United States
Environmental Protection
Agency

EPA-600/R-01-079

October 2001

Research and Development

HEAVY DUTY DIESEL FINE PARTICULATE MATTER EMISSIONS: DEVELOPMENT AND APPLICATION OF ON-ROAD MEASUREMENT CAPABILITIES

Prepared for

Office of Air Quality Planning and Standards

Prepared by

National Risk Management
Research Laboratory
Research Triangle Park, NC 27711

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Heavy Duty Diesel Fine Particulate Matter Emissions:

Development and Application of On-Road Measurement Capabilities

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Abstract

EPA's On-road Diesel Emissions Characterization Facility, which has been collecting real-world gaseous emissions data for the past 6 years, has recently undergone extensive modifications to enhance the facility's particulate matter (PM) measurement capabilities, with specific emphasis on fine PM or $PM_{2.5}$ (particles less than 2.5 μm in aerodynamic diameter). At present, the facility's capabilities are focused on continuous sampling and analysis, using fast responding instruments such as the Electrical Low-Pressure Impactor (ELPI), the Tapered-Element Oscillating Microbalance (TEOM), and a particle-bound Polycyclic Aromatic Hydrocarbon (PAH) analyzer, all of which require a dilute exhaust sample. This dilute sample has been drawn directly from the vehicle exhaust via a stack dilution system, and sampled from the ambient exhaust plume via probes in the trailer. Dilute samples have also been collected on filters for chemical and gravimetric analysis. Experimental results indicate that stack dilution sampling does not adequately represent real-world conditions as determined from initial plume sampling. Therefore, future efforts will be directed toward improved plume characterization techniques.

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Acronyms and Abbreviations

Accel	Acceleration
Aethal.	Aethalometer made by Magee Scientific Company
APPCD	Air Pollution Prevention and Control Division
ASCII	American standard code for information interchange
CD-RW	Compact disc rewritable
CEM	Continuous emissions monitor
CNC	Condensation nucleus counter
CO	Carbon monoxide
CO_2	Carbon dioxide
CPC	TSI Model 3025a condensation particle counter
D.R.	Dilution ratio
DAS	Data acquisition system
dP	Differential pressure
DQI	Data quality indicator
DQO	Data quality objective
ELPI	Electrical low pressure impactor
EPA	Environmental Protection Agency
ERR	Error
HDDV	Heavy-duty diesel vehicle
hr	Hour
Hz	Hertz
ID	Identifier
JCC	Johnston Community College
kph	Kilometers per hour
KW1	Kenworth truck as-received
KW2	Kenworth truck after engine overhaul

LAN	Local area network
LDDV	Light-duty diesel vehicle
MEC/FTP	Modified energy conservation/federal test procedure
mph	Miles per hour
NA	Not available
NDIR	Non-dispersive infrared
NIEHS	National Institute of Environmental and Health Sciences
NIST	National Institute of Standards and Technology
NO_X	Nitrogen oxides
O_2	Oxygen
ODEC	On-road Diesel Emissions Characterization facility
PAH	Polycyclic aromatic hydrocarbons
part.	Particle
PC	Personal computer
PM	Particulate matter
ppm	Parts per million
QA	Quality assurance
QC	Quality control
R&P	Rupprecht & Patashnich
rpm	Revolutions per minute
RSD	Relative standard deviation
SAE	Society of Automotive Engineers
SCFM	Standard cubic feet per minute
sec	Second
SMPS	Scanning mobility particle sizer
TEOM	Tapered element oscillating microbalance
THC	Total hydrocarbons

u.d.s.	Unit-density spheres
UC-Davis	University of California at Davis
UDDSHDV	Urban dynamometer driving schedule for heavy-duty vehicles
W.G.	Water gauge
WVU	West Virginia University

Conversion Table

English Unit	Metric Equivalent
1 ^oR	1.8 K
1 inch	2.54 cm
1 ft	0.3048 m
1 ft^3	0.0283 m^3
1 hp	745.7 W
1 lb	0.4536 kg
1 mi	1.609 km

Chapter 1

Introduction

Because of the current level of interest in fine particulate matter (PM) and its health effects, EPA has refocused a substantial amount of its research to study emissions sources that produce fine PM (HEI, 1994). Diesel engines, already under substantial EPA scrutiny for their NO_X emissions, are also known to emit large quantities of small particles (Kittelson et al., 1978). In fact, a majority of the PM found in diesel exhaust is in the nanometer size range. What is not known is how much of the fine PM in ambient air actually comes from diesel engines. Moreover, the relative contributions of stationary sources (e.g. generators, welders), farm machinery, light-duty diesel vehicles (LDDVs), and heavy-duty diesel vehicles (HDDVs) to the total PM-2.5 (particles $\leq 2.5\mu m$ in aerodynamic diameter) emissions inventory are also largely unknown.

A substantial amount of diesel fine PM data has been collected by many researchers covering concentrations, size distributions, dilution effects, and other properties. Most of this data was collected using engines mounted on dynamometers and, to a lesser extent, chassis dynamometer facilities. These facilities allow for the collection of data under very controlled, repeatable conditions. Many of these conditions are of a steady-state nature, where the emissions are allowed to stabilize before data or samples are collected. Quite often, these steady-state tests prove useful for comparing different instrumentation and dilution arrangements. However, there is no consensus on how well steady-state tests represent “real world” emissions. On the other hand, the more transient tests (i.e., those designed to mimic real world operation) typically suffer from poor measurement repeatability. Fine PM measurements in particular are problematic because many of the most sensitive instruments cannot follow such a rapidly changing response. Nonetheless, it is likely that it will take a combination of both types of tests (steady-state and transient) to fully characterize fine PM emissions from HDDVs.

The Air Pollution Prevention and Control Division of EPA’s Office of Research and Development has developed its on-road approach as sort of a “reality check” for HDDV emissions estimates. By replacing assumptions with measurements, and simulation parameters with real-world operating conditions, the On-road Diesel Emissions Characterization (ODEC) facility provides another dimension to the data currently available for quantifying and characterizing HDDV emissions. Fine PM measurement capabilities have been recently added as an extension of this original objective. This report describes the on-road test facility, as adapted to fine PM measurements. Example data are also presented for on-road testing as collected directly from the stack and from the ambient plume along the edge of the trailer. Finally, as these descriptions and data represent an ongoing research effort, there are a number of recommendations for improving and expanding the capabilities of the on-road sampling program.

Chapter 2

Description of Heavy-Duty Test Facility

The general capabilities of the ODEC facility, as described in greater detail elsewhere, are shown in Figure 2-1 (Brown et al., 2001). Its purpose is to allow emissions testing of heavy-duty diesel vehicles (HDDVs) in a manner that represents the "real world" as closely as possible. Fully integrated into a class 8b truck, the facility is designed to be completely self-contained, able to collect several hours' data while traveling along the same public roadways that are used by the at-large fleet of motor vehicles. A majority of the data are collected in real-time by continuous analyzers which allows comparisons between emissions and vehicle operating modes. These data include vehicle parameters, engine parameters, and emissions measurements.

The vehicle and engine parameters include everything necessary to convert emissions data to fuel-, distance-, and energy-specific units. There are also some "informational" parameters, like

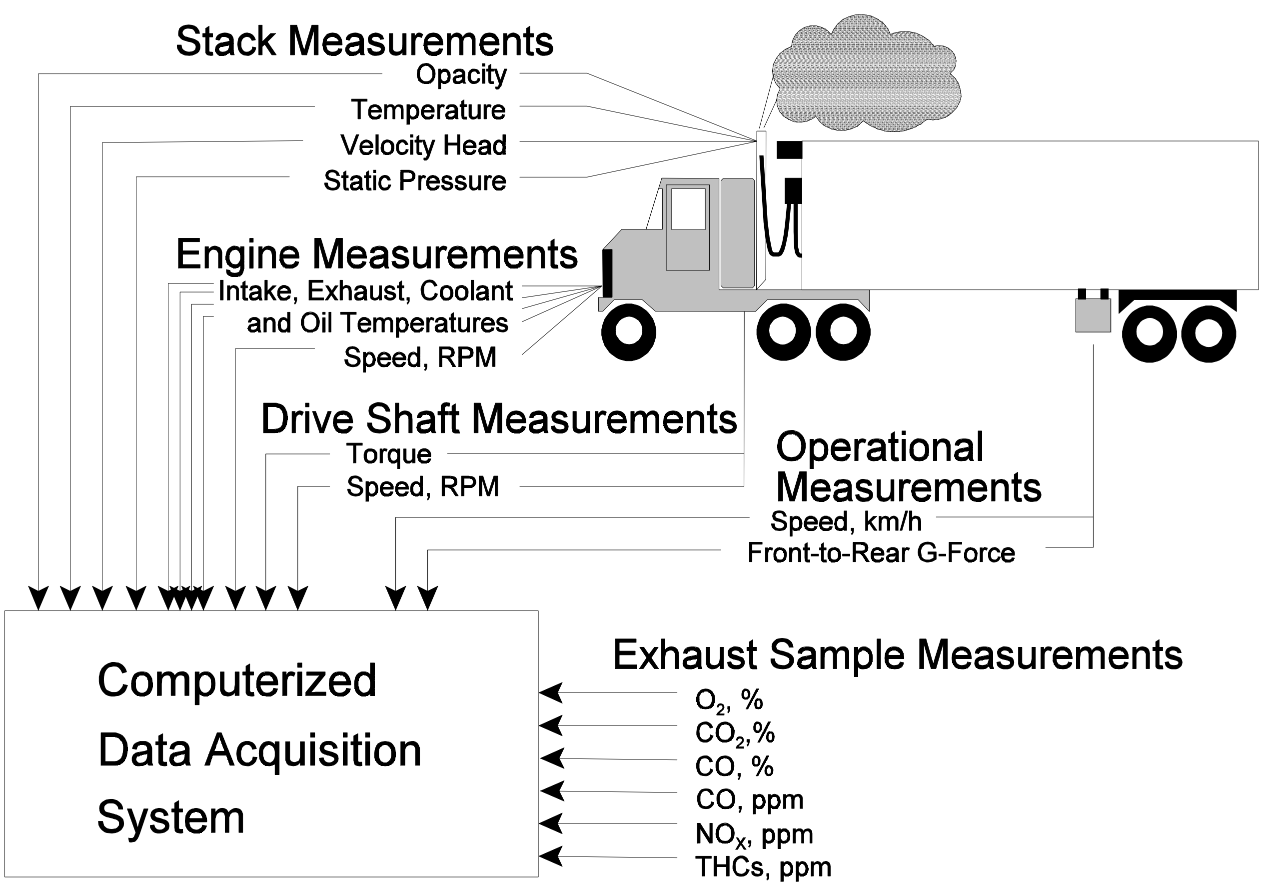


Figure 2-1. On-Road Diesel Emissions Characterization Facility.

engine fluid temperatures, that may not contribute numerically to the processed data set. All of these are measured by electronic sensors that feed signals to a central data acquisition system (DAS) mounted in the trailer instrument rack. This same computer also receives signals from the gaseous emissions analyzers and the sensors that measure the exhaust flow parameters. Cumulatively, all of the measurements shown in Figure 2-1 form the “core capabilities” of the facility, those that remain intact as more task-specific capabilities are added and removed.

Capabilities added for fine PM characterization included a dilution sampling system, plume sampling equipment, and the ability to operate a number of sophisticated fine PM instruments. Of all the instrumentation that is available to measure and characterize fine PM, none of it is compatible with raw diesel exhaust. Even in the shortest of measurement paths, the amount of deposited material would cause instability in the measurements from any analyzer; which is why a particulate filter is an integral part of any gaseous pollutant measurement system. Deposition is not the only consideration. Typical exhaust concentrations also far exceed the measurement ranges of the most useful fine PM analyzers. Ideally, the diluted sample should accurately represent the exhaust as it dilutes normally in ambient air. The ODEC facilty follows two approaches to approximate this ideal: (1) a direct-dilution system that draws sample from the raw exhaust and dilutes it with clean air, and (2) drawing a naturally-diluted sample directly from the truck’s exhaust plume. Each is described below.

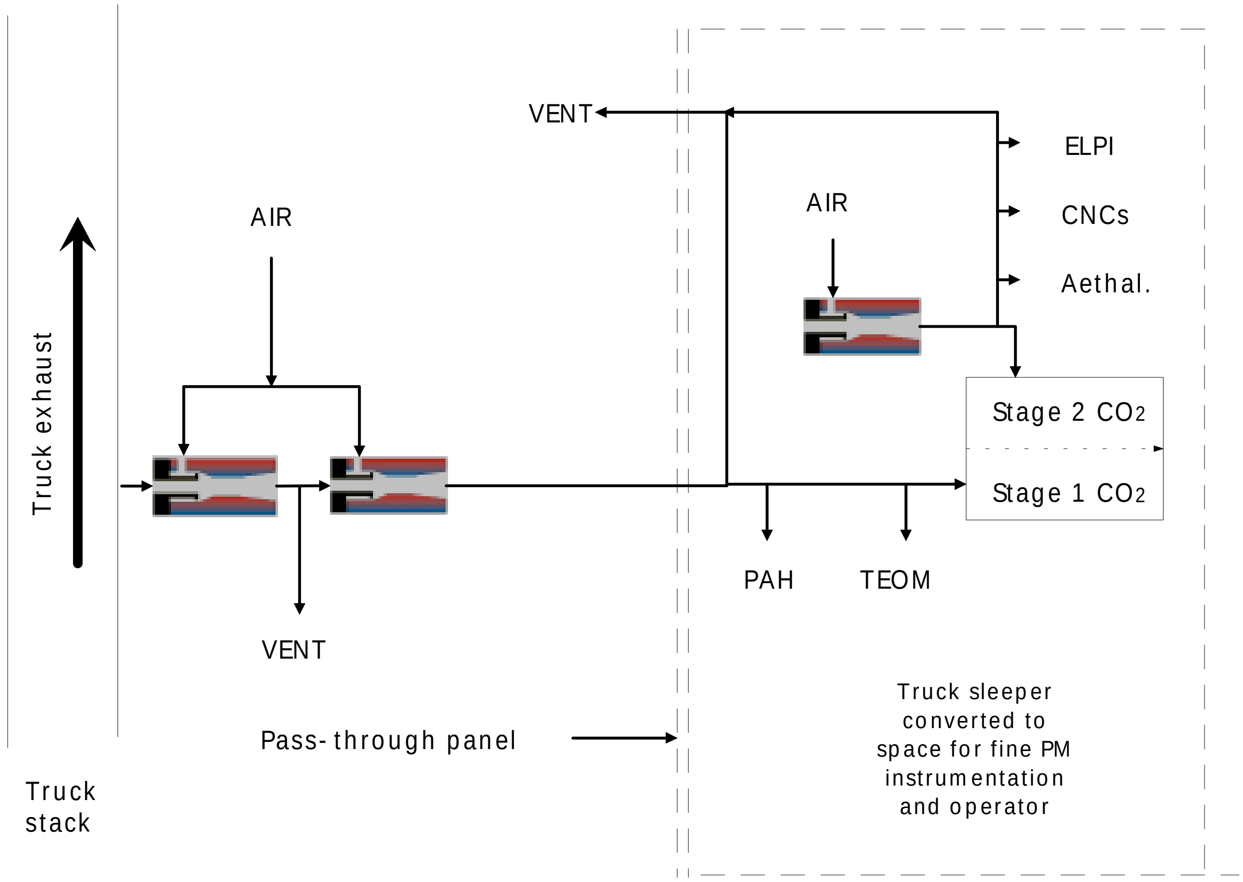
2.1 Direct-Dilution Apparatus

The most commonly deployed dilution apparatus for diesel exhaust is the full-flow dilution tunnel (Federal Register, 1983). Used by both chassis and engine dynamometer facilities for both gaseous and PM measurements, the tunnel approach consists of supplying the entire exhaust stream into a large tunnel that pulls a constant flow. The advantage of this system for emissions measurement is that the actual exhaust flow does not have to be measured. These systems typically quantify the tunnel flow and the tunnel concentrations. By maintaining constant tunnel flow, the system creates a constant proportionality between measured concentrations and calculated emissions. For raw exhaust sampling, the emissions would be proportional to both flow and concentration, both of which fluctuate substantially under typical operating conditions. Dilution tunnel sampling reduces the likelihood of inaccurate emissions measurements being caused by imprecise matching of multiple time-series data streams. This makes the constant flow dilution tunnel a very good choice for measurements where mass emissions are the primary objective.

For fine PM, however, there is a growing evidence that dilution tunnels may be unsuitable. Several researchers have demonstrated that particle size measurements can be fundamentally altered by changes in dilution ratios, residence times, and physical characteristic of the sampling system (Williams et al., 1988; Kittelson et al., 1999; Brown et al., 2000). In dilution tunnels, because of their constant flow design, the dilution ratio fluctuates with the exhaust flow, thus introducing another variable into the fine PM measurement. When two engines of different sizes are tested at the same facility, even running the same cycle, a bias will be introduced by the difference in the range of dilution ratios. Chassis dynamometer facility testing of an ODEC facility truck showed ratios ranging from 2:1 to 23:1, while a study using passenger cars describes factors "between 5 and 50" (Maricq et al., 1999). Both of these ranges include ratios where nanoparticles are likely to form by heterogeneous nucleation.

Other considerations that are specific to an on-road system include the size of the dilution system, its power demands, and how the raw exhaust is delivered to its inlet. Obviously, the only space large enough to have a dilution tunnel is in the trailer. Even if the truck exhaust could be piped from the tractor stack to the trailer, it would introduce considerable residence time, particle loss, and safety issues. The tunnel apparatus itself would add weight to the facility, and its power demands would require an upgrade to the on-board generator and power distribution system. Such a system has recently been built by the University of California at Riverside.

Based on all of these concerns, the dilution tunnel approach was rejected in favor of the "ejector dilutor" system used by Kittelson in much of his work (Kittelson et al., 1978). As shown in Figure 2-2, this system uses air-powered ejectors to draw in sample and mix it with a rapid flow of filtered air. Depending on the desired dilution ratio, the sample inlet to any stage may include an orifice. For the system shown here, two cascaded ejectors with no orifice constitute the first dilution stage, which brings the particle concentration down to a level that minimizes orifice clogging in subsequent stages. After secondary dilution, ratios as high as 1000:1 can be achieved. The dilution air is provided by a diesel powered air compressor that furnishes as much as 50 SCFM at a pressure of >100 psig. A coalescing filter removes suspended oil droplets before an air-purged molecular sieve dryer removes water and carbon dioxide from the air stream. The final two filters remove all fine particles as small as 100 nm and remaining organics.



The dilution ratio is calculated from CO_2 measurements. As shown in Figure 2-2, a dual-channel analyzer measures each dilution stage. The raw exhaust CO_2 is, of course, measured by the continuous emissions monitoring (CEM) system inside the trailer laboratory. Also installed is a "diluent" CO_2 analyzer, which measures the background concentration in the compressed air supply. Appendix A shows how dilution ratios and other parameters are calculated and used in subsequent calculations.

2.2 Dilution Schedule

In studying the impact of exhaust dilution on diesel fine PM, the two parameters of interest are dilution ratio and residence time. Several studies have suggested that the amount of time the exhaust spends at a ratio between 5:1 and 50:1 fundamentally affects the number of ultrafine particles (<0.1 μm) that are formed by heterogeneous nucleation (Kittelson et al., 1999). In real-world plumes, the dilution ratio increases steadily over time, so the concentrations of exhaust constituents asymptotically approach background levels. In a stack dilution system, this process is duplicated in a variety of ways. In systems where fine PM is of no interest, samples are often diluted in one step, and only to a level that would prevent condensation of volatile components. In a fine PM sampling system, real-world dilution might be approximated by a succession of stages, each with a characteristic ratio and residence time. Figure 2-3 shows how a multi-stage dilution system might be used to simulate a more gradual dilution. The system modeled here would use five of the eductors shown in Figure 2-2: three close-coupled eductors, with no additional dead space or orifices, followed by two stages with transport tubing (which introduce residence time) and orifices (which increase dilution ratios) Given complete control over the ratios and residence times at each stage, the accuracy of the dilution schedule's simulation is limited only by the number of stages, which in turn is limited by cost, complexity, and practical considerations.

The Figure 2-3 example is a representation of what might happen in the exhaust plume of a tractor-trailer. The exhaust experiences a rapid dilution as a result of being released into the turbulent region behind the tractor. The dilution becomes more gradual as the plume passes along the length of the trailer, only to be disturbed once more by the recirculating flow field at the end of the trailer. Once beyond the trailer's wake, the plume dilutes even more gradually than before (at least until disturbed by another vehicle). One of the PM-related goals of the on-road diesel program is to quantify all of these effects (i.e., generate a "real data" version of Figure 2-3), so that a "target" dilution schedule can be developed.

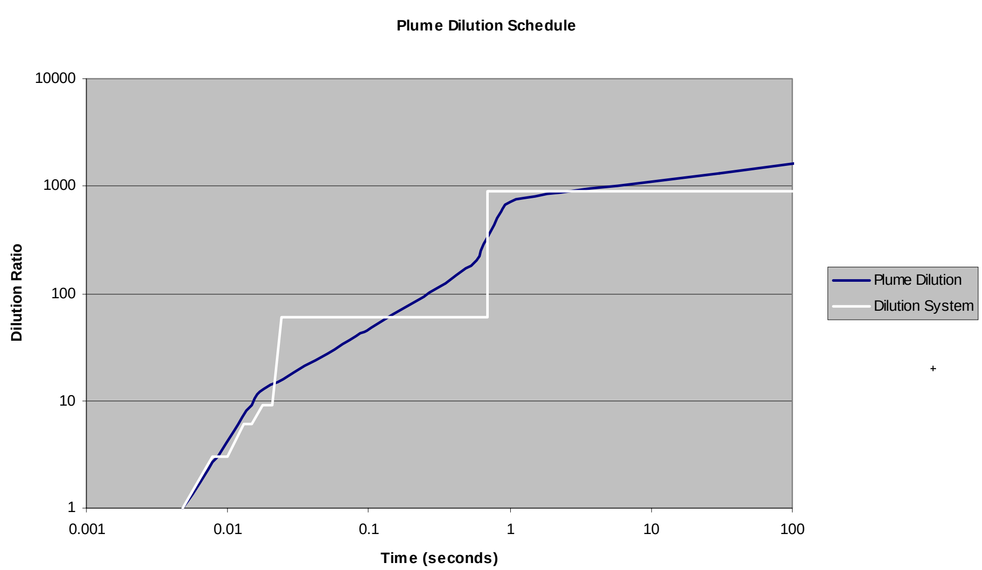


Figure 2-3. Dilution System Mimicking Plume Dilution.

2.3 Plume Sampling

An alternate approach to using a dilution system is to pull an ambient sample from somewhere within the emissions "plume" of the truck. This is possible because the "high-dump" (elevated) exhaust stack that is most common on class 8 trucks typically creates a plume that is seldom completely disrupted as it passes along the length of the trailer. In fact, this type of sampling has been done before, using a small laboratory mounted on a flatbed truck (Kittelson et al., 1988). Figure 2-4 shows the dilution schedule resulting from that study. Since the ODEC facility's laboratory is already built into the trailer, plume sampling is simply a matter of mounting probes directly behind the truck's exhaust stack. For convenience of mounting, the probe connectors are drilled through the existing plastic windows located along the top starboard edge of the trailer. These are located

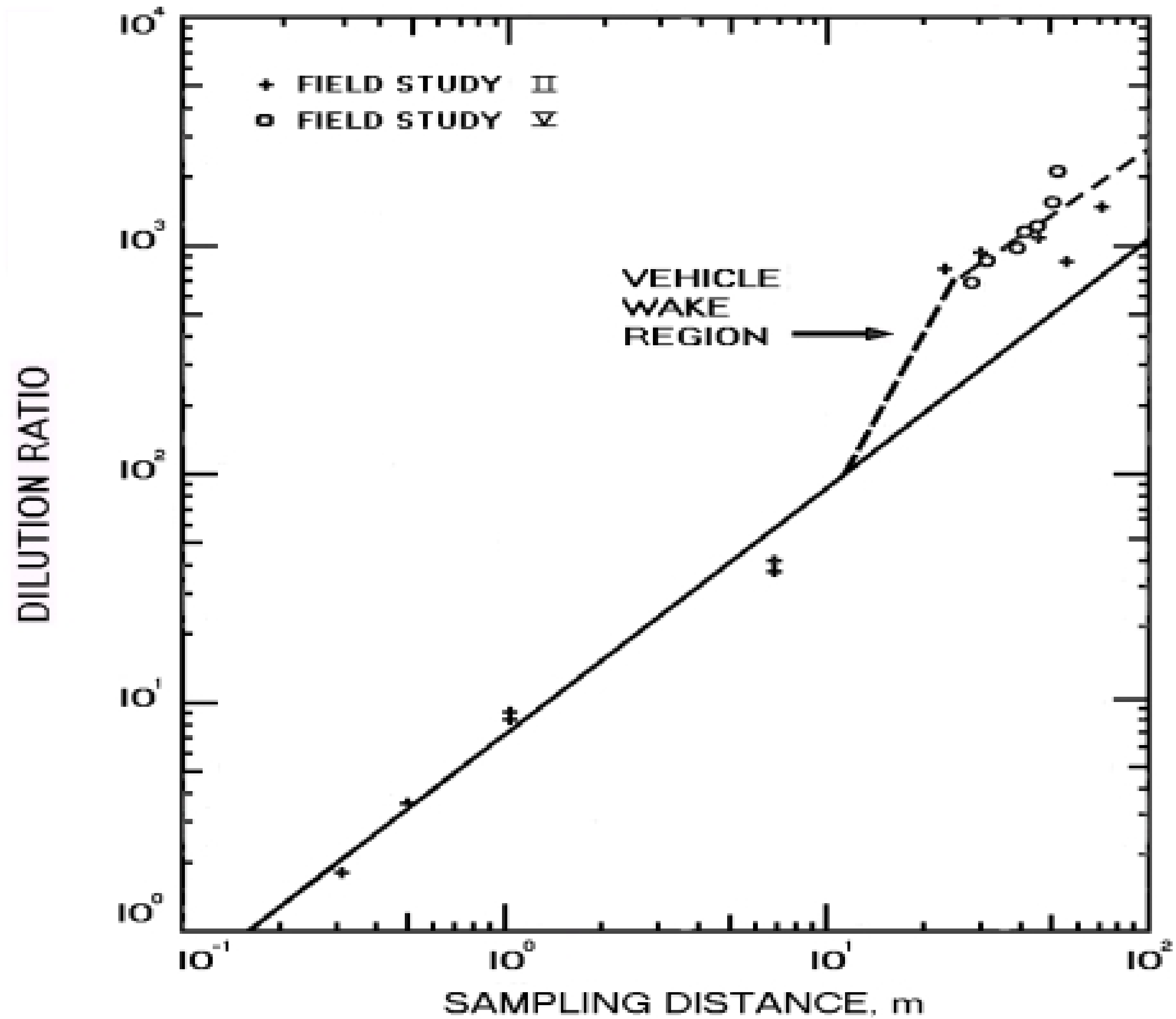


Figure 2-4. Plume Dilution Schedule from 1988 Study.

nominally 2 meters, 6 meters, 8 meters, and 11 meters behind the exhaust stack. When a particular probe is being sampled, the PM and diluent analyzers are mounted inside the trailer just below the probe. Clean power, calibration gas, and signal connections are run from the main instrument rack, so the instruments are simply an extension of the trailer laboratory (even when they are located in the cargo space of the trailer).

2.4 Operator Control Center

The ODEC facility has always been designed for a cab-stationed instrument operator. Historically, the operator's control center has consisted of a few switches and readouts with a computer console attached to the trailer-mounted DAS. When the dilution system is used, all of the associated flow and pressure instruments are mounted in the cab with the operator, as are the fine PM instruments themselves. Since many of these instruments are designed to be operated and controlled by external computers, multiple computers are needed. This requirement posed a threefold challenge: (1) physically locating several computers in the already-crowded truck cab, (2) providing usable operator interfaces to all of these computers, and (3) ensuring that simultaneous data collected by multiple computers is synchronized.

Due to space and power constraints, a single-chassis "multicomputer" device was constructed using an industrial-grade passive backplane with four single-board plug-in computers. Each computer has its own disk drives, ports, and processing capabilities, sharing only a case and power supply. Externally, the mouse, keyboard, and monitor ports are all attached to a console switching device that allows one console to operate all of the computers (including the DAS, still located in the trailer). The operator can switch from one computer to another with keyboard "hot keys" without disrupting any computer's ongoing tasks (i.e. collecting real-time data). The switching device also has the capability to "scan" through the computers at user-selectable intervals, for round-robin monitoring without operator input.

As a matter of convenience, the computers are also connected to a local area network (LAN) that allows for file transfers and device sharing among them. This is useful when data are archived onto removable media, as only one computer needs to have a large-capacity removable device. The most useful capability of the network, however, is in keeping the computers synchronized. Using a shareware utility called Tardis, licensed by HC Mingham-Smith Ltd., one computer becomes the time standard for all of the other computers on the network. This ensures that all data are time-stamped appropriately for subsequent processing and comparison.

During plume sampling, the fine PM instruments are located in the trailer. This creates no major operational problems because most of the instruments are controlled through their computer interface. Those that are not computer-controlled are designed for unattended operation. From a connectivity standpoint, there are two options for communicating with the trailer mounted fine PM instruments. The first option is to attach each instrument to a nearby computer which communicates with one of the cab-mounted computers over the network. This option requires no additional wiring between the cab and trailer, but it does require additional computers and network connections. The second option is to run the serial port cabling from each instrument all the way to the cab-mounted multi-computer. Both of these options have been used successfully, but the latter is the preferred long-term options as it requires fewer computers and is, in general, less complicated.

2.5 Particle Measurement Instruments

2.5.1 Electrical Low Pressure Impactor (ELPI)

The Dekati ELPI uses a cascade impactor to provide real-time size classification and quantification of particulate with aerodynamic diameters from 0.03 to 10 μm. As shown in Figure 2-5, particles entering the ELPI are first bombarded with ions created by a corona discharge. These ions are subsequently removed by the ion trap, which theoretically also removes all particles smaller than 20 nm. The impactor itself removes particles beginning with the largest aerodynamic cut point of 10400 nm. As each particle is collected, its charge is drained to a highly sensitive electrometer, which, in turn, is connected to a computerized data acquisition system (DAS) built into the ELPI. The impactor is operated at low pressure in order to increase the Cunningham slip correction factor and, hence, allow particles as small as 30 nm to attain Stokes numbers high enough to impact (Dekati, 1999).

The impactor can be operated in several configurations. In its most commonly used configuration, all of the electrical components are active and the impaction plates are covered with aluminum foil substrates that are coated with a thin layer of vacuum grease. The grease prevents particles from "bouncing" off the impaction surface and possibly depositing on the wrong impactor stage. Of course, greased substrates do not provide good samples for laboratory analysis, so it is not uncommon for researchers to sacrifice a little size accuracy for the sake of some chemical or physical

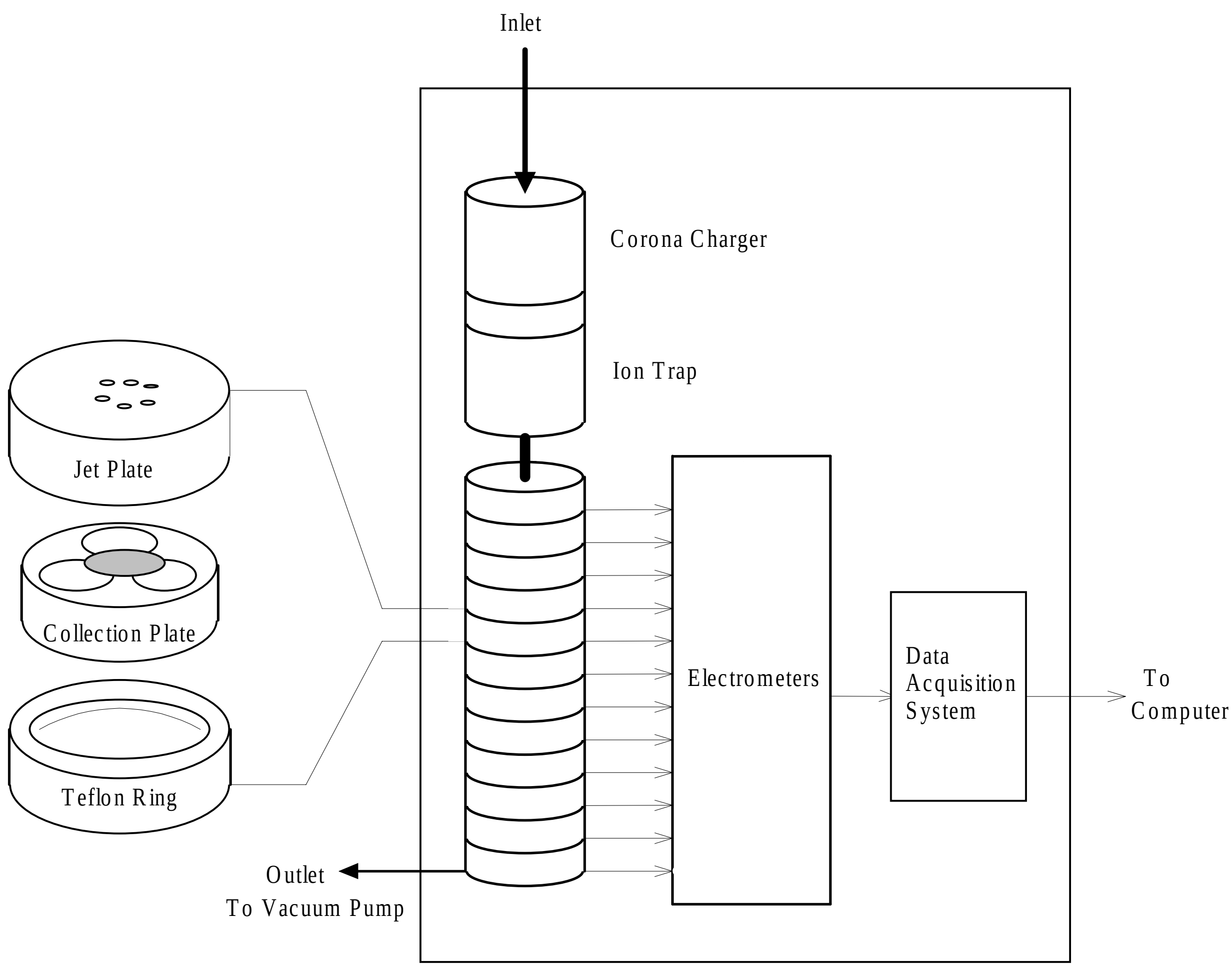


Figure 2-5. Electrical Low Pressure Impactor.

property data. As with any other impactor, the substrates can be conditioned and weighed before and after use. So, provided proper care is taken in coordinating the operation of the impactor and the electronics, it is possible to obtain comparative gravimetric and particle count data. The gravimetric data would be biased by the removal of nanoparticles in the charger, but this effect would likely be negligible, and can be eliminated entirely by turning off the charger and sacrificing the particle count data.

ELPI operation is monitored and controlled by Windows-based application software running on an external computer. The application displays several windows, including a control console, a size distribution bargraph, line plots of raw or processed data from each stage, and a table of numerical values. The console controls the various hardware functions of the ELPI, including the charger, the ion trap, the flush pump, and the gain on the electrometers. There are also controls to "zero" one or more of the electrometers; during this procedure, the flush pump supplies filtered air to the ELPI inlet while the software compensates for electrometer zero drift. The ELPI software saves measurement data at an interval specified by the user; the user also specifies the file name and format at the beginning of each test run.

2.5.2 Polycyclic Aromatic Hydrocarbon (PAH) Analyzer

This analyzer, produced by EcoChem Analytics, provides real-time measurements of the surface-bound PAH using the principle of photoelectric ionization. Particles passing through the ionization chamber are bombarded with ultraviolet light from an Excimer lamp (see Figure 2-6). This lamp produces monochromatic radiation with a half bandwidth of 2%, narrow and specific enough so that only the PAH coated aerosols are positively charged, while gas molecules and non-carbonaceous aerosols remain neutral. The sample then passes through an electric field that removes the liberated electrons and all negatively charged particles. The filter element that collects the remaining particles is mounted to a Faraday cage. The electrical current imparted to the filter by the charged particles is measured with an electrometer.

Total microprocessor control assures that all voltages, flows, and background currents are within specifications. The fast-responding Excimer lamp is operated in "chopped" mode (continuously cycling on and off) so that background currents caused by pre-charged particles can be quantified and subtracted out.

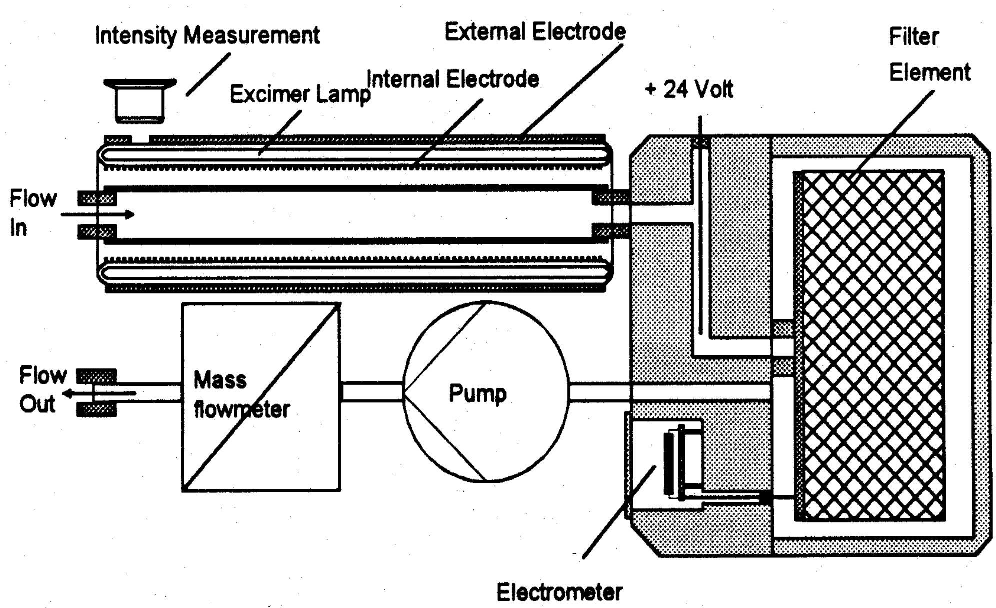


Figure 2-6. PAH Analyzer.

2.5.3 Tapered Element Oscillating Microbalance (TEOM)

The TEOM Model 1105, manufactured by Rupprecht and Patashnick Co., Inc., produces a real-time measurement of particulate mass using Hooke's Law. The PM-laden sample enters the TEOM and passes through a Teflon®-coated glass filter that is fixed on the end of an oscillating tube (see Figure 2-7). The mass of the filter is increased by the PM deposition, which changes the natural frequency of the oscillation. The frequency is measured by the TEOM every 0.42 second. The TEOM is able to report the total mass deposited, and by using a mass flow controller to maintain a constant volumetric flow rate, can calculate the mass deposition rate and PM mass concentration.

A typical sample of heavy-duty diesel exhaust provided to the TEOM must be diluted at least by a ratio of 30:1, to prevent instantly clogging the filter, and must be either dilute or warm enough to prevent condensation of water vapor. The actual filter element is heated, which prevents capture of very volatile organics but also contributes to the noise of the instrument by evaporating semi-volatile compounds such as PAH. New Windows®-based software (only a beta version of which is currently available) allows control of the TEOM and display of the raw frequency data as well as the calculated mass data. Data can be reported every 0.42 second, although 10-second averages are normally recorded by the software.

2.5.4 Aethalometer

The Aethalometer (manufactured by the Magee Scientific Company) uses an optical

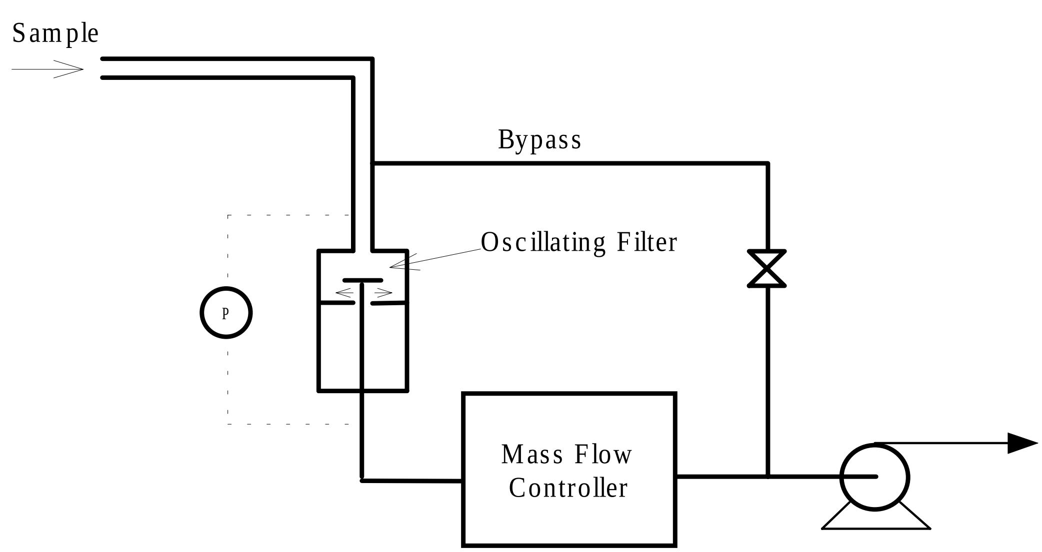


Figure 2-7. Tapered Element Oscillating Microbalance.

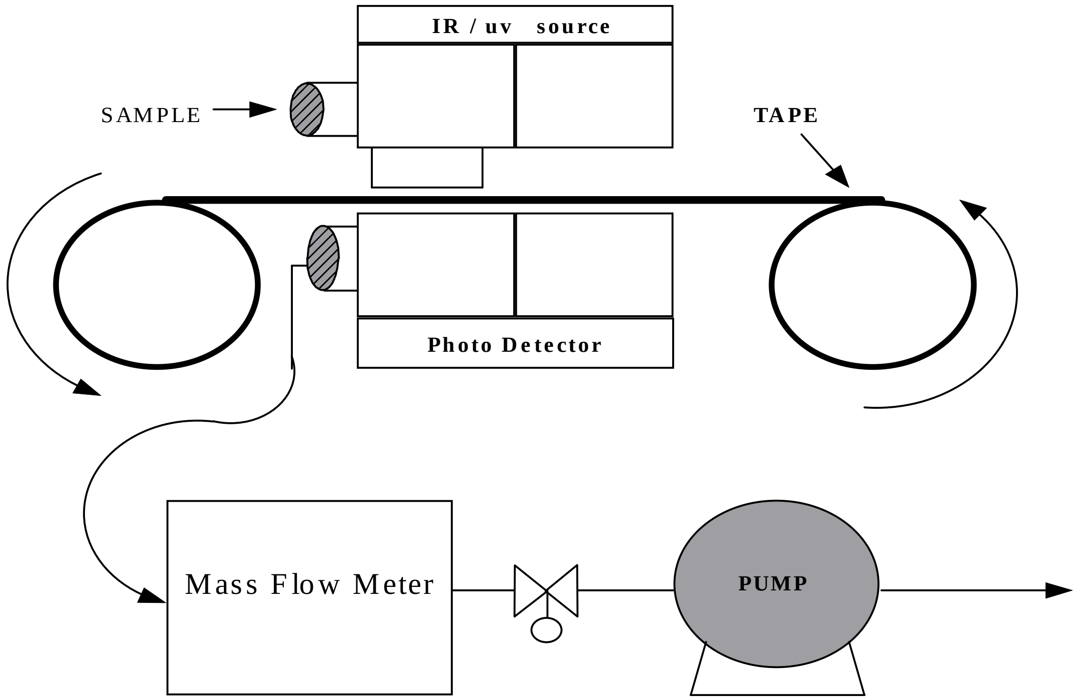


Figure 2-8. Aethalometer (Black Carbon Measurement).

measurement to calculate the amount of "black carbon" deposited on a quartz filter. At certain frequencies of near-infrared light, the attenuation of the light transmitted through the sample is linearly proportional to the amount of black carbon on the filter. Similarly, PAHs and other organic molecules frequently present in diesel exhaust absorb light in the ultraviolet frequencies, which are also measured by the instrument as "blue carbon." As shown in Figure 2-8, the sample enters the aethalometer and is deposited on a filter in the form of a long tape. A source of near-IR and uv light is shown through both the sample and through a clean portion of the tape to provide a baseline measurement. When the filter tape becomes too dark for the attenuation to be measured, the tape automatically advances, presenting a clean spot for deposition.

