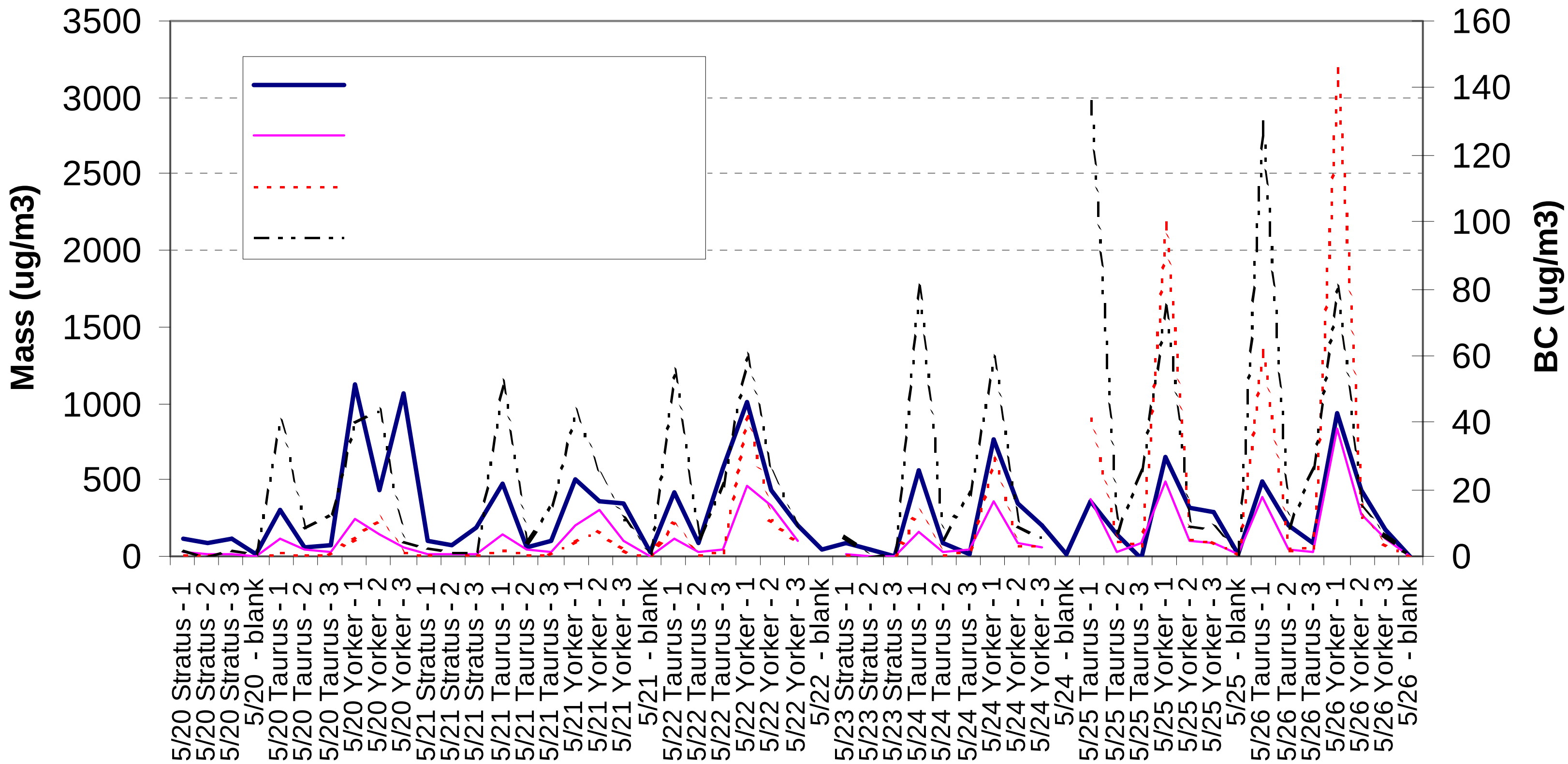


Figure 4-6. Comparison of Averaged Continuous Mass and Black Carbon to Corresponding Filter Mass Concentrations for Each

the filter values) than the 47 C data, possibly indicating reduced particle size for the 47 C data. However, black carbon mass concentration from the PA is also higher for the measurements with dilution air at ambient temperature. This finding is independent of particle size, so these differences may reflect run-to-run variations in emission rates. When the tunnel is at 47C, the nephelometer and photoacoustic instruments are at about 30C (not feasible to heat them to 47C), so particle loss along the sample lines associated with the temperature gradient are possible. One way to deal with this would be to educt a sample (with some dilution) from the dynamometer at high temperature, and use the eduction dilution to quench the sample quickly.

Figures 4-7 and 4-8 show the cumulative QCM response for the three test vehicles. The vertical axis shows accumulated mass, so the average concentration for the three cycles taken together is the final mass divided by the total sampled volume (at 1 LPM flow rate, 29 minutes sampling time, the total sample volume is about 1/34.5 cubic meters). The New Yorker concentration should also be multiplied by a factor of 20, as this was the dilution ratio for this vehicle. The QCM average mass concentrations for Phases 1-3 agree reasonably well with the DRI filter sampler results for the first run (time weight average of Phase 1-3). (For example, the New Yorker time weighted average for all phases was 655 ug/m3, while the QCM time weighted average for the first run was about 628 ug/m3.) Run #84016 (New Yorker) and #84017 (Taurus) were done with the dynamometer CVS dilution air at ambient temperature. These runs look different than the other runs done at 47 Degrees C. However, note that the Taurus run #84012 (47 C) shows more decrease of mass during the hot soak than does the other run (#84016) done at ambient conditions. This is a bit of a paradox, given that the elevated temperature would likely make for less volatile aerosol to begin with.

A summary of the OCM results is shown in Table 4-5. Figures 4-9 through 4-11 show all the OCM results in Kansas City and Ann Arbor.

It is too soon to draw any conclusions from these runs, given the variability. The QCM average mass concentrations for the Pilot Study are being processed by EPA and will be examined in greater detail relative to the other measurements in the final version of this report.

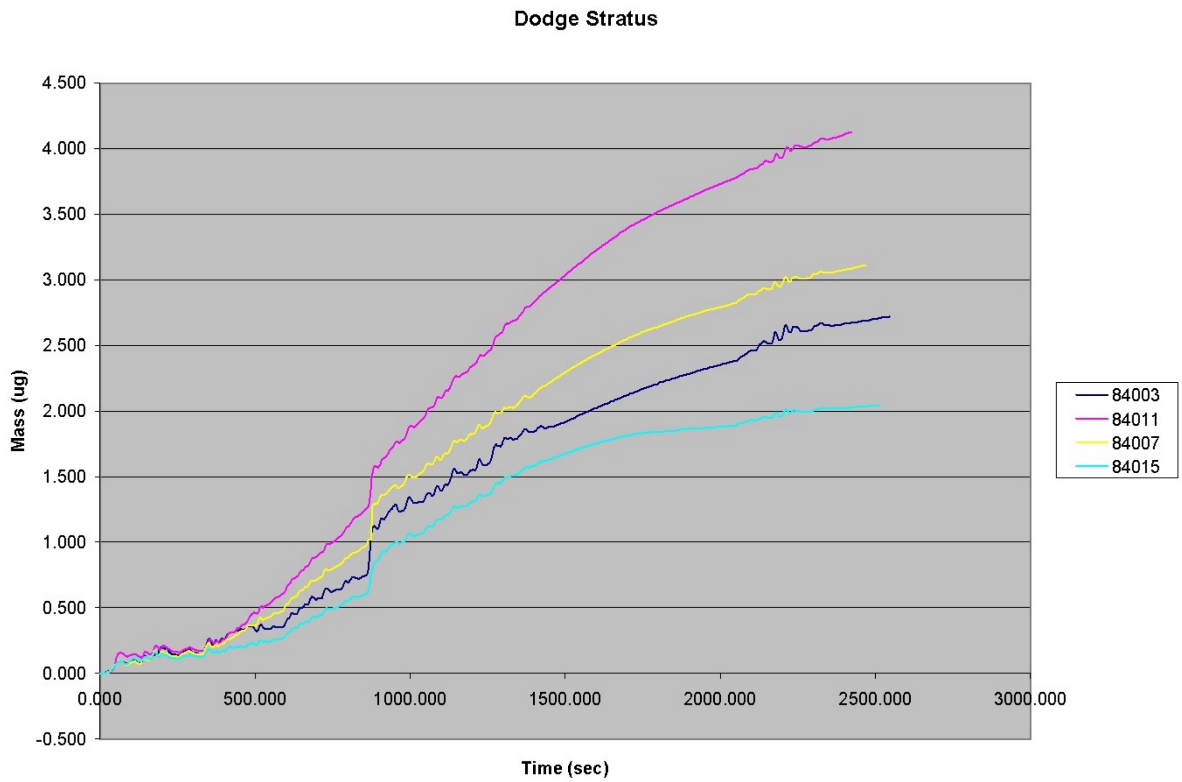


Figure 4-7. Cumulative QCM Response for the Dodge Stratus.

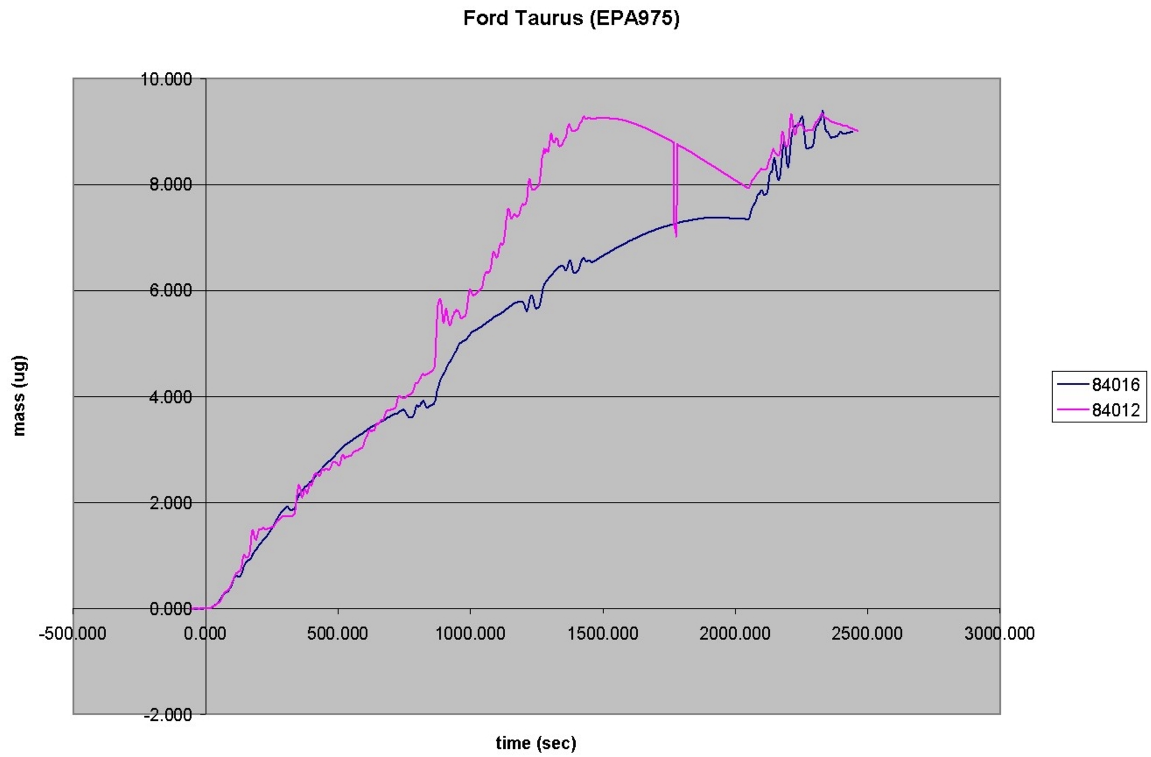


Figure 4-8. Cumulative QCM Response for the Ford Taurus.

Table 4-5. Summary of QCM Results

Date	Test No.	Vehicle	Phase	Elapsed	Collected	Sample	Dilution	QCM	CVS	Distance	Emissions	Emissions	
				Time	Mass	Flow	Ratio	Conc.	Volume	Traveled		Composite	
				(sec)	ug	(Lpm)		ug/m3	cu.ft.	mi.	mg/mi.	g/mi. (FTP)	
47DEG. C													
5/20/2004	KC Test 84003	STRATUS	1	309.5	0.164	0.986	1.0	32.24	2350.138	1.18	1.825979592		
			2	1114.6	1.691	0.987	1.0	92.22	8890.3	8.64	2.685521665		
			3	310.1	0.264	0.990	1.0	51.58	2346.3	1.20	2.856803133	0.002653192	
5/21/2004	KC Test 84007	STRATUS	1	310.8	0.180	0.969	1.0	35.86	2363.852	1.18	2.029602319		
			2	1114.0	2.021	0.969	1.0	112.39	8928.3	8.63	3.292697374		
			3	309.174	0.224	0.973	1.0	44.68	2364.2	1.19	2.514271198	0.00317347	
5/22/2004	KC Test 84011	STRATUS	1	310.0	0.210	0.973	1.0	41.79	2348.568	1.19	2.331926544		
			2	1114.7	2.720	0.968	1.0	151.20	8879.3	8.65	4.396030538		
			3	309.1	0.283	0.969	1.0	56.67	2347.7	1.19	3.172099067	0.004204292	
5/23/2004	KC Test 84015	STRATUS	1	309.3	0.146	0.958	1.0	29.55	2342.480	1.18	1.663335699		
			2	1115.7	1.461	0.970	1.0	81.00	8868.4	8.64	2.353844783		
			3	309.6	0.111	0.970	1.0	22.17	2338.0	1.19	1.230158617	0.002240496	
											Ave./Std.	0.003067863	0.000848354
47 DEG. C													
5/20/2004	KC Test 84005	FORD TAURUS	1	309.6	0.040	1.042	10.9	94.29	2360.614	1.20	5.271922657		
			2	1114.6	0.089	1.048	10.9	62.84	8926.3	8.64	1.838491768		
			3	309.7	0.044	1.055	10.8	100.60	2362.6	1.19	5.640808758	0.002280978	
5/21/2004	KC Test 84008	FORD TAURUS	1	309.7	0.083	0.960	9.9	274.08	2364.414	1.19	15.42178759		
			2	1120.0	0.032	0.960	9.9	125.62	8928.2	8.63	3.679664008		
			3	303.0	0.051	0.962	9.9	104.47	2364.4	1.20	5.84651719	0.004441776	
5/22/2004	KC Test 84012	FORD TAURUS	1	309.9	1.747	0.970	1.0	348.68	2348.312	1.19	19.52479458		
			2	1114.4	7.449	0.970	1.0	413.47	8869.4	8.65	12.00778436		
			3	308.6	1.248	0.964	1.0	251.76	2346.2	1.19	14.08979991	0.012541285	
											Ave./Std.	N/A	N/A
AMBIENT													
5/24/2004	KC Test 84016	FORD TAURUS	1	309.5	1.971	0.980	1.0	389.94	2514.441	1.17	23.66308173		
			2	1114.4	4.489	0.980	1.0	246.62	9347.8	8.62	7.573420292		