The aethalometer has an on-board computer to calculate concentration data from optical attenuation. It will store the data on a PC-compatible floppy disk and send an analog signal of either "black" or "blue" carbon concentration. While the near-IR wavelength data can be processed in a matter of seconds, the uv data requires a timebase of one minute, which is currently the fastest processing time of the instrument mounted in the ODEC facility.

2.5.5 Condensation Nucleus Counters

A condensation nuclei counter (CNC) uses an optical detector to count particles from 3 nm to 1 micron in diameter. The aerosol is passed through an atmosphere saturated with n-butanol (see Figure 2-9) while the flow volume is rapidly expanded. Condensing butanol on the particles enlarges them to a diameter large enough to be counted by the laser and photo-diode detector. The CNC reports particle counts through an analog connection or through a serial connection with a computer. The instrument is very versatile, used to measure total particulate counts, or providing size distribution data when used as a component of the Scanning Mobility Particle Sizer (SMPS).

For the ODEC facility, either a TSI Model 3010 or 3025a Condensation Particle Counter (CPC) was used. Generically, both instruments are CNCs, but of slightly different design and operating characteristics. The Model 3025a is the latest version of CNC offered by TSI, Inc., which was used in most ODEC experiments.

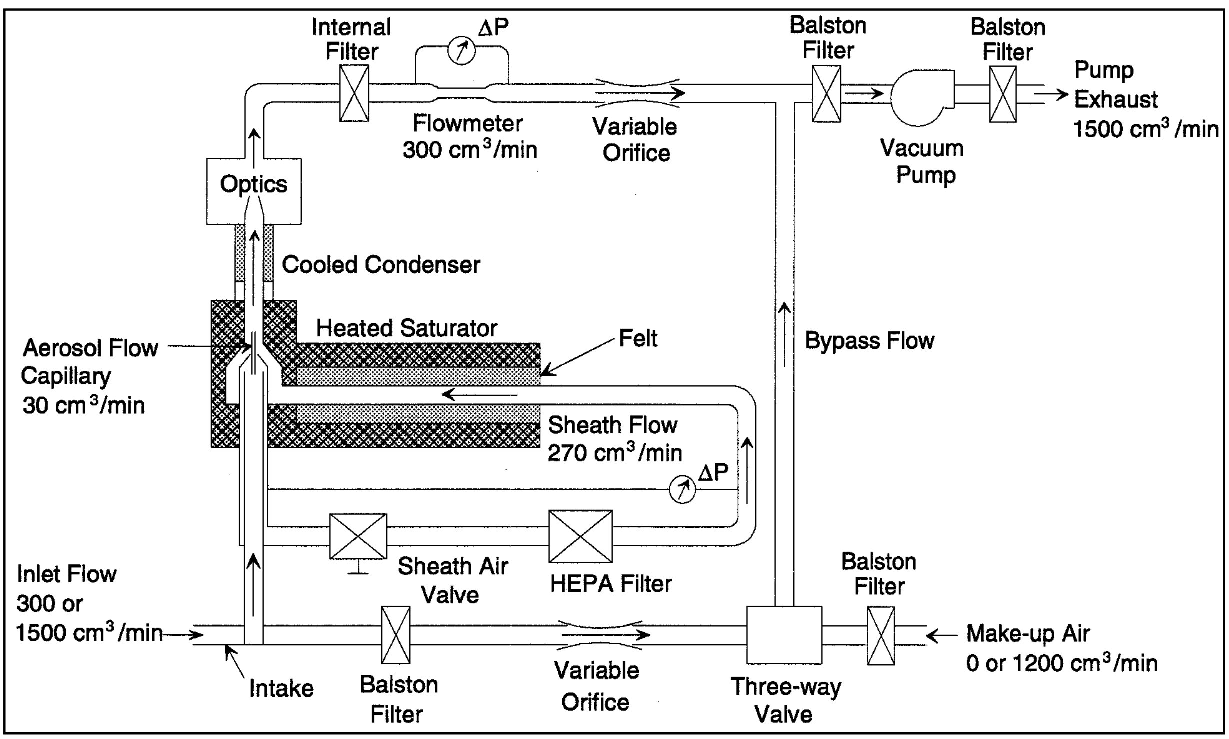


Figure 2-9. Condensation Nucleus Counter.

Chapter 3

Dilution Stack Sampling Data

The on-road facility currently incorporates a 1990 Kenworth T800 tractor as its test vehicle. When this truck was purchased, it had already logged over 900,000 miles and was due for an overhaul of its Detroit Diesel Series 60 engine. Prior to having this work done, however, the vehicle was tested "as-received" using two types of tests. During "parametric" testing, the truck systematically follows a test matrix representing the full range of load, grade, speed, and acceleration conditions. During "highway" testing, the truck travels along an interstate highway with no specific agenda other than covering the distance safely and efficiently; speed and acceleration vary randomly with grade, speed limit, and traffic effects. Table 3-1 summarizes the tests that were performed prior to the engine overhaul.

Following the overhaul, the truck was tested again using the highway section and the same parametric test matrix (see Table 3-2). This way, the emissions impact of the engine overhaul can be measured and characterized. For purposes of data organization (Appendix B), the truck/engine configurations are designated "KW1" (pre-rebuild) and "KW2" (post-rebuild). Each of the two data sets includes both stack-sampling data and plume-sampling data. This report provides a general overview of these data starting with the stack dilution sampling.

3.1 Dilution Stack Sampling Results

Drawing sample directly from the stack for fine PM measurements has advantages and disadvantages. The advantages relate to the ability to control the dilution process: a well-designed system should maintain a steady dilution ratio and introduce little or no "background" to the dilute sample. Ideally, the real-time data from dilute-sample analyzers should be comparable to their raw-sample counterparts, and "back-calculating" raw concentrations should be straightforward. The disadvantages come into play when reality intrudes on this ideal. Fine PM doesn't behave like gaseous species when it dilutes, so unless the "artificial" dilution accurately simulates a real-world plume, the resulting measurements may be biased. Even so, this "accurate" simulation may be difficult to maintain, as stack temperature variations and orifice deposition may affect ratios over time.

Table 3-1. On-Road Tests Conducted with Pre-Rebuild Kenworth

Test ID	Load lb GCW	Grade(s) %	Speeds mph	Comments	Data Points
3F00V	79280	Zero	15, 35, 55, 65	Constant Speed Testing	24
3F00C	79280	Zero	Idle & Accelerations	Coast Down & Acceleration	12 Idle 12 Accel
3H00V	61060	Zero	15, 35, 55, 65	Constant Speed Testing	24
3H00C	61060	Zero	Idle & Accelerations	Coast Down & Acceleration	12 Idle 12 Accel
3E00V	42840	Zero	15, 35, 55, 65	Constant Speed Testing	24
3E00C	42840	Zero	Idle & Accelerations	Coast Down & Acceleration	12 Idle 12 Accel
3F3&6	79280	3.1 6.0	15, 35 15, Max	Uphill Grade Tests	26
3H3&6	61060	3.1 6.0	15, 35, 50 15, 35, Max	Uphill Grade Tests	17
3E3&6	42840	3.1 6.0	15, 35, 55 15, 35, 50, Max	Uphill Grade Tests	28
3F-SEQ	79280	Zero	Various	Dyno Sequence Simulations	9
3DRI [a]	79280	Various	60 $\pm$ 10	Open Highway Tests - Tunnel	Continuous
3FIL [a]	61060	Various	65 $\pm$ 10	Open Highway Tests - Filters	Continuous
3DIOX [a]	61060	Various	65 $\pm$ 10	Open Highway Tests - Dioxin	Continuous

[a] Each of these series represents several days' testing

The dilution system of Figure 2-2 was used to deliver sample to the cab-mounted analyzers described earlier. This multi-stage system provides sample at two different dilution levels: 30:1 sample flows to the Aethalometer, TEOM, and PAH analyzer, while the more sensitive ELPI and CPCs receive sample at dilution ratios just above 1000:1. This higher dilution ratio is a trade-off between having one or both of the CPCs go off-scale (as they sometimes do) and losing the capability to measure dilution ratio into the "noise range" of the "dilute" CO_2 instrument.

Table 3-2. On-Road Tests Conducted with Post-Rebuild Kenworth

Test ID	Load lb GCW	Grade(s) %	Speeds mph	Comments	Data Points
5F0V	74000	Zero	15, 35, 55, 65	Constant Speed Testing	24
5F0C	74000	Zero	Idle & Accelerations	Coast Down & Acceleration	12 Idle 12 Accel
5H0V	61440	Zero	15, 35, 55, 65	Constant Speed Testing	24
5H0C	61440	Zero	Idle & Accelerations	Coast Down & Acceleration	12 Idle 12 Accel
5E0V	42600	Zero	15, 35, 55, 65	Constant Speed Testing	24
5E0C	42600	Zero	Idle & Accelerations	Coast Down & Acceleration	12 Idle 12 Accel
5F3&6	74000	3.1 6.0	15, 35, 45 15, 30, Max	Uphill Grade Tests	27
5H3&6	61440	3.1 6.0	15, 35, 50 15, 35, 40, Max	Uphill Grade Tests	27
5E3&6	42600	3.1 6.0	15, 35, 55 15, 35, 50, Max	Uphill Grade Tests	27
5F-SEQ	74000	Zero	Various	Dyno Sequence Simulations	9
5Plume [a]	61440	Various	65 ± 10	Open Highway Tests - Plume [b]	Continuous
5NOxB [a]	61440	Various	65 ± 10	Open Highway Tests - Burst [c]	Continuous
5DIOX [a]	61440	Various	65 ± 10	Open Highway Tests - Dioxin	Continuous

[a] Each of these series represents several days' testing
[b] Characterization of fine PM emissions in the plume
[c] Includes tracer experiments for plume dilution schedule timing

Figure 3-1 shows example data from five instruments sampling simultaneously. Obviously, with its one minute averaging time, the aethalometer is not useful for modal emissions data and will not be discussed further. The CPC that is shown has a three-screen diffusion battery on the front end, providing a D50 cutpoint (i.e., the particle size at which 50% of the particles penetrate the sizing device) of 0.079 μm. A second CPC, which did not have a diffusion battery removing the nanoparticles, frequently went off-scale due to high particle loadings. Overall, the CPCs, ELPI, and

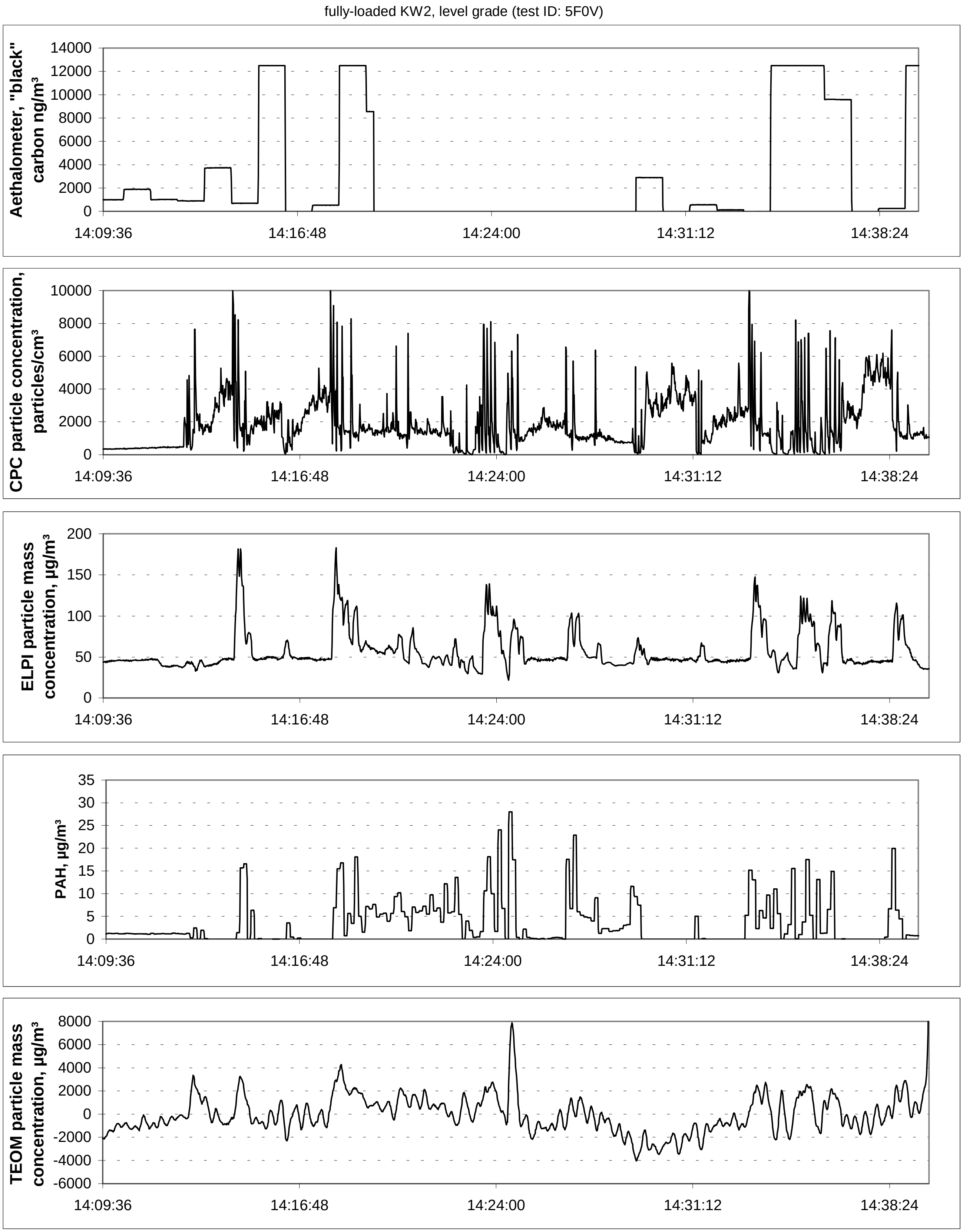


Figure 3-1. Raw Test Data from Dilution Stack Sampling Instruments.

PAH analyzer responses show enough of the same graphical features (i.e. peaks at the same time) to indicate that they represent the same events. A strong cross correlation among the various instruments, however, was not found. In addition, the TEOM shows only a few peaks that correspond to the others, with many negative values. Therefore, it too is of little use to gathering modal emissions data.

Figure 3-2 illustrates how PM concentration varies with operating conditions. With reasonable consistency, the concentrations spike during the operating transients and stabilize during steady-state operation. Inspecting the acceleration sections of the speed trace closely, the actual shift points can be identified as small plateaus in the climbing speed trace. Near the top of the acceleration curve, where there is more distance between the shift points, it becomes apparent that the concentration spikes correspond to the time period immediately after the shift, when engine speed is low and power demand is high. Another interesting observation is that each of the two deceleration events also initiates a concentration spike. As with most transient emissions, there is little quantitative reproducibility with the spikes, so this report makes no attempt to correlate fine PM emissions to any operating parameter. Nonetheless, mass emissions are reported for a number of operating conditions in a later section.

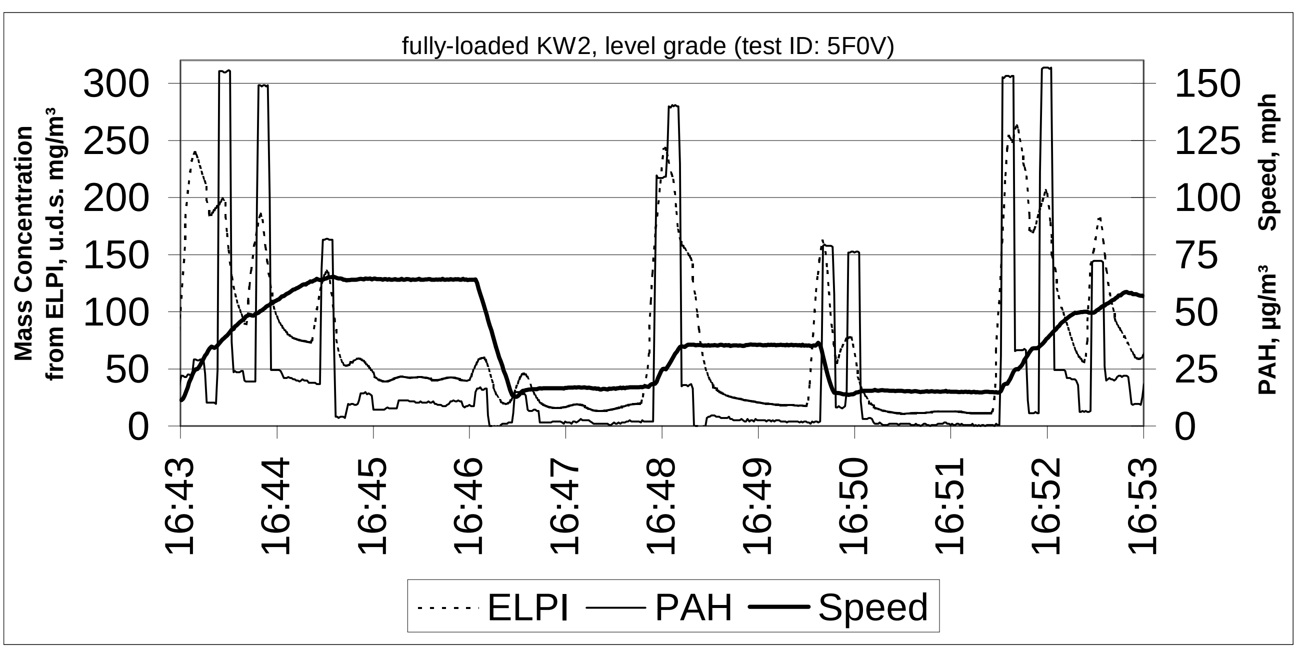


Figure 3-2. Emissions Variation with Vehicle Operation.

3.2 Aerosol Characteristics from Dilution Stack Sampling

Diesel exhaust PM size distributions are typically trimodal in shape, meaning that the frequency distribution will exhibit three peaks (or modes) that may or may not overlap one another. Figure 3-3 shows an exaggerated view of such a distribution. In reality, for the typical exhaust from a modern diesel engine, the coarse mode is negligible. The accumulation mode will account for most of the particle mass emissions, as shown here, but would often be dwarfed by the nuclei mode on a distribution graph where the frequency is expressed as a particle number concentration.

Figure 3-4 shows particle size distributions, as measured by the ELPI, during the KW1 test series. As can be observed, the size “bins” define a large accumulation mode peak just above 100 nm, while the skewness of the distribution suggests the existence of a nuclei mode peak which is beyond the lower limit of the ELPI’s measurement range. The curves are generated by a fitting algorithm which explores both lognormal and bimodal-lognormal fitting functions. The “nuclei tails” shown in the graphs indicate that the bimodal function provides a better fit, but because there is a lot of uncertainty in the nuclei mode parameters, no further information about that mode can be provided. The “tails” notwithstanding, the idle and steady state emissions appear to have comparable size

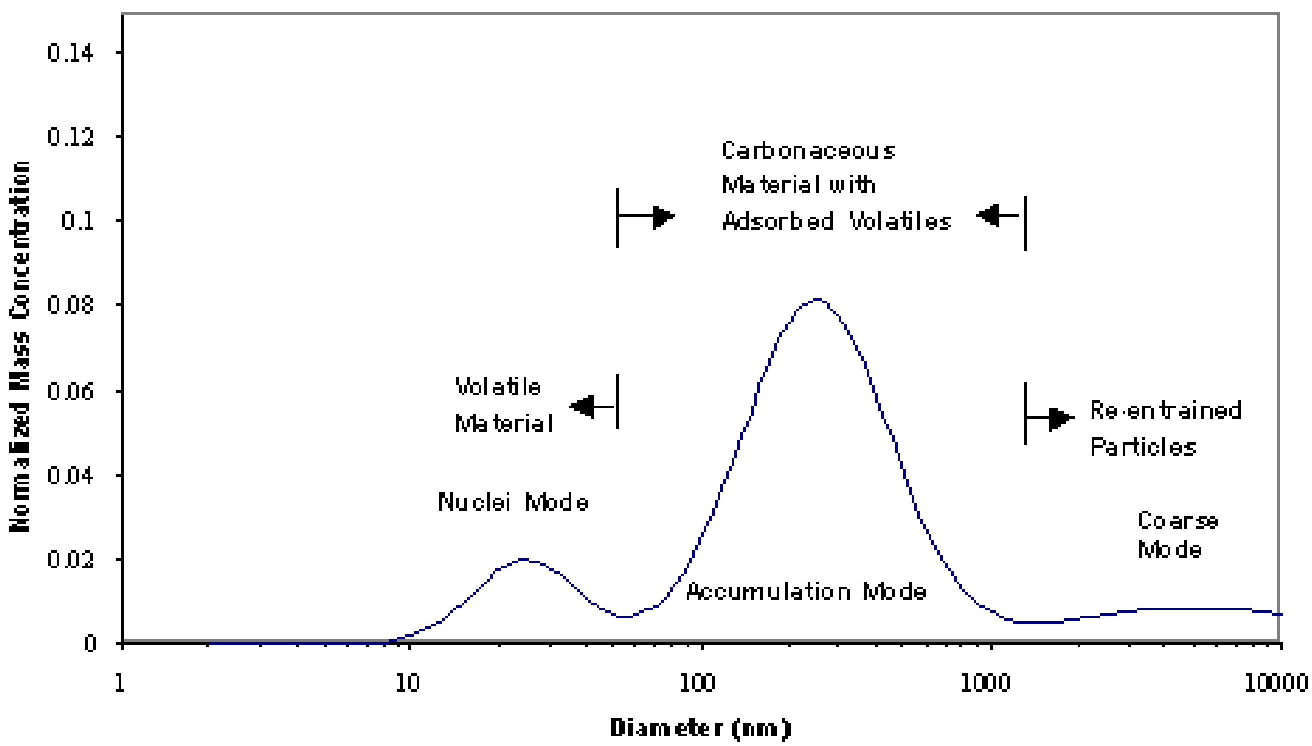


Figure 3-3. Typical Fine PM Size Distribution.

fully-loaded KW1, level grade (test ID: 3F00V)

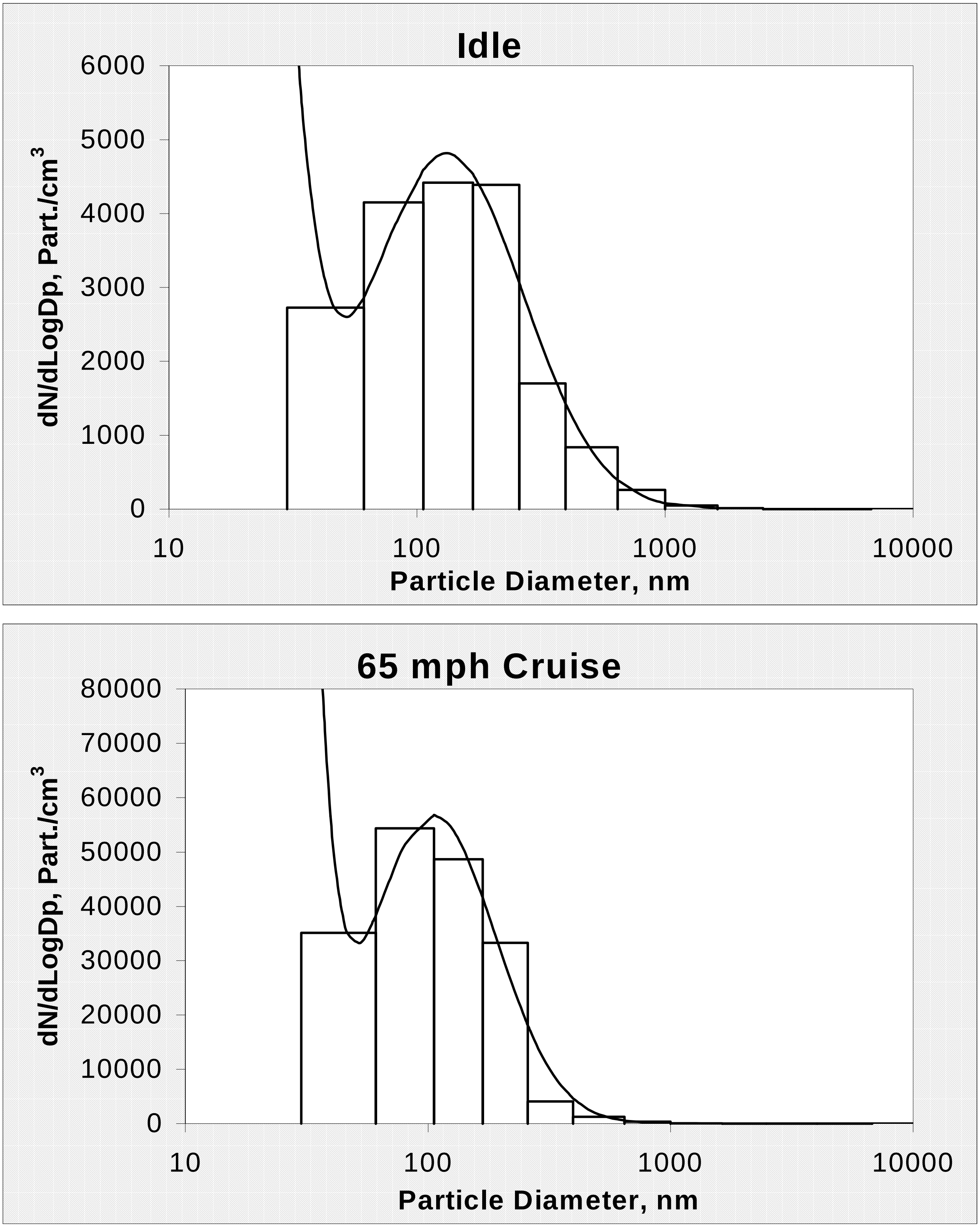


Figure 3-4. Pre-Rebuild Kenworth, Sampled from the Stack.

distributions.   Figure 3-5 shows the size distributions for the Kenworth as measured after the engine overhaul. These data were actually collected during the engine break-in period following the overhaul, so it is possible that they are more representative of “break-in” emissions than of what can be expected over the life of the engine. Nonetheless, within the measurement precision of the ELPI, there appears to be no systematic bias in the size distribution between the pre-rebuild and post-rebuild emissions.

3.3 Mass Emission Rates

Given that neither the Aethalometer nor the TEOM met the project’s data quality objectives, and the CPCs provide no particle size information, the only instruments that are convertible to mass emission rates are the ELPI and the PAH analyzer. The ELPI measures total PM mass concentration in terms of equivalent aerodynamic diameter (i.e., “unit density spheres”or u.d.s.), based on its impactor cut points and stage counts. The PAH analyzer uses a manufacturer-supplied factor to convert its current readings (in femtoamperes) to mass concentrations of surface-bound PAH compounds. Calculating mass emission rates for either instrument is simply a matter of multiplying the readings by the corresponding dilution ratio and the exhaust stack flow (Appendix B).

Figure 3-6 shows ELPI data, measured from the KW1 test series, as compared to operating modes. Each bar represents the average of three runs at that operating condition. Again, because of dilution ratio stability, this type of analysis is best done with stack dilution data. It appears that there are at least two parameters affecting the mass emissions. The most obvious parameter is power demand. Low power conditions such as low-speed / zero grade tests are uniformly low in PM emissions, whereas the highest steady-state emissions correspond to heavy-load / steep grade conditions that require full power. The other parameter is transient operation. For all but the lightest load, the highest emissions correspond to accelerations, where the truck’s engine speed is ramping up and down repeatedly. The transient effect appears even more dominant in the KW2 data (Figure 3-7), where acceleration emissions for each load are more than double the corresponding level-grade steady-state emissions. For PAH emissions, shown in Figure 3-8, the trends are similar. Of the level grade test conditions (where power demand is lowest), only the highest speed points register any PAH emissions at all.

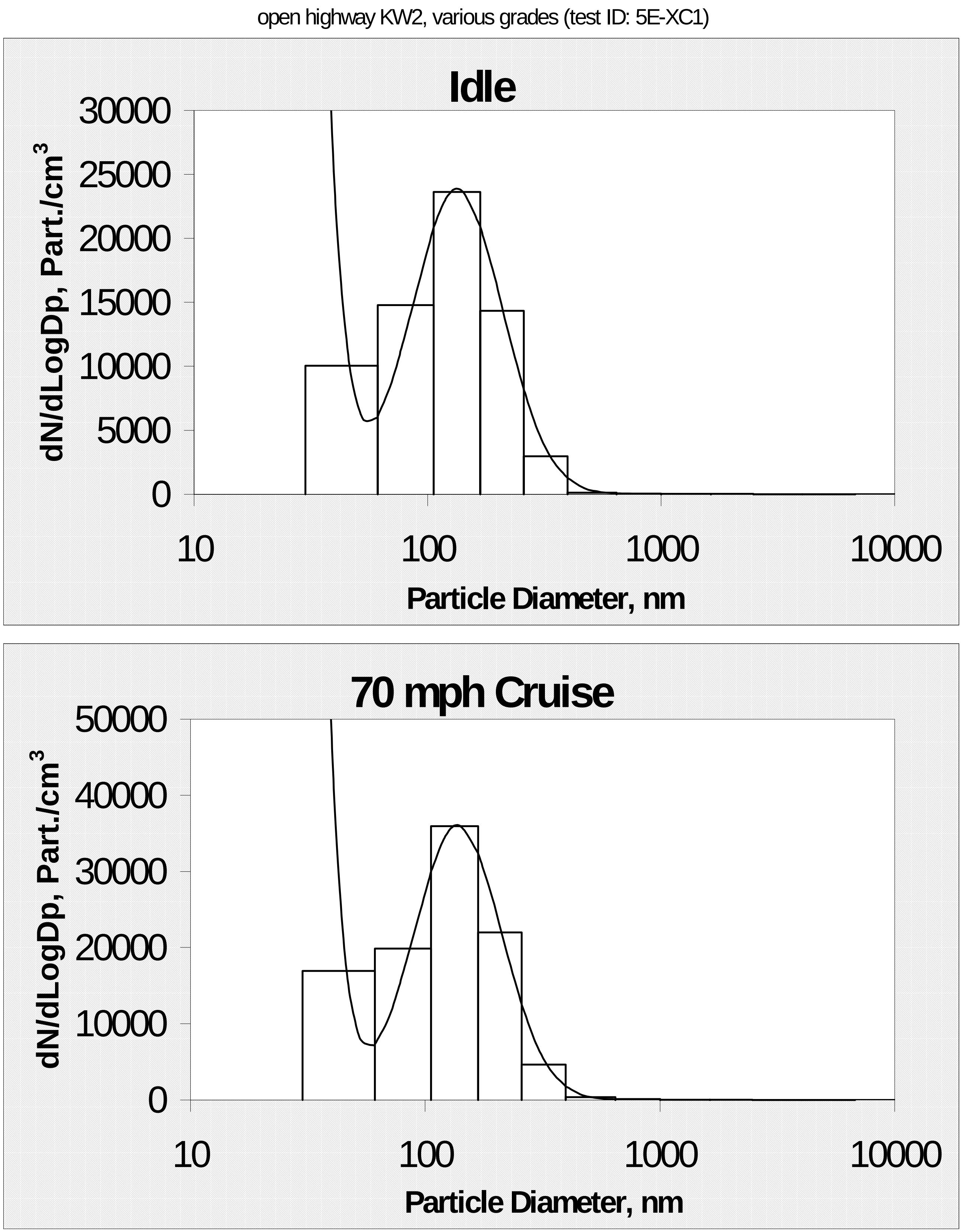


Figure 3-5. Post-Rebuild Kenworth, Sampled from the Stack.

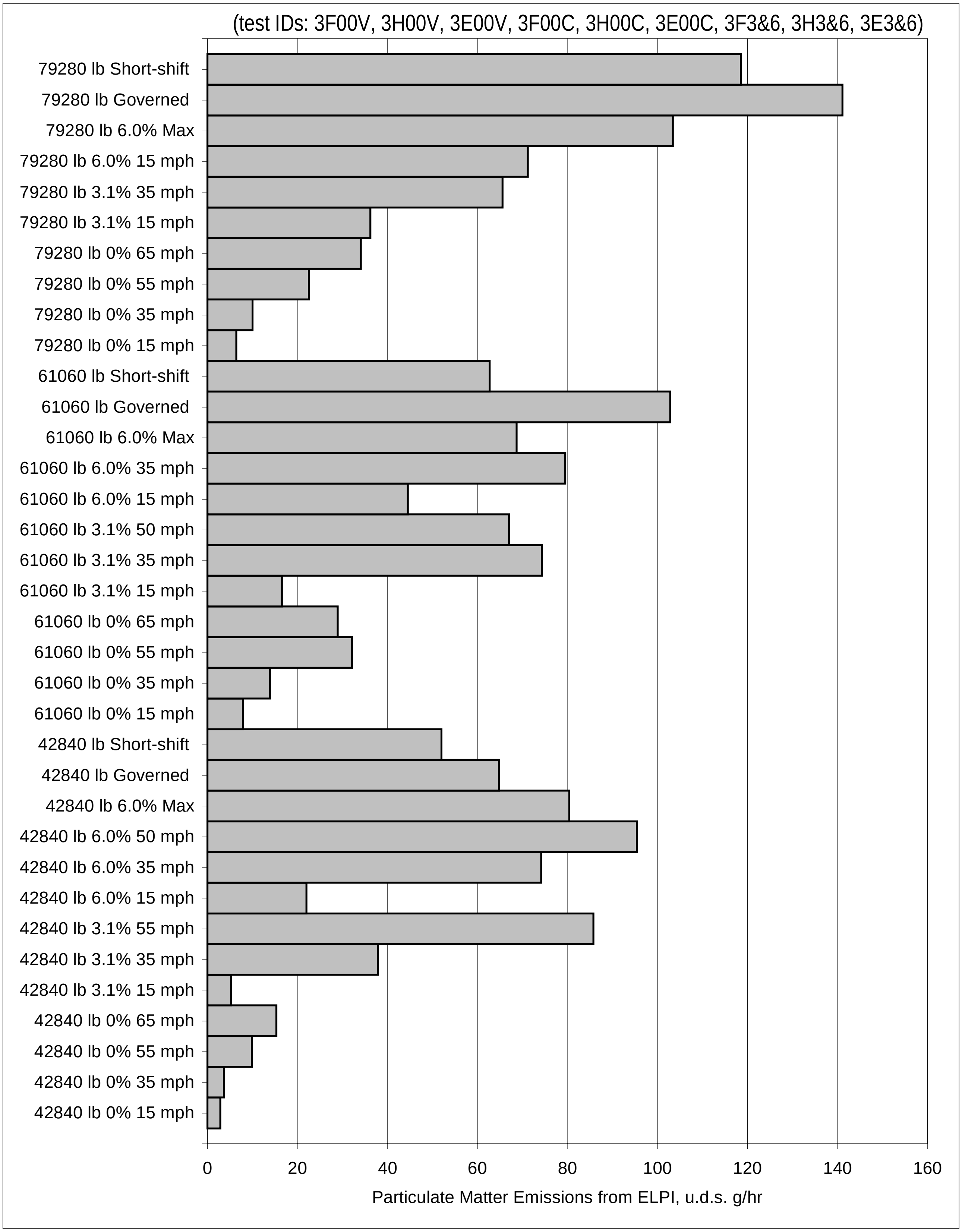


Figure 3-6. Mass Emissions from KW1.

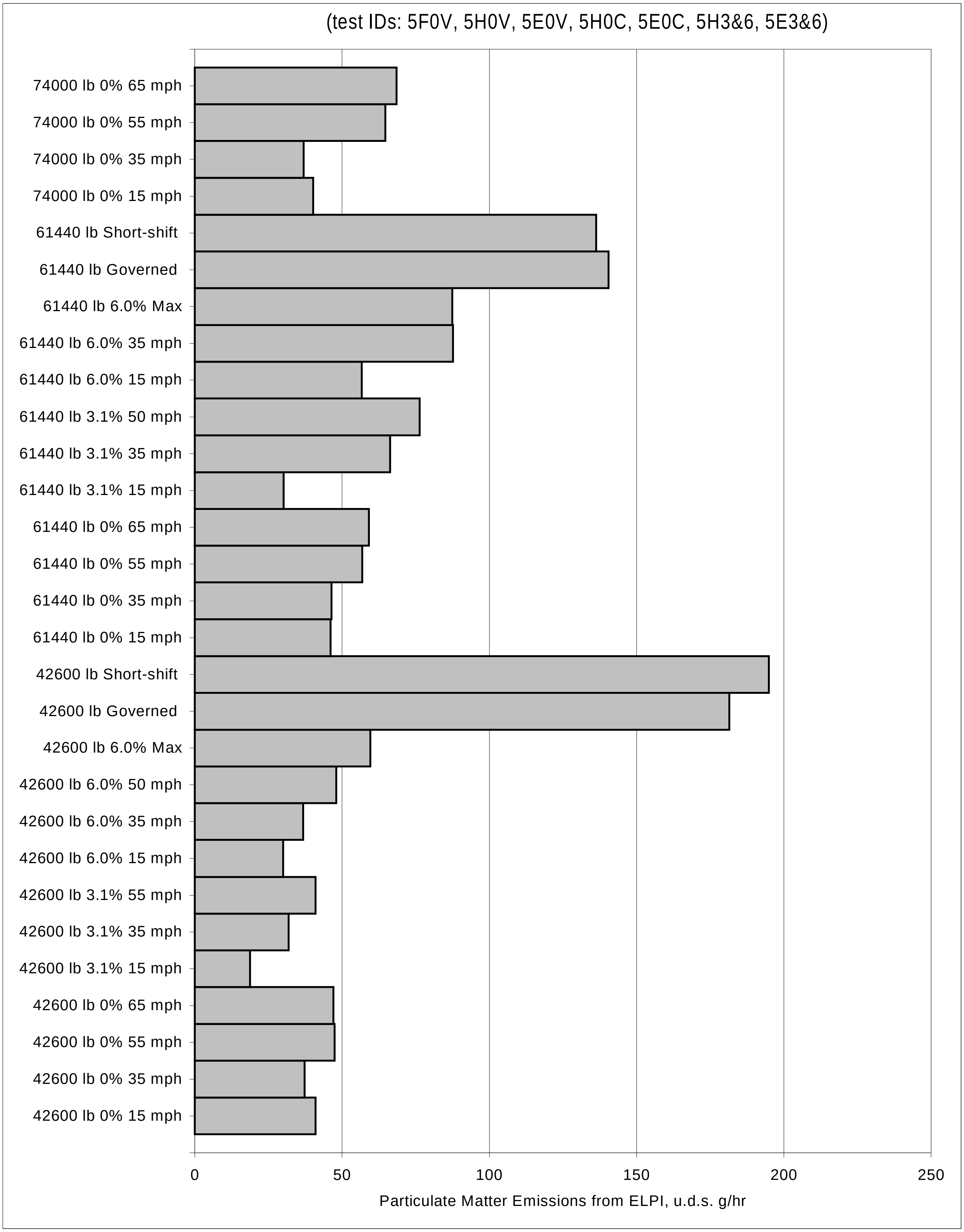


Figure 3-7. Mass Emissions from KW2.

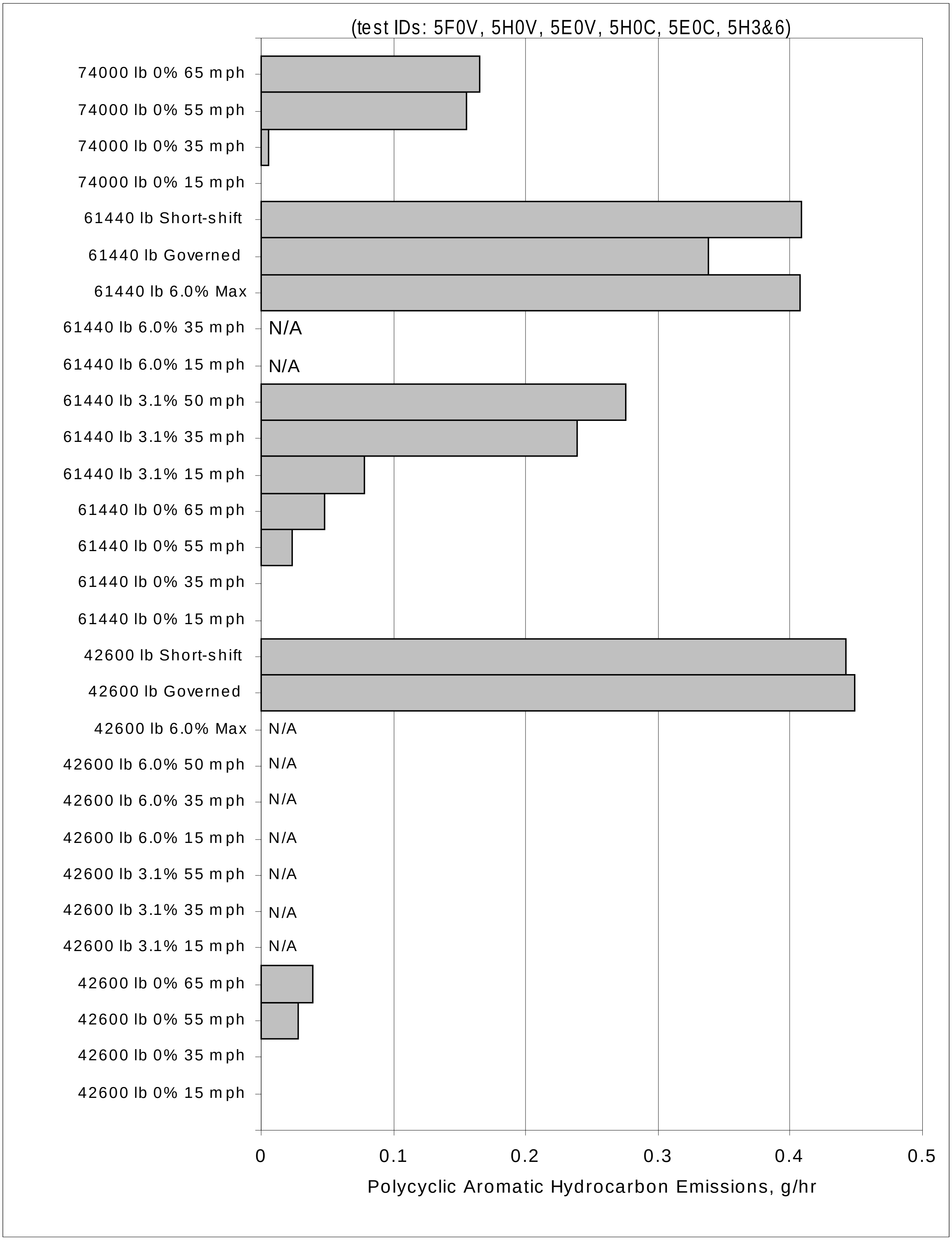


Figure 3-8. PAH Emissions from KW2 (N/A = no valid data available for this test condition).

3.4 Overview of Emissions Trends

As with any other "transient" pollutant, PM tends to vary widely with vehicle operating mode. Time-series traces such as Figure 3-1 show a response that experiences numerous "spikes" of high emissions, most of which correspond to some identifiable event in the truck's operation (e.g., pulling off from a stop, changing gears). For some measurements (ELPI and CPCs), there is a "baseline" emissions level that is maintained between the spikes, which is loosely correlated with power demand. For the instruments that depend more on "bulk" sampling (less dilute samples, emissions more related to mass than particle number), the "baseline" is practically zero. In essence, diesel engines produce particles all the time while they are running, even when they are idling, but operating transients can produce more particles in a shorter period of time than any other mode.

Chapter 4
Plume Characterization

Thermodynamics defines a state variable as one whose value depends solely on the equilibrium state of the system, regardless of the "path" by which this state was attained. Fine PM concentration is not a state variable; its value has everything to do with the "path" by which a given state of dilution was attained. For the study of fine PM from ducted sources, the "system" is represented by a suitably small volume of source gas which disperses, either through natural or artificial means, into a larger volume of ambient air. When the point source is a diesel engine, this volume of source gas (exhaust) undergoes simultaneous changes of temperature and concentration, a path which leads through states where new particles can form in the atmosphere and the primary particles emitted by the source can transform. Where gaseous sampling regards dilution as a variable, fine PM sampling treats it as a process. Numerous studies have been conducted of how dilution ratio and residence time (i.e., "dilution schedule") affect fine PM measurement and exposure (Kittelson et al., 1999; Abdul-Khalek et al., 1998).

4.1 Plume Dilution Process

The challenge of plume characterization is one of tracking a pollutant as it passes through space, time, and dilution states simultaneously. Prior to release, diesel exhaust moves through space rapidly, due to the truck's motion and to flow within the exhaust pipe. Even though its dilution state remains essentially constant, the passage of time affects fine PM through any combination of nucleation, adsorption, agglomeration, deposition, and possibly molecular rearrangement (i.e., "folding" of long chain hydrocarbons to form more compact particles). All of these transformation processes continue after release, some to a lesser extent, some greater, as affected by changes in dilution and movement through the ambient air. Essentially, in roughly the time it takes a truck to pass by a stationary object and have its wake dissipate, the exhaust gas goes from (1) a fast moving, constant concentration state, through (2) a rapid fluid deceleration and dilution, to (3) a slowly moving, slowly diluting state approaching ambient conditions.

This project has attempted to characterize the plume dilution schedule for a class 8 truck with elevated exhaust pulling a cargo van trailer. Of particular interest is that portion of the schedule from release to a ratio of 50:1, which includes the range of maximum nucleation potential (from 5:1 to 50:1). This is an independent analysis of the dilution process itself, based solely on measurement of gaseous species that are not affected by transformation processes (as is the case for fine PM).

4.1.1 Initial Hypothesis

As represented earlier in Figure 2-3, tractor-trailer exhaust is not expected to undergo a steady dilution process. Rather, at least four distinct stages are expected. Stage 1 takes place immediately after the exhaust is released. During this stage the exhaust stream comes into immediate contact with the flow field moving around the truck's exterior surfaces. Relative to its initial state, the exhaust is rapidly accelerated and diluted by the passing air, some of which moves into a recirculation zone between the truck and trailer. Stage 2 takes place as the exhaust plume passes along the length of the trailer. The flow entering this stage consists of a mixture of the flow leaving the recirculation zone and any flow that bypassed it entirely. At this stage, the plume dilutes more gradually, and may experience a smaller series of eddies caused by the viscous drag along the trailer surfaces. It is at this stage that the plume is sampled both for fine PM and one or more tracer gases for dilution ratio measurement. Stage 3 is another rapid mixing and recirculating eddy at the rear of the trailer. Finally, Stage 4 is what remains after the eddy dissipates (i.e., ambient dispersion independent of the source vehicle).

Plume dilution at any point along the length of the truck is expected to vary quite randomly, primarily because of wind effects. Headwinds would tend to shorten the time interval between release and capture (the "delay time"), most likely reducing the measured dilution ratio. Tailwinds and sidewinds from either direction would likely increase the measured dilution ratio or even separate the plume entirely. Therefore, the population of measured ratios at any one point is expected to be a skewed distribution qualitatively resembling Figure 4-1, where the left tail is a result of headwinds, and the longer right tail is a combined result of tailwinds, sidewinds, and possibly plume wander cause by the truck following a curved path. Theoretically, in the absence of sidewinds and curved-path plume wander, the distribution would be symmetrical.

The delay time population is also expected to have a skewed distribution, but for a different reason. Where headwinds and tailwinds would contribute symmetrically to delay time population variance, the skewness would come from the recirculating eddies. For the specific case of a tractor trailer, if a majority of the exhaust enters the large eddy between the tractor and trailer, the "typical"

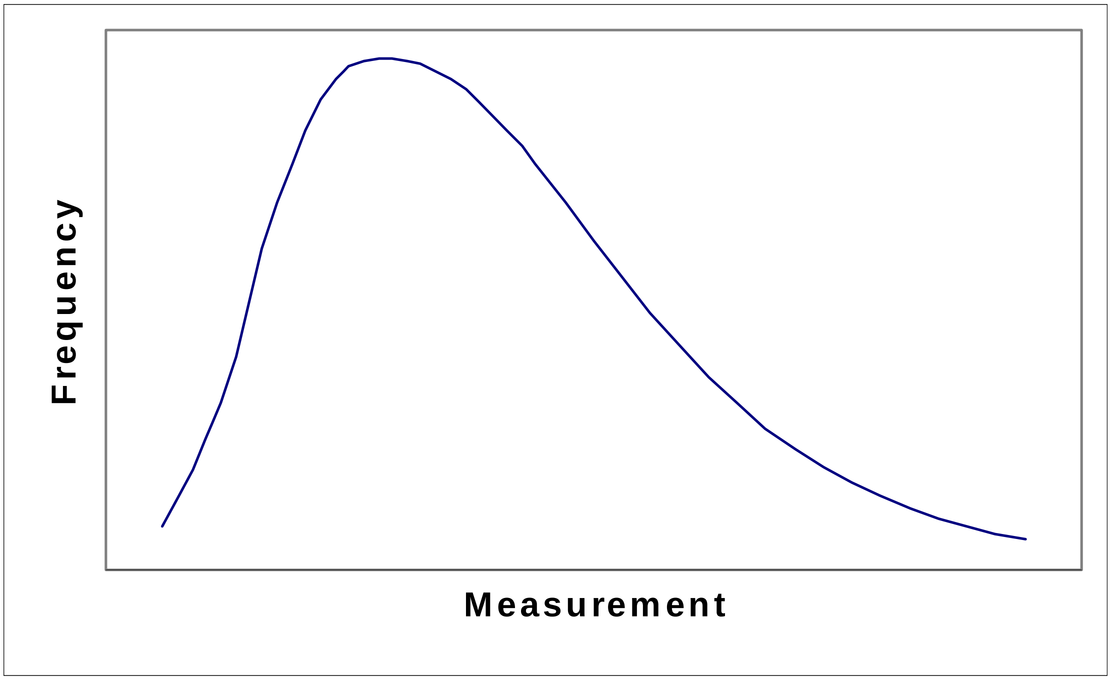


Figure 4-1. Positively Skewed Distribution.

delay time would be considerably longer than what would be predicted by airspeed alone (i.e., the longer tail in the distribution would be in the direction of shorter delay times, representing the small portion of exhaust that escapes the eddy). If a majority of the exhaust escapes capture in the eddy, the converse would be true (and Figure 4-1 would also qualitatively represent the delay time population). An attempt was made to at least partially characterize the plume dilution process as described below.

4.1.2 Plume Dilution Ratio Measurement

Any number of gaseous species can be used as a tracer to quantify dilution ratio. Ideally, a unique tracer (one that is not present in the exhaust or in the ambient air) would be injected into the exhaust and measured before and after dilution. The challenge of this approach is finding such a "unique" tracer for which calibration gases and highly selective, fast-responding instrumentation are readily available. As a practical matter, the unique tracer approach is often abandoned in favor of one or more constituents already being emitted and measured in the raw sample. The disadvantage here is that there is often a significant background concentration to account for. If this background concentration varies over time (as most combustion products do), it must be measured continuously (i.e., it takes at least three measurements to calculate one ratio). Nonetheless, given that instrumentation and calibration standards are generally more available for combustion products, this is the more popular approach and the one used in this project.

Since it is preferable to avoid constituents that are emitted mostly under transient conditions (e.g., CO and unburned hydrocarbons), the tracer choices for this facility came down to CO_2 and NO_X. CO_2 has the advantage of being present at higher concentrations in the exhaust (reducing worries about detectability at high dilution ratios), but its substantial background in ambient air (~350 ppm) makes it difficult to measure high ratios in ambient plumes. NO_X has lower background levels, but those levels (along with the background "noise" and drift that plague ultra-sensitive NO_X analyzers) may become significant at high dilution ratios. Also, when operating in traffic, these same gases are also produced by surrounding vehicles, further complicating the measurements.

Initially, a dual-channel CO_2 analyzer was chosen because it was less costly and more compact than an equivalent NO_X instrument. Figure 4-2 shows a data sample using that analyzer to test the 1990 Kenworth before engine overhaul. These data represent this truck repeatedly traversing a 10-mile section of mountainous interstate. It appears that the typical dilution ratio for the 11 meter sampling position was ~200:1 at highway speeds, but there is not enough low-speed data to determine whether the ratios varied with speed. As expected, there are more outliers toward higher dilution

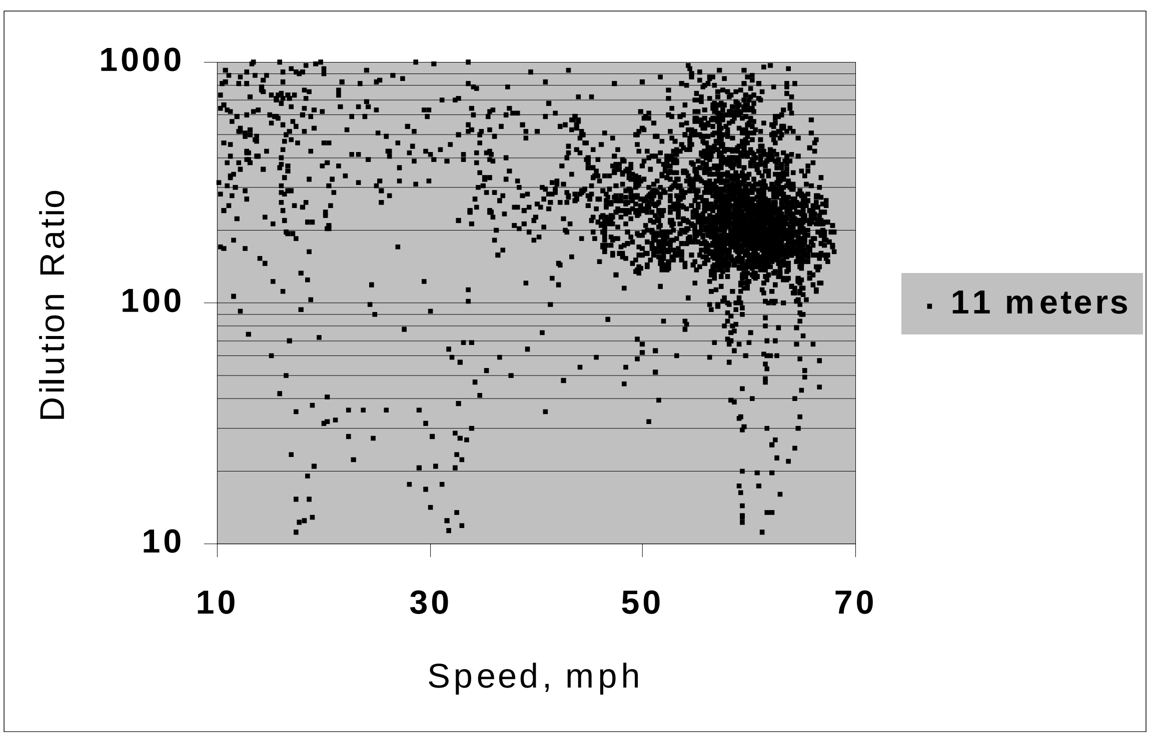


Figure 4-2. 11 Meter Plume Dilution Measurements Using CO_2.

ratios than there are toward low dilution ratios. Figure 4-3 shows ratios, for this same truck under similar operating conditions, measured using NO_X analyzers. Again, the 11 meter ratios concentrate around ~200:1 at highway speeds and at speeds as low as 35 mph. Ratios at the 2 meter sampling location concentrate at ~50:1 for highway speeds. Figure 4-4 shows histograms of the dilution data. Collectively, these three figures illustrate two key points about plume dilution ratio: (1) it is possible to measure this ratio with either CO_2 or NO_X, and the results are comparable; and (2) the population of ratio measurements at a given point is, as expected, skewed toward higher dilution ratios.

4.1.3 Plume Dilution Data Analysis

Scatter plots and histograms are useful tools for illustrating tendencies and trends in large data sets. Eventually, however, the data need to be summarized numerically so that the information can be put to use. Elementary statistics defines three numerical measures of central tendency: mean, median, and mode. The mean is the most representative of the entire data set, because it weighs every element equally, including the outliers. The median is also affected by outliers, but only by the number of outlying elements, not the extent to which they spread the distribution. For this reason, along with the fact that it is easy to calculate, the median is often used to describe large data sets with broad, often skewed, distributions. The mode, however, is the only central tendency measurement that defines

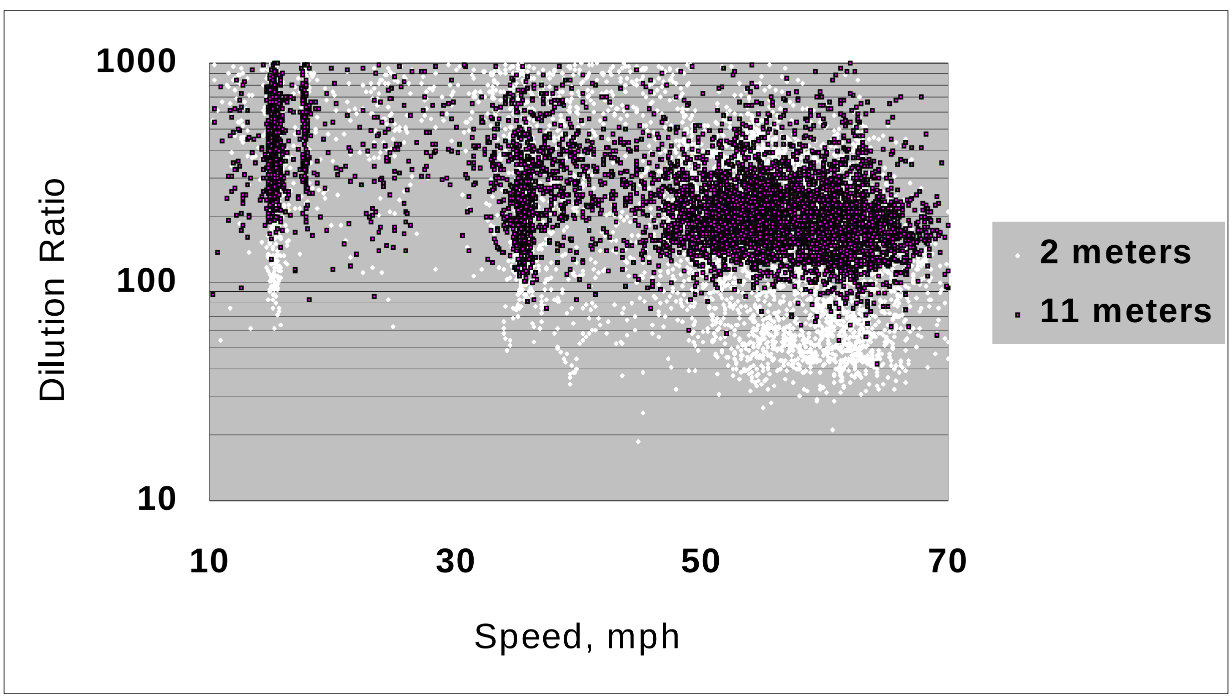


Figure 4-3. 2 Meter and 11 Meter Plume Dilution Measurements Using NO_X.

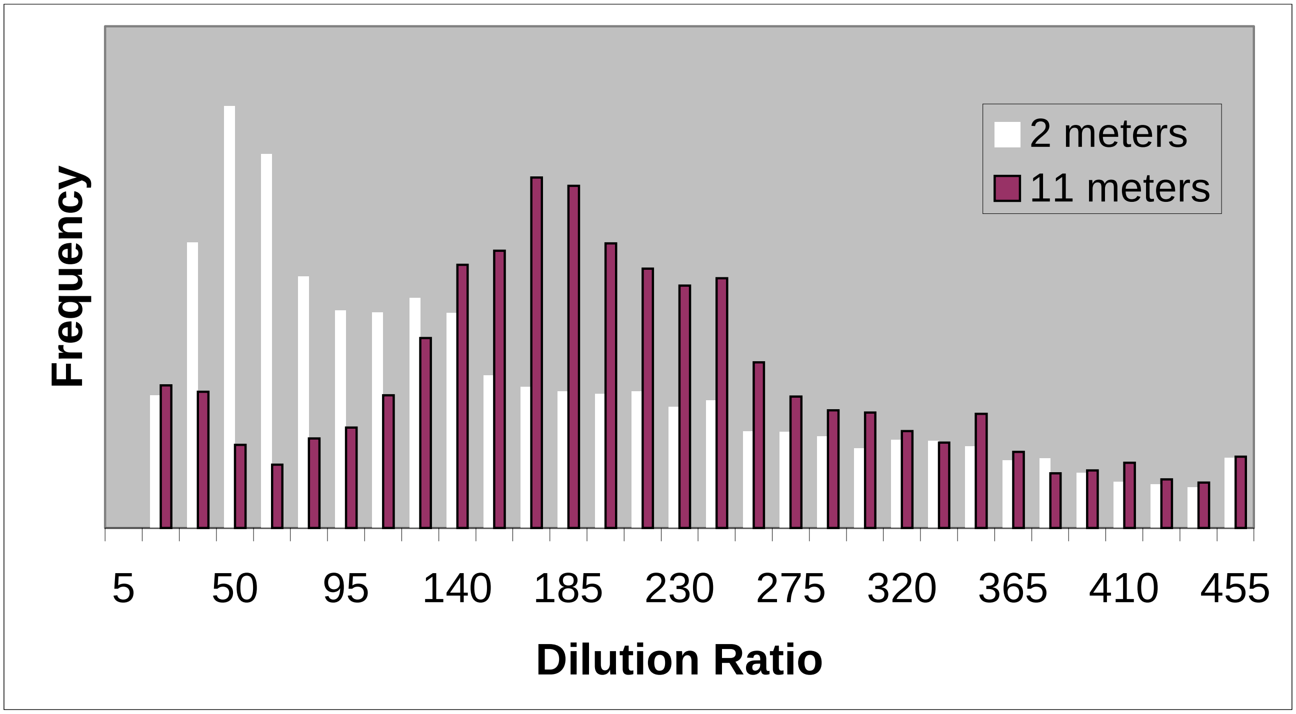


Figure 4-4. Histogram of Plume Dilution Ratios.

where the data are most concentrated without being affected by outliers.

For dilution data sets, the outliers are primarily a function of the air movement effects described earlier. Random wind gusts can cause the plume to be delayed or accelerated on its way from the exhaust pipe to the sampling probe, or they can cause the plume to move in a direction that moves the sampling probe away from its center. All of these conditions can cause variability in the measured dilution ratio. It is important to note, however, that the measurements can be affected by things that do not necessarily affect the dilution schedule within the plume. For example, a sidewind that puts the sampling probe near the edge of the plume raises the measured dilution ratio, but the actual ratio in the plume center is not affected (i.e., it's the same plume, just moved to a different place). In short, the outliers represent a measurement bias more than a variation in the plume dilution schedule. Since this bias is unavoidable, the project's approach was to collect and analyze large data sets, and to use the distribution mode (i.e., the only statistic not numerically affected by outliers) to represent conditions within the plume.

Figure 4-5 shows the processed results of three days' testing during which plume dilution data were collected. Each symbol represents the distribution mode from a parametric test run. Similar to Figure 4-2, the data show little speed dependency at speeds as low as 35 mph, but the value and

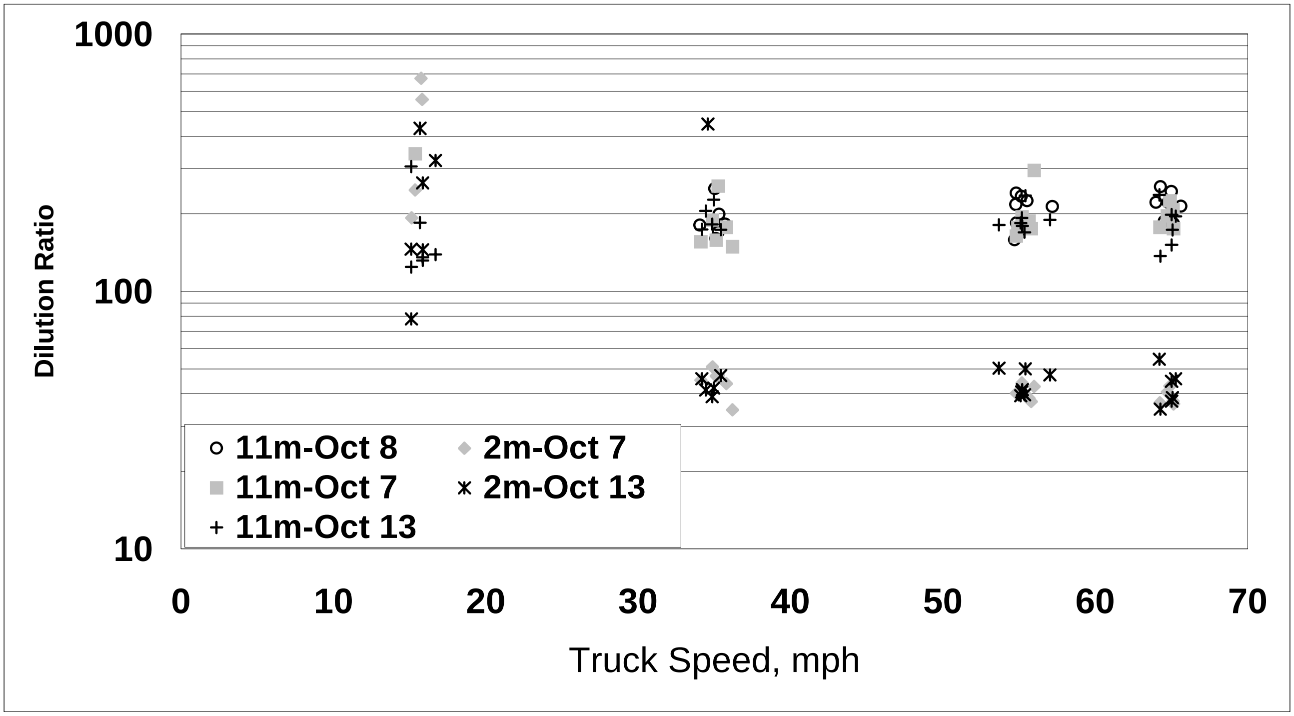


Figure 4-5. Plume Dilution Data from Three Days' Parametric Testing.

variability of the dilution ratio turn up sharply at slower speeds, where the truck's forward velocity no longer completely dominates the relative air velocity vector. The data show reasonable run-to-run and day-to-day repeatability at both the 2 meter and 11 meter plume sampling locations.

4.1.4 Plume Sampling Delay Time Characterization

In order to fully characterize the plume dilution schedule, each dilution ratio must be associated not with a distance, but with a time period. Appendix A details a procedure whereby sampling data are time-aligned to real-time data and, more importantly for dilution measurements, to other sampling data. This crude time alignment procedure, however, is limited to the time resolution of the raw data, which for most datasets is one second. Given that, at highway speeds, the truck can move over 100 feet in one second, a more precise time delay measurement is required. Specifically, a time delay value needs to be associated with each plume sampling location for any speed at which the dilution schedule is to be characterized.

The time delay was measured using a propane tracer gas injection. A computer controlled solenoid valve injects propane into the exhaust stack for 0.1 seconds before shutting off. The DAS records both the injection event and the subsequent response from the THC analyzer connected to the plume probe. Since this analyzer is not specific to propane (and since there is usually a significant

THC background level), it was important that the injection volume be sufficient to at least double the concentration from the background level.

The interval between injection and instrument response indicates the “total” delay, which is the sum of the plume delay and the sampling system delay. Similar experiments, where a propane calibration standard is injected at the probe tip, are used to measure the sampling system delay, so that the plume delay can be determined by subtraction. Figure 4-6 shows an example of the instrument responses to probe and exhaust injections. The resulting THC spikes are characterized by three parameters: the initial response time (when the THC measurement first rises above the baseline), the peak response time (when the measurement first reaches its maximum value for that peak), and the peak area (the sum of all readings above the baseline, minus the baseline area for the peak duration). Either the initial response times or the peak response times have the potential to provide the required delay time (because the plume and probe parameters are subtracted from one another), but there’s no predicting which will be more useful. The initial response time measurement may be affected by a noisy baseline, while the peak response time may vary with the breadth of the peak. The peak area is a measure of how much of the injected propane is actually captured by the sampling system, which is a function of plume dilution (for plume measurements) and injection rate (for plume and probe measurements).

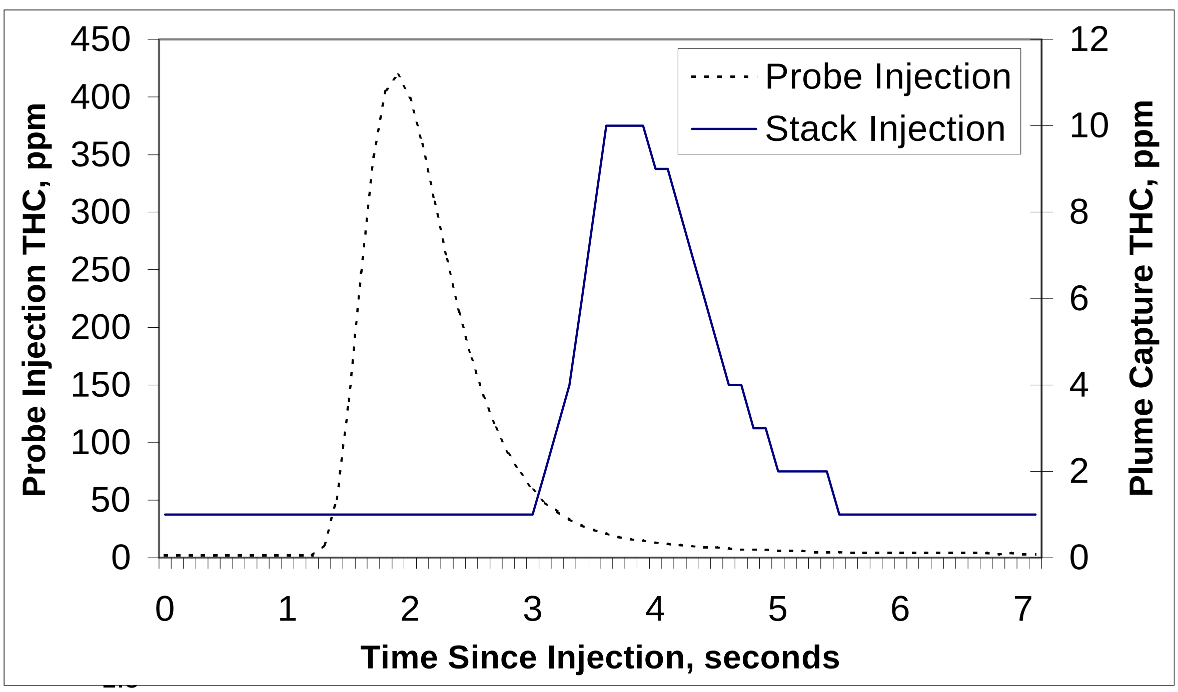


Figure 4-6. Probe and Plume Responses to Propane Injection Event.

Figure 4-7 summarizes the injections that were performed. The points to the right represent probe injections, which produce a very repeatable time delay for a wide range of peak areas. The points to the left represent plume measurements. Not surprisingly, the points concentrate toward the shorter delays, with outliers stretching into longer delay times; this is consistent with the initial hypothesis about the way air movement affects the plume. Some of the scatter is also a function of speed, as illustrated in Figure 4-8, but there is little quantitative confidence in this correlation. For the 2 meter sampling location, the net delay measures 0.1 seconds, which is the minimum measurable delay using the current software.

4.1.5 Dilution Schedule

Applying the appropriate error bars for dilution ratio and delay time results in the dilution schedule shown in Figure 4-9. Each of these traces compares to the left portion of Figure 2-3, where the parameters of a staged dilution system were used to simulate a “target” dilution schedule. Here, there appears to be little difference between the schedules for 55 and 65 mph highway speeds, suggesting that a dilution system designed to simulate on-road dilution might need adjustment to simulate multiple speed conditions. Obviously, this schedule needs some refinement and "gap filling" before a dilution system can be designed around it, but this effort has demonstrated the ability to

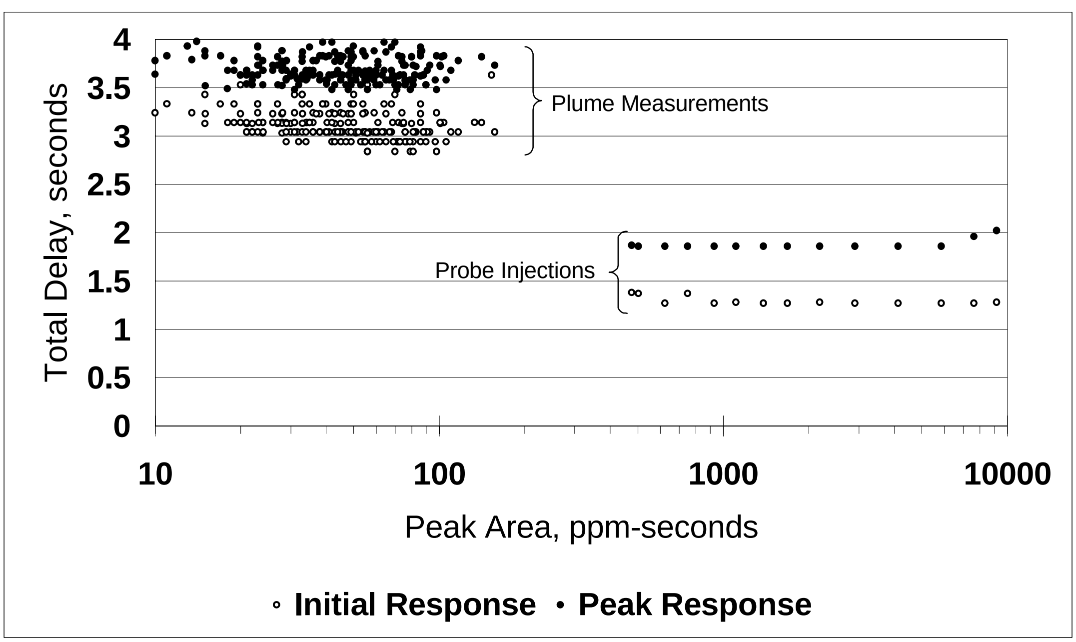


Figure 4-7. Probe and 11 Meter Plume Tracer Delay Times.

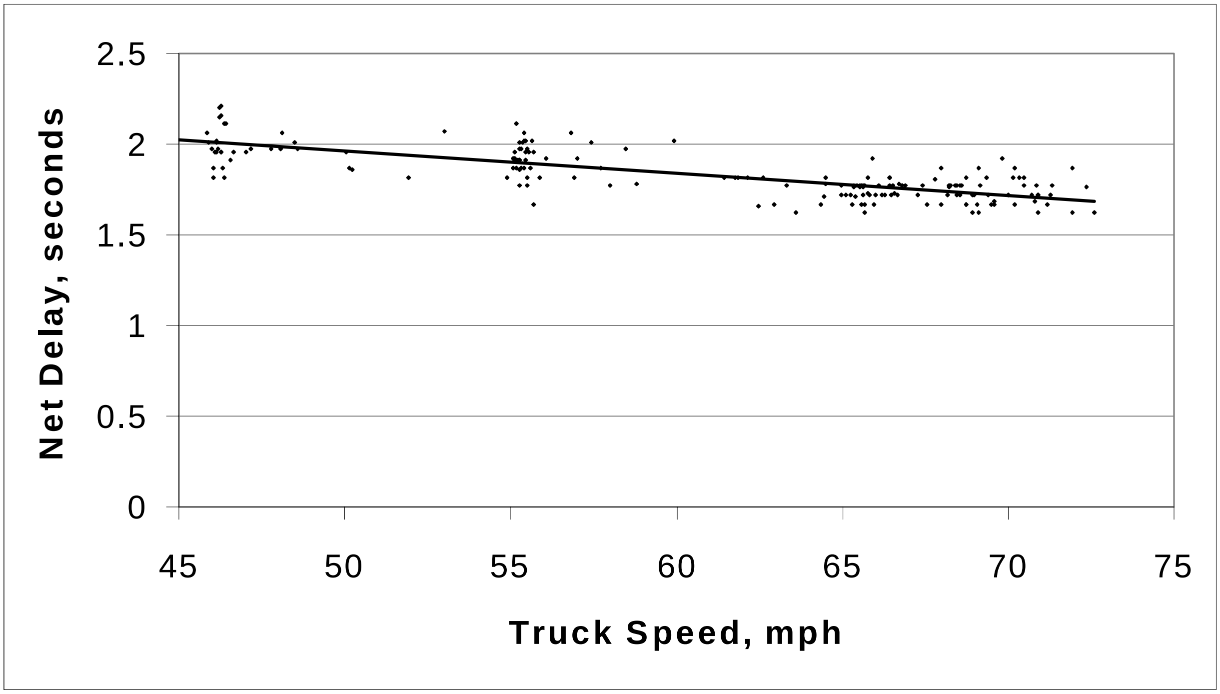


Figure 4-8. Effect of Truck Speed on Plume Delay Time.

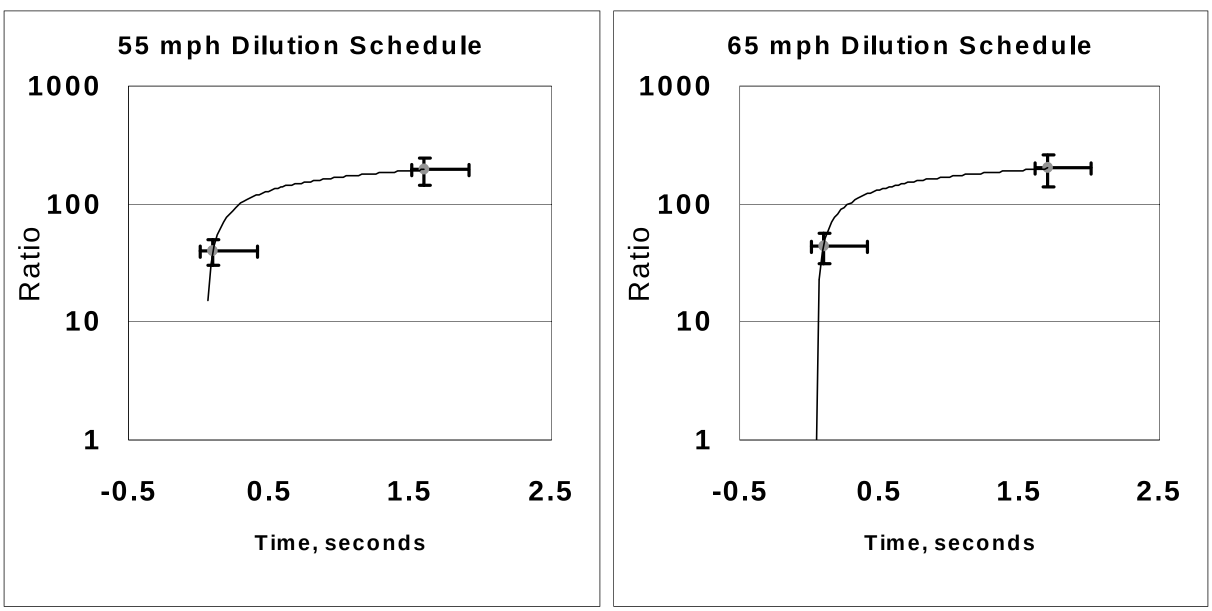


Figure 4-9. Plume Dilution Schedules for Highway Speeds.

collect and analyze the necessary to data to define the plume dilution schedule. simulate multiple speed conditions.

4.2 Plume Sampling for Fine PM

Like stack sampling, plume sampling has its advantages and disadvantages. Advantages include not having to build and operate a dilution system and not having to worry about whether that dilution system is biasing the PM measurements. The main disadvantages are related to the fact that an ambient plume is not a dependable sample delivery device. Sometimes, due to crosswinds and/or vehicle speed, the plume never makes it to the sampling probe in the trailer. Also, the dilution ratio can vary substantially within a matter of seconds. In essence, where stack sampling has dilution under control but carries lingering concerns about PM measurements, plume sampling provides good “real world” PM measurements whose utility is limited by the availability of dilution data.

Figure 4-10 shows an example particle size distribution for the KW1 test series as sampled from its plume. The most noticeable difference between this figure and the corresponding “stack sample” figure (Figure 3-3) is the lack of skewness here. This would indicate that the dilution system may be promoting the formation of nuclei-mode particles. Since those particles are only marginally detectable by the ELPI, the “nuclei-tail” observation is nothing more than speculation. Proving a sampling bias would require the use of CNCs or some other instrumentation capable of detecting the full range of nanoparticle sizes. Nonetheless, there is enough of an indication to warrant continued exploration of plume dilution schedules.

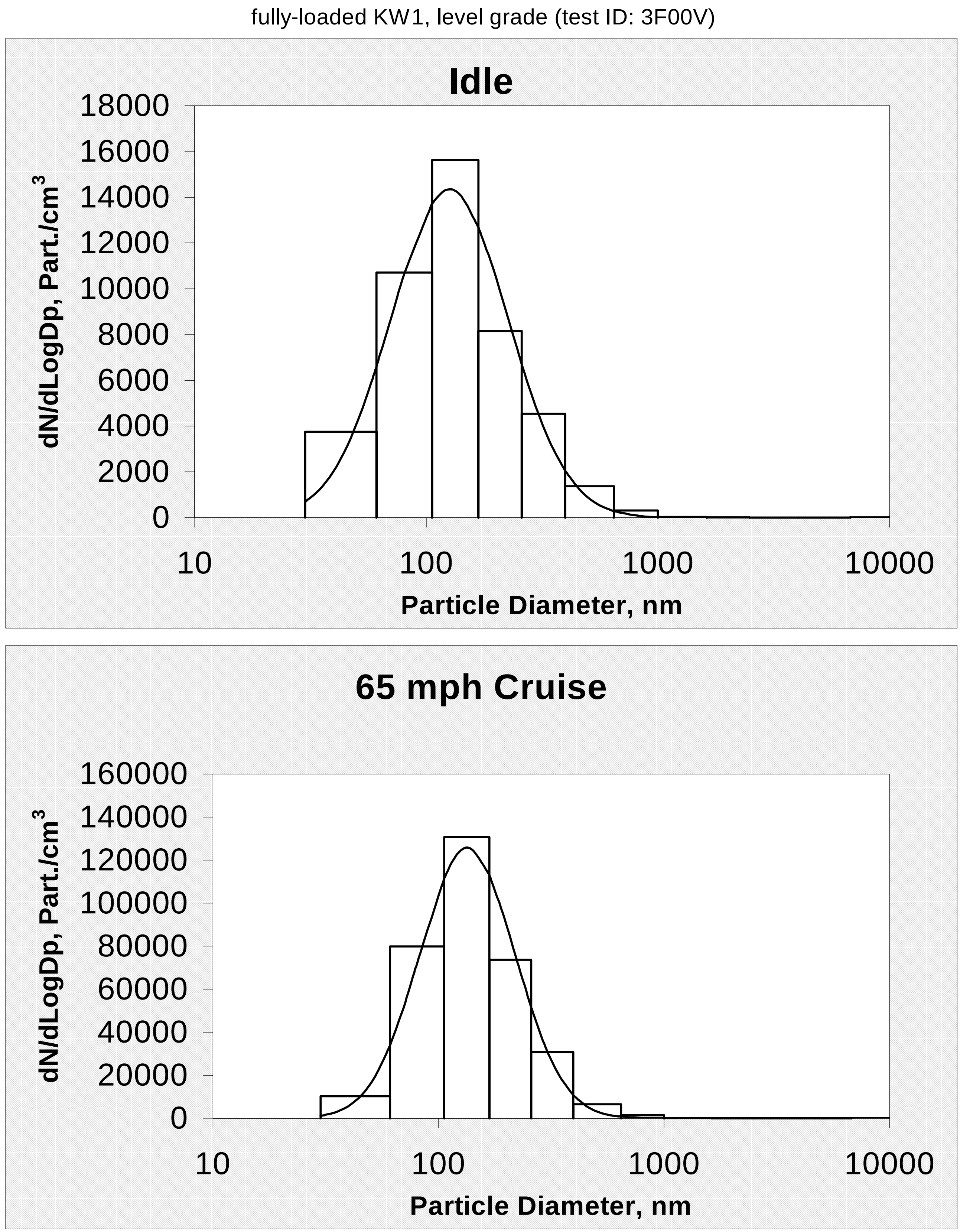


Figure 4-10. Pre-Rebuild Kenworth, Sampled from Plume.

Chapter 5
Conclusions and Recommendations

5.1 Conclusions

The following conclusions were reached from the testing conducted thus far in the research program:

1. Although the stack dilution system was designed and operated according to currently accepted practice, the character of the fine PM emissions do not reflect “real world” conditions as found in the plume sampling conducted to date. Therefore, stack dilution sampling will be temporarily discontinued in favor of future on-road plume characterization.

2. The overall process of cooling and dilution of the exhaust plume in the flow field of the moving tractor-trailer is poorly understood. Future efforts will be directed towards the characterization of the flow around the moving vehicle in order that an improved plume sampling approach can be determined and implemented.

3. The dilution ratio, delay time, and dilution schedule has been determined by plume sampling using CO_2, NO_X, and/or propane as the tracer. Although these data are extremely useful for planning future research, a truly unique tracer is needed to eliminate the problems with atmospheric background and contributions from other vehicles.

4. All testing conducted to date use commercially available off-the-shelf instrumentation much of which has limited application to the characterization of fine PM from diesel-powered vehicles. A comparative evaluation of this instrumentation is needed before proceeding with future emissions testing.

5.2 Recommendations

This report has presented descriptive details of the ODEC facility and fine PM data from that facility. Since fine PM measurement capabilities were only recently added to the facility, these results represent a work in progress. The two preceding chapters represent two efforts that are expected to continue for some time: collection of fine PM emissions data and characterization of exhaust plume dilution. Regarding those efforts, the following refinements are recommended:

1. The previous chapter mentions the alternative dilution ratio measurement approach of injecting a unique tracer into the exhaust. It is recommended that this alternative be implemented in conjunction with current testing activities. Of particular interest are alternative refrigerants which are thermally stable, absorb in the infrared, and are available in bulk quantities.

2. The plume delay time characterizations provided reasonably repeatable results at the 11 meter location using a 10 Hz sampling rate. The 2 meter location, however, showed a consistent 0.1-second delay (i.e., a single sampling interval). Since the dilution ratios at the 2-meter location are typically within the critical 5:1 to 50:1 range, it is recommended that the delay time be measured to greater resolution, if possible. It is also recommended that the plume dilution experiments continue with measurements at the 6- and 8-meter locations, and that options for sampling the plume behind the trailer be explored.

3. The ELPI manufacturer has recently begun offering, as an upgrade to existing units, a filter stage for its impactors. This stage, which is installed after the last impactor stage and connects to the same electrical detection circuitry, increases size measurement resolution below the last-stage cutoff of 30 nm. Since low-end size resolution is one of the primary concerns with the ELPI, it may be well worth the investment to upgrade one or both ELPI units.

4. If the TEOM is to provide an useful on-road data at all, the source of the negative readings must be identified and either eliminated or characterized (i.e., for data correction). The manufacturer has indicated that moisture condensation may be causing the mass

measurement drift back and forth as the filter continuously re-equilibrates to the varying moisture levels in the sample. The suggested remedy, insertion of a permeation dryer into the sample delivery system, does not sound like a good long-term solution (these dryers are sensitive to particle deposition, and are not easily cleaned). An alternative approach, albeit an expensive and complicated one, would be to operate two TEOMs in parallel, one with a high temperature filter on the inlet. If the moisture is, indeed, the cause of the drift, then that drift should register on both analyzers. The “filtered” analyzer could be used for background correction. It might be worth the effort to explore this option using a borrowed TEOM and possibly a stationary PM source.

5. As it is currently configured, the aethalometer is of little or no use to the project. The lengthy response time is caused by the instrument’s “dual beam” design that attempts to measure PAHs and other non-elemental carbon compounds using UV. Even the unit’s user’s manual indicates that its “UVPM” (**UV**-absorbing **P**articulate **M**aterial) measurements do not indicate true mass emissions of anything. Aethalometer models that use only the near-infrared beam deliver readings at one second intervals. It is recommended that the various options be explored to improve the time resolution of the aethalometer.

Chapter 6

Quality Assurance/Quality Control Activities

All testing activities for this project utilized EPA's On-Road Diesel Emissions Characterization (ODEC) facility. The ODEC Facility Manual is a separate document that includes design specifications, equipment details, personnel capabilities and work capacity, analytical operating procedures, QA/QC requirements, and health and safety requirements. This chapter discusses QA/QC objectives and activities specific to the testing described in this report. The project's Data Quality Objectives (DQOs) are reviewed, along with the Data Quality Indicator (DQI) goals and QC procedures.