Date	Test No.	Vehicle	Phase	Elapsed Time (sec)	Collected Mass ug	Sample Flow (Lpm)	Dilution Ratio	QCM Conc. ug/m3	CVS Volume cu.ft.	Distance Traveled mi.	Emissions mg/mi.	Emissions Composite g/mi. (FTP)	
			3	308.7	1.373	0.974	1.0	274.05	2505.3	1.18	16.41106554	0.009011035	
5/25/2004	KC Test 84019	FORD TAURUS	1	310.6	1.468	0.953	1.0	297.48	2581.209	1.18	18.40019195		
			2	1115.1	8.058	0.953	1.0	454.86	9574.7	8.64	14.27982604		
			3	309.9	1.562	0.954	1.0	317.14	2571.2	1.18	19.52089079	0.014852954	
5/26/2004	KC Test 84022	FORD TAURUS	1	310.0	2.038	0.970	1.0	406.70	2568.635	1.19	24.89911739		
			2	1114.7	6.720	0.970	1.0	372.90	9524.1	8.64	11.64269135		
			3	310.1	1.212	0.970	1.0	241.74	2553.8	1.18	14.84781105	0.012551043	
											Ave./Std.	0.012138344	0.002942744
47 DEG. C													
5/20/2004	KC Test 84006	CHRYSLER NY	1	311.4	0.084	0.933	19.2	333.72	2367.296	1.22	18.34328507		
			2	1114.1	0.726	0.941	19.3	802.49	8854.0	8.59	23.41204919		
			3	311.4	0.058	1.020	19.4	212.50	2360.0	1.21	11.72843726	0.02231874	
5/21/2004	KC Test 84009	CHRYSLER NY	1	309.4	0.042	0.959	18.9	160.41	2356.807	1.21	8.864481177		
			2	1115.3	0.482	0.960	18.9	510.83	8848.0	8.69	14.73353023		
			3	309.2	0.041	0.963	19.0	157.14	2355.9	1.17	8.965567919	0.014035471	
5/22/2004	KC Test 84013	CHRYSLER NY	1	310.7	0.075	0.952	18.8	286.73	2342.702	1.22	15.61094031		
			2	1113.7	0.857	0.950	18.9	917.30	8792.1	8.68	26.29779167		
			3	309.7	0.029	0.953	19.0	111.92	2343.1	1.20	6.211601288	0.024346924	
											Ave./Std.	0.020233712	0.005462785
AMBIENT													
5/24/2004	KC Test 84017	CHRYSLER NY	1	309.6	0.095	0.960	19.7	377.84	2497.896	1.22	21.94380696		
			2	1114.3	0.839	0.952	19.7	936.67	9163.7	8.68	28.01427409		
			3	308.8	0.102	0.967	19.8	405.35	2481.4	1.20	23.68682341	0.027392712	
5/25/2004	KC Test 84020	CHRYSLER NY	1	310.6	0.106	0.970	19.3	406.90	2570.282	1.21	24.50897862		
			2	1114.0	0.722	0.970	19.3	772.98	9454.2	8.65	23.91608964		
			3	308.1	0.037	0.970	19.4	143.91	2555.1	1.20	8.711827288	0.022895525	
5/26/2004	KC Test 84023	CHRYSLER NY	1	313.3	0.128	0.970	19.5	492.44	2549.899	1.20	29.60364162		
			2	1111.1	0.617	0.970	19.3	664.58	9372.4	8.65	20.38355521		
			3	309.5	0.088	0.970	19.4	341.22	2538.3	1.19	20.60441037	0.020882019	
												0.023723419	0.003333368