6.1 Data Quality Objectives

This project's goals are to evaluate Fine PM emissions as a function of operating mode, to determine aerosol characteristics, and to investigate the dilution processes that affect the exhaust plume of a tractor-trailer. To accomplish these goals, DQOs were established for vehicle operating parameters, exhaust flow, dilution ratio, and number-weighted particle size distribution, along with mass concentrations of total particles, PAHs, and "black" carbon. Table 6-1 lists these measurements and their dependencies, along with the associated DQOs. As shown, exhaust flow and dilution ratios are "composite measurements" (calculated from a combination of other measurements), so the DQOs are defined in terms of the measurements they depend on. Those measurements identified as "unspecified" were treated as such for the following reasons:

! The instruments used for these measurements, though commercially available, are not specifically designed for mobile testing. As the on-road testing program has demonstrated numerous times, it is impossible to predict how equipment will respond to the rigors of a mobile test environment.

! No "calibration standard" is available for these measurements; they are "composite measurements" similar to the exhaust flow and dilution ratios. The manufacturers estimate the precision and/or accuracy of the instruments by calibrating the underlying individual measurements (e.g. mass flows, pressures, frequencies). For the instruments that withstood the mobile test environment and delivered data that appeared reasonable, future DQOs will be established based on those same underlying measurements.

Table 6-1. Project Data Quality Objectives

Measurement	Method	Precision	Accuracy	Completeness
Truck Speed	Optical fifth-wheel	±1% RSD	±2%	>90%
Exhaust Flow	Calculated from below			
- Flow dP	dP transducer	±2%	±2%	>90%
- Stack Pressure	dP transducer	±2%	±2%	>90%
- Stack Temperature	K-type thermocouple	±1% RSD	±2%	>90%
- Exhaust O_2[a]	Magneto-Pneumatic CEM	3% Drift	±5% Bias	>90%
- Exhaust CO_2[a]	NDIR CEM	3% Drift	±5% Bias	>90%
- Exhaust CO[a]	NDIR CEM	3% Drift	±5% Bias	>90%
Dilution Ratios	Calculated from below			
- Diluent CO_2	NDIR CEM	3% Drift	±5% Bias	>50%
- Dilute Sample CO_2	NDIR CEM	3% Drift	±5% Bias	>50%
- Exhaust NO_X	Chemiluminescent CEM	3% Drift	±5% Bias	>90%
- Dilute Sample NO_X	Chemiluminescent CEM	3% Drift	±5% Bias	>50%
PM Size Distribution	ELPI	Unspecified	Unspecified	>50%
PM Mass Concentration	TEOM	Unspecified	Unspecified	>50%
PAH Concentration	Photo-ionization analyzer	Unspecified	Unspecified	>50%
Black Carbon Conc.	Optical attenuation CEM	Unspecified	Unspecified	>50%

[a]These concentrations are used to calculate exhaust gas molecular weight.

! For most of these instruments, the principal of operation is based on cutting-edge research that is ongoing. The bias, drift, and noise characteristics of the "front end" sensory element (the one whose response most strongly correlates to the instrument's overall output) are not fully characterized. Determining the utility of these instruments is a research effort in and of itself, one that is being undertaken by a number of government and University laboratories, as well as the manufacturers themselves.

6.2 Quality Control

Section 9 of the facility manual describes the QC activities for the ODEC facility. The procedures and schedules contained therein were established, as part of the overall operating plan, to allow assessment of the data with respect to the DQOs. QC-related activities include maintenance and standard operating procedures, instrument calibration checks, and corrective action procedures. Project-specific QC activities are detailed in Table 6-2. The project team has a policy of discarding data that do not meet DQOs. Under most circumstances, discarded tests are repeated to maintain completeness.

6.3 Data Quality Indicators

The DQIs provide a measure of the data uncertainty, and are often used as criterion for acceptance or rejection of collected data. Some of the DQIs are determined prior to and during testing (e.g. calibration checks for CEM data). These "immediately available" indicators are quite often used as triggers for re-calibration or other corrective action, and have even supported decisions to postpone or cancel tests. Conversely, unfavorable assessments of DQIs have also supported decisions to repeat tests while still in the field, thus conserving project resources. When DQIs are determined during data processing, corrective action options are limited. During this project, a number of data points have been rejected because of failure to meet DQOs. Where possible these are identified as "Not Available" or "Rejected" in the data summaries, and their effect on data completeness is calculated.

6.3.1 Truck Speed

The product literature for the Datron LS1 optical speed sensor specifies an accuracy of ±0.2% and a reproducibility of ±0.1% over the measurement range of 0.5 to 400 kph. The "Certificate of Calibration" for the specific unit installed on the ODEC facility states an accuracy of ±0.113% with no precision value indicated. Figure 6-1 correlates the speed measurement to a drive shaft speed sensor that was scaled using a NIST-traceable frequency source. The outliers at the low-speed end indicate when the truck is turning (the tractor and the trailer-mounted speed sensor travels less distance than the tractor does during turns). Notwithstanding these points, the correlation is a good indication of speed measurement precision. Figure 6-2 shows this precision for four ranges of truck speed, along with similar estimates of accuracy (the latter estimates force the correlation line through zero and add in the "ripple" of the shaft speed measurement). In general, the project relies heavily on the accuracy of the speed sensor's factory calibration, and monitors the slope of the Figure 6-1 correlation to indicate when the sensor's upscale response my have drifted.

Table 6-2. Project Quality Control Activities

Measurement/Device	QC Activity
Truck Speed Optical fifth wheel	Zero reading is verified regularly during testing (at least daily) by recording response while truck is stationary. Upscale readings are verified to be proportional to calibrated drive shaft speed measurement.
Exhaust Flow dP	Biennial calibration with inclined manometer
Stack Pressure	Biennial calibration with inclined manometer
Stack Temperature Thermocouple	Probe calibrated prior to installation by APPCD metrology laboratory.
Exhaust O_2	Calibration error checks prior to each test day. Pre- and Post-test system bias checks.
Exhaust CO_2	Calibration error checks prior to each test day. Pre- and Post-test system bias checks.
Exhaust CO	Calibration error checks prior to each test day. Pre- and Post-test system bias checks.
Diluent CO_2	Calibration error checks prior to each test day. Pre- and Post-test system bias checks.
Dilute Sample CO_2	Calibration error checks prior to each test day. Pre- and Post-test system bias checks.
Exhaust NO_X	Calibration error checks prior to each test day. Pre- and Post-test system bias checks.
Dilute Sample NO_X	Calibration error checks prior to each test day. Pre- and Post-test system bias checks.
PM Size Distribution ELPI	All electrometers zeroed prior to each days' testing. Instrument's internal sensors monitor most of the critical operating parameters. Impactor is cleaned after each test series (~20 hours total operating time), or when the software issues a warning.
PM Mass Concentration TEOM	Filter element is replaced when the operating software issues a warning. Flow meter is calibrated biennially.
PAH Concentration	All instrument parameters are checked prior to each days' testing: pump power between 40 and 55%, lamp frequency less than 21 kHz, intensity greater than 95%, and flow greater than 1.9 L/min. Flow meter is calibrated biennially.
Black Carbon Concentration	Displayed sample flow is verified at 4 $\pm$0.3 L/min during each test day. Prior to each test series, the inlet impactor is cleaned, and the used filter tape spots are inspected for distinct and uniform borders between exposed and unexposed areas. Flow meter is calibrated biennially.

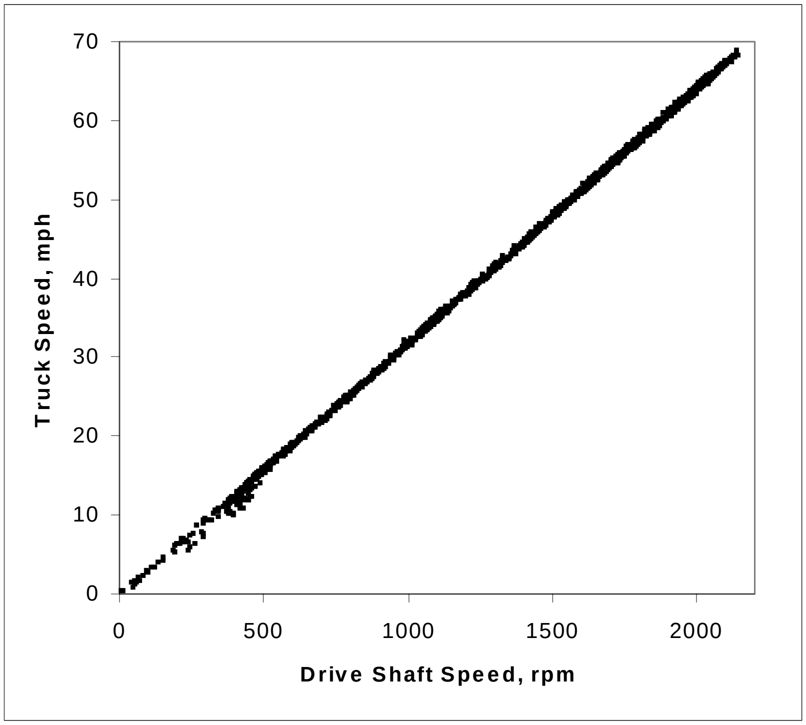


Figure 6-1. Truck Speed Correlation.

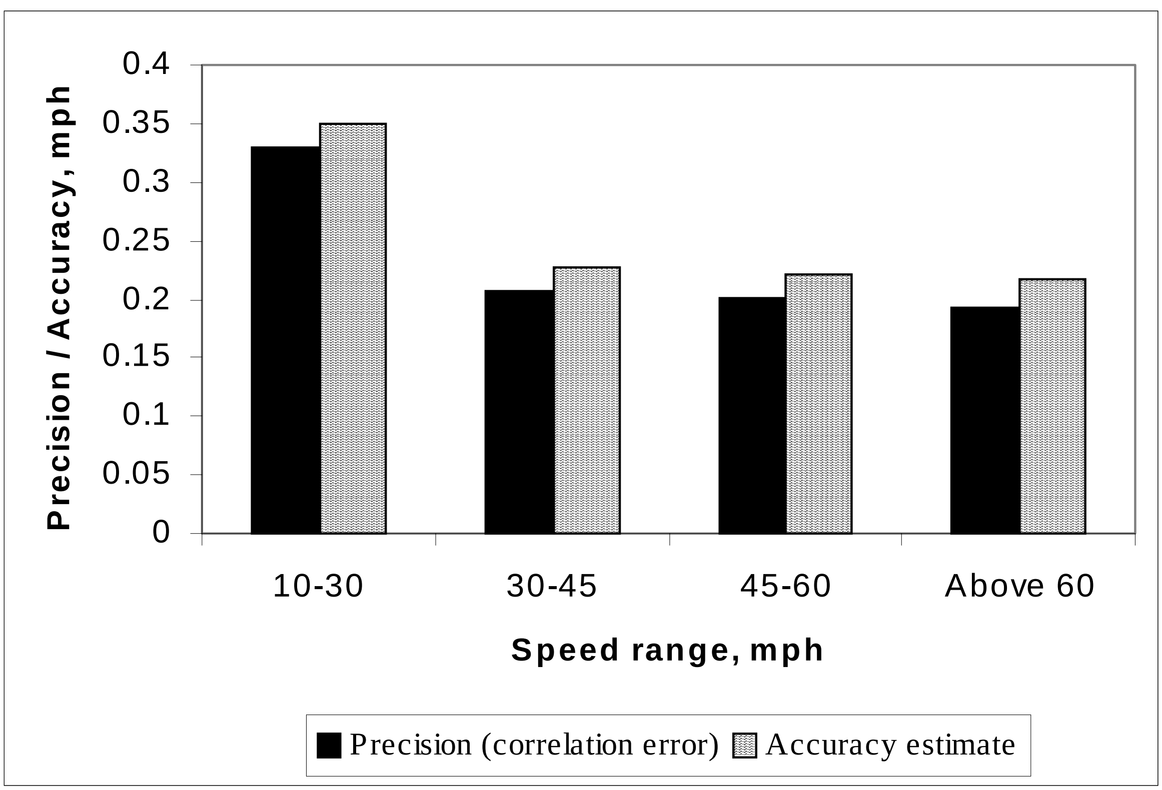


Figure 6-2. Truck Speed Error for Different Speed Ranges.

6.3.2 Flow Differential Pressure (dP)

The differential pressure transducer was calibrated against an inclined manometer which was temporarily installed and leveled within reach of the tubes that attach the transducer to the stack pitot. The transducer's mounting, plumbing, power, and signal connections were left undisturbed. The facility's DAS was used to record the responses to the differential pressure inputs. As shown in Figure 6-3, the measured response is quite linear; the errors that do exist appear to be random in nature (i.e., the errors do not become larger at either end of the range, or in the middle). Using a best-fit line (one that does not assume a slope of 1 and intercept of 0), the standard error (an indicator of precision) is 0.056 inch water gauge (W.G.). The standard error about the y=x line (shown in the figure to indicate the calibration accuracy for the facility) is 0.065 inch W.G.

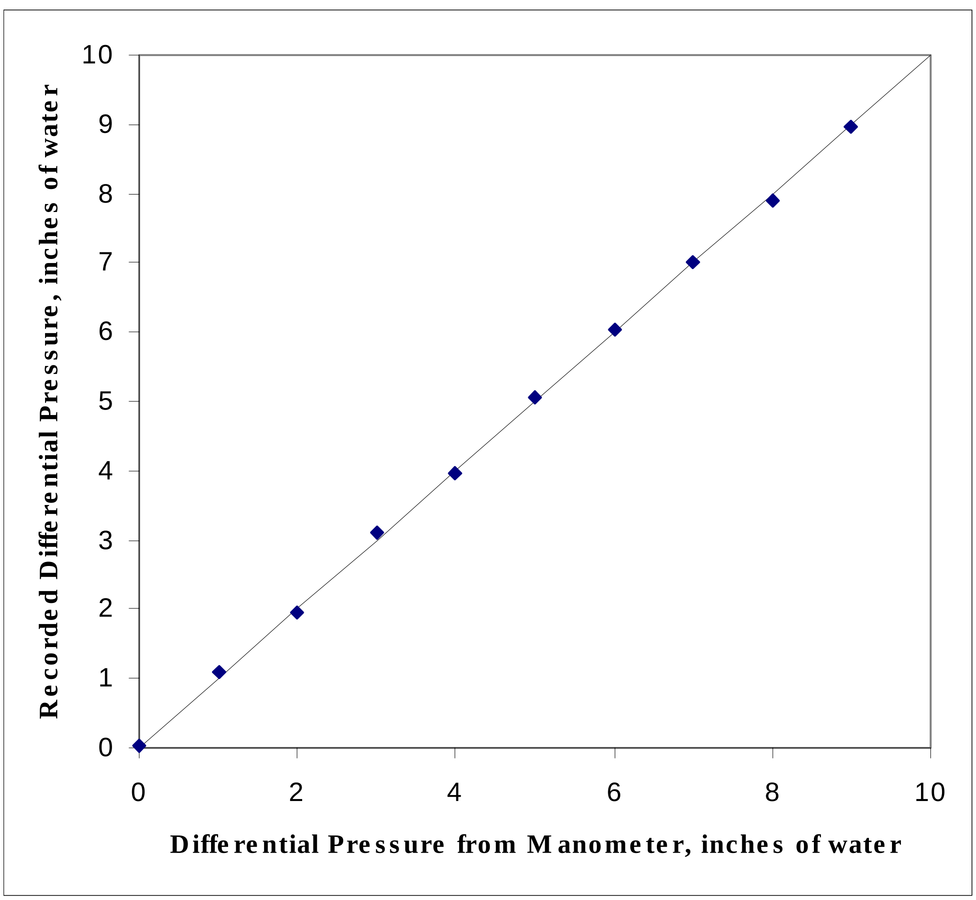


Figure 6-3. Flow dP Transducer Calibration.

6.3.3 Stack Pressure

Stack pressure is measured by the same type of differential pressure transducer that measures the flow dP. It was calibrated using the same equipment and procedure as the flow dP transducer, with the results presented in Figure 6-4. Again, the errors are random, the best-fit standard error (precision indicator) is 0.12 inch W.G., and the standard error about y=x (accuracy indicator) is 0.15 inch W.G.

6.3.4 Stack Temperature

This project has recorded few details about how the APPCD metrology laboratory calibrates thermocouple probes. Nonetheless, the stack temperature probe was calibrated over a nominal range of 50-400° C, yielding the results in Figure 6-5. It does appear that the probe consistently under-predicts the temperature at the high end of the range, leading to a calibration slope of 1.015. The standard error about this calibration line (precision indicator) is 0.2° C. The standard error about y=x (accuracy indicator) is 2.7° C, which amounts to about a 0.5% error for the temperatures typically recorded by this probe.

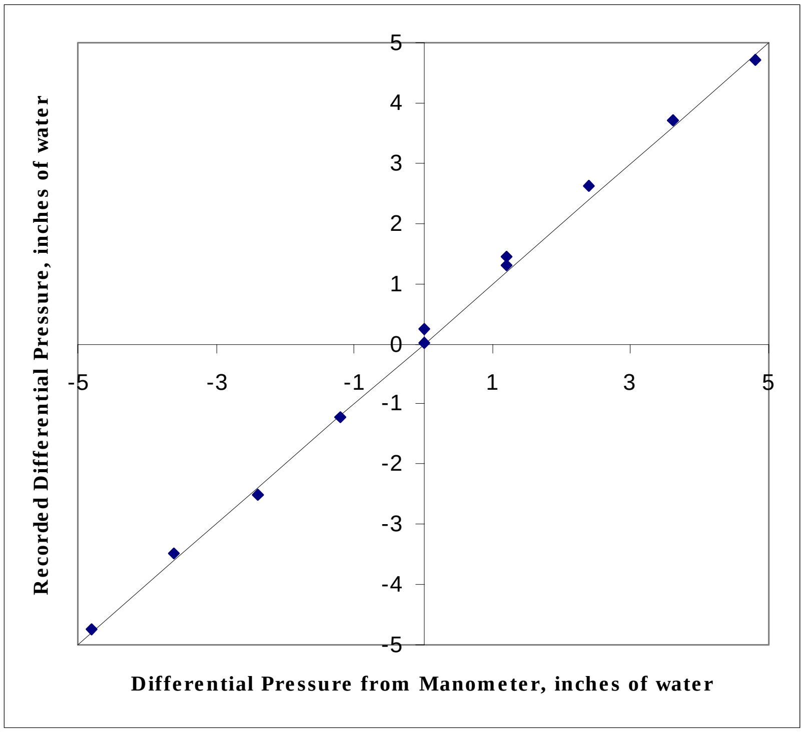


Figure 6-4. Static Pressure Transducer Calibration.

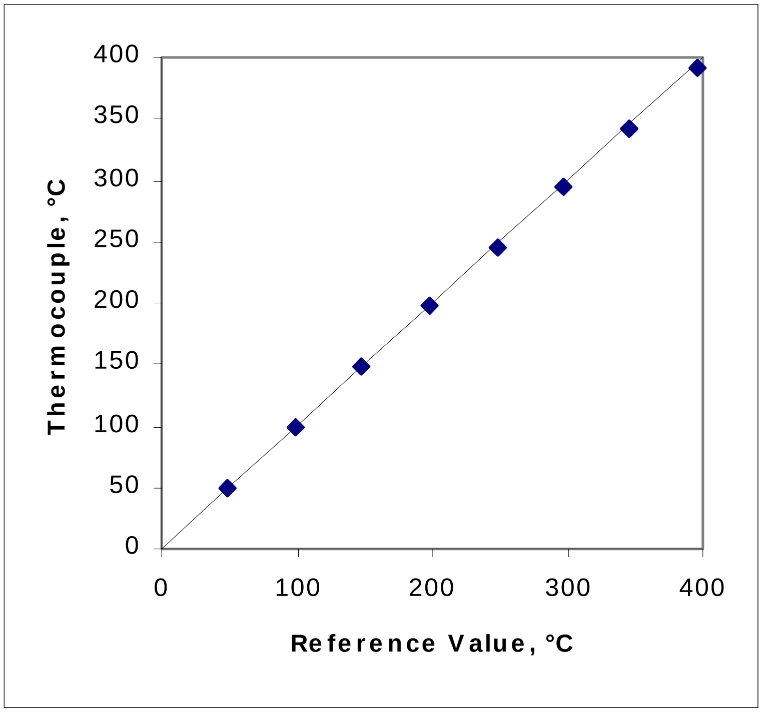


Figure 6-5. Stack Thermocouple Calibration.

6.3.5 CEM Measurements

The calibration and operation of all CEM instruments is explained in detail in the facility manual. The data quality objectives are derived from EPA's instrumental reference methods published in 40 CFR Part 60. Appendix D of this document contains calibration summary tables for all tests represented in Appendix C and in the body of this report. The reader can verify that, for any measurement that Appendix D shows failing to meet project DQOs, Appendix C will show that measurement (and all dependent measurements) as "NA" or "ERR" (NA indicates the instrument failed a calibration, where ERR indicates the instrument experienced another failure and a calibration was not performed).

6.3.6 Completeness

Table 6-3 shows the calculated completeness for all of the measurements with established DQOs. Just about every measurement had some missing or invalid data. Overall, the least dependable measurements were the CEM measurements from the dilute samples. These highly sensitive analyzers were prone to drift, and occasionally generated data that could not be correlated to the corresponding raw stack measurements. The values of 0% shown for the TEOM and Aethalometer reflect this report's earlier conclusion that these instruments are not suitable for mobile testing in their current configurations. Other than these two, all measurements delivered the quantity of valid data that was expected of them.

6.4 Overall Data Quality Assessment

Based on the DQIs determined in conjunction with the data collection effort, project personnel believe that the data represented by this report are of sufficient quality to support the observations and conclusions contained herein. Specifically, the project's policy of discarding data that do not meet DQOs leads to a great deal of confidence in the remaining data. Table 6-3 shows the calculated completeness for all of the measurements with established DQOs. Overall, the least dependable measurements were the CEM measurements from the "dilute" samples. These highly sensitive analyzers were prone to drift, and occasionally generated data that could not be correlated to the corresponding raw stack measurements. The values of 0% shown for the TEOM and Aethalometer reflect this report's earlier conclusion that these instruments are not suitable for mobile testing in their current configurations. Other than these two, all measurements delivered the quantity of valid data that was expected.

Table 6-3. Data Completeness

Measurement	Completeness
Truck Speed	100%
Exhaust Flow	94%
- Flow dP	96%
- Stack Pressure	100%
- Stack Temperature	100%
- Exhaust O_2	98%
- Exhaust CO_2	98%
- Exhaust CO	99%
Dilution Ratios	
- Diluent CO_2	86%
- Dilute Sample CO_2	77%
- Exhaust NO_X	91%
- Dilute Sample NO_X	72%
PM Size Distribution	98%
PM Mass Concentration	0%
PAH Concentration	100%
Black Carbon Concentration	0%

References

Abdul-Khalek, I. S., Kittelson, D. B., Graskow, B. R., and Wei, Q., "Diesel Exhaust Particle Size: Measurement Issues and Trends," SAE Paper No. 980525, Society of Automotive Engineers, Warrendale, PA, 1998.

Brown, J. E., King, F. G., Mitchell, W. A., Squier, W. C., Harris, D. B., and Kinsey, J.S., "On-Road Facility to Measure and Characterize Emissions from Heavy-Duty Diesel Vehicles," *J. Air & Waste Management Assoc.*, In Review (2001).

Brown, J. E., Clayton, M. J., Harris, D. B., and King, F. G., "Comparison of the Particle Size Distribution of Heavy-Duty Diesel Exhaust Using a Dilution Tailpipe Sampler and an In-Plume Sampler during On-Road Operation," *J. Air & Waste Management Assoc.*, (50):1407-1416 (2000).

Dekati Ltd., ELPI User Manual, Tampere, Finland, 1999.

Federal Register, 40 CFR Part 86, Subpart N, U.S. Government Printing Office, Washington, DC, 1983.

Health Effects Institute, *Pulmunary Toxicity of Inhaled Diesel Exhaust and Carbon Black in Chronically Exposed Rats,* Research Report No. 68, Cambridge, MA, 1994.

Kittelson, D.B., Kadue, P.A., Scherrer, H.C., and Lovrien, R.E., "Characterization of Diesel Particles in the Atmosphere." Coordinating Research Council AP-2 Project Group Final Report, Atlanta, GA, 1988.

Kittelson, D. B., Dolan, D. F., Diver, R. B., and Aufderheide, E., "Diesel Exhaust Particle Size Distributions – Fuel and Additive Effects," SAE Paper No. 780787, Society of Automotive Engineers, Warrendale, PA (1978).

Kittelson, D. B., Arnold, M., and Watts, W. F., Jr., "Review of Diesel Particulate Matter Sampling Methods: Final Report." EPA grant report published on web site: http://www.me.umn.edu/centers/cdr/Proj_EPA.html, National Vehicle and Fuels Emission Laboratory, Ann Arbor, MI, January 14, 1999.

Maricq, M. M., Chase, R. E., Podsiadlik, D. H., and Vogt, R., "Vehicle Exhaust Particle Size Distributions: A Comparison of Tailpipe and Dilution Tunnel Measurements," SAE Paper No. 1999-01-1461, Society of Automotive Engineers, Warrendale, PA (1999).

Williams, P. T., Abbass, M. K., Tam, L. P., Andrews, G. E., and Ng, K. L., "A Comparison of Exhaust Pipe, Dilution Tunnel and Roadside Diesel Particle SOF and Gaseous Hydrocarbon Emissions," SAE Paper No. 880351, Society of Automotive Engineers, Warrendale, PA (1988).

Appendix A

Data Reduction Procedures and Calculations

A.1 Calculation of Data Quality Indicators

Presented below are the formulae used to calculate the various DQIs that are required to assure data quality. Where possible, the DQIs are based on regression lines between measured and known values. When such is the case, precision is defined as the standard error of estimate about a best-fit regression line. This line is based solely on a specific calibration summary, not on the calibration parameters that are used in the calculation process (not always the same). When the standard error about a calibration parameter line is calculated, that is called accuracy.

A.1.1 Two Parameter Regression Line

$$\text{slope} = \frac{n \sum_{i=1}^{n} x_i y_i - \sum_{i=1}^{n} x_i \sum_{i=1}^{n} y_i}{n \sum_{i=1}^{n} (x_i)^2 - \left[\sum_{i=1}^{n} x_i \right]^2} \qquad \text{(A-1)}$$

$$\text{intercept} = \frac{\sum_{i=1}^{n} x_i^2 \sum_{i=1}^{n} y_i - \sum_{i=1}^{n} x_i \sum_{i=1}^{n} x_i y_i}{n \sum_{i=1}^{n} x_i^2 - \left[\sum_{i=1}^{n} x_i \right]^2} \qquad \text{(A-2)}$$

A.1.2 One Parameter Regression Line

$$\text{slope} = \frac{\sum_{i=1}^{n} y_i}{\sum_{i=1}^{n} x_i} \qquad \text{(A-3)}$$

A.1.3 Standard Error of Estimate

$$\text{error} = \sqrt{\frac{\sum_{i=1}^{n}(y_i - \text{slope} \times x_i - \text{intercept})}{n-1}} \quad \text{(A-4)}$$

When the calibration information consists of only a few points (e.g., CEM calibrations), the DQIs are defined in terms of bias (accuracy) and drift (precision) at each calibration point. DQOs are often defined in terms of a percentage of the instrument's range or, less commonly, a percentage of the actual reading. For this project, the DQIs are defined as a percentage of range.

$$\text{Bias} = \frac{Reading - Actual}{Range} \times \mathbf{100}\% \quad \text{(A-5)}$$

$$\text{Drift} = \frac{PreTest\ Reading - PostTest\ Reading}{Range} \times \mathbf{100}\% \quad \text{(A-6)}$$

A.2 Time Alignment

When analyzing continuous emissions from a vehicle stack, measurement time delay should be accounted for (Messer, J.T., Clark, N.N., Lyons, D.W., "Measurement Delays and Modal Analysis for a Heavy Duty Transportable Emissions Testing Laboratory," SAE Paper No. 950218, Society of Automotive Engineers, Warrendale, PA, 1995). Time delay results from the time taken for the gases to travel through the sampling system and from the response delay of the analyzers themselves; the cumulative effect of these delays often varies from one CEM channel to the next. For this project, time alignment is accomplished by correlating the emissions data from each analyzer with a real time variable (i.e. a measurement that does not experience a measurement time delay). This is consistent with Ramamurthy et al. (Ramamurthy, R., Clark, N.N., Atkinson, C.M., Lyons, D.W., "Models for Predicting Transient Heavy Duty Vehicle Emissions," SAE Paper No. 982652, Society of Automotive Engineers, Warrendale, PA, 1998) approach of cross-correlating instantaneous emissions with axle power data. In choosing from among several real-time "key" channels, the channel should be selected for its tendency to vary in ways similar to the emissions.

The first step in time aligning the data is to correlate the emissions data with the default key channel, "Flow dP" (the differential pressure reading from the exhaust flow sensor). In general, if this channel fails to correlate strongly with O_2 and CO_2 emissions, it means there is something wrong with one of those three channels (O_2, CO_2, and Flow dP). For the purposes of time-alignment, a "good" correlation is one where the Pearson product moment correlation (R-squared) values are above 0.3 (see Table A-1). The most important aspect, however, is the "peaking" of R-squared values.

Table A-1. Sample time delay determination

Subject Channel	Key Channel		Peak Correlation	Lag Seconds
O_2	Flow dP	Default	0.785	6
CO_2	Flow dP	Default	0.784	6
CO-Hi	Flow dP	Default	0.339	4
CO-Lo	Flow dP	Default	0.344	6
Horiba NO_X	Flow dP O2 CO2 G-force	Default Surrogate Surrogate Alternate	0.142 0.310 0.362 0.325	9 6 6 7
TECO NO_X	Flow dP O2 CO2 G-force	Default Surrogate Surrogate Alternate	0.117 0.330 0.345 0.326	10 7 7 8
THC	Flow dP	Default	0.194	4

"Peaking" refers to the tendency of a column of R-squared values to reach a maximum value a few rows from the top (the number of rows corresponding to the characteristic time delay for that measurement channel). This R-squared "column" is produced by successive shifting of the CEM and real-time data columns in relation to one another. The values in this column peak at the point where the correlation is most improved by shifting. The appearance of this peak is much more important than the actual R-squared values themselves. In fact, when choosing between several key channels with similar peak correlation values, a sharply peaking R-squared value is the trait to look for.

While it is not unusual for all of the CEM channels to correlate (and peak) with Flow dP, the correlations are often not as good for some of the more "transient" emissions (e.g. CO and hydrocarbons). Sometimes better correlations can be obtained by using an alternate variable (i.e. another real-time variable whose reading is expected to follow the same temporal variations as the subject CEM channel). An example of an alternative variable is the front-to-rear g-force, measured by an accelerometer bolted to the floor of the on-road test facility. Since spikes of transient emissions tend to correspond to g-force spikes (e.g., pull-offs, gear changes), this variable quite often proves superior to Flow dP in aligning CO and hydrocarbon channels.

When a CEM channel fails to correlate with either the default or alternate real-time channels, a "surrogate" is used. A surrogate is a CEM channel that is used in place of a real-time variable for time alignment. The surrogate formulae differ from the default and alternate formulae for two reasons: (1) the column of regressions must allow for the possibility that the surrogate channel may have a longer response lag than the subject channel, and (2) the surrogate's lag must be included in the calculation of the subject channel's response lag. In selecting a surrogate channel, it is not only important for the surrogate and subject channels to correlate, there must also be a high confidence level in the surrogate’s lag calculation. O_2 and CO_2 usually make good choices for surrogates because of their strong correlations with Flow dP.

Weaknesses of this methodology include (1) inadequate handling of time gaps in the data, and (2) doing nothing to counteract the "response dampening" that all extractive sampling systems experience. Time gaps in the data tend to make the correlation coefficients worse, because some of the correlated data are on opposite sides of the gap. However, if the gaps represent only a small proportion of the data records (e.g., a dozen ten-second gaps in two hours worth of data), the "peaking" of R-squared values is not substantially affected.

Response dampening refers to the emissions dispersion that occurs between the exhaust manifold and the analyzer. This causes the effect of any step change in source concentration to be "spread out" over several readings. So, even if the "delay" time is properly compensated by the rolling regression technique, the "spread" will continue to introduce timing-related inaccuracies into the calculated data.

A.3 Calculation of Emissions

This section shows how all of the raw data measurements come to together to calculate mass emissions. Where possible, the source of the equations is noted.

A.3.1 Calculation of Exhaust flow

Find average exhaust velocity per 40 CFR 60, App. A, Equation 2-9:

$$v_s = K_p C_p (\sqrt{\Delta P})_{avg} \sqrt{\frac{T_{s(avg)}}{P_s M_s}} \text{, ft/sec} \quad \text{(A-7)}$$

where $K_p \equiv$ Pitot tube constant

$C_p \equiv$ Pitot tube coefficient

$(\sqrt{\Delta P})_{avg} \equiv$ Average square root of pitot DP

$T_s, P_s, M_s \equiv$ Stack/exhaust temperature, pressure, and molecular weight

given that $$K_p = 85.49 \frac{ft}{sec}\left[\frac{(lb / lb - mole)(" Hg)}{(^oR)(" H_2O)}\right]^{1/2}$$

and C_p is specified by the pitot manufacturer (0.99 for standard, 0.84 for S-type)

Calculate wet and or dry volumetric flow rate (DSCFM) per 40 CFR 60, App. A, Equation 2-10:

$$Q_{sw} = 3600 v_s A \frac{T_{std}}{T_{s(avg)}} \frac{P_s}{P_{std}} \text{, SCFM} \quad \text{(A-8)}$$

$$Q_{sd} = 3600(1 - B_{ws}) v_s A \frac{T_{std}}{T_{s(avg)}} \frac{P_s}{P_{std}} \quad \text{(A-9)}$$

where $B_{ws} \equiv$ Water vapor fraction in exhaust gas

A ≡ Cross sectional area of stack/exhaust

T_{std} , P_{std} ≡ Standard Temperature and Pressure

A.3.2 Calculation of Exhaust Gas Molecular Weight

Calculate dry molecular weight from CEMS data per 40 CFR 60, App. A, Equation 3-1:

$$M_d = 0.440(\%CO_2) + 0.320(\%O_2) + 0.280(\%N_2 + \%CO) \qquad \text{(A-11)}$$

where $\%N_2 \simeq 100 - \%CO_2 - \%O_2 - \%CO$ (A-12)

Incorporate exhaust moisture content per 40 CFR 60, App. A, Equation 2-5:

$$M_s = M_d(1 - B_{ws}) + 18.0B_{ws} \qquad \text{(A-13)}$$

A.3.3 Calculation of Moisture Content

$$B_{ws} = 1 - \frac{158(1 - B_{wa})}{0.79(1 - B_{wa})[200 + (\%CO + \%CO_2)R_{HC}] + 2B_{wa}(100 - \%O_2 - \%CO_2 - \%CO)} \qquad \text{(A-14)}$$

where B_{wa} ≡ Water vapor fraction in ambient air

R_{HC} ≡ Molar ratio of Hydrogen to Carbon in the fuel

A.3.4 Calculation of Gaseous Pollutant Emissions

Convert gas concentrations to densities using the following factors

$$\frac{3.3\text{x}10^{-5}\ \frac{grams}{SCF}\ CO}{ppm\ CO} \qquad \text{(A-15)}$$

$$\frac{5.41 \times 10^{-5} \frac{grams}{SCF} NO_X}{ppm\ NO_X} \tag{A-16}$$

$$\frac{1.414 \times 10^{-5} \frac{grams}{SCF} THC}{ppm\ THC} \tag{A-17}$$

Multiply by exhaust flow and adjust units to get emissions in grams/hour

A.3.5 Calculation of PM Emissions

Calculate dilution ratio from appropriate analyzers

$$R = \frac{(Exhaust - Background)}{(Dilute - Background)} \tag{A-18}$$

For ELPI data, calculate the u.d.s. mass density of the sample

$$\rho = \sum_{stage=1}^{12} \frac{\pi \times D_{lm}^3 \times Count}{6} \tag{A-19}$$

where D_{lm} is the log mean aerodynamic diameter for the stage.
With the exception of the CPCs (from which mass data are not available), the other analyzers provide mass density measurement directly.

Multiply mass density by dilution ratio and exhaust flow to calculate emissions

Appendix B

Data Organization

This report is based on the data that have been generated from the heavy-duty on-road diesel emissions program since its focus shifted to fine PM in 1998. This data exists, in raw and processed forms, as several gigabytes on the project's principal data reduction computer located in building T-2 at the NIEHS "Burden's Creek" facility (commonly referred to as "Jenkins Road" by project personnel). The data are also routinely backed up onto Compact Disc Rewritable (CD-RW) media which are used to mirror portions of the data on other computers, as needed. No attempt has been made to encrypt or otherwise protect the dataset from unauthorized access. Portions of this data have been shared with a number of other researchers, some of which have referenced it in their publications.

B.1 Data File Organization

Table B-1 is a listing of the C:\Diesel directory of the data reduction computer. All data accompanying this report are copied from this directory tree. The bulk of the data are organized by truck, from the pickup truck through the current 'KW2' configuration (see Table B-2). The other directories contain background information for the development of the on-road test facility and, more

Table B-1. Contents of C:\Diesel directory

DRAW	<DIR>	Drawings of facility components and subsystems
FACILITY	<DIR>	All other files related to the facility
PICKUP	<DIR>	Data from prototype facility (pickup truck)
FORD_9	<DIR>	Data from JCC Ford CL-9000 tractor
FRGHTLNR	<DIR>	Data from JCC Freightliner tractor
KW1	<DIR>	Data from Kenworth with "as-received" engine
CENTURY1	<DIR>	Data from UC-Davis Freightliner Century tractor
KW2	<DIR>	Data from Kenworth with rebuilt engine
PART	<DIR>	PM developmental data
700_ANAL	WK1	Fuel analysis for sample collected July of 2000
ALIGN10	WK4	Time-alignment template for 10-channel 1 Hz CEM data
ALIGN8	WK4	Time-alignment template for 8-channel 1 Hz CEM data
ALIGN8A	WK4	Time-alignment template for 8-channel 10 Hz CEM data
ALIGN9	WK4	Time-alignment template for 9-channel 1 Hz CEM data
DRI_Y1	WK4	Time-alignment template for DRI tunnel data
VEL_Y1	WK4	Time-alignment template for 7-channel 1 Hz CEM data
MATRICES	WK4	Template file for generating test matrix sheets

Table B-2. Vehicles Tested During On-Road Diesel Emissions Program

#	ID	Class	Year	Make/Model	Miles	Engine	Rating	History
0	Pickup	2b	1993	Ford F-250	<10,000	Navistar 7.3l	185 hp	New
1	Ford_9	8b	1989	Ford CL-9000	105,000	Cummins NTC-315	315 hp	Short Trips
2	Frghtlnr	8b	1990	Freightliner Conventional	550,000	Caterpillar 3176	325 hp	Unknown
3	KW1	8b	1990	Kenworth T800	>900,000	Detroit Diesel Series 60	425 hp	Long Haul
4	Century1	8b	1994	Freightliner Century	~300,000	Detroit Diesel Series 60	500 hp	Long Haul
5	KW2	8b	1990	Kenworth T800	>900,000	Detroit Diesel Series 60	425 hp	Recent Rebuild

recently, its PM measurement capabilities. The C:\Diesel directory also contains a few template and summary files that are not specific to a specific truck.

Table B-3 shows one of the six truck directories: KW1. Any files that relate to this truck/engine configuration, but not to a specific test series, belong in this directory. Files from specific test series are stored in the subdirectories labeled by load and grade condition. Each of these test-series directories nominally represents a half-day's or full-day's testing, all conducted along the same section of road at the same load condition. Each directory contains all raw and processed data for that test series.

Table B-4 is an example data directory. In order to keep things organized, there is an established naming scheme for all files. Sometimes, the scheme is dictated or influenced by the software that creates the file; on rare occasions (i.e., when the software has an inflexible naming scheme that is inconsistent with ours), a file will be renamed during data processing to make it clearer what test it represents. The files in Table B-4 are listed chronologically. Raw data files are typically identified by a date, a sequence number, and a file type. For example, files named by the scheme DDDD-##.WK4 are calibration records, where DDDD is the test date and ## is the sequence number. The first file of a test day is typically a calibration record; there will always be at least two of these (a calibration error check and a system bias check) before any CEM data are collected.

Table B-3. Contents of C:\Diesel\KW1 directory

SHKDOWN	<DIR>	Shakedown exercise raw data files (seldom processed)
CD	<DIR>	Coastdown files
MIT	<DIR>	Collaborative study with MIT/Aerodyne TILDAS system
FULL_0	<DIR>	Fully-loaded zero-grade data from March 1999
HALF_0	<DIR>	Half-loaded zero-grade data from March 1999
EMPTY_0	<DIR>	Empty-trailer zero-grade data from March 1999
SEQUENCE	<DIR>	Dynamometer simulation sequence data
TUNNEL	<DIR>	DRI tunnel study data
FULL_3&6	<DIR>	Fully-loaded 3% and 6% grade data
HALF_3&6	<DIR>	Half-loaded 3% and 6% grade data
MT_3&6	<DIR>	Empty-trailer 3% and 6% grade data
FILTERS	<DIR>	Data from collection of filters for PM lab analysis
FULL_00	<DIR>	Fully-loaded zero-grade data from October 1999
HALF_00	<DIR>	Half-loaded zero-grade data from October 1999
EMPTY_00	<DIR>	Empty-trailer zero-grade data from October 1999
DIOXIN	<DIR>	Data from collection of dioxin samples w/ APTB
UNLINKED	<DIR>	Portable versions of selected reduced data files
BACKUP	<DIR>	Archival versions of selected updated files

Table B-4. Example Data Directory

0315-0.WK4	03150008	03150005.PRN
0315-1.WK4	0315-16.MEC	03150006.PRN
0315-2.WK4	03150009	03150008.PRN
0315-3.WK4	0315-17.MEC	03150009.PRN
03150001	03150010	03150010.PRN
0315-8.WVU	03150011	0315-CS.WK4
03150002	R&P0315b.prn	R&P0315a.xls
0315-10.WVU	0315-19.MEC	R&P0315b.xls
0315-11.UDS	11m0315.dat	R&P0315c.xls
03150003	0315-4.WK4	R&P0315d.xls
R&P0315a.prn	Box0315.dat	11m0315.txt
03150005	R&P0315c.prn	Box0315.txt
0315-13.WVU	R&P0315d.prn	11m0315.xls
03150006	03150001.PRN	
0315-14.UDS	03150002.PRN	
0315-15.UDS	03150003.PRN	

Other files are identified as follows:

DDDD####	Binary data file generated by computer monitoring truck's on-board data stream.
DDDD####.prn	On-board data stream file converted to ASCII.
DDDD-##.wvu	DAS file representing a run of the WVU 5-peak test sequence.
DDDD-##.uds	DAS file representing a run of the Urban Dynamometer Driving Schedule for Heavy Duty Vehicles ["schedule d" - tabulated in 40 CFR Part 86, Appendix i(d)].
DDDD-##.mec	DAS file representing a run of the Modified Energy Conservation/Federal Test Procedure (MEC/FTP) cycle.
DDDD-##.vel	[no examples in Table 3] DAS file representing constant velocity data during parametric testing. May also include other types of data collected at 1-second intervals during parametric testing.
DDDD-##.cen	[no examples in Table 3] DAS file representing data from UC-Davis Freightliner Century truck. This data receives a special filetype because the available data channels are different than what is typically available from the fully-integrated test vehicles.
DDDD-##.rtp	[no examples in Table 3] DAS file representing non-parametric data collected in the research triangle area.
DDDD-##.fil	[no examples in Table 3] DAS file representing on-road testing where filter samples are collected for the fine PM lab (there are additional channels that monitor the filter collection).
DDDD-##.dio	[no examples in Table 3] DAS file representing on-road testing where dioxin samples are collected in cooperation with APTB (additional channels for monitoring media and meter temps).
DDDD-##.dri	[no examples in Table 3] DAS file representing on-road testing in cooperation with Desert Research Institute (first attempts to collect Fine PM data on-road).
R&PDDDDx.prn	ASCII data file generated by computer monitoring Tapered Element Oscillating Microbalance (TEOM, manufactured by Rupprecht &

	Patashnich -- R&P). These files use a sequence letter (shown here as "x"), when needed, instead of a number.
SssDDDDx.dat	ASCII data file generated by computer operating an Electrical Low Pressure Impactor (ELPI). The "SSs" sequence (two or three characters long) identifies the sampling location (CAB - Truck cab, BOX - rail-mounted instrument enclosure, 2m - plume sampling 2 meters behind stack, 11m - plume sampling 11 meters behind stack, etc.). Also uses a sequence letter.
SssDDDDx.txt	Reprocessed ELPI data.
$^{R\&P}/_{SSs}$DDDDx.xls	TEOM and ELPI files converted to spreadsheets for easy incorporation into data reduction spreadsheets.
DDDD-cs#.wk4	Calibration summary file - links to calibration records to calculate slope/intercept parameters for the CEM instruments.
TLGgg.$^{wk4}/_{123}/_{xls}$	Processed data files for parametric tests. These are multilayered spreadsheets that bring together an entire test series (usually consisting of several raw data files, calibration records, and weather data) T is a numerical representation of the truck (chronologically, starting with Truck 1=Ford_9, up to Truck 5=KW2). L is the load (F=full, H=half, E=empty trailer). Ggg is the grade condition (3&6=3% and 6% grades, 0=zero grade, 00 and 000 are repeats of the zero grade condition).
TL-Iii#.$^{wk4}/_{xls}$	Processed data files for special purpose and sequence tests. For dynamometer sequence tests, "seq" goes into the "Iii" identifier.

B.2 Processed Data Files

Figure B-1 shows how the raw data is incorporated into the data reduction spreadsheets. Obviously, the number of incorporated files varies from one test series to the next (dashed borders and connecting lines indicate files that may not exist). For example, the calibration summary requires a minimum of three calibration record files for input, but may use any number, depending on how many times the instruments were re-calibrated prior to the test series. It is important to note that the data reduction spreadsheet only uses one calibration summary; so, if any instruments require re-calibration in the middle of a test series, both a new calibration summary and a new data reduction spreadsheet must be created for the subsequent data. The gray filled boxes in the Figure B-1 flow chart show files that are not specific to the particular test series. The ELPI setup files are specific to the instrument that collected the data, where the Coast Down data are specific to the truck-trailer configuration that is being tested (for more recent configurations, coast-down data is extraneous because of the facility's ability to measure power directly). The climate data is specific to the test date and time, but is rarely incorporated as a real time data stream; it usually consists of a single average compiled from a few hourly weather observations during the testing.

The spreadsheets are equipped with macros that update the file links, import the raw data, perform time-alignment of CEM data, and calculate time-series and summary data. Appendix A contains a brief discussion of time alignment; the facility manual details the calculation procedures and formulae. The actual number of spreadsheet layers varies: the minimal three-layer version has a "Raw Data" layer, a "Calculated" layer, and a "Summary" layer. The Century1 data include a "DDEC" layer for the on-board data stream (which, for those tests, provided some of the input channels for the calculated time-series data. Spreadsheets from more recent testing include a "Fine PM" layer which incorporates some of the ELPI and TEOM data. If any of the data are summarized in graphical form, these will appear in a "Graphs" layer.

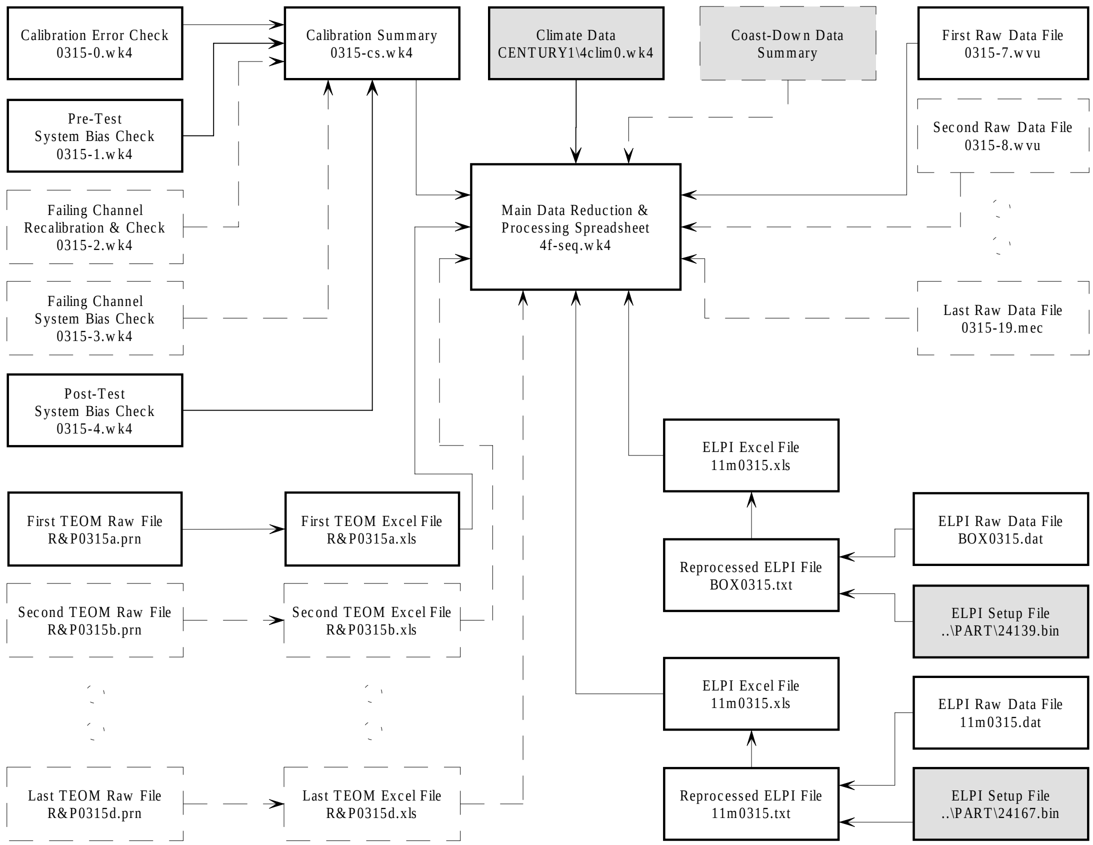


Figure B-1. Data File Dependency.

Figure B-2 is a somewhat dated representation of how the data flows within the main spreadsheet (i.e., it covers only gaseous pollutants). At the most macroscopic level, the spreadsheet's data flows from back to front. With the exception of a few measurements that require no further calculations (e.g., speed, rpm, and temperatures), all of the "Raw Data" layer values feed into formulas in the "Calculated" layer. The "Summary" layer calculates interval averages from all of the other layers. Additional data sources (e.g., onboard data stream, ELPI, TEOM) are added in layers behind the "Raw Data" layer.

Because the "Calculated" layer contains several formulas that are intended to propagate down through thousands of records, the spreadsheet employs a rather simplistic parsing technique to conserve disk storage and continuous memory usage. In short all of the formulas that calculate second-by-second data only exist in the top row of that table. The remaining rows store the data as values; this convention also avoids length recalculations when the time-series data are unchanged.

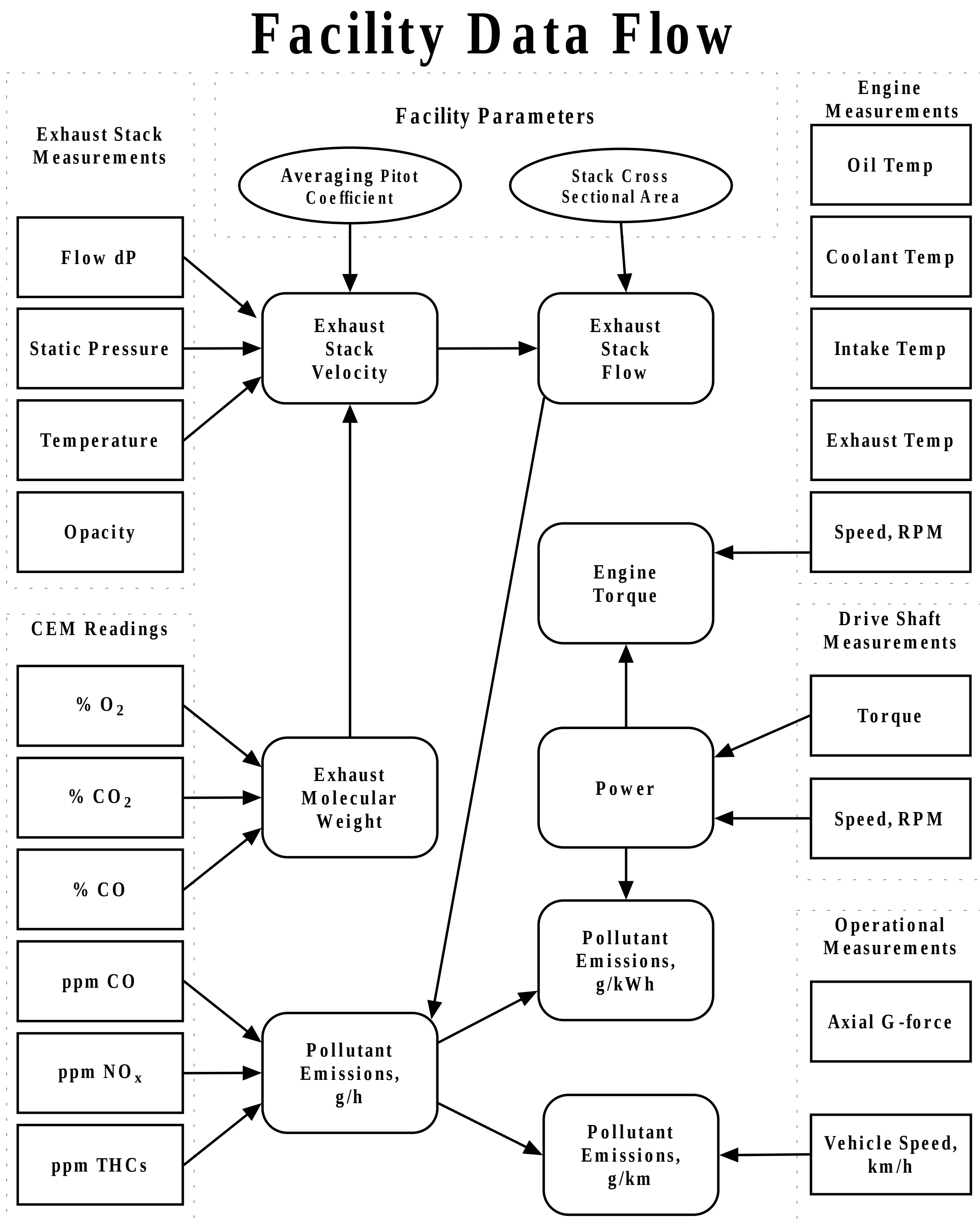


Figure B-2. Data Flow Schematic for Gaseous Pollutants.

When an all-inclusive recalculation is required, the user must run a macro that copies the formula down through the data, then immediately converts the formulas to values.

The "Summary" layer calculates interval averages from the real-time data, and presents them in a table that includes header information to describe the test series. Originally designed for parametric test data, the formulae in the table use the times entered to the far right in the table to define interval bounds and calculates average and total values, as appropriate. In spreadsheets where there are no specific intervals of interest (e.g., shakedown & route data) the table contains one row which calculates values for the entire test series.

The "Fine PM" layer is currently designed to incorporate ELPI and TEOM measurements into the main spreadsheet. At present, there are no macros to automate the incorporation process, and the process is not detailed in the facility manual or in a figure comparable to Figure B-2. The time alignment process uses the same "rolling regression" technique discussed in Appendix A, with variations in PM measurements matched to variations in CO. For this layer, the PM data are represented as mass concentrations ($\mu g/m^3$), which the TEOM measures directly and the ELPI estimates by converting the particle counts to unit-density-spherical (u.d.s.) mass values for each measurement bin.

The processing and interpretation of the PM data is continuously evolving. Figure B-3 shows how all of the pieces are expected to fit together. Essentially, because all of the PM analyzers receive a dilute sample, calculating emissions requires knowledge of the dilution ratios. These are measured using more sensitive versions of the same analyzers that measure exhaust concentrations. Dilution ratio is calculated using the following formula:

$$D.\ R. = \frac{(Exhaust\ -\ Background)}{(Dilute\ -\ Background)} \qquad \text{(B-1)}$$

where the background concentration represents either ambient air or the diluent gas, depending on where the dilute sample comes from. It is often assumed that these background concentrations do not vary greatly, and a single value is used for all of the D.R. calculations (i.e., the plume NO_X measurements), where the more rigorous technique is to measure the background continuously with a separate analyzer channel (i.e., the dilution system CO_2 measurements). Once the D.R. is known, it

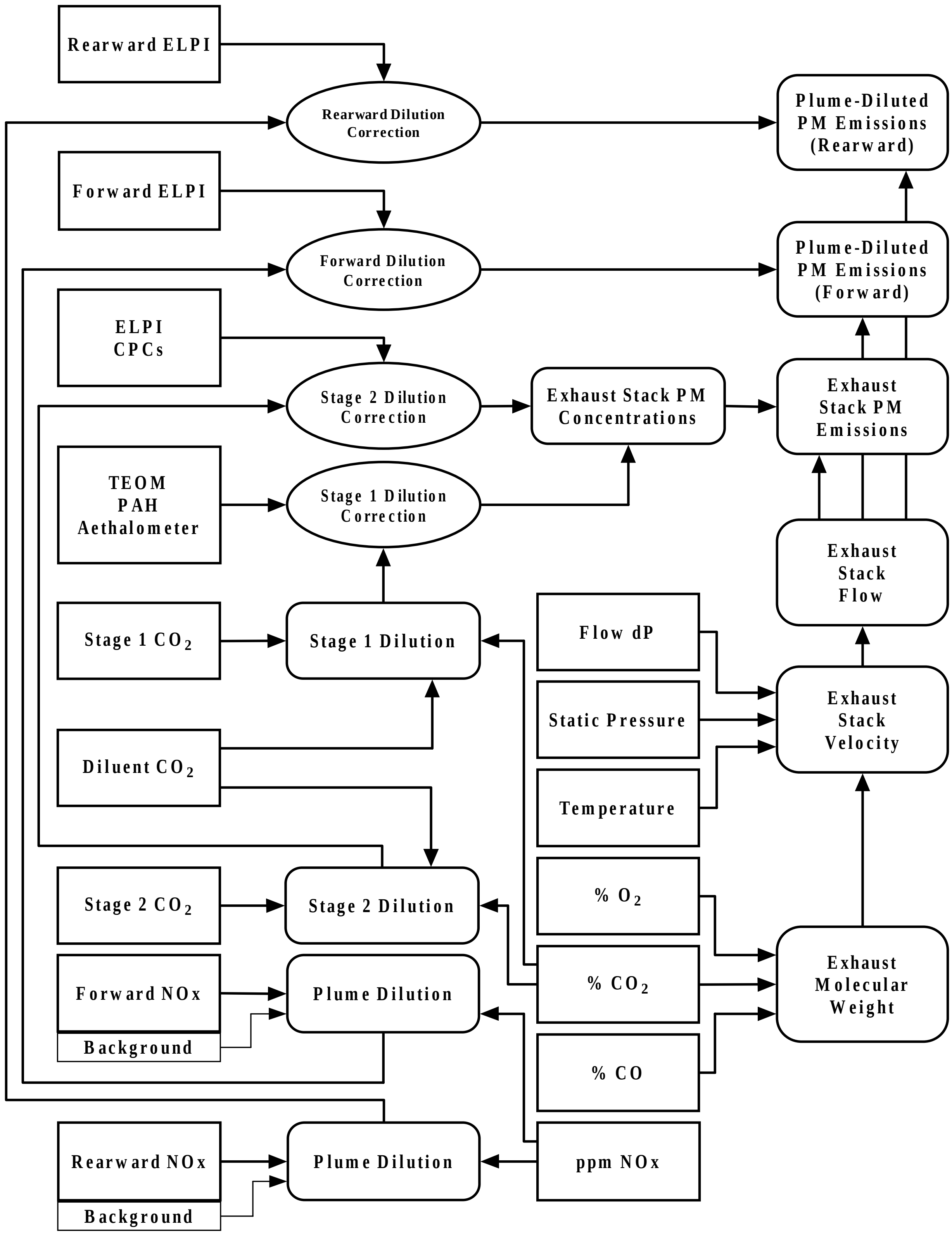


Figure B-3. Fine PM Data Calculations.

can simply be multiplied by the measured PM concentrations to get "as corrected" values which would be compatible with the exhaust flow measurements.

B.3 Types of Tests and Data

In general, different test series prove valuable for different types of comparisons. The parametric tests help identify general emissions trends under steady-state condition; these are also the tests that show the best data repeatability. The only transient tests that are done in a repetitious/parametric fashion are the level-grade accelerations and the dynamometer sequence tests. The data from these tests is less repeatable, but provide some insight nonetheless. For obvious reasons, the parametric test runs are bracketed by transients in the data files, and these transients are essential to time-aligning the data and identifying the parametric test intervals in the data.

Early in the project, some more realistic "route" tests were performed locally (i.e., with local grade variation contributing to data variability). The routes consisted of a "delivery" route which went through downtown Raleigh, an "urban interstate" route which traversed the entire Triangle area along I-40, and a "terminal entry/exit" segment that connected our staging area to the highway (it was assumed that the distance and traffic situation between Jenkins Road and I-40 is comparable to a commercial truck terminal; this assumption proved convenient for sequencing the tests in a realistic manner). The route tests were performed in triplicate for each load with the first two test trucks (Ford_9 and Frghtlnr). However, these tests proved very time consuming, and there was no straightforward way to interpret the data (too many input variable varying independently of one another). The only local tests that are now performed are shakedown exercises and sample collections (e.g., dioxin samples and filters for the fine PM lab). These tests are still valuable where "reality" is the primary consideration.

The original goal of the heavy-duty on-road emissions program was to compare emissions to operating parameters in a way that could lead to a modal emissions model. Parameters of interest were primarily those affecting power demand: load, grade, speed, and acceleration. The modal model goal is also applicable to fine PM measurements, but the parameter list may need to be expanded because of the atmospheric transformations that affect how PM emissions relate to PM inventories and exposures.

Shortly after the project began experimenting with fine PM analyzers connected to dilution systems, studies began surfacing to suggest that the parameters of the dilution system (e.g., the dilution ratios and residence times) were affecting the PM measurements. Then, with the commencement of in-plume sampling, the on-road program introduced yet another set of variables (e.g., truck airspeed, distance between stack and sampling probe). From the perspective of parametric testing, the only experimental parameter that has been added is the sampling location.

B.4 Currently Available Data

Table B-5 summarizes the data that were collected and processed for the Kenworth tractor before its engine overhaul (KW1 test series). The spreadsheets are listed in chronological order. Many of them have been converted from Lotus 1-2-3 to Microsoft EXCEL for subsequent data processing; in the table, an "X" indicates that the spreadsheet exists in the indicated filetype. In the data channel columns, an "X" indicates that the data was collected and verified, a blank means that the data was not collected or was invalidated. For PM data, there is also a "D" tag which indicates data for which valid dilution data were not available.

As shown here, the earliest tests for KW1 involved some preliminary plume dilution characterization, where the first on-road PM data were collected during the DRI tunnel study. Where that study used a single ELPI to characterize the truck's emissions, subsequent tests (the duplicate level grade tests-the "00" series), used more than one ELPI to compare results at various sampling locations.

Table B-6 shows the tests that were done in cooperation with UC-Davis during their "$SiNO_X$" catalyst demonstration project. This abbreviated series of tests was conducted on a Freightliner "Century" series truck with a 2000-spec engine. The TEOM was first introduced during these tests. The CPCs and the Magee Aethalometer were also deployed for the first time during this study (the resulting data have not been fully processed or interpreted, hence the gray area). All of these instruments, as well as the PAH analyzer and an ELPI, were fed sample from the two-stage dilution system which was developed for KW1 testing. The plume sampling equipment was operated during a few of the tests, but these activities were limited because they were peripheral to UC-Davis' goals.

Table B-5. Pre-Rebuild Kenworth Data

Spreadsheet	Files			CEMs			Dilution				ELPIs				
C:\DIESEL\KW1\..	WK4	123	XLS	CO	NOx	THC	2 meter	6 meter	8 meter	11 meter	Cab/Box	2 meter	6 meter	8 meter	11 meter
..\EMPTY_0\3E0-SA	X			X	X	X									
..\EMPTY_0\3E0-GA	X			X	X	X									
..\EMPTY_0\3E0-V	X			X	X	X									
..\HALF_0\3H0-SA	X			[1]	X	[1]									
..\HALF_0\3H0-GA	X			[1]	[1]	[1]									
..\HALF_0\3H0-V	X			X	X	X				X					
..\FULL_0\3F0-V	X			X	X	[1]				X					
..\FULL_0\3F0-SA	X			X	X	[1]				X					
..\FULL_0\3F0-GA	X			X	X	[1]				X					
..\SEQUENCE\3F-SEQ		X	X	X	X	X				X					
..\TUNNEL\3DRI1-1	X		X	[2]	[2]	[3]									
..\TUNNEL\3DRI1-2	X		X	[2]	[2]	[3]									
..\TUNNEL\3DRI2-1	X		X	[2]	[2]	[3]				X					
..\TUNNEL\3DRI2-2	X		X	X	X	[3]				X					
..\TUNNEL\3DRI2-3	X		X	X	X	[3]				X					
..\TUNNEL\3DRI2-4	X		X	X	X	[3]				X					
..\FULL_3&6\3F3&6		X	X	X	X	X	X			X	X				
..\HALF_3&6\3H3&6		X	X	X	X	X	X			X	X				
..\MT_3&6\3E3&6		X	X	X	X	X	X			X	X				
..\FULL_00\3F00A		X	X	X	X	X	X			X					
..\FULL_00\3F00C		X	X	X	X	X	X			X	X	X			X
..\FULL_00\3F00V	X		X	X	X	X	X			X	X	X			X
..\HALF_00\3H00A		X	X	X	X	X	[1]			X					
..\HALF_00\3H00C		X	X	X	X	X	[1]			X	X	[2]			X
..\HALF_00\3H00V	X		X	X	X	X	[1]			X	X	[2]			X
..\EMPTY_00\3E00A		X	X	X	X	[1]	X			X					
..\EMPTY_00\3E00C		X	X	X	X	[1]	X			X	X	X			X
..\EMPTY_00\3E00V	X		X	X	X	[1]	X			X	X	X			X
..\FILTERS\3FIL1		X	X	X	X	X									
..\FILTERS\3FIL2		X	X	X	[1]	[1]									
..\FILTERS\3FIL3		X	X	X	[1]	[1]					X				
..\FILTERS\3FIL4		X	X	X	X	[1]	X				X				
..\FILTERS\3FIL5		X	X	X	X	[1]	X				[2]				
..\FILTERS\3FIL6		X	X	X	X	X					[2]				
..\FILTERS\3FIL7		X	X	X	X	[1]									
..\FILTERS\3FIL8		X	X	X	X	[1]	X								
..\FILTERS\3FIL9		X	X	X	X	[1]	X								
..\FILTERS\3FIL10		X	X	X	X	[1]	X			X					
..\DIOXIN\DIOXIN1\3DIOX1		X	X	X	X	[1]	X			[1]	X	X			[2]
..\DIOXIN\DIOXIN2\3DIOX2		X	X	X	X	X	X			X	X	X			X
..\DIOXIN\DIOXIN3\3DIOX3		X	X	X	X	[1]	X			X	[2]	X			X
..\DIOXIN\DIOXIN4\3DIOX4		X	X	X	X	[1]				X					

[1] Data Validation Error [2] Matching Flow or Dilution Data Not Available [3] Other Error

Table B-6. Century Data Summary

Spreadsheet	Files			CEMs		Dilution				ELPIs					Other			
C:\DIESEL\CENTURY1\..	WK4	123	XLS	CO	NOx	THC	2 meter	6 meter	8 meter	11 meter	Cab/Box	2 meter	6 meter	8 meter	11 meter	TEOM	CPCs	PAH	Magee
..\GRADES\4H-RTP0		X		X	X	[1]					X								
..\FULL\4F0		X	X	X	X	X					X					X			
..\HALF\4H0-1		X	X	X	X	X					X					X			
..\HALF\4H0-2		X	X	X	X	X				X	X					[2]			
..\HALF\4H0-3		X	X	X	X	X				X	X					X			
..\HALF\4XIDLE		X		X	X	[1]													
..\HALF\4H0-4		X	X	X	X	X					X					X			
..\GRADES\4H-RTP1		X	X	X	X	X					X					X			
..\GRADES\4H-RTP2		X	X	X	X	X				X	[2]				X	X			
..\SEQUENCE\4F-SEQ		X	X	X	X	X					[2]				[2]	[2]			

[1] Data Validation Error

[2] Matching Flow or Dilution Data Not Available

The post-rebuild Kenworth data (KW2 test series) are summarized in Table B-7. These tests included the full complement of cab-mounted analyzers, as well as on-road plume sampling. Unfortunately, due to an alteration of the truck exhaust stack, there is some doubt as to whether these most recent tests are comparable to the earlier tests. It does appear that the plume sample is more dilute than the 2 meter and 11 meter samples that have been collected before, making the data substantially less useful (among the recommendations that will be made in this report is repeating some of these tests). The use of the "8 meter" location reflects the project's goal of quantifying the plume dilution schedule at multiple points along the length of the trailer. Assuming that comparable data can be collected at each of the four available sampling locations, these data should lead to the development of a representative curve for truck plume dilution.

Table B-7. Post-Rebuild Kenworth Data

Spreadsheet	Files			CEMs			Dilution				ELPIs					Other			
C:\DIESEL\KW2\..	WK4	123	XLS	CO	NOx	THC	2 meter	6 meter	8 meter	11 meter	Cab/Box	2 meter	6 meter	8 meter	11 meter	TEOM	CPCs	PAH	Magee
..\XCOUNTRY\5E-XC1		X	X	X	[1]	[1]					[2]		[2]						
..\XCOUNTRY\5E-XC2		X	X	[2]	[2]	[1]	X	X				X	X						
..\XCOUNTRY\5E-XC3		X	X	[2]	[2]	[2]	X	X				X	X						
..\DIOXIN\REGFUEL\5DIOX1		X	X	X	X	[1]													
..\DIOXIN\REGFUEL\5DIOX2		X	X	X	[1]	[1]													
..\DIOXIN\REGFUEL\5DIOX3A		X	X	X	[1]	[1]													
..\DIOXIN\REGFUEL\5DIOX3B		X	X	X	X	[1]													
..\DIOXIN\REGFUEL\5DIOX4A		X	X	X	X	[1]													
..\DIOXIN\REGFUEL\5DIOX4B		X	X	X	X	[1]													
..\DIOXIN\REGFUEL\5DIOX5A		X	X	X	X	[1]													
..\DIOXIN\REGFUEL\5DIOX5B		X	X	X	X	[1]													
..\DIOXIN\REGFUEL\5DIOX6		X	X	X	X	[1]													
..\DIOXIN\REGFUEL\5DIOX7		X	X	X	X	[1]													
..\DIOXIN\REGFUEL\5DIOX8		X	X	X	X	[1]													
..\DIOXIN\LOWSFUEL\5DIOX9A		X	X	X	X	[1]													
..\DIOXIN\LOWSFUEL\5DIOX9B		X	X	X	X	[1]													
..\DIOXIN\LOWSFUEL\5DIOX10A		X	X	X	X	[1]													
..\DIOXIN\LOWSFUEL\5DIOX10B		X	X	X	X	[1]													
..\DIOXIN\LOWSFUEL\5DIOX11A		X	X	X	X	[1]													
..\DIOXIN\LOWSFUEL\5DIOX11B		X	X	X	X	[1]													
..\PLUME\5PLUME1		X	X	X	X	[1]	X			[1]		X			[2]				
..\PLUME\5PLUME2A		X	X	X	X	[1]	X			[1]									
..\PLUME\5PLUME2B		X	X	X	X	[1]	X			[1]									
..\FULL_3&6\5F3&6A		X	X	X	X	[1]	X				[2]	X				[2]			
..\FULL_3&6\5F3&6B		X	X	X	X	X	X				[2]	X				[2]			
..\HALF_3&6\5H3&6A		X	X	X	X	X	X				X	X				X			
..\HALF_3&6\5H3&6B		X	X	X	X	X	X				X	X				X			
..\MT_3&6\5E3&6		X	X	X	X	X	X				X	X				[2]			
..\FULL_0\5F0C		X	X	X	X	X	[3]		[3]		[2]	[2]		[2]		[2]			
..\FULL_0\5F0V		X	X	X	X	X	X		[3]		X	X		[2]		X			
..\HALF_0\5H0C		X	X	X	X	[1]	[3]		[3]		X	[2]		[2]		X			
..\HALF_0\5H0V		X	X	X	X	[1]	X		[3]		X	[3]		[3]		X			
..\MT_0\5E0C		X	X	X	X	X	[3]		[3]		X	X		[2]		X			
..\MT_0\5E0V		X	X	X	X	X	X		[3]		X	X		[2]		X			
..\SEQUENCE\5F-SEQ		X	X	X	[1]	[1]	[3]		[3]		[2]	[2]		[2]		[2]			
..\SEQUENCE\5F-SEQ2		X	X	X	X	X	[3]		[1]		[2]	[2]		[2]		[2]			
..\PLUMECPC\5F-CPC1		X		X	X	[1]	[3]		[3]			[2]		[2]					
..\PLUMECPC\5F-CPC2		X		X	X	[1]	X		[3]			X		[2]					

[1] Data Validation Error   [2] Matching Flow or Dilution Data Not Available   [3] Other Error

Appendix C

Processed Data Summaries

DIESEL VEHICLE ROAD TESTING SUMMARY Date: 08/31/99

Source Description: 1990 Kenworth with Detroit Diesel Series 60 Engine Empty Truck Weight ==> 42840 Lb

Test Number:	3F3&6	Grades	3% & 6%
Operator(s):	JEB,FGK	Load Weight	36440 Lb
Test Start Time:	0:17:43	Force Constant, F0	447.7 Lb
Test Stop Time:	3:16:37	Force Coefficient, F2	0.2053 Lb/mph^2

			Vehicle Operating Parameters			Carbon Monoxide		Nitrogen Oxides		Hydrocarbons (as C)		Dil Sampler	Plume Dilution	
Test Description	Start Time	Stop TIme	Engine RPM	Truck MPH	Measured HP	ppm dry	g/hour	ppm dry	g/hour	ppm wet	g/hour	Cab ELPI ı.d.s. mg/m^3	Ratio @ 2 meters	Ratio @ 11 meters
3.1% Grade Steady State	0:37:53	0:38:34	1966	43.9	360.5	515	796	966	2459	6.9	5.7	#N/A	1930	312
6.0% Grade Steady State	0:40:13	0:41:12	1892	29.9	353.0	551	829	1030	2534	7.1	5.7	#N/A	3912	1106
6.0% Grade Steady State	0:47:59	0:48:26	1886	29.8	358.0	544	829	1022	2560	8.2	6.7	#N/A	2866	778
3.1% Grade Steady State	0:55:36	0:56:27	2122	47.4	358.3	436	697	974	2556	7.8	6.7	#N/A	1505	310
6.0% Grade Steady State	0:58:26	1:00:50	1840	15.1	179.7	200	202	509	840	7.8	4.1	#N/A	1825	832
6.0% Grade Steady State	1:11:35	1:12:35	1904	30.1	346.5	567	865	919	2311	9.5	7.8	#N/A	2849	660
3.1% Grade Steady State	1:18:42	1:21:15	1928	15.8	107.2	174	141	473	629	11.1	4.7	#N/A	1013	723
6.0% Grade Steady State	1:23:21	1:24:49	1883	29.7	346.4	535	805	935	2312	9.2	7.4	#N/A	2153	920
6.0% Grade Steady State	1:32:24	1:33:59	1975	16.2	183.9	169	188	499	907	9.4	5.5	#N/A	3811	752
3.1% Grade Steady State	1:40:13	1:41:18	2177	34.5	208.5	148	197	980	2135	6.9	4.9	43	1835	455
6.0% Grade Steady State	1:43:45	1:45:58	1936	15.6	175.1	178	197	494	901	8.2	4.8	71	1449	651
6.0% Grade Steady State	1:53:44	1:55:09	1901	15.3	69.6	189	200	518	898	8.2	4.6	71	2957	728
3.1% Grade Steady State	2:01:48	2:04:20	1840	15.0	102.6	179	139	514	656	10.7	4.3	30	2150	928
6.0% Grade Maximum	2:06:17	2:07:09	1724	45.3	285.8	653	863	793	1732	8.1	5.3	94	214	283
6.0% Grade Maximum	2:13:43	2:14:14	1833	56.4	0.0	538	759	837	1989	7.8	6.0	94	211	175
3.1% Grade Steady State	2:20:26	2:21:19	2177	34.7	245.3	140	187	993	2163	6.5	4.5	55	570	319
6.0% Grade Maximum	2:22:39	2:23:30	1798	49.9	289.5	628	850	759	1739	11.2	7.6	100	155	223
6.0% Grade Maximum	2:30:03	2:30:47	1533	52.0	236.0	1062	1246	845	1701	7.0	4.4	117	105	230
3.1% Grade Steady State	2:36:52	2:39:09	1997	16.4	43.3	168	146	463	657	9.3	4.2	42	2898	751
6.0% Grade Maximum	2:40:53	2:41:49	1698	50.3	253.0	721	946	820	1767	5.7	3.9	106	164	228
6.0% Grade Maximum	2:47:54	2:48:35	1838	55.4	269.7	714	970	697	1582	6.5	4.2	132	104	167
3.1% Grade Steady State	2:55:00	2:56:48	1614	25.7	167.4	283	261	645	970	6.1	2.9	73	1745	576

DIESEL VEHICLE ROAD TESTING SUMMARY Date: 08/31/99

Source Description: 1990 Kenworth with Detroit Diesel Series 60 Engine Empty Truck Weight ==> 42840 Lb

Test Number:	3H3&6	Grades	3% & 6%
Operator(s):	JEB,FGK	Load Weight	18220 Lb
Test Start Time:	21:00:55	Force Constant, F0	399.4 Lb
Test Stop Time:	23:58:29	Force Coefficient, F2	0.2152 Lb/mph²

			Vehicle Operating Parameters			Carbon Monoxide		Nitrogen Oxides		Hydrocarbons (as C)		Dil Sampler	Plume Dilution	
Test Description	Start Time	Stop TIme	Engine RPM	Truck MPH	Measured HP	ppm dry	g/hour	ppm dry	g/hour	ppm wet	g/hour	Cab ELPI u.d.s. g/hr	Ratio @ 2 meters	Ratio @ 11 meters
3.1% Grade Steady State	21:14:18	21:15:34	1644	51.9	285.6	765	1018	866	1890	5.2	3.5	53	#NUM!	#NUM!
6.0% Grade Steady State	21:17:19	21:17:54	1720	38.3	327.4	627	862	1049	2376	4.2	3.1	69	2616	612
6.0% Grade Steady State	21:26:29	21:27:29	1921	15.6	133.2	194	169	520	741	6.3	2.9	47	1649	503
3.1% Grade Steady State	21:35:36	21:36:36	1870	15.4	87.0	319	286	506	633	13.8	5.3	22	385	461
6.0% Grade Steady State	21:38:57	21:39:32	1482	32.9	284.7	1196	1316	1138	2121	6.0	3.7	76	901	536
6.0% Grade Steady State	21:46:34	21:47:15	1538	34.2	296.8	1229	1497	996	1988	6.6	4.3	84	819	398
3.1% Grade Steady State	21:53:07	21:54:07	1591	35.4	191.9	375	363	653	1028	3.9	2.0	71	162	228
6.0% Grade Steady State	21:58:07	21:59:07	1379	15.3	150.8	455	471	944	1598	19.0	10.5	67	1205	646
6.0% Grade Steady State	22:06:20	22:06:52	1604	35.6	310.8	801	1008	937	1943	19.7	13.5	79	1496	480
3.1% Grade Steady State	22:13:17	22:13:38	1650	51.9	317.6	624	829	922	2012	13.8	9.9	72	252	195
6.0% Grade Steady State	22:16:53	22:17:28	2201	17.7	166.0	110	117	1001	1748	14.0	7.9	29	787	713
6.0% Grade Steady State	22:25:10	22:25:36	2206	17.7	164.6	117	123	828	1431	10.8	6.0	35	1351	713
3.1% Grade Steady State	22:34:12	22:35:12	1365	15.2	80.0	137	121	912	1327	12.7	5.9	11	127	445
3.1% Grade Steady State	22:50:58	22:51:37	1589	35.2	182.2	309	292	621	960	6.7	3.4	72	122	183
3.1% Grade Steady State	23:07:13	23:08:13	1403	15.6	83.3	129	105	849	1126	10.6	4.5	16	146	354
3.1% Grade Steady State	23:23:38	23:24:16	1669	52.4	320.9	593	807	860	1928	5.8	4.3	75	205	177
3.1% Grade Steady State	23:38:36	23:39:32	1600	35.5	183.6	353	342	591	934	6.3	3.2	80	115	153

DIESEL VEHICLE ROAD TESTING SUMMARY

Date: 09/01/99

Source Description: 1990 Kenworth with Detroit Diesel Series 60 Engine

Empty Truck Weight ==> 42840 Lb

Test Number:	3E3&6	Grades	3% & 6%
Operator(s):	JEB,FGK	Load Weight	0 Lb
Test Start Time:	20:51:06	Force Constant, F0	293.0 Lb
Test Stop Time:	23:40:35	Force Coefficient, F2	0.2093 Lb/mph²

			Vehicle Operating Parameters			Carbon Monoxide		Nitrogen Oxides		Hydrocarbons (as C)		Dil Sampler	Plume Dilution	
Test Description	Start Time	Stop TIme	Engine RPM	Truck MPH	Measured HP	ppm dry	g/hour	ppm dry	g/hour	ppm wet	g/hour	Cab ELPI ı.d.s. mg/m³	Ratio @ 2 meters	Ratio @ 11 meters
3.1% Grade Steady State	21:03:40	21:04:21	1807	57.2	349.0	834	1212	875	2141	7.8	6.2	100	172	188
6.0% Grade Lugging	21:06:00	21:07:03	1370	43.2	282.0	1838	1994	1087	1944	6.8	4.0	110	168	319
6.0% Grade Steady State	21:14:12	21:14:52	2144	48.1	324.8	472	746	943	2387	7.1	5.9	108	1201	442
3.1% Grade Steady State	21:20:10	21:21:20	2204	35.5	150.9	136	139	659	1103	8.1	4.3	43	143	235
6.0% Grade Steady State	21:23:11	21:23:57	2175	34.8	231.0	174	218	1060	2173	9.2	6.1	44	353	265
6.0% Grade Steady State	21:31:46	21:33:18	1832	15.0	95.2	218	146	540	588	12.6	4.4	23	803	633
6.0% Grade Steady State	21:42:45	21:43:45	1790	14.6	98.3	188	118	550	565	11.8	3.9	24	#N/A	#N/A
6.0% Grade Steady State	21:50:10	21:50:38	1595	35.5	251.4	597	676	649	1208	8.3	5.0	98	#N/A	#N/A
3.1% Grade Steady State	21:56:48	21:59:01	1879	15.4	59.0	320	181	450	417	26.4	7.7	6	#N/A	#N/A
6.0% Grade Steady State	22:01:01	22:01:46	2140	47.8	344.8	446	710	949	2481	9.4	8.0	88	#N/A	#N/A
6.0% Grade Steady State	22:07:59	22:08:27	1591	35.5	231.3	533	575	666	1176	8.7	5.1	80	#N/A	#N/A
3.1% Grade Steady State	22:14:27	22:15:20	1557	35.0	143.6	244	196	723	944	9.5	4.0	35	#N/A	#N/A
6.0% Grade Steady State	22:17:33	22:20:09	1772	14.4	93.6	193	121	553	567	13.0	4.3	19	#N/A	#N/A
6.0% Grade Steady State	22:26:48	22:27:25	2144	48.0	409.6	442	706	908	2290	8.3	6.9	90	#N/A	#N/A
3.1% Grade Steady State	22:33:04	22:35:37	1816	14.6	71.7	315	164	464	396	27.4	7.4	5	#N/A	#N/A
6.0% Grade Maximum	22:37:22	22:38:04	1706	53.8	428.0	636	885	925	2122	9.3	7.1	75	#N/A	#N/A
6.0% Grade Maximum	22:43:56	22:44:19	1766	55.7	437.1	609	888	846	2021	8.2	6.4	89	#N/A	#N/A
3.1% Grade Steady State	22:50:16	22:51:17	2210	35.3	186.2	134	136	609	1017	9.9	5.3	36	#N/A	#N/A
6.0% Grade Maximum	22:52:47	22:53:26	1707	53.8	431.8	598	841	894	2069	7.3	5.6	79	#N/A	#N/A
6.0% Grade Maximum	22:59:10	22:59:40	1626	57.5	387.4	1011	1283	812	1694	6.3	4.3	97	#N/A	#N/A
3.1% Grade Steady State	23:05:00	23:05:35	1896	59.9	372.8	252	369	520	1245	9.0	7.0	81	#N/A	#N/A
6.0% Grade Maximum	23:06:51	23:07:34	1780	56.0	438.5	544	797	878	2116	9.9	7.9	72	#N/A	#N/A

DIESEL VEHICLE ROAD TESTING SUMMARY

Date: 10/07/99

Source Description: 1990 Kenworth with Detroit Diesel Series 60 Engine

Empty Truck Weight ==> 42840 Lb

Test Number:	3F00-A	Grades	Level
Operator(s):	MC,FGK	Load Weight	0 Lb
Test Start Time:	10:44:43	Force Constant, F0	270.1 Lb
Test Stop Time:	13:09:56	Force Coefficient, F2	0.1802 Lb/mph²

			Vehicle Operating Parameters			Carbon Monoxide		Nitrogen Oxides		Hydrocarbons (as C)		Dil Sampler	Plume Dilution			
Test Description	Start Time	Stop TIme	Engine RPM	Truck MPH	Measured HP	ppm dry	g/hour	ppm dry	g/hour	ppm wet	g/hour	Cab ELPI u.d.s. g/hr	Ratio @ 2 meters	2m ELPI u.d.s. g/hr	Ratio @ 11 meters	11m ELPI u.d.s. g/hr
Governed (normal) Accel	10:55:30	10:57:17	1811	38.2	0.0	615	773	714	1593	11.9	7.3	130	(574)	(736)	(965)	(70)
Short-shift Acceleration	11:05:33	11:07:41	1512	38.8	0.0	692	762	790	1474	9.3	5.0	1355	214	430	551	305
Short-shift Acceleration	11:19:29	11:21:23	1515	37.8	0.0	747	834	782	1493	11.2	6.0	128	1102	1816	1233	67
Short-shift Acceleration	11:29:16	11:31:20	1513	39.6	0.0	724	825	799	1544	8.6	4.7	126	236	503	757	287
Governed (normal) Accel	11:43:04	11:44:54	1797	38.8	0.0	613	742	713	1526	10.7	6.5	141	3848	5867	1468	94
Governed (normal) Accel	11:53:04	11:54:50	1823	38.9	0.0	585	740	716	1576	9.2	5.8	136	161	323	737	412
Short-shift Acceleration	12:06:45	12:08:50	1551	36.6	0.0	685	741	749	1411	10.4	5.5	116	2103	3179	764	39
Short-shift Acceleration	12:17:05	12:19:25	1529	36.9	0.0	565	607	722	1294	9.9	5.0	89	154	286	550	186
Governed (normal) Accel	12:31:11	12:32:58	1779	37.1	0.0	633	747	696	1490	12.4	7.2	154	(268)	(408)	1629	97
Governed (normal) Accel	12:41:20	12:43:13	1774	38.5	0.0	585	707	701	1498	9.7	5.7	140	312	620	717	338
Short-shift Acceleration	12:55:21	12:57:10	1528	35.6	0.0	722	781	770	1440	9.7	5.0	134	3296	4394	1415	589
Governed (normal) Accel	13:05:16	13:07:08	1802	40.3	0.0	593	733	723	1549	9.3	5.6	145	160	363	709	338

DIESEL VEHICLE ROAD TESTING SUMMARY

Date: 10/07/99

Source Description: 1990 Kenworth with Detroit Diesel Series 60 Engine

Empty Truck Weight ==> 42840 Lb

Test Number:	3F00-V	Grades	Level
Operator(s):	MC,FGK	Load Weight	0 Lb
Test Start Time:	16:03:01	Force Constant, F0	270.1 Lb
Test Stop Time:	17:25:20	Force Coefficient, F2	0.1802 Lb/mph²