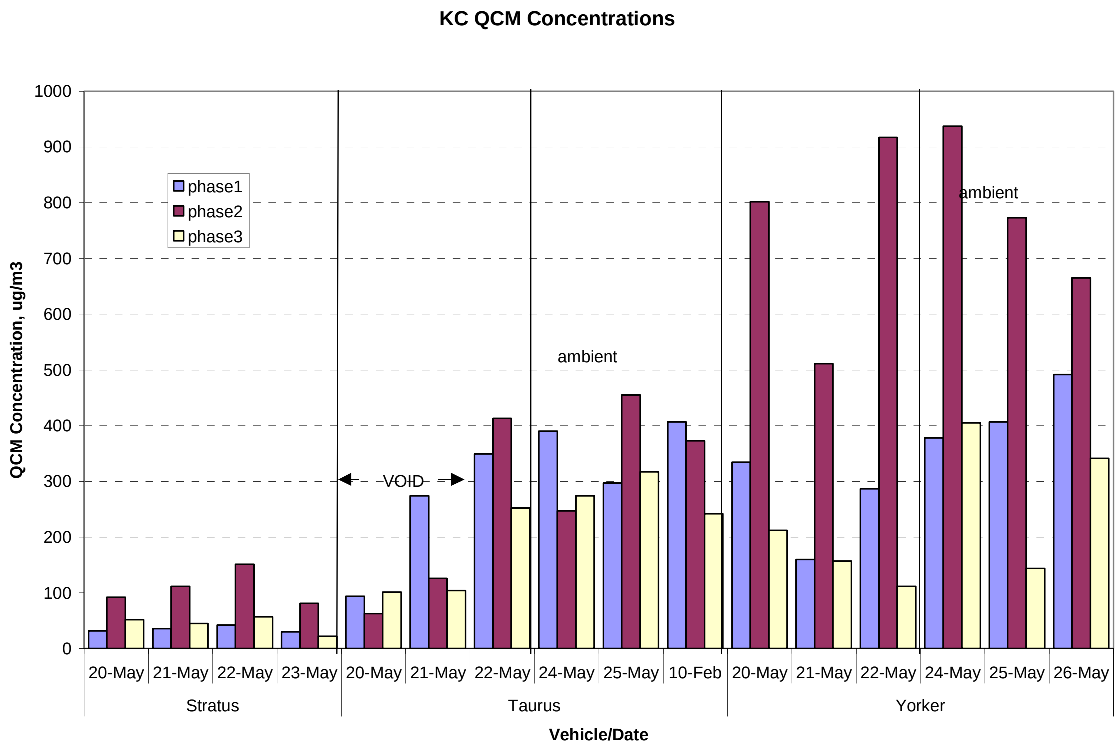


Figure 4-9. Kansas City QCM Summary

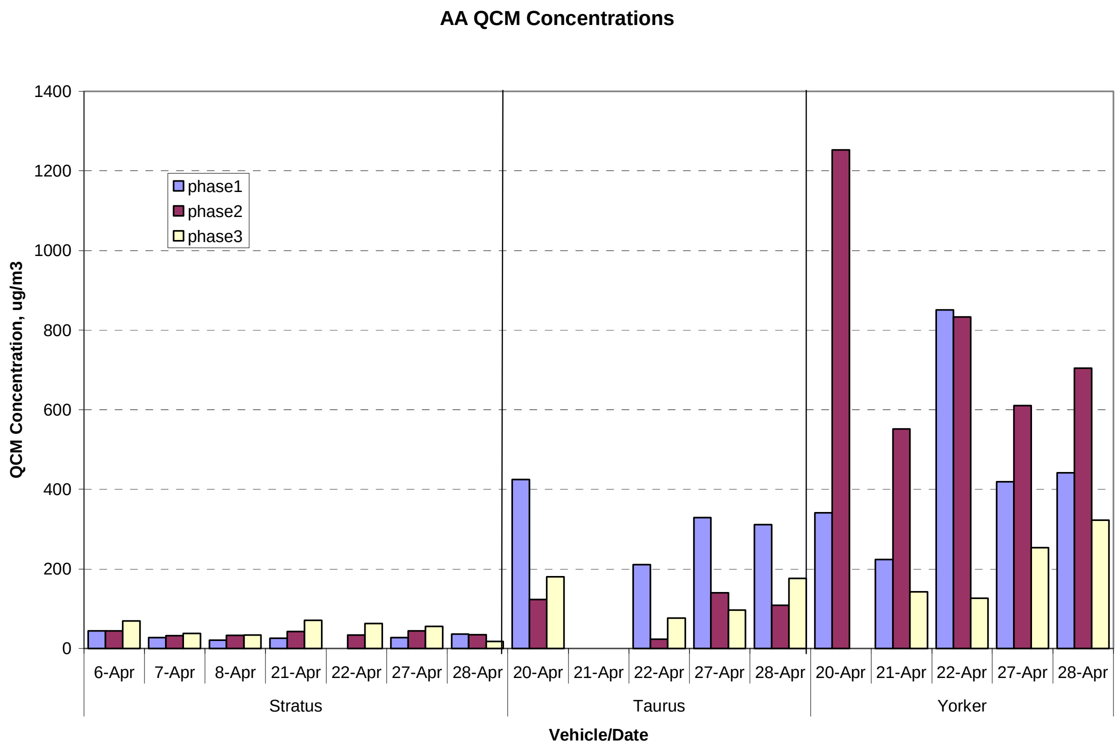


Figure 4-10. Ann Arbor QCM Summary

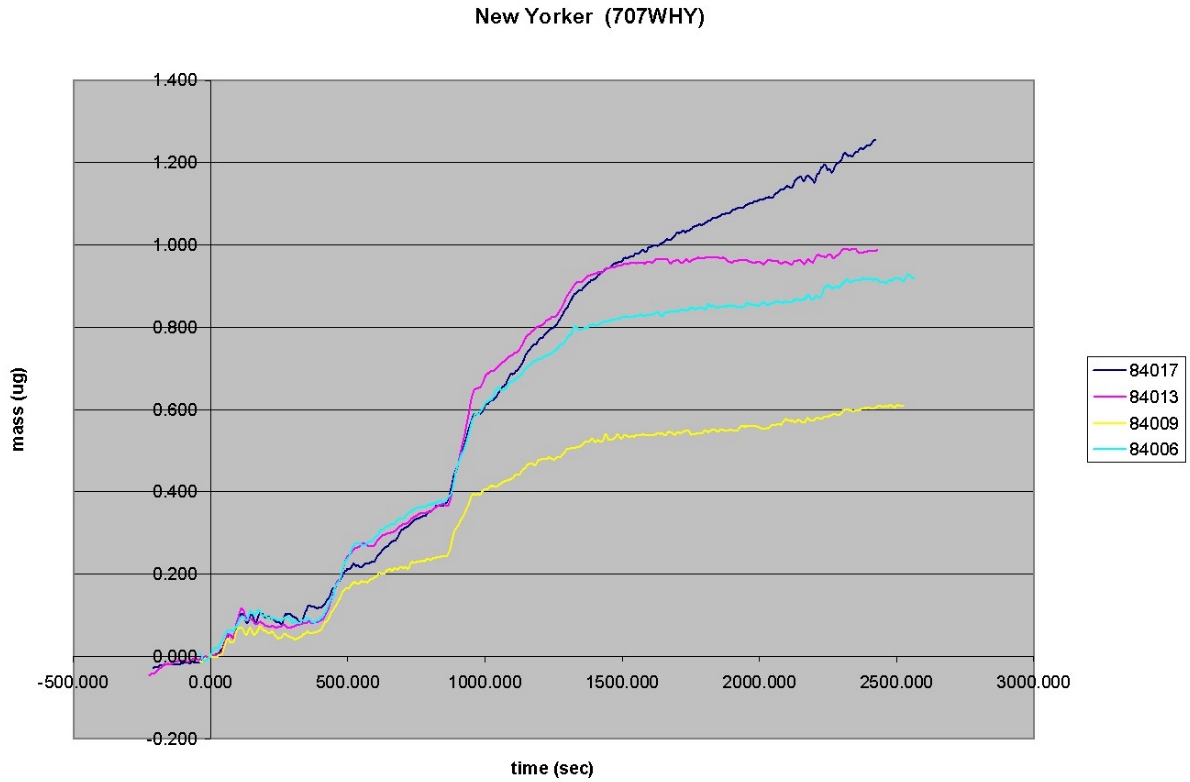


Figure 4-11. Cumulative QCM Response for the Chrysler New Yorker

4.4 SEMTECH Pre-Conditioning Runs

All three test vehicles were driven on a designated route which will be used in the full program to precondition vehicles. Figure 4-12 shows the speed and acceleration plot for the precondition and drive on the Dodge Stratus. The speed/acceleration profile for the drive is shown in Figure 4-13.

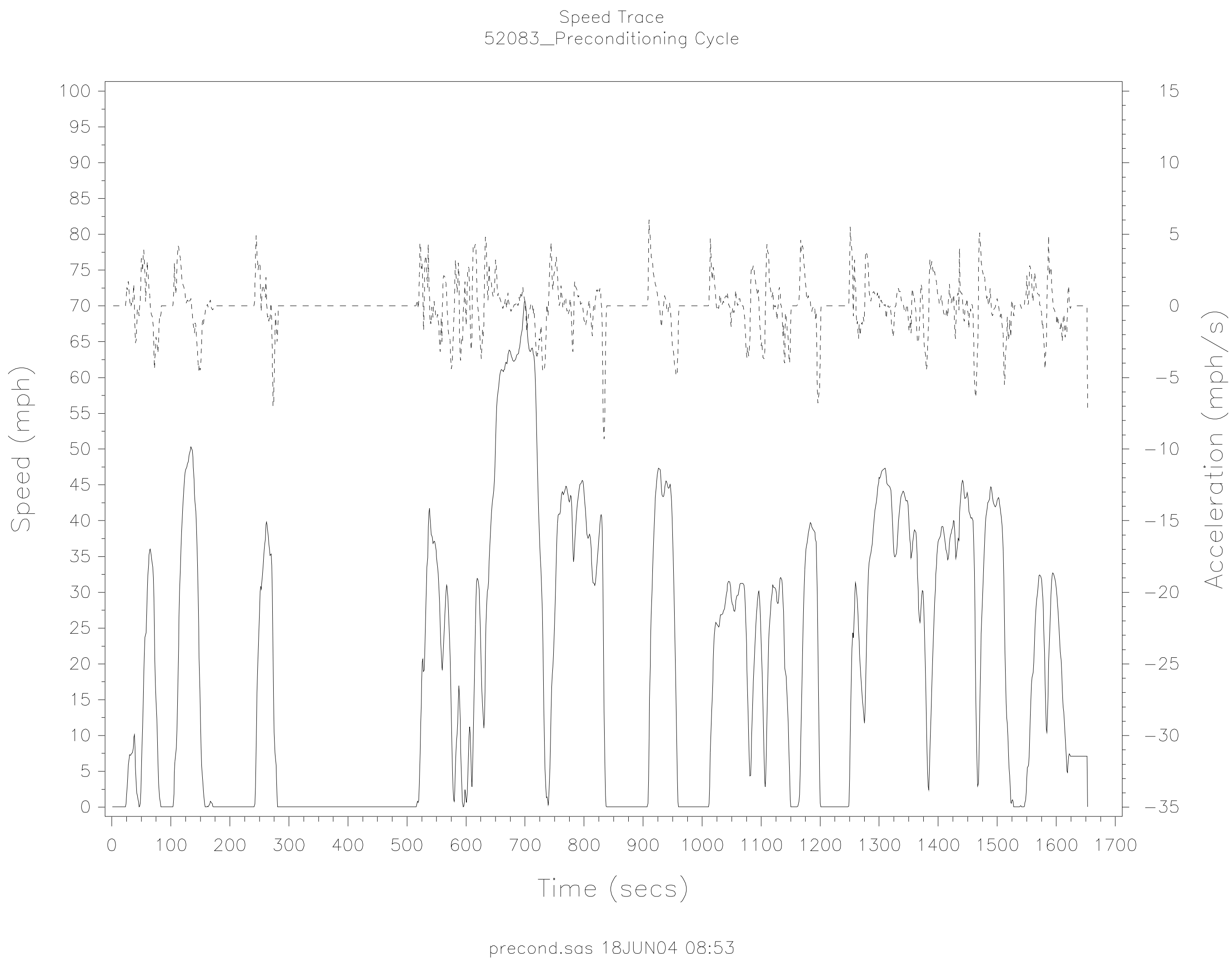


Figure 4-12. Speed Trace for Preconditioning Run for the Dodge Stratus

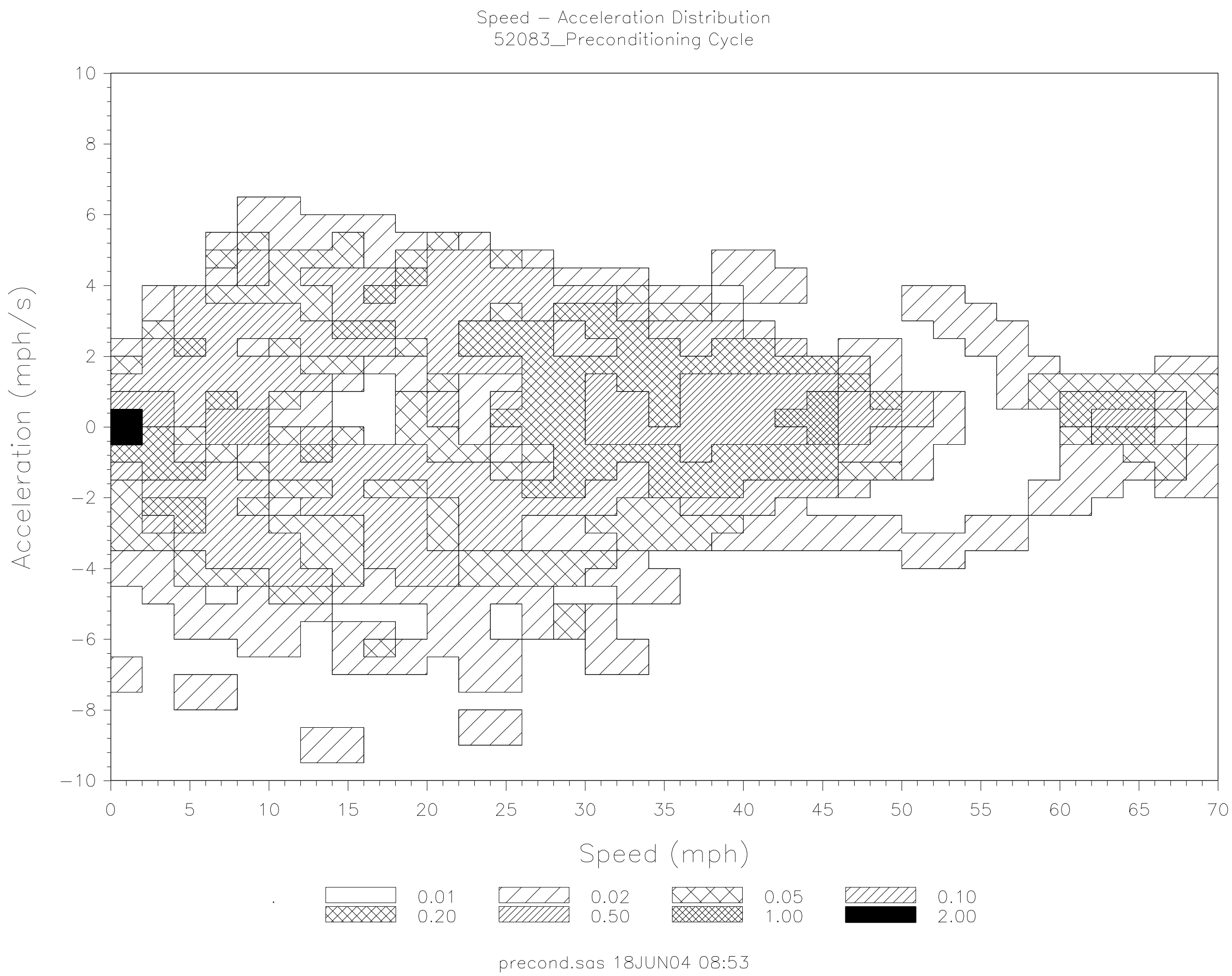


Figure 4-13. Speed-Acceleration Distribution for the Preconditioning Run for the Dodge Stratus

4.5 Emission Events as a Function of Vehicle Driving

Figure 4-14 shows the Bag 2 of a run on the Taurus from run number 84022. Figure 4-15 shows the contour plot of the region of vehicle operation where NOx emissions predominantly occur. This data was generated from the BKI second-by-second data after the emissions were time aligned with the speed. As shown in the plot, most emissions were at high speed and/or high acceleration situations. These kind of data reductions can be used to model the relationship between speed/acceleration and emissions can also be generated with time aligned PM data.