			Vehicle Operating Parameters			Carbon Monoxide		Nitrogen Oxides		Hydrocarbons (as C)		Dil Sampler	Plume Dilution			
Test Description	Start Time	Stop TIme	Engine RPM	Truck MPH	Measured HP	ppm dry	g/hour	ppm dry	g/hour	ppm wet	g/hour	Cab ELPI u.d.s. g/hr	Ratio @ 2 meters	2m ELPI u.d.s. g/hr	Ratio @ 11 meters	11m ELPI u.d.s. g/hr
Steady State Test	16:06:02	16:06:25	1530	34.6	95.7	149	99	671	731	13.3	4.6	17	(785)	(49)	(7156)	(216)
Steady State Test	16:07:36	16:08:44	1738	55.4	157.2	92	66	951	1124	9.0	3.4	18	52	26	315	31
Steady State Test	16:09:29	16:10:28	1512	34.2	70.0	210	126	566	559	16.9	5.3	7	48	8	204	12
Steady State Test	16:11:40	16:12:39	1787	57.0	168.3	93	70	932	1158	8.8	3.5	21	52	30	238	31
Steady State Test	16:15:56	16:16:55	1737	55.4	166.1	91	67	949	1154	8.6	3.4	20	40	28	179	29
Steady State Test	16:17:36	16:18:35	1545	35.0	71.4	216	127	525	506	17.9	5.4	8	43	10	257	17
Steady State Test	16:19:46	16:20:44	1730	55.1	162.3	92	68	964	1181	8.6	3.4	19	40	28	188	29
Steady State Test	16:26:26	16:27:25	1696	65.0	203.6	110	89	995	1310	7.0	3.0	33	44	45	200	45
Steady State Test	16:28:27	16:29:26	1887	15.7	25.2	278	144	290	247	29.5	7.8	5	(457)	(14)	625	20
Steady State Test	16:30:53	16:31:52	1731	55.2	150.6	91	65	923	1077	9.3	3.5	18	44	25	225	29
Steady State Test	16:35:57	16:36:56	1699	65.0	226.5	131	118	979	1446	7.0	3.3	42	39	62	156	58
Steady State Test	16:37:46	16:38:40	1541	34.9	69.8	211	119	511	473	17.5	5.1	9	44	9	218	13
Steady State Test	16:40:19	16:41:18	1701	65.1	203.0	115	93	979	1286	8.0	3.4	30	39	47	175	46
Steady State Test	16:44:58	16:45:57	1676	64.2	195.7	107	82	973	1218	7.0	2.8	29	53	43	252	43
Steady State Test	16:46:51	16:47:50	2004	16.7	28.0	277	174	281	291	29.6	9.5	10	(355)	(40)	532	52
Steady State Test	16:48:30	16:49:29	1564	35.4	71.0	181	96	507	442	17.1	4.7	11	50	12	220	17
Steady State Test	16:50:25	16:51:24	1814	15.1	21.6	289	150	273	234	35.1	9.3	6	(354)	(12)	767	24
Steady State Test	16:55:57	16:56:56	1529	34.4	73.6	148	81	784	703	15.5	4.4	7	44	5	239	11
Steady State Test	16:57:36	16:58:35	1824	15.1	25.4	345	183	284	247	39.6	10.7	4	99	5	350	16
Steady State Test	17:00:13	17:01:12	1733	55.2	171.8	94	70	952	1167	10.3	4.0	22	44	31	218	33
Steady State Test	17:02:08	17:03:02	1911	15.9	26.8	337	208	272	276	39.3	12.4	6	157	8	383	15
Steady State Test	17:08:54	17:09:53	1704	65.3	184.0	92	73	974	1257	8.1	3.4	28	47	37	205	40

Source Description: 1990 Kenworth with Detroit Diesel Series 60 Engine

Empty Truck Weight ==> 42840 Lb

Test Number:	3H00-A	Grades	Level
Operator(s):	MC, RL, FGK	Load Weight	0 Lb
Test Start Time:	8:35:52	Force Constant, F0	270.1 Lb
Test Stop Time:	11:03:34	Force Coefficient, F2	0.1802 Lb/mph²

			Vehicle Operating Parameters			Carbon Monoxide		Nitrogen Oxides		Hydrocarbons (as C)		Dil Sampler	Plume Dilution			
Test Description	Start Time	Stop TIme	Engine RPM	Truck MPH	Measured HP	ppm dry	g/hour	ppm dry	g/hour	ppm wet	g/hour	Cab ELPI u.d.s. g/hr	Ratio @ 2 meters	2m ELPI u.d.s. g/hr	Ratio @ 11 meters	11m ELPI u.d.s. g/hr
Short-shift Acceleration	8:47:25	8:49:12	1526	35.1	212.7	579	637	715	1320	15.9	7.4	56	#N/A	#N/A	414	211
Governed (normal) Accel	8:56:57	8:58:25	1787	35.8	238.0	613	731	649	1389	14.9	8.3	4	#N/A	#N/A	247	256
Short-shift Acceleration	9:14:33	9:16:10	1518	36.2	219.2	650	717	699	1297	13.7	6.7	2	#N/A	#N/A	358	259
Governed (normal) Accel	9:23:46	9:25:13	1779	35.8	243.8	626	745	638	1367	13.3	7.4	106	#N/A	#N/A	336	285
Governed (normal) Accel	9:37:03	9:38:28	1760	35.0	238.9	644	761	640	1371	14.0	7.9	117	#N/A	#N/A	639	366
Short-shift Acceleration	9:48:51	9:50:34	1535	35.9	219.5	604	686	711	1339	15.4	7.7	76	#N/A	#N/A	(275)	(231)
Governed (normal) Accel	10:02:03	10:03:32	1723	37.0	234.9	659	749	652	1348	13.5	7.5	115	#N/A	#N/A	419	339
Short-shift Acceleration	10:04:09	10:12:51	976	30.7	86.3	284	266	376	559	15.9	4.6	34	#N/A	#N/A	(286)	(47)
Short-shift Acceleration	10:24:41	10:25:59	1540	32.0	218.3	683	761	678	1317	13.4	6.9	109	#N/A	#N/A	(493)	(375)
Short-shift Acceleration	10:33:45	10:35:22	1562	36.5	226.9	651	718	682	1301	11.7	5.9	99	#N/A	#N/A	(282)	(238)
Governed (normal) Accel	10:47:41	10:49:11	1794	36.7	233.7	638	733	634	1307	13.7	7.6	133	#N/A	#N/A	(700)	(510)
Governed (normal) Accel	10:56:29	10:58:00	1769	37.8	243.6	641	762	643	1354	11.5	6.6	142	#N/A	#N/A	322	312

DIESEL VEHICLE ROAD TESTING SUMMARY Date: 10/08/99

Source Description: 1990 Kenworth with Detroit Diesel Series 60 Engine

Empty Truck Weight ==> 42840 Lb

Test Number:	3H00-V	Grades	Level
Operator(s):	MC, RL, FGK	Load Weight	0 Lb
Test Start Time:	12:33:39	Force Constant, F0	270.1 Lb
Test Stop Time:	13:42:46	Force Coefficient, F2	0.1802 Lb/mph²

			Vehicle Operating Parameters			Carbon Monoxide		Nitrogen Oxides		Hydrocarbons (as C)		Dil Sampler	Plume Dilution			
Test Description	Start Time	Stop TIme	Engine RPM	Truck MPH	Measured HP	ppm dry	g/hour	ppm dry	g/hour	ppm wet	g/hour	Cab ELPI u.d.s. g/hr	Ratio @ 2 meters	2m ELPI u.d.s. g/hr	Ratio @ 11 meters	11m ELPI u.d.s. g/hr
Steady State Test	12:35:25	12:35:56	2047	65.1	251.6	106	112	934	1607	10.9	6.1	#N/A	#N/A	#N/A	234	103
Steady State Test	12:38:04	12:39:26	1690	64.5	186.1	108	85	987	1253	9.0	3.7	#N/A	#N/A	#N/A	238	57
Steady State Test	12:40:18	12:41:01	1725	54.8	133.4	88	62	923	1066	10.1	3.7	#N/A	#N/A	#N/A	286	32
Steady State Test	12:42:13	12:43:12	1683	64.3	171.5	95	69	1000	1190	8.5	3.3	#N/A	#N/A	#N/A	261	43
Steady State Test	12:49:54	12:50:53	1717	65.6	201.8	108	85	947	1210	6.9	2.8	29	#N/A	#N/A	287	66
Steady State Test	12:53:53	12:54:51	1889	15.7	21.9	261	131	293	240	27.3	7.0	7	#N/A	#N/A	(7696)	(287)
Steady State Test	12:56:14	12:57:13	1721	54.8	124.8	88	59	887	970	9.9	3.5	19	#N/A	#N/A	246	31
Steady State Test	12:57:44	12:58:43	1561	35.3	57.1	209	107	469	394	18.0	4.8	13	#N/A	#N/A	(476)	(27)
Steady State Test	12:59:24	13:00:23	2015	16.8	23.0	301	178	273	267	34.3	10.4	9	#N/A	#N/A	(8186)	(610)
Steady State Test	13:01:10	13:02:09	1550	35.1	57.9	191	101	502	434	20.0	5.5	14	#N/A	#N/A	(486)	(31)
Steady State Test	13:02:58	13:03:56	1893	15.7	22.5	276	162	302	290	31.6	9.5	8	#N/A	#N/A	(25892)	(1810)
Steady State Test	13:07:42	13:08:41	1721	54.8	147.3	81	52	934	992	9.3	3.2	22	#N/A	#N/A	256	30
Steady State Test	13:09:19	13:10:18	1560	35.3	60.5	202	88	487	349	18.9	4.2	8	#N/A	#N/A	583	47
Steady State Test	13:11:43	13:12:41	1699	65.0	199.0	108	85	969	1246	7.2	3.0	33	#N/A	#N/A	265	67
Steady State Test	13:13:15	13:13:49	1715	54.7	134.4	146	105	477	565	8.5	3.2	52	#N/A	#N/A	357	134
Steady State Test	13:16:27	13:17:26	1734	55.2	144.8	82	55	904	1005	8.6	3.0	24	#N/A	#N/A	269	34
Steady State Test	13:18:12	13:19:11	1546	35.0	50.6	237	115	436	347	20.4	5.1	10	#N/A	#N/A	(1084)	(43)
Steady State Test	13:21:17	13:22:16	1672	64.0	176.6	97	72	986	1203	7.3	2.9	24	#N/A	#N/A	286	48
Steady State Test	13:25:07	13:26:06	1730	55.2	133.8	85	54	898	948	8.1	2.7	20	#N/A	#N/A	367	35
Steady State Test	13:26:56	13:27:55	1877	15.6	20.7	290	178	279	281	30.6	9.6	8	#N/A	#N/A	(9631)	(493)
Steady State Test	13:28:43	13:29:42	1505	34.0	59.4	198	112	536	501	17.7	5.2	13	#N/A	#N/A	(463)	(33)
Steady State Test	13:30:24	13:31:23	1906	15.8	21.0	339	202	274	268	37.7	11.5	6	#N/A	#N/A	(3733)	(161)

DIESEL VEHICLE ROAD TESTING SUMMARY Date: 10-13-99

Source Description: 1990 Kenworth with Detroit Diesel Series 60 Engine

Empty Truck Weight ==> 42840 Lb

Test Number:	3E00-A
Operator(s):	JEB,FGK
Test Start Time:	9:10:28
Test Stop Time:	11:32:33

Grades	Level
Load Weight	0 Lb
Force Constant, F0	293.0 Lb
Force Coefficient, F2	0.2093 Lb/mph²

			Vehicle Operating Parameters			Carbon Monoxide		Nitrogen Oxides		Hydrocarbons (as C)		Dil Sampler	Plume Dilution			
Test Description	Start Time	Stop TIme	Engine RPM	Truck MPH	Measured HP	ppm dry	g/hour	ppm dry	g/hour	ppm wet	g/hour	Cab ELPI u.d.s. g/hr	Ratio @ 2 meters	2m ELPI u.d.s. g/hr	Ratio @ 11 meters	11m ELPI u.d.s. g/hr
Governed (normal) Accel	9:20:50	9:21:58	1796	33.7	211.7	722	826	563	1143	#VALUE!	#VALUE!	46	329	335	396	463
Governed (normal) Accel	9:29:44	9:30:50	1792	33.3	212.2	727	824	553	1125	#VALUE!	#VALUE!	53	247	348	315	550
Short-shift Acceleration	9:48:30	9:49:59	1503	32.1	174.9	564	616	597	1042	#VALUE!	#VALUE!	31	172	202	337	428
Governed (normal) Accel	9:58:14	9:59:20	1788	34.2	216.3	717	861	532	1141	#VALUE!	#VALUE!	69	220	349	287	547
Governed (normal) Accel	10:10:19	10:11:26	1787	33.2	210.4	726	849	517	1092	#VALUE!	#VALUE!	67	277	402	343	545
Short-shift Acceleration	10:19:21	10:20:40	1501	33.5	194.3	657	736	598	1109	#VALUE!	#VALUE!	50	133	215	248	400
Short-shift Acceleration	10:32:00	10:33:34	1502	37.8	181.2	562	605	617	1059	#VALUE!	#VALUE!	43	120	187	418	503
Governed (normal) Accel	10:40:56	10:42:03	1771	33.3	212.3	704	823	525	1080	#VALUE!	#VALUE!	72	251	430	438	716
Governed (normal) Accel	10:53:31	10:54:37	1778	33.4	211.1	717	856	520	1105	#VALUE!	#VALUE!	81	282	510	353	643
Short-shift Acceleration	11:02:33	11:03:52	1505	34.2	192.2	661	730	609	1123	#VALUE!	#VALUE!	59	109	202	287	444
Short-shift Acceleration	11:15:08	11:16:27	1459	33.1	184.6	716	775	618	1125	#VALUE!	#VALUE!	62	160	280	332	479
Short-shift Acceleration	11:23:51	11:25:11	1492	34.3	193.9	700	773	615	1142	#VALUE!	#VALUE!	67	97	200	264	445

DIESEL VEHICLE ROAD TESTING SUMMARY

Date: 10-13-99

Source Description: 1990 Kenworth with Detroit Diesel Series 60 Engine

Empty Truck Weight ==> 42840 Lb

Test Number:	3E00-V	Grades	Level
Operator(s):	JEB,FGK	Load Weight	0 Lb
Test Start Time:	12:10:07	Force Constant, F0	270.1 Lb
Test Stop Time:	13:25:38	Force Coefficient, F2	0.1802 Lb/mph²

			Vehicle Operating Parameters			Carbon Monoxide		Nitrogen Oxides		Hydrocarbons (as C)		Dil Sampler	Plume Dilution			
Test Description	Start Time	Stop TIme	Engine RPM	Truck MPH	Measured HP	ppm dry	g/hour	ppm dry	g/hour	ppm wet	g/hour	Cab ELPI u.d.s. g/hr	Ratio @ 2 meters	2m ELPI u.d.s. g/hr	Ratio @ 11 meters	11m ELPI u.d.s. g/hr
Steady State Test	12:21:44	12:22:43	1734	55.2	139.6	109	82	863	1070	#VALUE!	#VALUE!	11	43	23	221	46
Steady State Test	12:23:41	12:24:40	1699	64.9	182.7	119	100	908	1247	#VALUE!	#VALUE!	17	44	40	231	77
Steady State Test	12:25:22	12:26:21	1725	54.9	112.2	127	91	819	958	#VALUE!	#VALUE!	9	40	16	182	32
Steady State Test	12:27:18	12:28:17	1902	15.8	17.0	432	299	227	258	#VALUE!	#VALUE!	3	(518)	(30)	(581)	(43)
Steady State Test	12:29:42	12:30:41	1748	55.6	128.6	110	82	855	1051	#VALUE!	#VALUE!	10	38	19	185	36
Steady State Test	12:31:33	12:32:32	1906	15.8	19.2	447	315	230	267	#VALUE!	#VALUE!	3	(1216)	(29)	(1632)	(35)
Steady State Test	12:35:37	12:36:36	1494	34.1	55.0	286	167	493	473	#VALUE!	#VALUE!	5	46	5	178	15
Steady State Test	12:37:51	12:38:49	1714	54.8	117.5	123	87	830	966	#VALUE!	#VALUE!	8	40	16	186	34
Steady State Test	12:39:51	12:40:50	1829	15.1	17.4	452	306	224	248	#VALUE!	#VALUE!	3	(1476)	(51)	(556)	(24)
Steady State Test	12:42:39	12:43:38	1696	64.7	164.9	106	85	889	1162	#VALUE!	#VALUE!	13	42	29	210	58
Steady State Test	12:46:40	12:47:39	1607	36.2	66.3	212	130	677	682	#VALUE!	#VALUE!	4	37	11	181	29
Steady State Test	12:48:55	12:49:54	1695	65.1	183.9	115	97	905	1249	#VALUE!	#VALUE!	17	39	37	201	70
Steady State Test	12:51:09	12:52:07	1747	56.0	137.8	110	85	847	1078	#VALUE!	#VALUE!	9	44	21	(307)	(47)
Steady State Test	12:55:00	12:55:59	1895	15.8	20.3	442	311	243	281	#VALUE!	#VALUE!	4	(628)	(33)	(1024)	(116)
Steady State Test	12:57:06	12:58:05	1555	35.3	56.1	255	148	624	598	#VALUE!	#VALUE!	3	48	6	(317)	(25)
Steady State Test	12:59:19	13:00:18	1837	15.1	18.0	486	324	232	255	#VALUE!	#VALUE!	3	(302)	(18)	(956)	(66)
Steady State Test	13:01:34	13:02:33	1746	55.8	132.0	109	84	855	1079	#VALUE!	#VALUE!	11	38	19	182	43
Steady State Test	13:03:30	13:04:29	1684	64.2	166.9	109	88	906	1203	#VALUE!	#VALUE!	13	38	27	201	63
Steady State Test	13:07:47	13:08:45	1561	35.1	59.1	227	136	659	651	#VALUE!	#VALUE!	4	62	10	(376)	(29)
Steady State Test	13:10:07	13:11:06	1697	65.1	175.5	115	97	900	1246	#VALUE!	#VALUE!	16	37	32	181	63
Steady State Test	13:12:18	13:13:17	1539	34.9	54.4	283	168	603	587	#VALUE!	#VALUE!	3	51	6	(307)	(22)
Steady State Test	13:14:40	13:15:39	1845	15.4	18.2	469	339	235	279	#VALUE!	#VALUE!	3	(342)	(20)	(495)	(39)

DIESEL VEHICLE ROAD TESTING SUMMARY Date: 03/06/00

Source Description: 1995 Freightliner Century with 1998 Detroit Diesel Series 60 Engine Empty Truck Weight ==> 46000 Lb

Test Number:	4F0	Grades	Level
Operator(s):	MC,FGK,RL	Load Weight	30367 Lb
Test Start Time:	9:58:39	Force Constant, F0	#N/A Lb
Test Stop Time:	14:10:22	Force Coefficient, F2	#N/A Lb/mph²

			Vehicle Operating Parameters			Carbon Monoxide		Nitrogen Oxides		Hydrocarbons (as C)		Dilution Sampler	
Test Description	Start Time	Stop TIme	Engine RPM	Truck MPH	DDEC HP	ppm dry	g/hour	ppm dry	g/hour	ppm wet	g/hour	ELPI l.d.s. mg/m³	TEOM mg/m³
0-25 accel after City	10:38:54	10:39:32	1777	11.8	125.1	189	303	358	678	14.9	10.1	29	24
0-25 accel after Crawl	11:55:36	11:56:08	1674	10.8	189.8	292	484	112	233	19.6	14.1	52	67
0-25 accel after Crawl	12:38:49	12:39:20	1697	12.4	181.0	304	465	350	815	18.7	13.3	44	41
0-25 accel after Crawl	13:09:15	13:09:39	1705	11.2	223.6	267	361	411	781	17.5	11.2	24	30
0-55 accel after Crawl	10:32:15	10:33:13	1816	28.8	317.8	249	381	465	1019	14.8	10.0	27	32
0-55 accel after Crawl	10:57:54	10:58:57	#N/A	28.0	0.0	243	399	448	1145	16.8	12.5	28	31
0-55 accel after Crawl	12:28:46	12:29:53	1696	29.6	306.2	237	362	588	1363	15.1	10.7	28	31
0-55 accel after Crawl	12:58:17	12:59:24	1788	27.7	310.8	239	352	492	1068	18.8	12.4	23	31
0-55 accel after Crawl	13:41:12	13:42:19	1795	28.3	316.2	249	347	508	1133	26.9	17.1	26	36
0-55 accel after unknown	11:24:39	11:28:10	1647	44.4	198.2	130	197	557	1215	11.8	7.9	25	18
25 cruise after City	10:39:32	10:41:51	1569	24.4	43.4	190	174	253	358	27.0	12.0	19	11
25 cruise after Crawl	11:56:08	11:58:21	1931	23.5	50.5	206	226	24	48	26.5	14.9	4	23
25 cruise after Crawl	12:39:20	12:44:44	1412	23.8	40.0	188	127	443	493	28.5	9.8	10	5
25 cruise after Crawl	13:09:39	13:11:47	1968	24.0	49.6	196	182	195	303	25.5	12.0	36	22
55 cruise after City	10:20:45	10:23:32	1582	52.4	151.3	91	104	644	1161	8.2	4.7	14	7
55 cruise after City	10:43:54	10:45:10	1655	52.9	143.4	58	75	606	1238	9.7	6.2	16	4
55 cruise after Crawl	12:59:24	13:01:55	1640	52.4	132.2	58	66	592	1112	12.4	7.3	15	11
55 cruise after Crawl	13:42:19	13:44:46	1664	53.2	136.3	56	51	578	867	12.9	6.1	17	10
55 cruise after Crawl	10:58:56	11:00:28	#N/A	53.2	0.0	61	81	581	1220	9.8	6.4	17	4
55 cruise after Idle	10:33:14	10:34:08	1654	52.9	128.7	57	66	608	1146	8.9	5.3	15	3
55 cruise after Idle	11:26:06	11:28:20	1643	52.5	158.4	71	89	591	1191	10.2	6.3	18	12
55 cruise after Idle	12:15:05	12:16:46	1647	52.6	179.1	84	110	618	1156	11.9	6.8	20	8

DIESEL VEHICLE ROAD TESTING SUMMARY Date: 03/07/00

Source Description: 1995 Freightliner Century with 1998 Detroit Diesel Series 60 Engine Empty Truck Weight ==> 46000 Lb

Test Number:	4H0-1	Grades	Level
Operator(s):	MC,FGK,RL	Load Weight	12147 Lb
Test Start Time:	9:42:06	Force Constant, F0	#N/A Lb
Test Stop Time:	10:52:46	Force Coefficient, F2	#N/A Lb/mph²

			Vehicle Operating Parameters			Carbon Monoxide		Nitrogen Oxides		Hydrocarbons (as C)		Dilution Sampler	
Test Description	Start Time	Stop TIme	Engine RPM	Truck MPH	DDEC HP	ppm dry	g/hour	ppm dry	g/hour	ppm wet	g/hour	ELPI ɹ.d.s. mg/m³	TEOM mg/m³
Unspecified UC-Davis Test	9:46:44	10:01:50	1486	22.9	92.2	275	205	491	656	20.5	7.3	20	10
Unspecified UC-Davis Test	10:03:48	10:32:28	1275	31.6	81.1	105	77	465	522	17.5	5.0	14	7

DIESEL VEHICLE ROAD TESTING SUMMARY

Date: 03/07/00

Source Description: 1995 Freightliner Century with 1998 Detroit Diesel Series 60 Engine

Empty Truck Weight ==> 46000 Lb

Test Number:	4H0-2	Grades	Level
Operator(s):	MC,FGK,RL	Load Weight	12147 Lb
Test Start Time:	16:15:18	Force Constant, F0	#N/A Lb
Test Stop Time:	20:57:58	Force Coefficient, F2	#N/A Lb/mph²

			Vehicle Operating Parameters			Carbon Monoxide		Nitrogen Oxides		Hydrocarbons (as C)		Dilution Sampler		Plume Dilution	
Test Description	Start Time	Stop TIme	Engine RPM	Truck MPH	DDEC HP	ppm dry	g/hour	ppm dry	g/hour	ppm wet	g/hour	ELPI ı.d.s. mg/m³	TEOM mg/m³	Ratio @ #N/A	Ratio @ 11 meters
55-65 after 55cruise	16:50:28	16:50:39	1832	58.2	430.1	147	304	548	1818	11.8	12.5	#VALUE!	#VALUE!	#VALUE!	477.2
55-65 after 55cruise	18:13:18	18:13:28	1821	57.4	420.2	134	292	505	1743	13.3	14.2	#VALUE!	#VALUE!	#VALUE!	438.9
55-65 after 55cruise	19:15:21	19:15:31	1816	58.0	438.2	167	350	702	2407	11.4	12.0	#VALUE!	#VALUE!	#VALUE!	348.9
65-0 after 65 cruise	16:52:18	16:52:53	909	19.6	15.2	60	27	401	244	12.3	2.7	#VALUE!	#VALUE!	#VALUE!	496.0
65-0 after 65 cruise	19:19:52	19:20:33	1136	27.2	25.0	48	31	236	151	13.2	3.7	#VALUE!	#VALUE!	#VALUE!	212.4
65-0 after 65 cruise	19:33:35	19:34:16	1192	21.4	26.8	84	44	165	148	17.1	4.6	#VALUE!	#VALUE!	#VALUE!	235.0
55-25 after 55 cruise	17:27:18	17:27:34	1394	35.9	5.7	57	54	95	140	11.4	4.9	23	#VALUE!	#VALUE!	296.1
55-25 after 56 cruise	19:49:06	19:49:21	1447	39.3	32.0	55	51	119	182	11.6	5.4	#VALUE!	#VALUE!	#VALUE!	81.1
0-55 after crawl	19:10:33	19:11:20	1793	26.5	253.0	233	341	343	924	19.1	13.5	#VALUE!	#VALUE!	#VALUE!	867.2
0-55 after crawl	19:45:25	19:46:22	1785	28.2	231.0	205	292	346	890	17.5	11.9	#VALUE!	#VALUE!	#VALUE!	624.5
0-25 after crawl	19:26:12	19:26:35	1615	11.5	141.2	239	283	284	459	21.0	10.0	#VALUE!	#VALUE!	#VALUE!	2158.9
0-25 after crawl	20:08:52	20:09:21	1687	9.9	102.9	188	206	258	397	32.2	13.7	#VALUE!	#VALUE!	#VALUE!	2145.7
0-25 after crawl	20:33:59	20:34:38	1570	10.3	83.2	127	103	289	354	23.0	8.6	#VALUE!	#VALUE!	#VALUE!	1860.2
25 cruise after idle	18:03:40	18:05:16	1935	23.6	40.5	214	188	175	252	30.0	12.9	#VALUE!	#VALUE!	#VALUE!	895.6
25 cruise after idle	18:21:49	18:22:55	#N/A	23.4	0.0	212	182	178	251	33.1	14.2	#VALUE!	#VALUE!	#VALUE!	651.0
25 cruise after idle	19:59:38	20:01:49	1385	23.1	30.6	239	129	284	255	49.0	13.3	#VALUE!	#VALUE!	#VALUE!	391.2
25 cruise after 55cru	17:27:34	17:33:57	1731	23.2	36.4	171	123	390	438	26.2	9.9	#VALUE!	#VALUE!	#VALUE!	684.9
25 cruise after 55cru	17:46:16	17:48:50	1946	23.9	47.8	164	145	264	383	24.3	11.0	#VALUE!	#VALUE!	#VALUE!	766.5
25 cruise after 55cru	19:49:21	19:51:25	1852	22.9	40.2	183	149	275	367	27.0	11.0	#VALUE!	#VALUE!	#VALUE!	351.3
25 cruise after crawl	19:26:35	19:28:11	1566	24.7	26.6	218	139	240	245	35.7	11.6	#VALUE!	#VALUE!	#VALUE!	281.9
25 cruise after crawl	20:09:21	20:11:44	1676	23.5	32.3	234	167	218	245	44.2	16.4	#VALUE!	#VALUE!	#VALUE!	537.8
25 cruise after crawl	20:34:38	20:36:13	1874	22.9	32.5	228	182	172	226	36.2	14.7	#VALUE!	#VALUE!	#VALUE!	349.2

DIESEL VEHICLE ROAD TESTING SUMMARY

Date: 03/08/00

Source Description: 1995 Freightliner Century with 1998 Detroit Diesel Series 60 Engine

Empty Truck Weight ==> 46000 Lb

Test Number:	4H0-3	Grades	Level
Operator(s):	MC,FGK,RL	Load Weight	12147 Lb
Test Start Time:	11:22:54	Force Constant, F0	#N/A Lb
Test Stop Time:	15:12:48	Force Coefficient, F2	#N/A Lb/mph²

			Vehicle Operating Parameters			Carbon Monoxide		Nitrogen Oxides		Hydrocarbons (as C)		Dilution Sampler		Plume Dilution	
Test Description	Start Time	Stop TIme	Engine RPM	Truck MPH	DDEC HP	ppm dry	g/hour	ppm dry	g/hour	ppm wet	g/hour	ELPI ɹ.d.s. mg/m³	TEOM mg/m³	Ratio @ #N/A	Ratio @ 11 meters
idle after 55 cruise	12:44:52	12:54:17	600	-0.2	6.7	71	13	385	115	16.2	1.5	1	0	#VALUE!	1806.3
idle after 55 cruise	13:06:08	13:14:18	600	-0.2	7.0	75	13	387	114	21.5	2.0	3	1	#VALUE!	2145.2
idle after 55 cruise	12:26:45	12:28:47	599	-0.2	5.8	79	13	316	88	18.2	1.6	1	1	#VALUE!	984.9
idle after city	13:55:41	14:00:44	620	-0.1	7.9	75	18	332	110	21.6	2.1	4	0	#VALUE!	955.7
idle after city	14:17:14	14:18:52	600	-0.2	7.5	62	10	325	89	22.8	1.9	1	-1	#VALUE!	702.1
0-25 accel, cruise after crawl	12:21:57	12:22:15	1922	13.3	194.2	218	290	265	560	17.6	11.0	68	33	#VALUE!	543.6
0-55 accel, cruise after city	12:58:18	12:59:25	1849	25.2	194.5	258	329	286	674	21.4	11.8	47	31	#VALUE!	493.3
25-55 accel, cruise after city	13:48:43	13:49:21	1769	43.0	271.4	201	316	433	1060	16.4	12.0	29	22	#VALUE!	320.5
0-25 accel, cruise after city	14:08:31	14:09:09	1789	14.7	94.8	269	285	316	478	19.7	8.7	67	33	#VALUE!	817.5
0-55 accel, cruise after city	14:35:13	14:36:16	1765	29.5	213.8	250	331	419	945	16.5	10.0	47	34	#VALUE!	512.1
0-55 accel, cruise after crawl	14:40:30	14:41:24	1748	27.4	217.8	307	415	408	982	17.8	10.8	56	42	#VALUE!	592.3
65-0 idle after 65 cruise	15:03:49	15:04:20	1285	29.9	8.7	30	25	58	75	11.2	4.2	23	22	#VALUE!	150.2
25-55 after city	12:22:14	12:23:00	1869	35.3	243.5	226	315	327	873	21.7	13.2	28	22	#VALUE!	310.2
25-55 after city	14:08:56	14:10:18	1846	31.6	150.7	164	212	412	793	17.6	9.4	24	15	#VALUE!	570.5
0-25 after city	13:48:12	13:49:09	1838	30.2	187.1	181	246	354	776	17.8	10.7	34	25	#VALUE!	776.4

DIESEL VEHICLE ROAD TESTING SUMMARY Date: 03/09/00

Source Description: 1995 Freightliner Century with 1998 Detroit Diesel Series 60 Engine Empty Truck Weight ==> 46000 Lb

Test Number:	4H0-4		Grades	Level
Operator(s):	MC,FGK,RL		Load Weight	12147 Lb
Test Start Time:	9:13:03		Force Constant, F0	#N/A Lb
Test Stop Time:	15:15:11		Force Coefficient, F2	#N/A Lb/mph²

			Vehicle Operating Parameters			Carbon Monoxide		Nitrogen Oxides		Hydrocarbons (as C)		Dilution Sampler	
Test Description	Start Time	Stop TIme	Engine RPM	Truck MPH	DDEC HP	ppm dry	g/hour	ppm dry	g/hour	ppm wet	g/hour	ELPI ı.d.s. mg/m³	TEOM mg/m³
64cru after 55 cru & 55-64	14:21:12	14:24:37	1825	62.2	157.1	69	77	361	669	8.4	4.9	0	21
64cru after 55 cru & 55-64	14:39:19	14:42:06	1793	62.1	176.4	62	84	391	828	6.3	4.2	0	15
64cru after 55 cru & 55-64	13:37:28	13:38:28	1931	61.7	247.0	63	97	434	1065	7.7	5.8	37	16
55 cruise after crawl	13:54:25	13:58:29	1647	52.7	109.2	73	57	545	706	9.5	3.9	0	12
55 cruise after crawl	14:08:35	14:13:50	1657	52.9	138.3	69	58	573	794	9.6	4.2	0	12
55 cruise after funky accel	14:18:52	14:21:05	1653	52.7	169.8	72	57	542	705	9.7	4.0	0	13
55 cruise after city	14:36:10	14:39:19	1679	53.1	171.9	70	59	568	793	8.3	3.7	0	12
55 cruise after city	13:34:43	13:37:28	1655	53.0	132.8	65	56	586	827	9.3	4.1	33	10
idle after	10:32:00	10:34:16	600	-0.2	6.9	84	14	386	104	-5.7	0.0	1	0
idle after	10:40:17	10:44:03	600	-0.2	6.1	85	16	322	100	-5.7	0.0	1	0
idle after	10:49:56	10:54:23	600	-0.2	5.9	85	16	332	102	12.8	1.7	4	1
idle after	11:00:35	11:04:51	599	-0.2	4.5	72	13	325	96	40.7	3.7	4	1
idle after	11:10:28	11:15:57	599	-0.2	6.9	75	14	369	110	48.8	4.5	5	0
idle after	11:21:34	11:25:59	657	0.4	6.7	79	18	306	97	24.8	2.7	3	-1
0-25 after city	11:49:47	11:50:08	1640	12.0	144.9	160	167	336	538	20.5	10.2	50	21
0-25 after city	12:00:33	12:00:53	1655	11.2	151.9	238	292	347	600	21.2	11.7	56	24
0-25 after crawl	12:08:03	12:08:26	1512	10.1	140.9	242	280	353	536	23.4	10.4	46	20
0-25 after city	12:19:02	12:19:24	1675	11.8	136.2	249	287	341	548	21.6	10.5	70	31
0-55 after city	12:27:47	12:28:34	1764	26.7	269.6	262	393	434	1124	20.8	14.1	69	36
0-55 after city	12:38:04	12:38:50	1792	28.5	265.0	278	406	455	1166	16.3	11.2	78	37
0-55 after city	12:53:42	12:54:29	1789	26.8	275.5	247	362	434	1092	16.8	10.9	71	30
55-25 after 55 cruise	12:58:24	12:58:37	1395	40.6	3.9	41	37	161	235	10.3	4.3	27	5

DIESEL VEHICLE ROAD TESTING SUMMARY Date: 03/10/00

Source Description: 1995 Freightliner Century with 1998 Detroit Diesel Series 60 Engine Empty Truck Weight ==> 46000 Lb

Test Number:	4h-rtp1	Grades	Various
Operator(s):	MC,FGK,RL	Load Weight	12147 Lb
Test Start Time:	10:26:21	Force Constant, F0	#N/A Lb
Test Stop Time:	15:42:08	Force Coefficient, F2	#N/A Lb/mph²

			Vehicle Operating Parameters			Carbon Monoxide		Nitrogen Oxides		Hydrocarbons (as C)		Dilution Sampler	
Test Description	Start Time	Stop TIme	Engine RPM	Truck MPH	DDEC HP	ppm dry	g/hour	ppm dry	g/hour	ppm wet	g/hour	ELPI .d.s. mg/m³	TEOM mg/m³
JB,28s after 0-70acc	12:08:19	12:08:50	1418	58.7	87.7	102	158	204	419	8.0	4.1	31	24
JB,30s after 0-70acc	12:32:39	12:33:09	1337	56.5	12.8	24	36	71	79	8.1	3.3	27	11
JB,30s after 70cruise	12:55:18	12:55:48	1349	55.3	17.5	2	17	141	156	7.3	2.8	22	5
cold start idle	10:28:28	10:53:55	706	0.4	13.1	231	58	614	230	20.1	2.6	13	1
upgrade, 0-max-0 after idle	12:17:22	12:22:46	1358	50.8	226.0	123	192	445	1278	-4.9	0.1	25	15
upgrade, 0-max-0 after idle	12:42:49	12:46:17	1599	48.9	209.5	116	177	465	1250	10.5	6.9	34	17
upgrade, 0-max-0 after idle	13:05:33	13:08:56	1614	50.1	214.5	109	173	483	1274	11.1	7.7	33	17
upgrade, 0-max-0 after 55	13:18:23	13:21:09	1602	56.2	186.1	71	104	392	1062	9.2	5.5	22	7
upgrade, 0-max-0 after 55	13:31:44	13:34:31	1564	55.5	182.1	58	92	388	1048	9.8	5.5	20	6
upgrade, 0-max-0 after 55	13:45:09	13:48:02	1773	53.4	172.3	69	107	335	983	13.3	7.8	28	12
upgrade, 0-max-2 after crawl	14:41:02	14:44:35	1634	50.1	208.2	111	169	445	1178	12.6	8.7	35	17
upgrade, 0-max-3 after crawl	14:59:12	15:02:41	1600	52.0	216.6	115	165	482	1194	10.3	6.3	31	16
upgrade, 0-max-4 after crawl	15:16:35	15:20:05	1669	52.0	215.0	105	157	419	1147	12.3	7.6	33	13
upgrade, 0-max-5 after 55	15:29:28	15:31:04	1683	51.1	310.5	67	128	516	1764	9.7	8.1	21	3
SS upgrade after idle	12:18:35	12:20:07	2024	64.9	225.2	52	97	437	1334	-5.4	0.0	30	14
SS upgrade after idle	12:44:22	12:45:31	1581	65.6	131.1	44	59	408	852	10.3	5.4	18	6
SS upgrade after idle	13:06:50	13:08:16	1653	65.9	186.6	39	71	509	1206	9.3	6.4	20	7
SS upgrade after 55cruise	13:18:49	13:20:27	1709	65.7	190.7	67	90	480	1222	9.5	5.7	22	4
SS upgrade after 55cruise	13:32:14	13:33:38	1677	65.5	198.0	46	73	505	1256	9.7	5.8	18	-2
SS upgrade after 55cruise	13:45:49	13:47:03	2008	64.4	133.2	70	90	340	814	17.0	9.2	29	13
SS upgrade after crawl	14:42:13	14:43:50	1645	65.5	207.6	70	109	517	1260	11.1	7.6	24	3
SS upgrade after crawl	15:00:06	15:02:01	1624	66.4	245.0	80	118	637	1551	9.7	6.2	19	7

DIESEL VEHICLE ROAD TESTING SUMMARY Date: 03/14/00

Source Description: 1995 Freightliner Century with 1998 Detroit Diesel Series 60 Engine Empty Truck Weight ==> 46000 Lb

Test Number:	4h-rtp2		Grades	Various
Operator(s):	MC,FGK,RL		Load Weight	12147 Lb
Test Start Time:	9:46:29		Force Constant, F0	#N/A Lb
Test Stop Time:	15:14:21		Force Coefficient, F2	#N/A Lb/mph²

			Vehicle Operating Parameters			Carbon Monoxide		Nitrogen Oxides		Hydrocarbons (as C)		Dilution Sampler		Plume Dilution		
Test Description	Start Time	Stop TIme	Engine RPM	Truck MPH	DDEC HP	ppm dry	g/hour	ppm dry	g/hour	ppm wet	g/hour	ELPI ı.d.s. mg/m³	TEOM mg/m³	Ratio @ #N/A	Ratio @ 11 meters	11m ELPI ı.d.s. mg/m³
cold start idle	9:48:00	10:25:11	697	-0.2	6.2	576	138	434	166	50.7	6.1	#N/A	4	#N/A	2841.6	46.7
idle after full speed upgrade	11:01:42	11:08:42	600	-0.2	6.5	72	11	403	103	15.6	1.2	#N/A	-6	#N/A	2737.3	79.8
idle after full speed upgrade	11:24:46	11:31:46	600	-0.2	7.3	62	10	412	106	16.2	1.3	#N/A	0	#N/A	2569.5	68.7
idle after full speed upgrade	11:49:56	11:56:56	600	-0.2	7.8	55	9	254	72	15.6	1.3	#N/A	8	#N/A	595.2	16.9
55 cruise after upgrade ss	12:13:06	12:15:06	1808	56.3	93.9	67	72	227	627	29.0	14.1	#N/A	1	#N/A	215.9	14.0
55 cruise after upgrade ss	12:25:52	12:27:52	1827	56.1	93.4	57	58	267	612	14.9	7.8	#N/A	8	#N/A	170.7	17.5
55 cruise after upgrade ss	12:39:05	12:41:05	1591	66.4	142.5	68	61	534	916	10.9	5.2	#N/A	10	#N/A	154.7	19.1
0-70 accel after Jake	14:37:29	14:37:54	1355	56.0	62.6	88	85	82	202	8.0	3.8	#N/A	0	#N/A	152.5	13.8
0-70 accel after Jake	14:49:00	14:49:25	1368	58.5	47.5	112	98	93	187	7.6	3.7	#N/A	0	#N/A	123.9	17.2
0-70 accel after Jake	15:01:01	15:01:26	1369	57.1	49.9	70	73	73	184	7.0	3.4	#N/A	0	#N/A	132.8	7.8

DIESEL VEHICLE ROAD TESTING SUMMARY

Date: 9-26/27-00

Source Description: 1990 Kenworth with rebuilt Detroit Diesel Series 60 Engine

Empty Truck Weight ==> 42600 Lb

Test Number: 5F3&6a
Operator(s): MC, FGK, RL
Test Start Time: 22:19:02
Test Stop Time: 0:36:21

Grades 3% & 6%
Load Weight 31400 Lb
Force Constant, F0 399.8 Lb
Force Coefficient, F2 0.2030 Lb/mph²

			Vehicle Operating Parameters			Carbon Monoxide		Nitrogen Oxides		Hydrocarbons (as C)		Dilution Sampler			Plume Dilution	
Test Description	Start Time	Stop TIme	Engine RPM	Truck MPH	Measured HP	ppm dry	g/hour	ppm dry	g/hour	ppm wet	g/hour	ELPI u.d.s. g/hr	PAH g/hr	TEOM g/hr	Ratio @ 2 meters	2m ELPI u.d.s. g/hr
3.1% Grade Steady State	22:36:21	22:37:06	2042	45.8	393.6	146	353	734	1906	#N/A	#N/A	#N/A	#N/A	#N/A	1081	117
6.0% Grade Steady State	22:39:15	22:40:57	1896	15.5	205.9	126	154	567	931	#N/A	#N/A	#N/A	#N/A	#N/A	1240	74
6.0% Grade Maximum	23:05:58	23:06:44	1888	48.5	377.8	329	642	914	2205	#N/A	#N/A	#N/A	#N/A	#N/A	174	209
3.1% Grade Steady State	23:13:05	23:14:05	2180	34.8	279.2	115	702	1035	2176	#N/A	#N/A	#N/A	#N/A	#N/A	999	85
6.0% Grade Maximum	23:15:35	23:16:31	1819	45.4	379.4	322	610	983	2319	#N/A	#N/A	#N/A	#N/A	#N/A	246	123
6.0% Grade Maximum	23:23:29	23:24:09	1909	51.5	402.0	274	592	904	2284	#N/A	#N/A	#N/A	#N/A	#N/A	119	225
3.1% Grade Steady State	23:31:05	23:33:49	1848	15.2	113.5	177	194	548	620	#N/A	#N/A	#N/A	#N/A	#N/A	1173	36
6.0% Grade Steady State	23:35:43	23:36:58	1877	29.8	404.6	200	639	939	2349	#N/A	#N/A	#N/A	#N/A	#N/A	1646	129
6.0% Grade Steady State	23:45:36	23:46:37	1874	15.3	206.7	138	269	557	958	#N/A	#N/A	#N/A	#N/A	#N/A	1960	132
3.1% Grade Steady State	23:54:08	23:56:49	1903	15.6	117.4	150	171	538	622	#N/A	#N/A	#N/A	#N/A	#N/A	863	32
6.0% Grade Steady State	23:59:17	0:00:12	1896	30.1	409.6	207	590	993	2491	#N/A	#N/A	#N/A	#N/A	#N/A	1287	108
6.0% Grade Maximum	0:06:46	0:07:20	1884	48.6	392.5	289	544	942	2285	#N/A	#N/A	#N/A	#N/A	#N/A	235	152
3.1% Grade Steady State	0:14:09	0:14:40	2017	45.2	386.7	125	415	686	1793	#N/A	#N/A	#N/A	#N/A	#N/A	987	136
6.0% Grade Steady State	0:16:49	0:19:14	1857	15.2	199.1	121	257	577	907	#N/A	#N/A	#N/A	#N/A	#N/A	1879	110
6.0% Grade Steady State	0:26:57	0:27:41	1900	30.2	388.1	198	629	894	2245	#N/A	#N/A	#N/A	#N/A	#N/A	1206	116