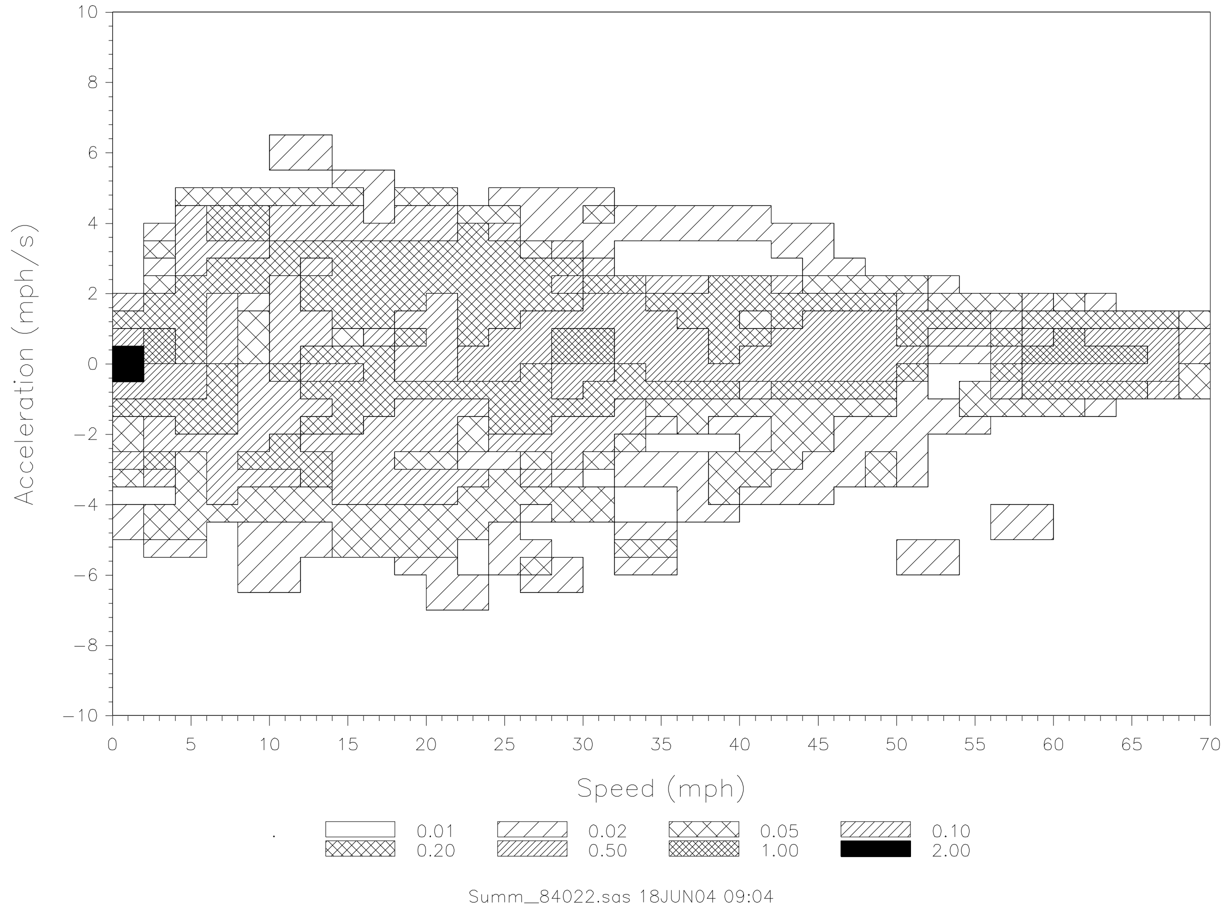


Figure 4-14. Dynamometer Speed/Acceleration Profile for Run #84022

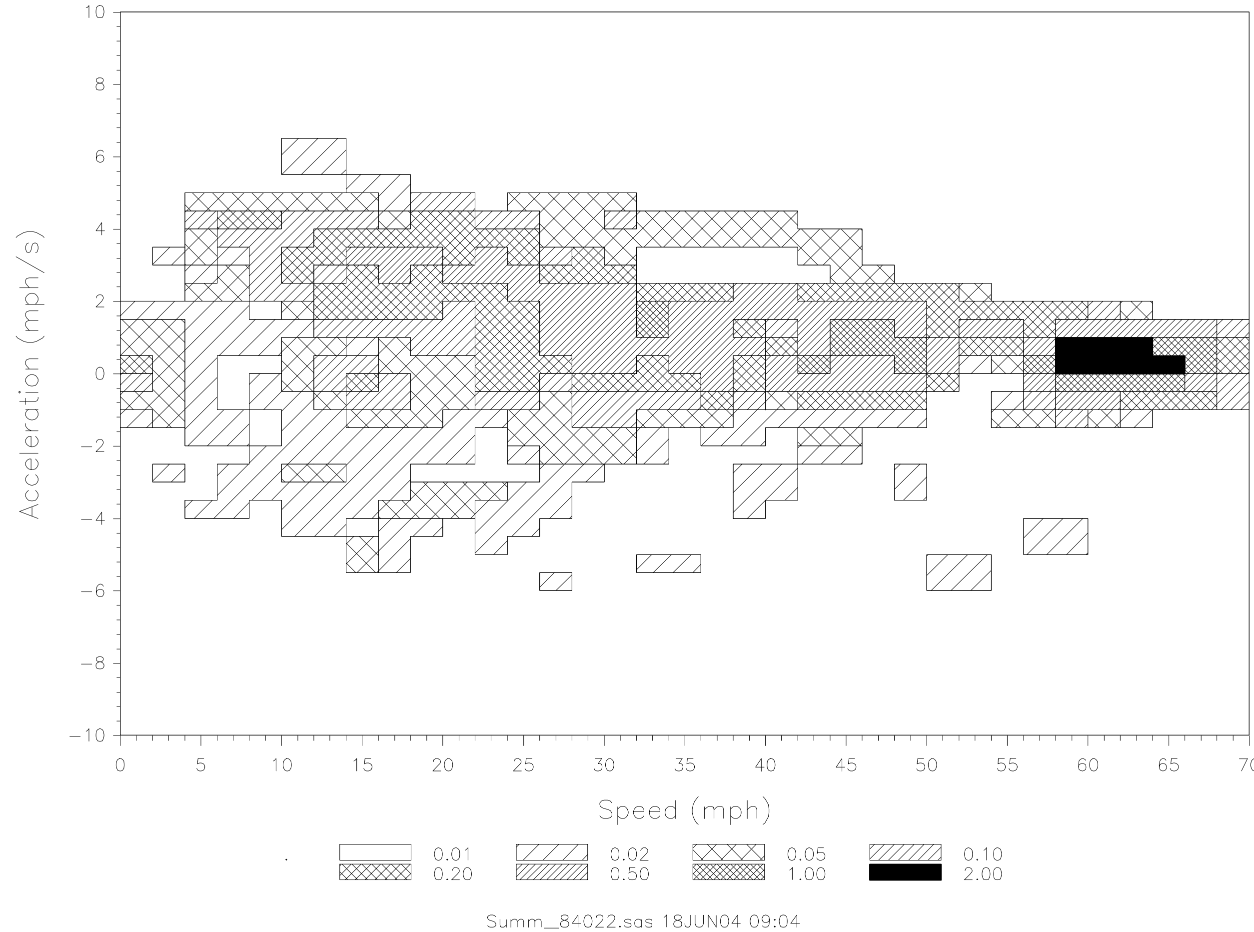


Figure 4-15. Dynamometer NOx Emission Generation Contour Plot for Run #84022

4.6 Composite LA92 Results from Dynamometer and SEMTECH

SEMTECH sampling was performed concurrently with all dynamometer testing. By-phase and total composite emission rates as measured using each system (SEMTECH vs. dynamometer) were then calculated and are presented in Table 4-6 below. Results in Table 4-6 are based on time-aligned test data to which the necessary corrections (humidity, dilution, flow) have been applied.

For each system, phase-specific grams/mile emission rates were calculated by dividing the total phase emissions by the distance the vehicle traveled during that phase. For all calculations, mileage was that as measured by the front dynamometer rollers. Composite emission rates for the entire run were calculated using the following formula:

$$C = 0.43\left[\frac{Pol1 + Pol2}{D1 + D2}\right] + 0.57\left[\frac{Pol2 + Pol3}{D2 + D3}\right]$$

Where:

C = Composite emission rate for the run (grams/mile)
Pol1 = Total pollutant (HC, CO, CO2, or NOx) emissions for phase 1 (grams)
Pol2 = Total pollutant (HC, CO, CO2, or NOx) emissions for phase 2 (grams)
Pol3 = Total pollutant (HC, CO, CO2, or NOx) emissions for phase 3 (grams)
D1 = Phase 1 distance traveled (miles)
D2 = Phase 2 distance traveled (miles)
D3 = Phase 3 distance traveled (miles)

Comparison of phase-specific and total composite emission rates Table 4-6 below shows a relatively good correlation between the two methods of measurement.

The BKI dynamometer numbers are based on speed and emissions time aligned second-by-second data. These estimates are integrated values for each phase. The SEMTECH rates have also been estimated by using speed and emissions time alignment methodology developed by Sensors. Table 4-6 shows good correlation for CO2, CO, and NOx but not for HC. Although EPA staff identified incorrect flow rate readings obtained by the SEMTECH unit, the data presented in Table 4-6 is based on emission rate estimates with corrected flow rates. The data from Table 4-6 is also graphically in Figure 4-16, which provides plots of BKI dynamometer composite results vs. SEMTECH composite results. This again shows good correlation for CO2, CO, and NOx but less of a correlation between SEMTECH and BKI dynamometer HC results.

The data in Table 4-6 and Figure 4-16 is only based on testing conducted 5/20 through 5/24. As shown in Table 2-12 (Section 2.7), several testing problems occurred during this time period that could strongly influence the accuracy of the SEMTECH readings (and consequently the correlation between the two datasets). It is anticipated that analysis of additional SEMTECH vs. dynamometer data (including analysis of data from testing conducted 5/25 and 5/26) will show a better correlation between the two systems. The 5/25 and 5/26 test data is currently undergoing SEMTECH flow meter bias corrections and will be included in future reporting.

The Phase 1 NOx reading for run ID 84015 (2004 Stratus tested 5/23/04) is unusually high relative to other NOx readings for this vehicle (both for this run as well as for other runs). Review of the second-by-second raw dynamometer data for this run shows NOx readings around 89.5 ppm for the first 60 seconds of testing. Subsequent readings then drop to under 1 ppm (which is equivalent to PPM readings for other Stratus runs). Investigation into the cause of this unusually high NOx reading should be performed to identify the root cause of this anomaly.

Table 4-7 provides a side-by-side comparison of SEMTECH vs. Dynamometer composite results for each test, categorized by vehicle. The composite results shown in bold-faced font indicate which system had higher emission measurement readings. Percentage difference between the two systems (relative to the lower of the two readings) is also shown for each run, and results with overall differences greater than 100% are highlighted in yellow. As shown in Table 2-12, the runs with overall differences greater than 100% were performed when SEMTECH HC readings were questionable due to calibration issues. For the New Yorker, all SEMTECH HC readings were fairly consistent and were consistently higher than the BKI dynamometer readings. For the Taurus, the SEMTECH HC reading for the first run (ID 84005) was much lower than the SEMTECH HC readings for the last two runs (IDs 84008 and 84012). BKI dynamometer HC readings were fairly consistent for all Taurus runs. This calls into question the SEMTECH HC reading on the first Taurus run. Additional analysis of the correlation of SEMTECH results vs. BKI dynamometer results will be performed.

Table 4-6. Comparison of SEMTECH and Dynamometer Emission Measurements

Run ID #	Phase	HC (gm/mile)		CO (gm/mile)		CO2 (gm/mile)		NOx (gm/mile)		Distance (miles)
		SMTCH	**BKI**	**SMTCH**	**BKI**	**SMTCH**	**BKI**	**SMTCH**	**BKI**	
84003	1	0.29	0.55	2.84	3.11	641.24	654.38	0.44	0.38	1.17
	2	0.03	0.04	0.45	0.35	368.84	379.46	0.09	0.07	8.63
	3	0.01	0.02	0.27	0.16	459.08	439.90	0.13	0.10	1.42
	Comp	0.04	0.06	0.56	0.48	390.13	398.48	0.11	0.09	11.22
84005	1	1.84	5.30	40.71	37.93	694.39	684.07	7.90	7.55	1.20
	2	1.09	2.29	21.16	18.27	422.06	418.80	7.03	6.24	8.62
	3	1.55	3.78	29.71	26.78	606.90	582.03	8.44	7.76	1.19
	Comp	1.16	2.55	22.78	19.89	449.12	443.99	7.18	6.41	11.01
84006	1	7.46	5.65	38.03	36.31	736.63	700.09	1.89	1.78	1.22
	2	2.59	1.00	23.07	11.53	792.01	491.26	2.59	1.60	8.58
	3	2.92	2.08	20.32	17.24	670.50	618.32	2.01	1.70	1.21
	Comp	2.87	1.32	23.67	13.26	780.48	511.39	2.51	1.62	11.01
84007	1	0.34	0.56	3.03	3.18	653.71	665.12	0.48	0.46	1.18
	2	0.04	0.04	0.40	0.31	385.06	392.18	0.10	0.09	8.61
	3	0.03	0.03	0.47	0.34	577.51	552.43	0.17	0.14	1.19
	Comp	0.06	0.06	0.54	0.46	412.31	417.43	0.13	0.11	10.99
84008	1	2.48	4.94	35.86	34.50	669.51	673.00	7.82	7.70	1.19
	2	3.02	2.20	19.77	17.62	405.60	412.24	7.03	6.37	8.62
	3	5.14	3.50	24.99	23.34	595.41	576.67	8.69	8.07	1.20
	Comp	3.14	2.44	20.97	18.90	432.56	437.27	7.19	6.55	11.00
84009	1	7.21	5.43	35.11	31.40	739.66	691.33	1.76	1.87	1.21
	2	2.38	1.01	25.27	12.40	749.42	475.33	2.58	1.73	8.67
	3	3.32	2.33	31.70	27.05	656.03	600.76	1.91	1.78	1.17
	Comp	2.70	1.33	26.23	14.40	742.58	495.18	2.49	1.74	11.05
84011	1	0.84	0.76	3.05	3.35	673.42	700.45	0.53	0.50	1.19
	2	0.05	0.04	0.50	0.40	404.68	428.10	0.12	0.09	8.63
	3	0.03	0.03	0.43	0.25	585.94	574.40	0.17	0.13	1.19
	Comp	0.09	0.08	0.63	0.54	431.19	452.39	0.14	0.11	11.01
84012	1	7.59	5.50	39.16	36.76	683.17	681.67	8.08	7.77	1.19
	2	3.01	2.25	20.44	17.98	401.73	411.96	6.93	6.28	8.63
	3	5.24	3.80	25.78	22.83	593.60	577.03	8.65	8.17	1.19
	Comp	3.40	2.53	21.78	19.29	429.58	437.36	7.11	6.49	11.01
84013	1	8.22	5.75	33.53	30.07	761.78	715.54	1.61	1.64	1.22
	2	3.20	1.27	31.85	15.55	747.03	477.02	2.64	1.74	8.67
	3	3.06	2.09	23.70	19.93	652.28	603.48	2.25	2.02	1.20
	Comp	3.46	1.56	31.38	16.62	741.27	498.39	2.56	1.75	11.08

Run ID #	Phase	HC (gm/mile)		CO (gm/mile)		CO2 (gm/mile)		NOx (gm/mile)		Distance (miles)
		SMTCH	**BKI**	**SMTCH**	**BKI**	**SMTCH**	**BKI**	**SMTCH**	**BKI**	
84015	1	0.76	0.63	3.21	3.27	632.09	647.02	0.47	2.33	1.18
	2	0.04	0.03	0.45	0.34	368.37	383.36	0.08	0.08	8.63
	3	0.04	0.05	0.53	0.42	535.27	518.41	0.12	0.12	1.19
	Comp	0.08	0.07	0.60	0.50	393.56	406.34	0.10	0.19	11.00
84016	1	5.43	5.91	46.38	43.14	679.21	693.98	7.90	7.82	1.17
	2	2.07	2.34	22.18	19.49	406.74	421.94	6.89	6.38	8.60
	3	3.54	3.89	27.16	23.13	593.17	584.57	8.54	8.22	1.18
	Comp	2.35	2.63	23.77	20.96	433.65	447.19	7.05	6.58	10.96
84017	1	4.00	5.93	36.97	34.53	739.37	725.21	1.80	1.75	1.22
	2	1.93	1.28	19.20	10.85	595.64	461.37	2.02	1.47	8.66
	3	2.18	2.31	24.16	21.17	634.82	616.86	2.21	1.90	1.20
	Comp	2.06	1.60	20.49	12.82	605.98	486.16	2.02	1.51	11.08