Source Description: 1990 Kenworth with rebuilt Detroit Diesel Series 60 Engine

Empty Truck Weight ==> 42600 Lb

Test Number:	5F3&6b	Grades	3% & 6%
Operator(s):	MC, FGK, RL	Load Weight	31400 Lb
Test Start Time:	1:01:25	Force Constant, F0	399.8 Lb
Test Stop Time:	2:26:10	Force Coefficient, F2	0.2030 Lb/mph²

			Vehicle Operating Parameters			Carbon Monoxide		Nitrogen Oxides		Hydrocarbons (as C)		Dilution Sampler			Plume Dilution	
Test Description	Start Time	Stop TIme	Engine RPM	Truck MPH	Measured HP	ppm dry	g/hour	ppm dry	g/hour	ppm wet	g/hour	ELPI u.d.s. g/hr	PAH g/hr	TEOM g/hr	Ratio @ 2 meters	2m ELPI u.d.s. g/hr
3.1% Grade Steady State	1:05:57	1:06:54	2031	45.5	398.9	184	431	813	2170	14.4	12.4	#N/A	#N/A	#N/A	988	168
6.0% Grade Maximum	1:08:09	1:09:14	1764	44.7	375.4	326	678	1038	2387	12.8	9.5	#N/A	#N/A	#N/A	264	203
6.0% Grade Steady State	1:15:31	1:16:44	1868	30.4	341.7	254	539	769	1866	14.2	10.2	#N/A	#N/A	#N/A	45	29
3.1% Grade Steady State	1:23:19	1:24:35	2166	34.7	264.9	99	275	573	1262	10.1	7.2	#N/A	#N/A	#N/A	1090	105
6.0% Grade Steady State	1:26:24	1:27:23	1887	30.0	407.1	172	555	917	2355	14.2	11.9	#N/A	#N/A	#N/A	2896	232
6.0% Grade Steady State	1:36:01	1:37:38	1896	15.5	194.4	128	214	554	883	11.1	5.7	#N/A	#N/A	#N/A	1501	100
3.1% Grade Steady State	1:44:24	1:45:31	1643	36.8	299.0	156	468	721	1410	8.8	5.6	#N/A	#N/A	#N/A	511	95
6.0% Grade Steady State	1:47:23	1:49:32	1881	15.3	202.4	122	233	568	915	8.8	4.6	#N/A	#N/A	#N/A	2624	154
6.0% Grade Steady State	1:57:06	1:58:41	1870	15.3	194.3	131	226	578	881	9.0	4.4	#N/A	#N/A	#N/A	1024	79
3.1% Grade Steady State	2:06:09	2:08:46	1862	15.3	114.5	174	181	545	625	16.4	5.9	#N/A	#N/A	#N/A	1551	50
6.0% Grade Maximum	2:10:20	2:11:28	1812	40.6	383.7	340	664	972	2306	11.8	9.0	#N/A	#N/A	#N/A	250	348
6.0% Grade Steady State	2:18:15	2:18:52	1897	30.1	416.6	212	847	903	2315	13.8	11.5	#N/A	#N/A	#N/A	2154	244

DIESEL VEHICLE ROAD TESTING SUMMARY

Date: 9-27-00

Source Description: 1990 Kenworth with rebuilt Detroit Diesel Series 60 Engine

Empty Truck Weight ==> 42600 Lb

Test Number:	5H3&6	Grades	3% & 6%
Operator(s):	MC, FGK, RL	Load Weight	18840 Lb
Test Start Time:	3:06:57	Force Constant, F0	356.4 Lb
Test Stop Time:	5:02:40	Force Coefficient, F2	0.1903 Lb/mph²

			Vehicle Operating Parameters			Carbon Monoxide		Nitrogen Oxides		Hydrocarbons (as C)		Dilution Sampler			Plume Dilution	
Test Description	Start Time	Stop TIme	Engine RPM	Truck MPH	Measured HP	ppm dry	g/hour	ppm dry	g/hour	ppm wet	g/hour	ELPI u.d.s. g/hr	PAH g/hr	TEOM g/hr	Ratio @ 2 meters	2m ELPI u.d.s. g/hr
6.0% Grade Steady State	3:58:50	4:00:22	1873	15.3	161.2	122	176	548	759	13.4	5.9	68	#N/A	#N/A	3236	133
3.1% Grade Steady State	4:07:44	4:09:43	1823	15.0	94.7	235	202	546	584	25.3	8.5	31	0.06	4	1564	50
6.0% Grade Steady State	4:12:51	4:15:01	1848	15.1	166.1	122	178	570	800	13.2	5.9	42	0.19	-36	1886	88
6.0% Grade Steady State	4:22:07	4:23:23	2053	34.3	321.3	272	602	884	2136	18.4	12.5	71	#NUM!	#NUM!	774	229
3.1% Grade Steady State	4:30:27	4:31:23	2190	35.0	228.2	97	633	491	1028	12.4	8.3	96	0.35	35	496	111
6.0% Grade Steady State	4:32:49	4:34:07	2136	34.3	365.4	195	700	1011	2550	15.5	11.6	79	0.27	-41	770	247
6.0% Grade Maximum	4:40:28	4:41:08	1920	53.4	375.8	308	558	841	2113	13.3	10.4	88	0.41	56	124	289
3.1% Grade Steady State	4:47:44	4:50:54	1843	15.1	92.1	236	195	539	595	26.2	9.1	30	0.06	7	1479	51
6.0% Grade Maximum	4:52:17	4:53:18	1815	46.7	397.5	259	479	973	2373	13.8	10.8	64	0.32	31	276	441
6.0% Grade Maximum	4:59:25	5:00:07	1857	54.3	396.9	290	559	908	2246	12.4	9.8	77	0.28	66	157	156

DIESEL VEHICLE ROAD TESTING SUMMARY

Date: 9-27-00

Source Description: 1990 Kenworth with rebuilt Detroit Diesel Series 60 Engine

Empty Truck Weight ==> 42600 Lb

Test Number:	5H3&6
Operator(s):	MC, FGK, RL
Test Start Time:	18:46:31
Test Stop Time:	20:43:01

Grades	3% & 6%
Load Weight	18840 Lb
Force Constant, F0	356.4 Lb
Force Coefficient, F2	0.1903 Lb/mph²

			Vehicle Operating Parameters			Carbon Monoxide		Nitrogen Oxides		Hydrocarbons (as C)		Dilution Sampler			Plume Dilution	
Test Description	Start Time	Stop TIme	Engine RPM	Truck MPH	Measured HP	ppm dry	g/hour	ppm dry	g/hour	ppm wet	g/hour	ELPI u.d.s. g/hr	PAH g/hr	TEOM g/hr	Ratio @ 2 meters	2m ELPI u.d.s. g/hr
3.1% Grade Steady State	18:59:28	19:00:08	2158	48.5	347.2	153	260	1101	2522	17.6	13.0	108	0.26	-2	494	88
6.0% Grade Steady State	19:02:32	19:04:12	1813	14.8	162.1	137	232	617	895	14.0	6.5	68	0.26	0	2225	124
6.0% Grade Steady State	19:12:02	19:12:34	2008	34.5	325.1	494	686	1065	2399	17.0	12.2	120	0.30	-22	791	75
3.1% Grade Steady State	19:18:48	19:19:45	2188	35.0	233.1	98	371	1053	1965	15.9	9.5	47	0.18	-14	577	79
6.0% Grade Steady State	19:21:29	19:22:51	2035	34.3	369.9	403	733	1095	2579	17.1	13.0	92	0.36	-116	1220	379
6.0% Grade Maximum	19:29:13	19:29:54	1888	49.4	398.8	353	549	932	2283	15.0	11.9	99	0.41	32	179	578
3.1% Grade Steady State	19:35:41	19:36:22	2020	48.2	317.7	384	515	1016	2246	15.2	10.7	63	0.26	32	219	56
6.0% Grade Steady State	19:37:35	19:39:26	2040	38.2	357.8	369	754	1032	2448	16.2	12.2	83	0.40	-77	524	296
6.0% Grade Steady State	19:50:08	19:50:44	2146	34.2	388.1	217	555	1030	2592	16.1	13.2	76	0.43	20	1756	680
3.1% Grade Steady State	19:57:41	19:59:42	1810	14.9	93.1	195	200	537	682	23.0	9.3	30	0.11	11	1462	80
6.0% Grade Maximum	20:01:47	20:02:27	1863	41.7	415.4	290	563	1002	2473	15.3	12.3	103	0.51	75	1399	2619
6.0% Grade Steady State	20:09:55	20:11:04	1847	15.1	163.6	140	210	549	817	13.6	6.5	59	0.26	25	2473	193
3.1% Grade Steady State	20:18:21	20:18:44	2188	35.0	233.2	94	583	1041	1970	13.8	8.4	56	0.19	23	422	54
6.0% Grade Maximum	20:20:33	20:21:23	1881	43.8	398.0	318	549	950	2331	16.1	12.8	94	0.52	78	359	690
6.0% Grade Steady State	20:28:51	20:30:01	1845	15.1	153.4	132	183	551	804	14.2	6.6	47	0.27	29	1192	84
3.1% Grade Steady State	20:36:15	20:36:55	2098	48.3	317.1	202	297	964	2235	14.4	10.5	58	0.30	38	270	65
6.0% Grade Steady State	20:39:12	20:40:50	1806	14.8	159.1	132	174	597	848	12.2	5.6	56	0.28	29	1319	96

Source Description: 1990 Kenworth with rebuilt Detroit Diesel Series 60 Engine

Empty Truck Weight ==> 42600 Lb

Test Number:	5E3&6	Grades	3% & 6%
Operator(s):	MC, FGK, RL	Load Weight	0 Lb
Test Start Time:	21:21:37	Force Constant, F0	270.1 Lb
Test Stop Time:	0:22:45	Force Coefficient, F2	0.1802 Lb/mph²

			Vehicle Operating Parameters			Carbon Monoxide		Nitrogen Oxides		Hydrocarbons (as C)		Dilution Sampler			Plume Dilution	
Test Description	Start Time	Stop TIme	Engine RPM	Truck MPH	Measured HP	ppm dry	g/hour	ppm dry	g/hour	ppm wet	g/hour	ELPI u.d.s. g/hr	PAH g/hr	TEOM g/hr	Ratio @ 2 meters	2m ELPI u.d.s. g/hr
3.1% Grade Steady State	21:32:56	21:33:36	1732	54.9	272.0	139	155	598	1124	9.5	5.7	33	#N/A	#N/A	69	75
6.0% Grade Steady State	21:35:04	21:35:40	2144	48.1	398.4	192	342	1003	2617	14.4	12.2	34	#N/A	#N/A	846	188
6.0% Grade Maximum	22:02:49	22:03:43	1633	51.6	383.1	332	488	1021	2301	13.4	9.9	53	#N/A	#N/A	134	211
3.1% Grade Steady State	22:08:40	22:09:56	2206	35.4	167.5	104	303	673	1159	14.6	8.0	38	#N/A	#N/A	213	64
6.0% Grade Maximum	22:11:15	22:12:14	1861	49.6	311.6	324	507	791	1893	13.5	9.2	25	#N/A	#N/A	108	184
6.0% Grade Steady State	22:21:22	22:22:13	1803	14.8	108.9	183	220	563	730	19.9	8.2	24	#N/A	#N/A	1021	48
3.1% Grade Steady State	22:30:01	22:31:29	1856	15.3	63.7	358	304	457	567	44.7	17.5	14	#N/A	#N/A	734	52
6.0% Grade Steady State	22:33:19	22:33:42	2145	48.0	399.1	212	353	1001	2609	19.2	16.2	49	#N/A	#N/A	401	209
6.0% Grade Steady State	22:40:30	22:41:29	2026	48.5	338.1	467	738	840	2065	20.0	13.6	38	#N/A	#N/A	159	185
3.1% Grade Steady State	22:47:17	22:48:01	2209	35.4	168.2	104	248	674	1158	14.5	7.9	31	#N/A	#N/A	189	56
6.0% Grade Steady State	22:49:30	22:50:56	2119	34.9	274.2	264	514	989	2079	14.6	9.8	39	#N/A	#N/A	698	131
6.0% Grade Steady State	22:57:29	22:58:32	1979	16.3	112.9	180	219	493	711	18.2	8.3	28	#N/A	#N/A	731	36
3.1% Grade Steady State	23:04:30	23:06:16	2051	16.9	76.2	281	265	438	618	31.9	14.2	15	#N/A	#N/A	697	52
6.0% Grade Steady State	23:08:35	23:09:23	2145	48.1	400.2	193	371	1014	2673	14.5	12.4	42	#N/A	#N/A	811	213
6.0% Grade Steady State	23:15:07	23:15:58	2063	47.9	336.4	431	592	804	2013	20.0	13.5	38	#N/A	#N/A	173	228
3.1% Grade Steady State	23:21:06	23:21:42	1711	54.1	279.5	121	224	590	1161	8.8	5.6	38	#N/A	#N/A	73	76
6.0% Grade Steady State	23:23:21	23:24:23	2180	34.8	278.8	110	291	1008	2170	12.7	8.8	42	#N/A	#N/A	1178	123
6.0% Grade Maximum	23:30:22	23:30:46	1684	53.1	391.7	281	365	978	2178	13.9	10.2	34	#N/A	#N/A	113	315
3.1% Grade Steady State	23:36:40	23:37:21	2211	35.4	167.6	97	258	668	1153	16.6	9.1	26	#N/A	#N/A	208	43
6.0% Grade Steady State	23:39:12	23:40:07	2181	34.8	276.2	108	362	1018	2175	14.5	10.0	29	#N/A	#N/A	1066	109
6.0% Grade Steady State	23:46:13	23:46:36	2143	48.0	405.1	196	421	953	2554	15.6	13.6	87	#N/A	#N/A	920	507
3.1% Grade Steady State	23:53:09	23:54:47	1944	16.0	71.2	332	276	448	600	38.7	16.3	28	#N/A	#N/A	981	58

DIESEL VEHICLE ROAD TESTING SUMMARY

Date: 10/10/00

Source Description: 1990 Kenworth with rebuilt Detroit Diesel Series 60 Engine

Empty Truck Weight ==> 42600 Lb

Test Number:	5F0a	Grades	Level
Operator(s):	MC, FGK, RL	Load Weight	31400 Lb
Test Start Time:	9:11:21	Force Constant, F0	399.8 Lb
Test Stop Time:	12:16:01	Force Coefficient, F2	0.2030 Lb/mph²

			Vehicle Operating Parameters			Carbon Monoxide		Nitrogen Oxides		Hydrocarbons (as C)		Dilution Sampler			Plume Dilution	
Test Description	Start Time	Stop TIme	Engine RPM	Truck MPH	Measured HP	ppm dry	g/hour	ppm dry	g/hour	ppm wet	g/hour	ELPI u.d.s. g/hr	PAH g/hr	TEOM g/hr	Ratio @ 2 meters	2m ELPI u.d.s. g/hr
Governed (normal) Accel	9:47:30	9:49:22	1884	38.1	288.7	445	572	802	1898	25.6	17.3	#N/A	#N/A	#N/A	#N/A	#N/A
Governed (normal) Accel	10:01:07	10:03:01	1883	36.6	264.5	505	615	766	1773	25.4	16.1	#N/A	#N/A	#N/A	#N/A	#N/A
Short-shift Acceleration	10:18:19	10:20:46	1410	40.9	259.9	773	965	1003	2090	19.1	11.7	#N/A	#N/A	#N/A	#N/A	#N/A
Governed (normal) Accel	10:34:26	10:36:19	1852	36.2	260.9	494	596	774	1730	22.3	13.8	#N/A	#N/A	#N/A	#N/A	#N/A
Governed (normal) Accel	10:46:13	10:48:08	1881	36.8	269.4	464	558	760	1749	23.1	14.6	#N/A	#N/A	#N/A	#N/A	#N/A
Short-shift Acceleration	10:58:47	11:00:53	1358	37.0	236.6	1007	1232	996	2002	18.7	11.2	#N/A	#N/A	#N/A	#N/A	#N/A
Governed (normal) Accel	11:10:30	11:12:30	1869	37.3	267.8	460	559	765	1762	22.0	13.7	#N/A	#N/A	#N/A	#N/A	#N/A
Governed (normal) Accel	11:22:57	11:24:45	1857	36.0	261.1	519	624	774	1738	23.0	14.1	#N/A	#N/A	#N/A	#N/A	#N/A
Short-shift Acceleration	11:34:20	11:36:41	1357	38.5	239.2	752	939	1007	2084	17.5	10.6	#N/A	#N/A	#N/A	#N/A	#N/A
Short-shift Acceleration	11:47:10	11:49:17	1365	37.7	237.6	1041	1287	1016	2097	17.5	10.6	#N/A	#N/A	#N/A	#N/A	#N/A
Short-shift Acceleration	11:58:55	12:01:09	1482	39.1	261.9	786	962	947	2004	18.3	11.2	#N/A	#N/A	#N/A	#N/A	#N/A
Short-shift Acceleration	12:11:45	12:13:47	1364	35.9	228.9	1013	1235	986	1974	16.4	9.5	#N/A	#N/A	#N/A	#N/A	#N/A

DIESEL VEHICLE ROAD TESTING SUMMARY

Date: 10-10-00

Source Description: 1990 Kenworth with rebuilt Detroit Diesel Series 60 Engine

Empty Truck Weight ==> 42600 Lb

Test Number:	5F0	Grades	Level
Operator(s):	MC, FGK, RL	Load Weight	31400 Lb
Test Start Time:	13:27:53	Force Constant, F0	399.8 Lb
Test Stop Time:	14:52:33	Force Coefficient, F2	0.2030 Lb/mph²

			Vehicle Operating Parameters			Carbon Monoxide		Nitrogen Oxides		Hydrocarbons (as C)		Dilution Sampler			Plume Dilution	
Test Description	Start Time	Stop TIme	Engine RPM	Truck MPH	Measured HP	ppm dry	g/hour	ppm dry	g/hour	ppm wet	g/hour	ELPI u.d.s. g/hr	PAH g/hr	TEOM g/hr	Ratio @ 2 meters	2m ELPI u.d.s. g/hr
Steady State Test	13:32:48	13:33:48	1732	66.0	263.6	102	373	610	1179	14.2	8.8	83	0.24	0	36	98
Steady State Test	13:34:32	13:35:32	1740	55.2	153.6	114	143	584	785	16.4	7.0	50	0.17	0	32	43
Steady State Test	13:36:12	13:37:44	1846	15.2	19.5	341	277	298	316	51.7	16.8	40	0.00	1	97	41
Steady State Test	13:39:04	13:40:05	1764	56.0	190.7	110	185	568	878	16.2	8.0	107	0.23	1	30	67
Steady State Test	13:48:00	13:48:45	1610	36.2	50.6	262	282	530	515	35.4	10.7	37	0.00	0	85	29
Steady State Test	13:49:37	13:50:37	1766	56.0	153.1	116	152	586	787	16.4	7.0	70	0.17	0	42	46
Steady State Test	13:51:32	13:52:32	1902	15.7	15.3	283	191	314	350	43.9	15.1	46	0.00	27	(2069)	(82)
Steady State Test	13:54:20	13:55:20	1722	65.6	172.3	108	469	602	875	15.6	7.2	83	0.20	305	28	59
Steady State Test	13:58:38	13:59:38	1832	15.1	18.6	347	335	303	327	55.3	18.4	48	0.00	-19	152	31
Steady State Test	14:00:46	14:01:22	1622	36.5	81.8	194	270	612	585	27.3	8.2	47	0.03	-2	44	21
Steady State Test	14:02:54	14:03:48	1716	65.3	229.8	109	387	598	1027	13.0	7.1	106	0.27	28	30	98
Steady State Test	14:05:03	14:06:03	1767	56.1	163.5	112	184	559	789	14.6	6.4	76	0.22	16	27	54
Steady State Test	14:13:59	14:14:21	1894	15.6	23.0	280	242	343	398	43.5	15.6	38	0.00	-13	(2167)	(225)
Steady State Test	14:15:10	14:16:10	1601	36.0	53.0	258	242	541	520	36.7	11.0	31	0.00	-5	73	38
Steady State Test	14:16:56	14:17:56	1800	14.8	14.5	308	317	300	327	56.3	18.9	31	0.00	-4	(964)	(76)
Steady State Test	14:19:22	14:20:22	1769	56.1	135.6	132	153	561	703	20.5	8.0	52	0.13	12	44	44
Steady State Test	14:21:19	14:22:19	1721	65.5	152.4	119	286	586	797	17.6	7.5	47	0.17	18	30	51
Steady State Test	14:25:30	14:26:30	1627	36.6	91.4	111	245	965	1017	22.5	7.5	37	0.00	-16	26	25
Steady State Test	14:27:59	14:28:59	1729	65.8	236.7	87	313	1150	1842	15.1	7.8	55	0.06	-44	30	34
Steady State Test	14:30:19	14:31:19	1595	35.9	71.8	149	190	890	899	27.3	8.7	37	0.00	-34	35	45
Steady State Test	14:32:16	14:33:16	1799	14.8	17.5	403	299	280	298	66.1	21.6	37	0.00	-12	107	45
Steady State Test	14:37:29	14:38:29	1637	36.8	49.8	210	255	731	720	34.6	10.6	34	0.00	-4	65	49

DIESEL VEHICLE ROAD TESTING SUMMARY

Date: 10-11-00

Source Description: 1990 Kenworth with rebuilt Detroit Diesel Series 60 Engine

Empty Truck Weight ==> 42600 Lb

Test Number:	5h0	Grades	Level
Operator(s):	MC, FGK, RL	Load Weight	18840 Lb
Test Start Time:	11:56:14	Force Constant, F0	356.4 Lb
Test Stop Time:	11:46:43	Force Coefficient, F2	0.1903 Lb/mph²

			Vehicle Operating Parameters			Carbon Monoxide		Nitrogen Oxides		Hydrocarbons (as C)		Dilution Sampler			Plume Dilution	
Test Description	Start Time	Stop TIme	Engine RPM	Truck MPH	Measured HP	ppm dry	g/hour	ppm dry	g/hour	ppm wet	g/hour	ELPI u.d.s. g/hr	PAH g/hr	TEOM g/hr	Ratio @ 2 meters	2m ELPI u.d.s. g/hr
Governed (normal) Accel	9:04:05	9:05:50	1873	35.3	244.6	487	580	658	1510	#VALUE!	#VALUE!	116	0.38	68	#N/A	#N/A
Short-shift Acceleration	9:18:04	9:19:53	1485	37.5	240.7	547	683	802	1715	#VALUE!	#VALUE!	106	0.52	50	#N/A	#N/A
Governed (normal) Accel	9:30:55	9:32:40	1882	35.6	240.9	478	558	683	1543	#VALUE!	#VALUE!	126	0.37	72	#N/A	#N/A
Short-shift Acceleration	9:41:31	9:43:03	1651	37.5	264.1	547	634	768	1657	#VALUE!	#VALUE!	120	0.62	70	#N/A	#N/A
Short-shift Acceleration	9:54:06	9:55:39	1649	37.5	262.8	582	658	766	1669	#VALUE!	#VALUE!	134	0.24	-24	#N/A	#N/A
Governed (normal) Accel	10:08:19	10:09:42	1824	37.1	282.1	576	683	779	1797	#VALUE!	#VALUE!	139	0.29	-1	#N/A	#N/A
Short-shift Acceleration	10:39:00	10:40:34	1666	38.7	266.9	669	768	815	1791	#VALUE!	#VALUE!	148	0.45	101	#N/A	#N/A
Short-shift Acceleration	10:49:45	10:51:18	1642	37.9	263.1	703	817	822	1765	#VALUE!	#VALUE!	138	0.26	99	#N/A	#N/A
Governed (normal) Accel	11:02:47	11:04:13	1825	36.6	273.0	581	693	765	1770	#VALUE!	#VALUE!	152	0.29	99	#N/A	#N/A
Governed (normal) Accel	11:13:41	11:15:05	1837	36.8	272.0	619	727	779	1777	#VALUE!	#VALUE!	148	0.36	119	#N/A	#N/A
Short-shift Acceleration	11:26:56	11:28:24	1652	35.5	263.5	614	715	809	1764	#VALUE!	#VALUE!	171	0.35	107	#N/A	#N/A
Governed (normal) Accel	11:37:35	11:39:00	1800	36.2	269.1	594	720	770	1751	#VALUE!	#VALUE!	161	0.34	46	#N/A	#N/A

DIESEL VEHICLE ROAD TESTING SUMMARY

Date: 10-11-00

Source Description: 1990 Kenworth with rebuilt Detroit Diesel Series 60 Engine

Empty Truck Weight ==> 42600 Lb

Test Number:	5h0	Grades	Level
Operator(s):	MC, FGK, RL	Load Weight	18840 Lb
Test Start Time:	11:56:14	Force Constant, F0	356.4 Lb
Test Stop Time:	13:04:42	Force Coefficient, F2	0.1903 Lb/mph²

			Vehicle Operating Parameters			Carbon Monoxide		Nitrogen Oxides		Hydrocarbons (as C)		Dilution Sampler			Plume Dilution	
Test Description	Start Time	Stop TIme	Engine RPM	Truck MPH	Measured HP	ppm dry	g/hour	ppm dry	g/hour	ppm wet	g/hour	ELPI u.d.s. g/hr	PAH g/hr	TEOM g/hr	Ratio @ 2 meters	2m ELPI u.d.s. g/hr
Steady State Test	12:01:52	12:02:52	1760	55.8	137.3	76	102	1078	1346	#VALUE!	#VALUE!	41	0.03	3	#N/A	#N/A
Steady State Test	12:03:34	12:04:34	1899	15.6	13.3	360	323	289	313	#VALUE!	#VALUE!	40	0.00	4	#N/A	#N/A
Steady State Test	12:05:43	12:06:31	1609	36.2	57.7	197	344	801	821	#VALUE!	#VALUE!	44	0.00	3	#N/A	#N/A
Steady State Test	12:07:50	12:08:50	1736	66.1	202.1	72	349	1197	1774	#VALUE!	#VALUE!	71	0.05	19	#N/A	#N/A
Steady State Test	12:11:47	12:12:47	1742	66.3	192.2	65	274	1194	1716	#VALUE!	#VALUE!	47	0.05	24	#N/A	#N/A
Steady State Test	12:13:36	12:14:36	1603	36.1	48.6	214	303	722	727	#VALUE!	#VALUE!	43	0.00	-93	#N/A	#N/A
Steady State Test	12:16:02	12:17:02	1768	56.1	112.8	87	139	996	1186	#VALUE!	#VALUE!	58	0.02	-13	#N/A	#N/A
Steady State Test	12:20:50	12:21:50	1607	36.1	68.8	154	306	884	886	#VALUE!	#VALUE!	48	0.00	-8	#N/A	#N/A
Steady State Test	12:22:26	12:23:26	1870	15.4	12.0	347	260	287	316	#VALUE!	#VALUE!	40	0.00	-5	#N/A	#N/A
Steady State Test	12:25:03	12:26:03	1743	66.3	211.3	77	294	1187	1787	#VALUE!	#VALUE!	67	0.05	0	#N/A	#N/A
Steady State Test	12:27:04	12:28:04	1747	55.4	141.6	70	144	1106	1294	#VALUE!	#VALUE!	43	0.02	-2	#N/A	#N/A
Steady State Test	12:31:08	12:32:08	1730	65.9	187.9	64	225	1201	1676	#VALUE!	#VALUE!	50	0.04	-5	#N/A	#N/A
Steady State Test	12:33:06	12:34:06	1594	35.8	52.0	206	262	761	770	#VALUE!	#VALUE!	45	0.00	-1	#N/A	#N/A
Steady State Test	12:34:58	12:35:58	1761	55.8	131.9	75	97	1067	1341	#VALUE!	#VALUE!	60	0.02	-3	#N/A	#N/A
Steady State Test	12:36:40	12:37:40	1851	15.2	5.8	325	305	247	273	#VALUE!	#VALUE!	50	0.00	-6	#N/A	#N/A
Steady State Test	12:41:21	12:42:21	1609	36.2	69.0	148	319	883	871	#VALUE!	#VALUE!	49	0.00	-72	#N/A	#N/A
Steady State Test	12:42:53	12:43:53	1852	15.3	13.4	357	252	280	317	#VALUE!	#VALUE!	44	0.00	-20	#N/A	#N/A
Steady State Test	12:45:11	12:46:11	1765	55.9	139.5	74	114	1087	1403	#VALUE!	#VALUE!	69	0.02	0	#N/A	#N/A
Steady State Test	12:47:34	12:48:34	1731	65.9	203.5	71	272	1197	1788	#VALUE!	#VALUE!	57	0.06	38	#N/A	#N/A
Steady State Test	12:51:44	12:52:44	1746	66.5	180.6	66	355	1183	1691	#VALUE!	#VALUE!	62	0.04	-20	#N/A	#N/A
Steady State Test	12:53:40	12:54:40	1811	14.9	12.2	313	389	283	300	#VALUE!	#VALUE!	53	0.00	-7	#N/A	#N/A
Steady State Test	12:55:54	12:56:54	1753	55.6	121.5	78	114	1044	1226	#VALUE!	#VALUE!	70	0.02	-1	#N/A	#N/A

DIESEL VEHICLE ROAD TESTING SUMMARY

Date: 10-12-00

Source Description: 1990 Kenworth with rebuilt Detroit Diesel Series 60 Engine

Empty Truck Weight ==> 42600 Lb

Test Number:	5e0a	Grades	Level
Operator(s):	MC, FGK, RL	Load Weight	0 Lb
Test Start Time:	11:56:14	Force Constant, F0	270.1 Lb
Test Stop Time:	10:40:26	Force Coefficient, F2	0.1802 Lb/mph²

			Vehicle Operating Parameters			Carbon Monoxide		Nitrogen Oxides		Hydrocarbons (as C)		Dilution Sampler			Plume Dilution	
Test Description	Start Time	Stop TIme	Engine RPM	Truck MPH	Measured HP	ppm dry	g/hour	ppm dry	g/hour	ppm wet	g/hour	ELPI u.d.s. g/hr	PAH g/hr	TEOM g/hr	Ratio @ 2 meters	2m ELPI u.d.s. g/hr
Governed (normal) Accel	8:59:55	9:01:06	1829	34.6	241.1	547	632	630	1432	28.5	16.1	145	0.32	221	#N/A	#N/A
Governed (normal) Accel	9:09:27	9:10:35	1801	33.7	238.1	631	709	639	1408	24.8	13.7	110	0.40	152	#N/A	#N/A
Short-shift Acceleration	9:14:58	9:16:11	1592	33.7	226.2	610	699	699	1445	19.4	10.8	102	0.38	104	#N/A	#N/A
Governed (normal) Accel	9:24:48	9:25:56	1814	33.8	234.8	632	712	648	1417	24.2	13.4	126	0.53	97	#N/A	#N/A
Short-shift Acceleration	9:37:45	9:38:56	1587	31.4	210.9	682	765	705	1443	20.3	10.8	118	0.32	35	#N/A	#N/A
Governed (normal) Accel	9:43:58	9:45:00	1853	35.9	256.6	643	743	706	1577	20.8	12.5	150	0.52	81	#N/A	#N/A
Governed (normal) Accel	9:52:11	9:53:15	1822	35.1	249.3	663	757	690	1531	19.4	11.3	244	0.49	87	#N/A	#N/A
Short-shift Acceleration	9:58:02	9:59:14	1602	36.0	237.6	736	832	752	1527	17.7	9.6	237	0.50	41	#N/A	#N/A
Short-shift Acceleration	10:06:16	10:07:16	1592	31.3	222.2	831	886	741	1482	17.5	9.2	147	0.51	66	#N/A	#N/A
Governed (normal) Accel	10:11:39	10:12:51	1847	34.8	234.4	597	682	681	1501	19.1	10.9	194	0.44	90	#N/A	#N/A
Short-shift Acceleration	10:20:37	10:21:38	1598	31.5	218.4	724	837	722	1472	16.9	9.2	254	0.47	82	#N/A	#N/A
Short-shift Acceleration	10:26:27	10:27:43	1560	35.1	220.9	753	853	757	1514	16.7	8.7	313	0.48	84	#N/A	#N/A
Governed (normal) Accel	10:34:53	10:36:01	1836	35.2	243.1	621	710	705	1546	19.2	11.1	302	0.43	47	#N/A	#N/A

DIESEL VEHICLE ROAD TESTING SUMMARY

Date: 10-12-00

Source Description: 1990 Kenworth with rebuilt Detroit Diesel Series 60 Engine

Empty Truck Weight ==> 42600 Lb

Test Number:	5e0v
Operator(s):	MC, FGK, RL
Test Start Time:	10:34:52
Test Stop Time:	11:48:43

Grades	Level
Load Weight	0 Lb
Force Constant, F0	270.1 Lb
Force Coefficient, F2	0.1802 Lb/mph²

			Vehicle Operating Parameters			Carbon Monoxide		Nitrogen Oxides		Hydrocarbons (as C)		Dilution Sampler			Plume Dilution	
Test Description	Start Time	Stop TIme	Engine RPM	Truck MPH	Measured HP	ppm dry	g/hour	ppm dry	g/hour	ppm wet	g/hour	ELPI u.d.s. g/hr	PAH g/hr	TEOM g/hr	Ratio @ 2 meters	2m ELPI u.d.s. g/hr
Steady State Test	10:36:52	10:37:52	1586	35.7	53.1	223	200	775	742	27.2	8.1	26	0.00	-11	28	27
Steady State Test	10:39:02	10:40:02	1762	56.0	123.0	92	135	1031	1330	19.2	7.9	38	0.03	-6	32	60
Steady State Test	10:42:30	10:43:30	1606	36.2	56.2	211	264	777	814	29.1	9.5	40	0.00	-6	38	14
Steady State Test	10:44:17	10:45:17	1768	56.2	121.2	92	66	1019	1265	20.6	8.1	54	0.03	1	27	53
Steady State Test	10:46:05	10:47:05	1600	36.0	46.6	255	283	693	680	32.7	10.0	40	0.00	0	30	31
Steady State Test	10:48:34	10:49:34	1789	56.9	130.4	86	142	1035	1323	20.1	8.1	40	0.04	9	24	44
Steady State Test	10:52:19	10:53:19	1884	15.6	14.5	380	274	291	320	60.3	20.5	34	0.00	2	317	41
Steady State Test	10:54:13	10:55:13	1601	36.1	51.0	234	267	737	780	34.3	11.3	40	0.00	-1	45	11
Steady State Test	10:56:04	10:57:04	1758	55.9	136.1	84	126	1078	1370	22.6	9.1	55	0.02	6	36	77
Steady State Test	10:57:50	10:58:50	1825	15.1	12.3	393	318	268	288	65.7	21.8	42	0.00	4	386	331
Steady State Test	11:00:32	11:01:32	1737	66.2	184.4	74	306	1190	1708	19.2	8.8	45	0.03	8	31	46
Steady State Test	11:04:50	11:05:50	1733	66.2	158.6	70	116	1161	1535	17.6	7.4	52	0.02	6	28	43
Steady State Test	11:06:59	11:07:59	1857	15.3	9.9	316	265	281	314	51.3	17.7	49	0.00	4	1715	1169
Steady State Test	11:09:46	11:10:46	1720	65.6	181.8	73	323	1200	1678	16.3	7.3	44	0.04	-132	25	48
Steady State Test	11:13:04	11:14:04	1624	36.6	51.8	206	258	738	690	28.2	8.3	38	0.00	-12	41	6
Steady State Test	11:15:06	11:16:06	1731	66.0	190.4	76	190	1204	1733	16.8	7.7	49	0.05	-5	33	72
Steady State Test	11:17:05	11:18:05	1750	55.6	127.0	85	120	1055	1308	19.0	7.5	47	0.02	3	29	37
Steady State Test	11:21:49	11:22:49	1641	37.0	57.3	201	326	771	822	29.6	9.9	41	0.00	-1	36	17
Steady State Test	11:23:48	11:24:48	1760	56.0	111.5	96	103	1003	1218	21.8	8.4	51	0.02	2	27	44
Steady State Test	11:25:24	11:26:24	1870	15.4	10.1	331	268	276	299	54.5	18.3	41	0.00	-5	692	829
Steady State Test	11:27:48	11:28:48	1726	65.8	181.0	73	252	1206	1713	17.0	7.7	46	0.04	12	25	29
Steady State Test	11:32:39	11:33:39	1725	65.8	187.7	74	194	1212	1716	15.2	6.9	47	0.05	5	35	35

Appendix D

CEM Calibration Summaries

PRE-TEST AND POST-TEST CALIBRATION SUMMARY

Source Description: 1990 Kenworth with Detroit Diesel Series 60 Engine   Date: 08/31/99

Test Number: 3F3&6

Monitor	Slope	Intercept
PM Sample CC	0.985	-5.111
PM Diluent CO	0.985	-4.569
Forward NOx	1.058	-0.407
Rearward NOx	1.058	-0.478

Monitor	Slope	Intercept
Horiba O2	0.980	0.087
Horiba CO2	0.998	0.011
Horiba CO	1.002	-61.838
Siemens CO	0.955	22.905
Horiba NOx	1.001	-33.572
TECO NOx	1.062	3.265
Horiba THC	0.968	-1.749

Monitor (Units) Range	Gas Tag Value	----- Direct Calibration ----- Monitor Reading	% Error	-- Pre-Test Cal Check -- Monitor Response	% Error	-- Post-Test Cal Check -- Monitor Response	% Error	% Drift
Horiba	0.00	-0.10	-0.4%	-0.08	-0.3%	-0.10	-0.4%	-0.1%
(% O2)	7.51	7.71	0.8%					
0-25%	13.90	14.03	0.5%	14.11	0.8%	14.08	0.7%	-0.1%
	21.04	20.75	-1.2%					
Horiba	0.00	-0.03	-0.2%	-0.02	-0.1%	-0.00	-0.0%	0.1%
(% CO2)	4.80	4.72	-0.5%					
0-16%	8.79	8.75	-0.3%	8.77	-0.1%	8.82	0.2%	0.3%
	13.60	13.66	0.4%					
Horiba	0	45	0.4%	14	0.1%	109	1.1%	1.0%
(ppm CO)	2980	2845	-1.3%					
0-10000 ppm	5501	5471	-0.3%	5547	0.5%	5557	0.6%	0.1%
	8500	8490	-0.1%					
Siemens	0.0	2.9	0.3%	-12.6	-1.3%	-35.4	-3.5%	-2.3%
(ppm CO)	301.6	314.5	1.3%					
0-1000 ppm	607.0	618.2	1.1%	619.1	1.2%	604.2	-0.3%	-1.5%
	916.0	943.4	2.7%					
Horiba	0	-8.2	-0.3%	6	0.2%	61	2.0%	1.8%
(ppm NOx)	888	942.2	1.8%					
0-3000 ppm	1638	1662.6	0.8%	1677	1.3%	1663	0.8%	-0.5%
	2570	2523.6	-1.5%					
TECO	0	-0.6	-0.0%	-5	-0.2%	-1	-0.0%	0.1%
(ppm NO)	888	897.1	0.3%					
0-3000 ppm	1638	1614.0	-0.8%	1558	-2.7%	1522	-3.9%	-1.2%
	2570	2563.8	-0.2%					
Horiba	0.00	-1.56	-1.6%	0.88	0.9%	2.73	2.7%	1.9%
(ppm THC)	29.88	30.18	0.3%	33.01	3.1%	32.32	2.4%	-0.7%
0-100 ppm			NA					
	89.40	89.45	0.1%					
Sample	0.0	-4.2	-0.4%	7.8	0.8%	2.6	0.3%	-0.5%
(ppm CO2)	298.8	291.3	-0.8%					
0-1000 ppm	550.0	543.3	-0.7%	577.8	2.8%	549.2	-0.1%	-2.9%
	850.9	860.2	0.9%					
Diluent	0.0	-5.1	-0.5%	7.9	0.8%	1.3	0.1%	-0.7%
(ppm CO2)	298.8	294.6	-0.4%					
0-1000 ppm	550.0	544.2	-0.6%	576.5	2.7%	549.6	-0.0%	-2.7%
	850.9	855.7	0.5%					
Forward	0.0	-0.7	-0.3%	1.2	0.5%	-0.4	-0.2%	-0.6%
(ppm NOx)	53.0	54.0	0.4%	51.4	-0.7%	49.5	-1.4%	-0.7%
0-250 ppm	88.0							
	210.0	212.1	0.8%	208.4	-0.6%			
Rearward	0.0	-0.1	-0.1%	1.2	0.5%	-0.3	-0.1%	-0.6%
(ppm NOx)	53.0	53.6	0.2%	51.1	-0.8%	50.0	-1.2%	-0.4%
0-250 ppm	88.0							
	210.0	211.4	0.5%	213.9	1.5%			

PRE-TEST AND POST-TEST CALIBRATION SUMMARY

Source Description: 1990 Kenworth with Detroit Diesel Series 60 Engine Date: 08/31/99

Test Number: 3H3&6

Monitor	Slope	Intercept
PM Sample CC	1.056	-7.926
PM Diluent CO	1.054	-3.604
Forward NOx	1.038	-1.539
Rearward NOx	0.990	0.072

Monitor	Slope	Intercept
Horiba O2	0.967	0.074
Horiba CO2	1.003	0.004
Horiba CO	1.039	-84.108
Siemens CO	0.973	18.939
Horiba NOx	1.052	-13.412
TECO NOx	NA	NA
Horiba THC	1.006	-2.457

Monitor		----- Direct Calibration -----		-- Pre-Test Cal Check --		-- Post-Test Cal Check --		
(Units) Range	Gas Tag Value	Monitor Reading	% Error	Monitor Response	% Error	Monitor Response	% Error	% Drift
Horiba	0.00	-0.04	-0.2%	-0.08	-0.3%	-0.08	-0.3%	0.0%
(% O2)	7.51	7.65	0.5%					
0-25%	13.90	13.90	0.0%	14.19	1.2%	14.41	2.0%	0.9%
	21.04	20.92	-0.5%					
Horiba	0.00	-0.02	-0.1%	-0.01	-0.1%	0.00	0.0%	0.1%
(% CO2)	4.80	4.72	-0.5%					
0-16%	8.79	8.81	0.1%	8.67	-0.7%	8.85	0.4%	1.1%
	13.60	13.60	-0.0%					
Horiba	0	-0	-0.0%	107	1.1%	55	0.5%	-0.5%
(ppm CO)	2980	2812	-1.7%					
0-10000 ppm	5501	5443	-0.6%	5356	-1.4%	5394	-1.1%	0.4%
	8500	8565	0.7%					
Siemens	0.0	-5.0	-0.5%	-16.0	-1.6%	-22.9	-2.3%	-0.7%
(ppm CO)	301.6	310.5	0.9%					
0-1000 ppm	607.0	617.1	1.0%	601.7	-0.5%	607.4	0.0%	0.6%
	916.0	939.1	2.3%					
Horiba	0	1.2	0.0%	8	0.3%	18	0.6%	0.3%
(ppm NOx)	888	935.4	1.6%					
0-3000 ppm	1638	1657.6	0.7%	1646	0.3%	1492	-4.9%	-5.1%
	2570	2533.9	-1.2%					
TECO	0	-4.7	-0.2%	-3	-0.1%	-1	-0.0%	0.0%
(ppm NO)	888	917.6	1.0%					
0-3000 ppm	1638	1658.2	0.7%	1581	-1.9%	1354	-9.5%	-7.6%
	2570	2565.2	-0.2%					
Horiba	0.00	-1.56	-1.6%	2.54	2.5%	2.34	2.3%	-0.2%
(ppm THC)	29.88	28.61	-1.3%	32.23	2.3%	32.03	2.2%	-0.2%
0-100 ppm			NA					
	89.40	88.09	-1.3%					
Sample	0.0	0.6	0.1%	4.4	0.4%	10.6	1.1%	0.6%
(ppm CO2)	298.8	290.9	-0.8%	284.2	-1.5%	296.9	-0.2%	1.3%
0-1000 ppm	550.0	554.9	0.5%					
	850.9	842.4	-0.8%					
Diluent	0.0	-0.9	-0.1%	2.3	0.2%	4.5	0.5%	0.2%
(ppm CO2)	298.8	292.0	-0.7%	284.1	-1.5%	289.6	-0.9%	0.5%
0-1000 ppm	550.0	553.3	0.3%					
	850.9	841.2	-1.0%					
Forward	0.0	-0.4	-0.2%	2.1	0.8%	0.9	0.4%	-0.5%
(ppm NOx)	53.0	55.4	1.0%	60.1	2.8%	45.0	-3.2%	-6.0%
0-250 ppm	88.0							
	210.0	212.1	0.9%					
Rearward	0.0	-1.2	-0.5%	0.8	0.3%	-1.0	-0.4%	-0.7%
(ppm NOx)	53.0	55.3	0.9%	59.6	2.6%	47.4	-2.2%	-4.9%
0-250 ppm	88.0							
	210.0	212.0	0.8%					