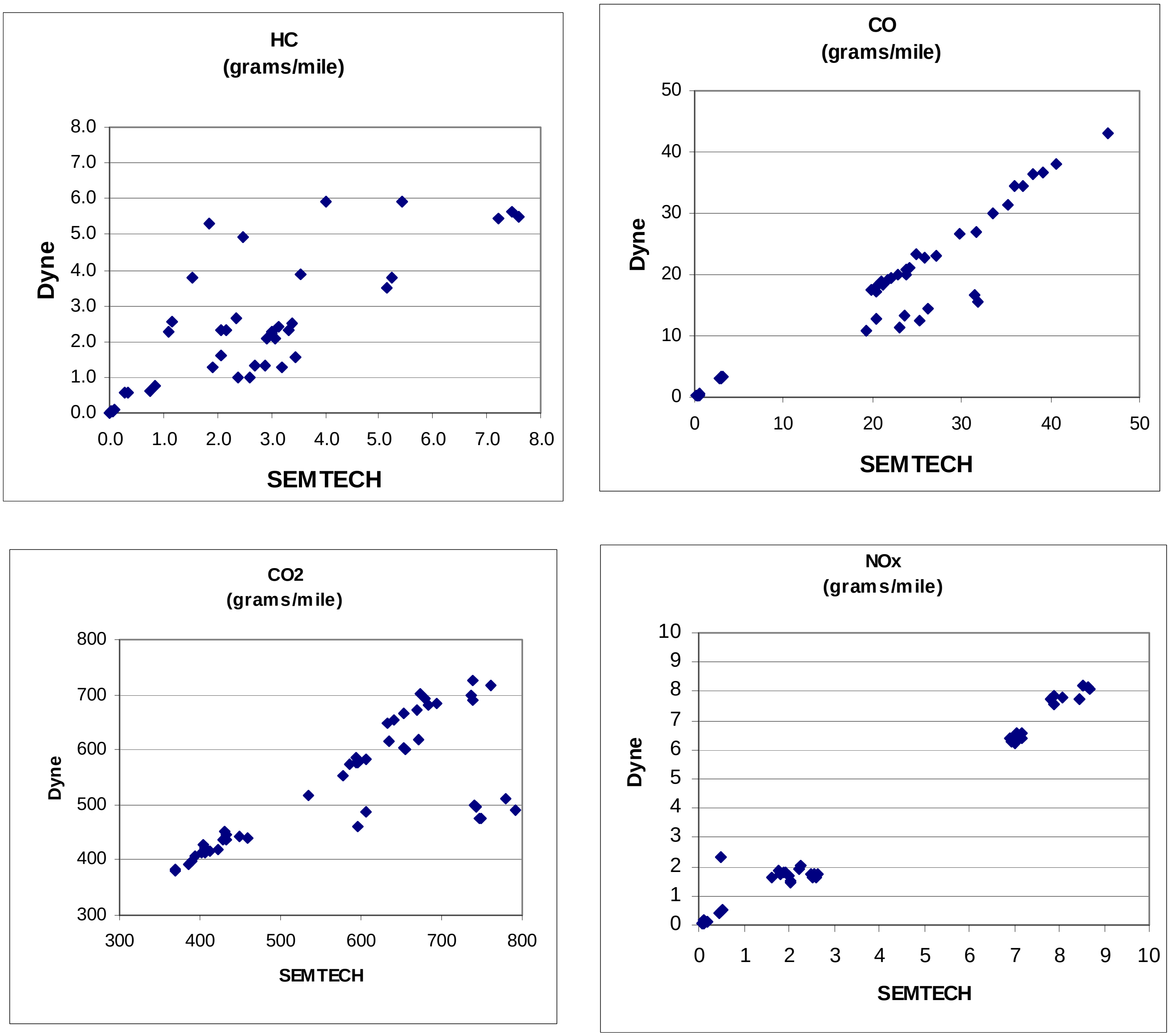


Figure 4-16. Plots of Dynamometer Measurements vs. SEMTECH Measurements

Table 4-7. By-Vehicle Comparison SEMTECH vs. Dynamometer Composite Results

Run ID #	HC (gm/mile)		% diff	CO (gm/mile)		% diff	CO2 (gm/mile)		% diff	NOx (gm/mile)		% diff
	SMTCH	BKI		SMTCH	BKI		SMTCH	BKI		SMTCH	BKI	
New Yorker												
84006	**2.873**	1.324	117	**23.67**	13.26	79	**780.5**	511.4	53	**2.513**	1.620	55
84009	**2.699**	1.331	103	**26.23**	14.40	82	**742.6**	495.2	50	**2.493**	1.745	43
84013	**3.457**	1.564	121	**31.38**	16.62	89	**741.3**	498.4	49	**2.559**	1.753	46
84017	**2.056**	1.601	28	**20.49**	12.82	60	**606.0**	486.2	25	**2.023**	1.514	34
Stratus												
84003	0.042	**0.064**	52	**0.558**	0.479	16	390.1	**398.5**	2	**0.109**	0.087	25
84007	0.058	**0.062**	6	**0.538**	0.461	17	412.3	**417.4**	1	**0.125**	0.109	14
84011	**0.092**	0.080	14	**0.627**	0.545	15	431.2	**452.4**	5	**0.145**	0.111	31
84015	**0.076**	0.066	16	**0.598**	0.496	21	393.6	**406.3**	3	0.102	**0.195**	92
Taurus												
84005	1.162	**2.551**	120	**22.78**	19.89	15	**449.1**	444.0	1	**7.176**	6.411	12
84008	**3.139**	2.435	29	**20.97**	18.90	11	432.6	**437.3**	1	**7.186**	6.555	10
84012	**3.402**	2.525	35	**21.78**	19.29	13	429.6	**437.4**	2	**7.109**	6.487	10
84016	2.347	**2.630**	12	**23.77**	20.96	13	433.7	**447.2**	3	**7.053**	6.583	7

5.0 Issues to be Resolved

CO2 emission results were higher on all three correlation vehicles at the Kansas City test site than were found in Ann Arbor (by about 5-10 % for Phases 1 and 3, and 10-20 % for Phase 2). Discussions have focused primarily on emission differences as a result of using different dynamometer types (water brake, twin roll Clayton in Kansas City versus an electric, 48" roll Horiba in Ann Arbor). Discussions have yielded several plausible explanations for these differences, which are summarized below.

It was observed in the field that operating at speeds above 60 mph may adversely affect the Clayton dynamometer loading, resulting in subsequent higher loading until speeds were reduced to about 20-30 mph. It was also noted that under continuous operation without breaking the 60 mph barrier, the load held fairly constantly. It was also noted that the greater differences in CO2 emissions seen in Phase 2, relative to Phase 1 and Phase 3 differences, with the Clayton dynamometer would be consistent with abnormally higher loading on the Clayton associated with speeds above 60 mph. Possible reasons for higher loads under the circumstances described include:

1) Possible foaming of 50/50 glycol/water mixture.

2) Setting of dead bands at 50 mph.

3) Innate characteristic of the Clayton PAU.

4) Leaking load/unload valves.

As the load has been observed to first go higher and then return to original values after low speed operation, leaking of the load/unload valves seems a remote possibility (if they were leaking, the PAU would either only load or only unload all the time, not back and forth).

Action items for BKI include reducing the glycol content of the cooling/loading fluid and performing dead band adjustments (preferably at ~60 mph). Coastdowns at a variety of speeds up to 65-70 mph should also be performed (with speed and torque being recorded) both before and after adjustments to determine the effect of the adjustments.

Additionally, coastdowns performed at Ann Arbor and in Kansas City should be compared. This would include the old and new coastdowns from Kansas City and the new (65-35 mph) coastdowns from Ann Arbor.

Driver differences could also be responsible for at least part of the CO2 differences. We therefore also propose to conduct two additional LA92s on the Taurus, using two different drivers.

In later discussions, it was pointed out that the set-up of the Clayton dynamometer located in Kansas City is a bit different than the set-up of similar dynamometers in Ann Arbor. In particular, speed measurement is taken from the front (or loaded) rolls in Kansas City, but taken from the rear (free wheeling) rolls in Ann Arbor. In general, speeds measured on the loaded rolls will be less than speeds measured on the rear rolls due to tire slippage on the loaded rolls, particularly with the aggressive nature of the LA92 driving cycle. As a result, when speed is measured from the front rolls, the test vehicle will be operated at a higher speed to compensate for the tire slippage, which could very well account for the differences in observed emission rates. *This seems to be the most plausible explanation. Accordingly, the set up in Kansas City will be changed to measure rear roll speed instead of front roll speed.*

Lastly, it is unclear whether the inertia of the rear rolls (~155 lbs.) has been accounted for in the flywheel system of the Clayton dynamometer used in Kansas City. Available literature will be searched to see if this determination can be made. Emissions tests will be repeated with the Taurus both before and after the changes are made, as discussed above. The BKI team is planning to conduct some additional testing in late June in Kansas City. In addition, in Ann Arbor coast down are being conducted on a clayton dynamometer. It is also anticipated that some additional emissions tests may also be conducted in Ann Arbor on the Clayton dynamometer.

The correlation between measurements of regulated pollutants made by the SEMTECH vs. those made by the BKI dynamometer requires investigation. Since the SEMTECH testing performed between 5/20 and 5/24 is suspect due to calibration issues, it is recommended that investigation be primarily focused on testing conducted subsequent to 5/24. Investigation into the cause of the high BKI dynamometer NOx readings for phase 1 of Run ID 84015 will also be performed.

Some issues have been identified regarding the correlation between particulate mass emissions as measured by the QCM vs. estimates using gravimetric analysis. Additional investigation is required to help resolve these correlation issues.