PRE-TEST AND POST-TEST CALIBRATION SUMMARY

Source Description: 1990 Kenworth with Detroit Diesel Series 60 Engine   Date: 09/01/99

Test Number: 3E3&6

Monitor	Slope	Intercept
PM Sample CC	1.047	-23.641
PM Diluent CO	1.039	-16.115
Forward NOx	1.008	-0.664
Rearward NOx	0.992	-0.612

Monitor	Slope	Intercept
Horiba O2	1.004	0.130
Horiba CO2	1.036	0.000
Horiba CO	0.998	-64.214
Siemens CO	0.992	5.027
Horiba NOx	1.050	-23.229
TECO NOx	NA	NA
Horiba THC	1.008	-2.215

Monitor (Units) Range	Gas Tag Value	----- Direct Calibration ----- Monitor Reading	% Error	-- Pre-Test Cal Check -- Monitor Response	% Error	-- Post-Test Cal Check -- Monitor Response	% Error	% Drift
Horiba	0.00	-0.09	-0.4%	-0.13	-0.5%	-0.13	-0.5%	0.0%
(% O2)	7.51	7.59	0.3%					
0-25%	13.90	13.80	-0.4%	13.87	-0.1%	13.56	-1.4%	-1.3%
	21.04	20.89	-0.6%					
Horiba	0.00	-0.02	-0.1%	-0.01	-0.1%	0.01	0.1%	0.1%
(% CO2)	4.80	4.72	-0.5%					
0-16%	8.79	8.61	-1.1%	8.71	-0.5%	8.26	-3.3%	-2.8%
	13.60	13.65	0.3%					
Horiba	0	-13	-0.1%	27	0.3%	101	1.0%	0.7%
(ppm CO)	2980	2787	-1.9%					
0-10000 ppm	5501	5431	-0.7%	5600	1.0%	5550	0.5%	-0.5%
	8500	8639	1.4%					
Siemens	0.0	-7.6	-0.8%	-2.1	-0.2%	-8.1	-0.8%	-0.6%
(ppm CO)	301.6	317.3	1.6%					
0-1000 ppm	607.0	626.3	1.9%	614.5	0.8%	598.9	-0.8%	-1.6%
	916.0	934.8	1.9%					
Horiba	0	6.7	0.2%	11	0.4%	33	1.1%	0.7%
(ppm NOx)	888	951.0	2.1%					
0-3000 ppm	1638	1658.8	0.7%	1659	0.7%	1505	-4.4%	-5.1%
	2570	2524.8	-1.5%					
TECO	0	-5.6	-0.2%	-5	-0.2%	-1	-0.0%	0.1%
(ppm NO)	888	915.2	0.9%					
0-3000 ppm	1638	1658.2	0.7%	1622	-0.5%	1463	-5.8%	-5.3%
	2570	2561.1	-0.3%					
Horiba	0.00	-0.59	-0.6%	0.68	0.7%	3.71	3.7%	3.0%
(ppm THC)	29.88	29.69	-0.2%	30.57	0.7%	33.11	3.2%	2.5%
0-100 ppm			NA					
	89.40	89.16	-0.2%					
Sample	0.0	9.9	1.0%	18.2	1.8%	27.0	2.7%	0.9%
(ppm CO2)	298.8	306.6	0.8%					
0-1000 ppm	550.0	559.8	1.0%	535.0	-1.5%	560.9	1.1%	2.6%
	850.9	844.4	-0.7%					
Diluent	0.0	9.2	0.9%	13.9	1.4%	17.1	1.7%	0.3%
(ppm CO2)	298.8	307.6	0.9%					
0-1000 ppm	550.0	559.4	0.9%	539.3	-1.1%	549.9	-0.0%	1.1%
	850.9	846.3	-0.5%					
Forward	0.0	-0.8	-0.3%	0.7	0.3%	0.6	0.2%	-0.1%
(ppm NOx)	53.0	52.2	-0.3%	56.4	1.4%	50.1	-1.2%	-2.5%
0-250 ppm	88.0							
	210.0	212.4	0.9%					
Rearward	0.0	-1.2	-0.5%	1.0	0.4%	0.2	0.1%	-0.3%
(ppm NOx)	53.0	51.6	-0.5%	56.9	1.6%	51.1	-0.8%	-2.3%
0-250 ppm	88.0							
	210.0	212.3	0.9%					

PRE-TEST AND POST-TEST CALIBRATION SUMMARY

Source Description: 1990 Kenworth with Detroit Diesel Series 60 Engine   Date: 10/07/99

Test Number: 3F00C

Monitor	Slope	Intercept
PM Sample CC	1.024	-5.310
PM Diluent CO	1.003	-8.018
Forward NOx	0.972	-0.178
Rearward NOx	0.987	1.844

Monitor	Slope	Intercept
Horiba O2	1.002	-0.106
Horiba CO2	0.981	-0.035
Horiba CO	1.015	-74.831
Siemens CO	0.983	6.723
Horiba NOx	0.993	6.107
TECO NOx	0.955	6.578
Horiba THC	0.917	0.672

Monitor		----- Direct Calibration -----		-- Pre-Test Cal Check --		-- Post-Test Cal Check --		
(Units) Range	Gas Tag Value	Monitor Reading	% Error	Monitor Response	% Error	Monitor Response	% Error	% Drift
Horiba	0.00	0.11	0.4%	0.11	0.4%	0.10	0.4%	-0.0%
(% O2)	7.51	7.69	0.7%					
0-25%	13.90	13.91	0.0%	13.92	0.1%	14.04	0.5%	0.5%
	21.04	20.89	-0.6%					
Horiba	0.00	0.09	0.6%	0.04	0.2%	0.04	0.2%	0.0%
(% CO2)	4.80	4.99	1.2%					
0-16%	8.79	9.03	1.5%	8.96	1.0%	9.03	1.5%	0.5%
	13.60	13.62	0.1%					
Horiba	0	46	0.5%	72	0.7%	75	0.8%	0.0%
(ppm CO)	2980	2939	-0.4%					
0-10000 ppm	5501	5470	-0.3%	5510	0.1%	5476	-0.2%	-0.3%
	8500	8519	0.2%					
Siemens	0.0	-1.5	-0.1%	-4.9	-0.5%	-8.8	-0.9%	-0.4%
(ppm CO)	301.6	312.3	1.1%					
0-1000 ppm	607.0	616.9	1.0%	607.2	0.0%	613.5	0.7%	0.6%
	916.0	929.0	1.3%					
Horiba	0	-3.8	-0.1%	-6	-0.2%	-6	-0.2%	-0.0%
(ppm NOx)	888	934.9	1.6%					
0-3000 ppm	1638	1647.9	0.3%	1648	0.3%	1640	0.1%	-0.3%
	2570	2558.2	-0.4%					
TECO	0	-2.3	-0.1%	-5	-0.2%	-8	-0.3%	-0.1%
(ppm NO)	888	897.1	0.3%					
0-3000 ppm	1638	1647.1	0.3%	1640	0.1%	1775	4.6%	4.5%
	2570	2557.3	-0.4%					
Horiba	0.00	0.10	0.1%	0.49	0.5%	-1.95	-2.0%	-2.4%
(ppm THC)	29.88	29.69	-0.2%	33.50	3.6%	30.18	0.3%	-3.3%
0-100 ppm			NA					
	89.40	90.14	0.7%					
Sample	0.0	1.5	0.1%	1.5	0.1%	8.9	0.9%	0.7%
(ppm CO2)	298.8	308.5	1.0%	308.5	1.0%			
0-1000 ppm	550.0	559.4	0.9%	559.4	0.9%			
	850.9	855.2	0.4%	855.2	0.4%	817.7	-3.3%	-3.7%
Diluent	0.0	0.2	0.0%	0.2	0.0%	15.7	1.6%	1.6%
(ppm CO2)	298.8	305.8	0.7%	305.8	0.7%			
0-1000 ppm	550.0	556.8	0.7%	556.8	0.7%			
	850.9	852.7	0.2%	852.7	0.2%	860.4	0.9%	0.8%
Forward	0.0	1.1	0.5%	1.1	0.5%	-0.8	-0.3%	-0.8%
(ppm NOx)	53.0	52.8	-0.1%	52.8	-0.1%	56.7	1.5%	1.6%
0-250 ppm	88.0							
	210.0	208.8	-0.5%	208.8	-0.5%			
Rearward	0.0	-2.3	-0.9%	-2.3	-0.9%	-1.5	-0.6%	0.3%
(ppm NOx)	53.0	49.5	-1.4%	49.5	-1.4%	54.1	0.4%	1.8%
0-250 ppm	88.0							
	210.0	205.9	-1.6%	205.9	-1.6%			

PRE-TEST AND POST-TEST CALIBRATION SUMMARY

Source Description: 1990 Kenworth with Detroit Diesel Series 60 Engine   Date: 10/07/99

Test Number: 3E00V

Monitor	Slope	Intercept
PM Sample CC	0.997	14.903
PM Diluent CO	0.998	-5.360
Forward NOx	1.021	-0.555
Rearward NOx	1.022	0.630

Monitor	Slope	Intercept
Horiba O2	1.009	-0.095
Horiba CO2	0.973	-0.047
Horiba CO	1.020	-116.445
Siemens CO	0.986	12.215
Horiba NOx	0.992	-2.908
TECO NOx	0.949	1.945
Horiba THC	0.998	-0.292

Monitor (Units) Range	Gas Tag Value	----- Direct Calibration ----- Monitor Reading	% Error	-- Pre-Test Cal Check -- Monitor Response	% Error	-- Post-Test Cal Check -- Monitor Response	% Error	% Drift
Horiba	0.00	0.11	0.4%	0.14	0.6%	0.05	0.2%	-0.4%
(% O2)	7.51	7.69	0.7%					
0-25%	13.90	13.91	0.0%	14.03	0.5%	13.71	-0.8%	-1.3%
	21.04	20.89	-0.6%					
Horiba	0.00	0.09	0.6%	0.04	0.3%	0.05	0.3%	0.0%
(% CO2)	4.80	4.99	1.2%					
0-16%	8.79	9.03	1.5%	9.06	1.7%	9.11	2.0%	0.4%
	13.60	13.62	0.1%					
Horiba	0	46	0.5%	91	0.9%	137	1.4%	0.5%
(ppm CO)	2980	2939	-0.4%					
0-10000 ppm	5501	5470	-0.3%	5516	0.2%	5501	0.0%	-0.2%
	8500	8519	0.2%					
Siemens	0.0	-1.5	-0.1%	-10.4	-1.0%	-14.4	-1.4%	-0.4%
(ppm CO)	301.6	312.3	1.1%					
0-1000 ppm	607.0	616.9	1.0%	604.5	-0.3%	602.2	-0.5%	-0.2%
	916.0	929.0	1.3%					
Horiba	0	-3.8	-0.1%	2	0.1%	4	0.1%	0.1%
(ppm NOx)	888	934.9	1.6%					
0-3000 ppm	1638	1647.9	0.3%	1655	0.6%	1652	0.5%	-0.1%
	2570	2558.2	-0.4%					
TECO	0	-2.3	-0.1%	-3	-0.1%	-1	-0.0%	0.0%
(ppm NO)	888	897.1	0.3%					
0-3000 ppm	1638	1647.1	0.3%	1780	4.7%	1670	1.1%	-3.7%
	2570	2557.3	-0.4%					
Horiba	0.00	0.10	0.1%	-0.20	-0.2%	0.78	0.8%	1.0%
(ppm THC)	29.88	29.69	-0.2%	31.45	1.6%	29.00	-0.9%	-2.4%
0-100 ppm			NA					
	89.40	90.14	0.7%					
Sample	0.0	3.3	0.3%	3.3	0.3%	-33.2	-3.3%	-3.6%
(ppm CO2)	298.8	297.0	-0.2%	297.0	-0.2%			
0-1000 ppm	550.0	559.3	0.9%	559.3	0.9%			
	850.9	853.1	0.2%	853.1	0.2%	824.6	-2.6%	-2.9%
Diluent	0.0	2.3	0.2%	2.3	0.2%	8.4	0.8%	0.6%
(ppm CO2)	298.8	295.4	-0.3%	295.4	-0.3%			
0-1000 ppm	550.0	556.3	0.6%	556.3	0.6%			
	850.9	846.6	-0.4%	846.6	-0.4%	869.6	1.9%	2.3%
Forward	0.0	0.7	0.3%	0.7	0.3%	0.4	0.2%	-0.1%
(ppm NOx)	53.0	53.2	0.1%	53.2	0.1%	51.7	-0.5%	-0.6%
0-250 ppm	88.0							
	210.0	210.9	0.4%	210.9	0.4%			
Rearward	0.0	-0.7	-0.3%	-0.7	-0.3%	-0.5	-0.2%	0.1%
(ppm NOx)	53.0	52.1	-0.3%	52.1	-0.3%	50.3	-1.1%	-0.7%
0-250 ppm	88.0							
	210.0	210.6	0.2%	210.6	0.2%			

PRE-TEST AND POST-TEST CALIBRATION SUMMARY

Source Description: 1990 Kenworth with Detroit Diesel Series 60 Engine Date: 10/08/99

Test Number: 3H00C

Monitor	Slope	Intercept
PM Sample CC	1.015	-12.510
PM Diluent CO	1.012	-14.139
Forward NOx	NA	NA
Rearward NOx	0.979	-0.090

Monitor	Slope	Intercept
Horiba O2	0.992	-0.093
Horiba CO2	0.968	-0.042
Horiba CO	1.009	-78.044
Siemens CO	0.988	0.181
Horiba NOx	0.996	-15.024
TECO NOx	0.963	1.693
Horiba THC	0.971	-0.664

Monitor (Units) Range	Gas Tag Value	Direct Calibration Monitor Reading	Direct Calibration % Error	Pre-Test Cal Check Monitor Response	Pre-Test Cal Check % Error	Post-Test Cal Check Monitor Response	Post-Test Cal Check % Error	% Drift
Horiba	0.00	0.07	0.3%	0.17	0.7%	0.02	0.1%	-0.6%
(% O2)	7.51	7.72	0.9%					
0-25%	13.90	13.90	-0.0%	14.10	0.8%	14.11	0.8%	0.0%
	21.04	20.90	-0.6%					
Horiba	0.00	0.04	0.3%	0.04	0.3%	0.04	0.3%	-0.0%
(% CO2)	4.80	4.92	0.8%					
0-16%	8.79	8.88	0.6%	8.97	1.2%	9.28	3.1%	1.9%
	13.60	13.55	-0.3%					
Horiba	0	61	0.6%	66	0.7%	88	0.9%	0.2%
(ppm CO)	2980	2921	-0.6%					
0-10000 ppm	5501	5408	-0.9%	5518	0.2%	5538	0.4%	0.2%
	8500	8561	0.6%					
Siemens	0.0	1.6	0.2%	5.9	0.6%	-6.2	-0.6%	-1.2%
(ppm CO)	301.6	327.1	2.6%					
0-1000 ppm	607.0	618.9	1.2%	617.1	1.0%	611.1	0.4%	-0.6%
	916.0	936.3	2.0%					
Horiba	0	7.0	0.2%	8	0.3%	22	0.7%	0.5%
(ppm NOx)	888	934.3	1.5%					
0-3000 ppm	1638	1644.7	0.2%	1656	0.6%	1665	0.9%	0.3%
	2570	2576.7	0.2%					
TECO	0	-6.2	-0.2%	-5	-0.2%	1	0.0%	0.2%
(ppm NO)	888	896.8	0.3%					
0-3000 ppm	1638	1627.1	-0.4%	1652	0.5%	1745	3.6%	3.1%
	2570	2539.2	-1.0%					
Horiba	0.00	-0.39	-0.4%	0.10	0.1%	1.27	1.3%	1.2%
(ppm THC)	29.88	30.27	0.4%	31.54	1.7%	31.35	1.5%	-0.2%
0-100 ppm			NA					
	89.40	89.45	0.1%					
Sample	0.0	1.0	0.1%	1.0	0.1%	23.7	2.4%	2.3%
(ppm CO2)	298.8	307.0	0.8%	307.0	0.8%			
0-1000 ppm	550.0	553.1	0.3%	553.1	0.3%			
	850.9	847.2	-0.4%	847.2	-0.4%	854.6	0.4%	0.7%
Diluent	0.0	-0.7	-0.1%	-0.7	-0.1%	28.7	2.9%	2.9%
(ppm CO2)	298.8	302.1	0.3%	302.1	0.3%			
0-1000 ppm	550.0	553.6	0.4%	553.6	0.4%			
	850.9	842.2	-0.9%	842.2	-0.9%	868.0	1.7%	2.6%
Forward	0.0	-0.1	-0.0%	-0.1	-0.0%	2.7	1.1%	1.1%
(ppm NOx)	53.0	57.0	1.6%	57.0	1.6%			
0-250 ppm	88.0							
	210.0	210.4	0.2%	210.4	0.2%	222.5	5.0%	4.9%
Rearward	0.0	-1.2	-0.5%	-1.2	-0.5%	1.4	0.6%	1.0%
(ppm NOx)	53.0	55.1	0.8%	55.1	0.8%			
0-250 ppm	88.0							
	210.0	212.4	1.0%	212.4	1.0%	216.9	2.8%	1.8%

PRE-TEST AND POST-TEST CALIBRATION SUMMARY

Source Description: 1990 Kenworth with Detroit Diesel Series 60 Engine   Date: 10/08/99

Test Number: 3H00V

Monitor	Slope	Intercept
PM Sample CC	1.010	-6.228
PM Diluent CO	1.007	-14.508
Forward NOx	NA	NA
Rearward NOx	0.980	-1.411

Monitor	Slope	Intercept
Horiba O2	0.992	-0.027
Horiba CO2	0.967	-0.048
Horiba CO	1.015	-93.912
Siemens CO	0.985	8.359
Horiba NOx	0.994	-22.867
TECO NOx	NA	NA
Horiba THC	1.006	-2.998

Monitor (Units) Range	Gas Tag Value	----- Direct Calibration ----- Monitor Reading	% Error	-- Pre-Test Cal Check -- Monitor Response	% Error	-- Post-Test Cal Check -- Monitor Response	% Error	% Drift
Horiba	0.00	0.07	0.3%	0.02	0.1%	0.03	0.1%	0.1%
(% O2)	7.51	7.72	0.9%					
0-25%	13.90	13.90	-0.0%	14.11	0.8%	13.96	0.2%	-0.6%
	21.04	20.90	-0.6%					
Horiba	0.00	0.04	0.3%	0.04	0.3%	0.06	0.3%	0.1%
(% CO2)	4.80	4.92	0.8%					
0-16%	8.79	8.88	0.6%	9.28	3.1%	8.99	1.3%	-1.8%
	13.60	13.55	-0.3%					
Horiba	0	61	0.6%	88	0.9%	97	1.0%	0.1%
(ppm CO)	2980	2921	-0.6%					
0-10000 ppm	5501	5408	-0.9%	5538	0.4%	5485	-0.2%	-0.5%
	8500	8561	0.6%					
Siemens	0.0	1.6	0.2%	-6.2	-0.6%	-10.7	-1.1%	-0.5%
(ppm CO)	301.6	327.1	2.6%					
0-1000 ppm	607.0	618.9	1.2%	611.1	0.4%	604.1	-0.3%	-0.7%
	916.0	936.3	2.0%					
Horiba	0	7.0	0.2%	22	0.7%	24	0.8%	0.0%
(ppm NOx)	888	934.3	1.5%					
0-3000 ppm	1638	1644.7	0.2%	1665	0.9%	1676	1.3%	0.4%
	2570	2576.7	0.2%					
TECO	0	-6.2	-0.2%	1	0.0%	0	0.0%	-0.0%
(ppm NO)	888	896.8	0.3%					
0-3000 ppm	1638	1627.1	-0.4%	1745	3.6%	1265	-12.4%	-16.0%
	2570	2539.2	-1.0%					
Horiba	0.00	-0.39	-0.4%	1.27	1.3%	4.69	4.7%	3.4%
(ppm THC)	29.88	30.27	0.4%	31.35	1.5%	33.98	4.1%	2.6%
0-100 ppm			NA					
	89.40	89.45	0.1%					
Sample	0.0	1.0	0.1%	23.7	2.4%	-11.4	-1.1%	-3.5%
(ppm CO2)	298.8	307.0	0.8%					
0-1000 ppm	550.0	553.1	0.3%					
	850.9	847.2	-0.4%	854.6	0.4%	842.2	-0.9%	-1.2%
Diluent	0.0	-0.7	-0.1%	28.7	2.9%	0.1	0.0%	-2.9%
(ppm CO2)	298.8	302.1	0.3%					
0-1000 ppm	550.0	553.6	0.4%					
	850.9	842.2	-0.9%	868.0	1.7%	850.3	-0.1%	-1.8%
Forward	0.0	2.1	0.9%	2.1	0.9%	2.3	0.9%	0.1%
(ppm NOx)	53.0	54.6	0.6%	54.6	0.6%			
0-250 ppm	88.0							
	210.0	211.9	0.7%	211.9	0.7%	226.7	6.7%	5.9%
Rearward	0.0	1.1	0.4%	1.1	0.4%	1.8	0.7%	0.3%
(ppm NOx)	53.0	53.0	-0.0%	53.0	-0.0%			
0-250 ppm	88.0							
	210.0	211.0	0.4%	211.0	0.4%	220.6	4.2%	3.8%

PRE-TEST AND POST-TEST CALIBRATION SUMMARY

Source Description: 1990 Kenworth with Detroit Diesel Series 60 Engine   Date: 10-13-99

Test Number: 3E00C

Monitor	Slope	Intercept
PM Sample CC	1.002	10.697
PM Diluent CO	1.005	10.424
Forward NOx	1.058	-3.527
Rearward NOx	1.094	-5.329

Monitor	Slope	Intercept
Horiba O2	1.010	-0.122
Horiba CO2	0.979	0.039
Horiba CO	1.025	-129.672
Siemens CO	0.992	4.481
Horiba NOx	0.996	31.671
TECO NOx	NA	NA
Horiba THC	ERR	ERR

Monitor (Units) Range	Gas Tag Value	----- Direct Calibration ----- Monitor Reading	% Error	-- Pre-Test Cal Check -- Monitor Response	% Error	-- Post-Test Cal Check -- Monitor Response	% Error	% Drift
Horiba	0.00	0.07	0.3%	0.15	0.6%	0.10	0.4%	-0.2%
(% O2)	7.51	7.72	0.9%					
0-25%	13.90	14.03	0.5%	14.08	0.7%	13.69	-0.8%	-1.5%
	21.04	21.04	0.0%					
Horiba	0.00	-0.07	-0.4%	-0.07	-0.4%	-0.01	-0.1%	0.3%
(% CO2)	4.80	4.87	0.4%					
0-16%	8.79	8.90	0.7%	8.96	1.1%	8.92	0.8%	-0.2%
	13.60	13.73	0.8%					
Horiba	0	75	0.8%	98	1.0%	155	1.5%	0.6%
(ppm CO)	2980	2900	-0.8%					
0-10000 ppm	5501	5431	-0.7%	5493	-0.1%	5491	-0.1%	-0.0%
	8500	8557	0.6%					
Siemens	0.0	-0.0	-0.0%	-1.2	-0.1%	-7.8	-0.8%	-0.7%
(ppm CO)	301.6	312.6	1.1%					
0-1000 ppm	607.0	621.1	1.4%	613.2	0.6%	601.4	-0.6%	-1.2%
	916.0	939.5	2.3%					
Horiba	0	-13.8	-0.5%	-35	-1.2%	-29	-1.0%	0.2%
(ppm NOx)	888	899.1	0.4%					
0-3000 ppm	1638	1618.1	-0.7%	1621	-0.6%	1603	-1.2%	-0.6%
	2570	2544.4	-0.9%					
TECO	0	-5.9	-0.2%	-6	-0.2%	-3	-0.1%	0.1%
(ppm NO)	888	915.8	0.9%					
0-3000 ppm	1638	1642.1	0.1%	1691	1.8%	1481	-5.2%	-7.0%
	2570	2578.4	0.3%					
Horiba	0.00		NA					
(ppm THC)	29.88		NA					
0-100 ppm			NA					
	89.40		NA					
Sample	0.0	4.5	0.5%	4.5	0.5%	-25.9	-2.6%	-3.0%
(ppm CO2)	298.8	299.7	0.1%	299.7	0.1%			
0-1000 ppm	550.0	550.5	0.1%	550.5	0.1%			
	850.9	846.1	-0.5%	846.1	-0.5%	831.8	-1.9%	-1.4%
Diluent	0.0	4.9	0.5%	4.9	0.5%	-25.6	-2.6%	-3.1%
(ppm CO2)	298.8	296.4	-0.2%	296.4	-0.2%			
0-1000 ppm	550.0	551.4	0.1%	551.4	0.1%			
	850.9	843.1	-0.8%	843.1	-0.8%	830.1	-2.1%	-1.3%
Forward	0.0	2.4	1.0%	2.4	1.0%	4.3	1.7%	0.8%
(ppm NOx)	53.0	54.4	0.6%	54.4	0.6%	52.4	-0.2%	-0.8%
0-250 ppm	88.0							
	210.0	208.3	-0.7%	208.3	-0.7%			
Rearward	0.0	2.6	1.0%	2.6	1.0%	7.2	2.9%	1.9%
(ppm NOx)	53.0	55.1	0.8%	55.1	0.8%	51.5	-0.6%	-1.4%
0-250 ppm	88.0							
	210.0	213.0	1.2%	213.0	1.2%			

PRE-TEST AND POST-TEST CALIBRATION SUMMARY

Source Description: 1990 Kenworth with Detroit Diesel Series 60 Engine Date: 10-13-99

Test Number: 3E00V

Monitor	Slope	Intercept
PM Sample CC	0.994	24.029
PM Diluent CO	0.999	20.786
Forward NOx	1.058	-3.527
Rearward NOx	1.094	-5.329

Monitor	Slope	Intercept
Horiba O2	1.019	-0.080
Horiba CO2	0.986	0.002
Horiba CO	1.034	-173.461
Siemens CO	0.995	8.619
Horiba NOx	1.018	29.988
TECO NOx	NA	NA
Horiba THC	ERR	ERR

Monitor		----- Direct Calibration -----		-- Pre-Test Cal Check --		-- Post-Test Cal Check --		
(Units) Range	Gas Tag Value	Monitor Reading	% Error	Monitor Response	% Error	Monitor Response	% Error	% Drift
Horiba	0.00	0.07	0.3%	0.10	0.4%	0.06	0.2%	-0.1%
(% O2)	7.51	7.72	0.9%					
0-25%	13.90	14.03	0.5%	13.69	-0.8%	13.73	-0.7%	0.2%
	21.04	21.04	0.0%					
Horiba	0.00	-0.07	-0.4%	-0.01	-0.1%	0.01	0.0%	0.1%
(% CO2)	4.80	4.87	0.4%					
0-16%	8.79	8.90	0.7%	8.92	0.8%	8.91	0.8%	-0.1%
	13.60	13.73	0.8%					
Horiba	0	75	0.8%	155	1.5%	181	1.8%	0.3%
(ppm CO)	2980	2900	-0.8%					
0-10000 ppm	5501	5431	-0.7%	5491	-0.1%	5480	-0.2%	-0.1%
	8500	8557	0.6%					
Siemens	0.0	-0.0	-0.0%	-7.8	-0.8%	-9.5	-1.0%	-0.2%
(ppm CO)	301.6	312.6	1.1%					
0-1000 ppm	607.0	621.1	1.4%	601.4	-0.6%	601.9	-0.5%	0.0%
	916.0	939.5	2.3%					
Horiba	0	-13.8	-0.5%	-29	-1.0%	-30	-1.0%	-0.0%
(ppm NOx)	888	899.1	0.4%					
0-3000 ppm	1638	1618.1	-0.7%	1603	-1.2%	1554	-2.8%	-1.6%
	2570	2544.4	-0.9%					
TECO	0	-5.9	-0.2%	-3	-0.1%	-3	-0.1%	0.0%
(ppm NO)	888	915.8	0.9%					
0-3000 ppm	1638	1642.1	0.1%	1481	-5.2%	1495	-4.8%	0.5%
	2570	2578.4	0.3%					
Horiba	0.00		NA					
(ppm THC)	29.88		NA					
0-100 ppm			NA					
	89.40		NA					
Sample	0.0	4.5	0.5%	-25.9	-2.6%	-22.5	-2.2%	0.3%
(ppm CO2)	298.8	299.7	0.1%					
0-1000 ppm	550.0	550.5	0.1%					
	850.9	846.1	-0.5%	831.8	-1.9%	831.7	-1.9%	-0.0%
Diluent	0.0	4.9	0.5%	-25.6	-2.6%	-16.0	-1.6%	1.0%
(ppm CO2)	298.8	296.4	-0.2%					
0-1000 ppm	550.0	551.4	0.1%					
	850.9	843.1	-0.8%	830.1	-2.1%	832.3	-1.9%	0.2%
Forward	0.0	2.4	1.0%	2.4	1.0%	4.3	1.7%	0.8%
(ppm NOx)	53.0	54.4	0.6%	54.4	0.6%	52.4	-0.2%	-0.8%
0-250 ppm	88.0							
	210.0	208.3	-0.7%	208.3	-0.7%			
Rearward	0.0	2.6	1.0%	2.6	1.0%	7.2	2.9%	1.9%
(ppm NOx)	53.0	55.1	0.8%	55.1	0.8%	51.5	-0.6%	-1.4%
0-250 ppm	88.0							
	210.0	213.0	1.2%	213.0	1.2%			

PRE-TEST AND POST-TEST CALIBRATION SUMMARY

Source Description: 1995 Freightliner Century with 1998 Detroit Diesel Series 60 Engine   Date: 03/06/00

Test Number: 4f0

Monitor	Slope	Intercept
Stage 1 CO2	0.895	49.992
Stage 2 CO2	0.985	-4.450
Diluent CO2	1.003	5.447
Forward NOx	ERR	ERR
Rearward NOx	ERR	ERR

Monitor	Slope	Intercept
Horiba O2	0.990	-0.016
Horiba CO2	0.982	-0.024
Horiba CO	1.017	-44.824
Siemens CO	0.975	18.264
Horiba NOx	0.984	0.721
TECO NOx	0.937	-21.414
Horiba THC	1.027	-2.809

Monitor (Units) Range	Gas Tag Value	----- Direct Calibration ----- Monitor Reading	% Error	-- Pre-Test Cal Check -- Monitor Response	% Error	-- Post-Test Cal Check -- Monitor Response	% Error	% Drift
Horiba	0.00	-0.03	-0.2%	0.01	0.1%	0.02	0.1%	0.0%
(% O2)	7.50	7.70	1.3%					
0-15%	13.70	13.91	1.4%	13.86	1.0%	13.86	1.1%	0.0%
	21.04	21.01	-0.2%					
Horiba	0.00	0.01	0.1%	0.02	0.1%	0.03	0.2%	0.1%
(% CO2)	4.81	4.97	1.0%					
0-16%	8.70	8.87	1.1%	8.85	0.9%	8.91	1.3%	0.4%
	13.50	13.46	-0.3%					
Horiba	0	12	0.1%	25	0.2%	64	0.6%	0.4%
(ppm CO)	3000	2949	-0.5%					
0-10000 ppm	5450	5404	-0.5%	5384	-0.7%	5424	-0.3%	0.4%
	8510	8513	0.0%					
Siemens	0	6	0.6%	-11	-1.1%	-26	-2.6%	-1.5%
(ppm CO)	302	301	-0.1%					
0-1000 ppm	607	614	0.7%	609	0.2%	599	-0.8%	-1.1%
	938	929	-0.9%					
Horiba	0	1	0.0%	-1	-0.0%	-1	-0.0%	0.0%
(ppm NOx)	888	927	1.3%					
0-3000 ppm	1635	1664	1.0%	1661	0.9%	1661	0.9%	0.0%
	2550	2548	-0.1%					
TECO	0	21	0.7%	22	0.7%	24	0.8%	0.1%
(ppm NO)	888	938	1.6%					
0-3000 ppm	1635	1685	1.7%	1777	4.7%	1758	4.1%	-0.7%
	2550	2552	0.1%					
Horiba	0.0	-0.8	-0.8%	1.7	1.7%	3.8	3.8%	2.1%
(ppm THC)	29.9	30.1	0.2%					
0-100 ppm	60.0	60.7	0.7%	60.7	0.7%	61.5	1.5%	0.8%
	89.4	89.5	0.1%					
Stage 1	0	-10	-0.2%	-10	-0.2%	-102	-2.0%	-1.8%
(ppm CO2)	833	853	0.4%	853	0.4%			
0-5000 ppm	1510	1631	2.4%	1631	2.4%	1631	2.4%	0.0%
	2750	2760	0.2%	2760	0.2%			
Stage 2	0	-1	-0.1%	-1	-0.1%	10	1.0%	1.1%
(ppm CO2)	299	290	-0.9%	290	-0.9%			
0-1000 ppm	551	549	-0.2%	549	-0.2%			
	833	841	0.8%	841	0.8%	859	2.6%	1.8%
Diluent	0	-9	-0.9%	-9	-0.9%	-2	-0.2%	0.7%
(ppm CO2)	299	295	-0.4%	295	-0.4%			
0-1000 ppm	551	555	0.4%	555	0.4%	537	-1.4%	-1.7%
	833	837	0.4%	837	0.4%	814	-1.9%	-2.3%
Forward	0.00	0.53	1.1%	0.53	1.1%	-0.72	-1.4%	-2.5%
(ppm NOx)	15.10							
0-50 ppm	27.50							
	42.50	43.12	1.2%	43.12	1.2%			
Rearward	0.00	-3.34	-6.7%	-3.34	-6.7%	-0.24	-0.5%	6.2%
(ppm NOx)	15.10							
0-50 ppm	27.50							
	42.50							

PRE-TEST AND POST-TEST CALIBRATION SUMMARY

Source Description: 1995 Freightliner Century with 1998 Detroit Diesel Series 60 Engine Date: 03/07/00

Test Number: 4h0-1

Monitor	Slope	Intercept
Stage 1 CO2	0.994	15.465
Stage 2 CO2	0.964	8.444
Diluent CO2	0.999	8.446
Forward NOx	ERR	ERR
Rearward NOx	ERR	ERR

Monitor	Slope	Intercept
Horiba O2	1.009	-0.133
Horiba CO2	0.991	0.018
Horiba CO	1.019	-59.673
Siemens CO	0.989	1.932
Horiba NOx	1.018	16.247
TECO NOx	0.992	-27.596
Horiba THC	1.072	-2.723

Monitor (Units) Range	Gas Tag Value	Direct Calibration Monitor Reading	Direct Calibration % Error	Pre-Test Cal Check Monitor Response	Pre-Test Cal Check % Error	Post-Test Cal Check Monitor Response	Post-Test Cal Check % Error	% Drift
Horiba	0.00	-0.04	-0.2%	0.18	1.2%	0.09	0.6%	-0.6%
(% O2)	7.50	7.65	1.0%					
0-15%	13.70	13.85	1.0%	13.94	1.6%	13.47	-1.5%	-3.1%
	21.04	20.98	-0.4%					
Horiba	0.00	-0.00	-0.0%	-0.03	-0.2%	-0.01	-0.1%	0.1%
(% CO2)	4.81	5.00	1.2%					
0-16%	8.70	8.87	1.0%	8.80	0.6%	8.71	0.1%	-0.6%
	13.50	13.43	-0.4%					
Horiba	0	-4	-0.0%	26	0.3%	91	0.9%	0.7%
(ppm CO)	3000	3002	0.0%					
0-10000 ppm	5450	5419	-0.3%	5418	-0.3%	5393	-0.6%	-0.3%
	8510	8490	-0.2%					
Siemens	0	1	0.1%	-3	-0.3%	-1	-0.1%	0.2%
(ppm CO)	302	319	1.8%					
0-1000 ppm	607	624	1.7%	618	1.1%	605	-0.2%	-1.3%
	938	936	-0.2%					
Horiba	0	-25	-0.8%	-20	-0.7%	-12	-0.4%	0.3%
(ppm NOx)	908	906	-0.1%					
0-3000 ppm	1635	1701	2.2%	1611	-0.8%	1570	-2.2%	-1.4%
	2550	2548	-0.1%					
TECO	0	21	0.7%	22	0.7%	33	1.1%	0.4%
(ppm NO)	908	901	-0.2%					
0-3000 ppm	1635	1651	0.5%	1751	3.9%	1603	-1.1%	-4.9%
	2550	2555	0.2%					
Horiba	0.0	-0.1	-0.1%	4.0	4.0%	1.1	1.1%	-2.9%
(ppm THC)	29.9	30.1	0.2%					
0-100 ppm	60.0	60.6	0.6%	57.9	-2.1%	59.1	-0.9%	1.2%
	89.4	89.0	-0.4%					
Stage 1	0	-4	-0.1%	-4	-0.1%	-27	-0.5%	-0.5%
(ppm CO2)	833	814	-0.4%	814	-0.4%			
0-5000 ppm	1510	1513	0.1%	1513	0.1%			
	2750	2720	-0.6%	2720	-0.6%	2784	0.7%	1.3%
Stage 2	0	5	0.5%	5	0.5%	-23	-2.3%	-2.8%
(ppm CO2)	299	298	-0.1%	298	-0.1%			
0-1000 ppm	551	554	0.3%	554	0.3%	572	2.1%	1.8%
	833	833	0.0%	833	0.0%			
Diluent	0	-6	-0.6%	-6	-0.6%	-11	-1.1%	-0.5%
(ppm CO2)	299	302	0.3%	302	0.3%			
0-1000 ppm	551	547	-0.4%	547	-0.4%	539	-1.2%	-0.8%
	833	829	-0.4%	829	-0.4%			
Forward	0.00	-0.16	-0.3%	-0.16	-0.3%			
(ppm NOx)	15.10	18.05	5.9%	18.05	5.9%			
0-50 ppm	27.50							
	42.50	41.97	-1.1%	41.97	-1.1%			
Rearward	0.00	0.12	0.2%	0.12	0.2%			
(ppm NOx)	15.10	19.43	8.7%	19.43	8.7%			
0-50 ppm	27.50							
	42.50	43.24	1.5%	43.24	1.5%			

PRE-TEST AND POST-TEST CALIBRATION SUMMARY

Source Description: 1995 Freightliner Century with 1998 Detroit Diesel Series 60 Engine   Date: 03/07/00

Test Number: 4h0-2

Monitor	Slope	Intercept
Stage 1 CO2	ERR	ERR
Stage 2 CO2	0.934	22.343
Diluent CO2	0.988	4.764
Forward NOx	ERR	ERR
Rearward NOx	1.011	0.195

Monitor	Slope	Intercept
Horiba O2	1.032	-0.088
Horiba CO2	0.997	0.008
Horiba CO	1.026	-91.232
Siemens CO	0.987	4.520
Horiba NOx	1.038	1.521
TECO NOx	1.033	-32.370
Horiba THC	1.021	-2.292

Monitor (Units) Range	Gas Tag Value	----- Direct Calibration ----- Monitor Reading	% Error	-- Pre-Test Cal Check -- Monitor Response	% Error	-- Post-Test Cal Check -- Monitor Response	% Error	% Drift
Horiba	0.00	-0.04	-0.2%	0.09	0.6%	0.09	0.6%	0.0%
(% O2)	7.50	7.65	1.0%					
0-15%	13.70	13.85	1.0%	13.47	-1.5%	13.24	-3.1%	-1.5%
	21.04	20.98	-0.4%					
Horiba	0.00	-0.00	-0.0%	-0.01	-0.1%	-0.01	-0.0%	0.0%
(% CO2)	4.81	5.00	1.2%					
0-16%	8.70	8.87	1.0%	8.71	0.1%	8.73	0.2%	0.1%
	13.50	13.43	-0.4%					
Horiba	0	-4	-0.0%	91	0.9%	87	0.9%	-0.0%
(ppm CO)	3000	3002	0.0%					
0-10000 ppm	5450	5419	-0.3%	5393	-0.6%	5406	-0.4%	0.1%
	8510	8490	-0.2%					
Siemens	0	1	0.1%	-1	-0.1%	-8	-0.8%	-0.7%
(ppm CO)	302	319	1.8%					
0-1000 ppm	607	624	1.7%	605	-0.2%	615	0.8%	1.0%
	938	936	-0.2%					
Horiba	0	-25	-0.8%	-12	-0.4%	9	0.3%	0.7%
(ppm NOx)	908	906	-0.1%					
0-3000 ppm	1635	1701	2.2%	1570	-2.2%	1576	-2.0%	0.2%
	2550	2548	-0.1%					
TECO	0	21	0.7%	33	1.1%	29	1.0%	-0.1%
(ppm NO)	908	901	-0.2%					
0-3000 ppm	1635	1651	0.5%	1603	-1.1%	1627	-0.3%	0.8%
	2550	2555	0.2%					
Horiba	0.0	-0.1	-0.1%	1.1	1.1%	3.4	3.4%	2.3%
(ppm THC)	29.9	30.1	0.2%					
0-100 ppm	60.0	60.6	0.6%	59.1	-0.9%	63.0	3.0%	3.9%
	89.4	89.0	-0.4%					
Stage 1	0	-4	-0.1%	-27	-0.5%	-41	-0.8%	-0.3%
(ppm CO2)	833	814	-0.4%					
0-5000 ppm	1510	1513	0.1%					
	2750	2720	-0.6%	2784	0.7%			
Stage 2	0	5	0.5%	-23	-2.3%	-25	-2.5%	-0.2%
(ppm CO2)	299	298	-0.1%					
0-1000 ppm	551	554	0.3%	572	2.1%	561	1.0%	-1.1%
	833	833	0.0%					
Diluent	0	-6	-0.6%	-11	-1.1%	1	0.1%	1.2%
(ppm CO2)	299	302	0.3%					
0-1000 ppm	551	547	-0.4%	539	-1.2%	567	1.6%	2.7%
	833	829	-0.4%					
Forward	0.00	-0.16	-0.3%			2.49	5.0%	5.0%
(ppm NOx)	15.10	18.05	5.9%					
0-50 ppm	27.50							
	42.50	41.97	-1.1%					
Rearward	0.00	0.12	0.2%	-0.38	-0.8%	-0.01	-0.0%	0.7%
(ppm NOx)	15.10	19.43	8.7%					
0-50 ppm	27.50			26.05	-2.9%	27.98	1.0%	3.9%
	42.50	43.24	1.5%					

PRE-TEST AND POST-TEST CALIBRATION SUMMARY

Source Description: 1995 Freightliner Century with 1998 Detroit Diesel Series 60 Engine Date: 03/08/00

Test Number: 4h0-2

Monitor	Slope	Intercept
Stage 1 CO2	1.004	64.627
Stage 2 CO2	0.989	22.782
Diluent CO2	1.038	-8.809
Forward NOx	ERR	ERR
Rearward NOx	1.021	0.047

Monitor	Slope	Intercept
Horiba O2	0.989	-0.076
Horiba CO2	0.993	0.080
Horiba CO	1.033	-32.838
Siemens CO	0.979	15.889
Horiba NOx	1.038	-4.560
TECO NOx	1.026	-29.153
Horiba THC	1.033	-3.381

Monitor (Units) Range	Gas Tag Value	----- Direct Calibration ----- Monitor Reading	% Error	-- Pre-Test Cal Check -- Monitor Response	% Error	-- Post-Test Cal Check -- Monitor Response	% Error	% Drift
Horiba	0.00	0.03	0.2%	0.05	0.4%	0.10	0.7%	0.3%
(% O2)	7.50	7.61	0.7%					
0-15%	13.70	13.93	1.5%	13.87	1.1%	13.99	1.9%	0.8%
	21.04	20.91	-0.8%					
Horiba	0.00	0.00	0.0%	-0.09	-0.6%	-0.07	-0.4%	0.1%
(% CO2)	4.81	4.91	0.6%					
0-16%	8.70	8.78	0.5%	8.67	-0.2%	8.69	-0.1%	0.1%
	13.50	13.48	-0.1%					
Horiba	0	-6	-0.1%	3	0.0%	61	0.6%	0.6%
(ppm CO)	3000	2950	-0.5%					
0-10000 ppm	5450	5389	-0.6%	5283	-1.7%	5336	-1.1%	0.5%
	8510	8538	0.3%					
Siemens	0	-6	-0.6%	-12	-1.2%	-20	-2.0%	-0.8%
(ppm CO)	302	314	1.2%					
0-1000 ppm	607	613	0.6%	611	0.4%	597	-1.0%	-1.4%
	938	928	-1.0%					
Horiba	0	-13	-0.4%	-6	-0.2%	15	0.5%	0.7%
(ppm NOx)	908	936	0.9%					
0-3000 ppm	1635	1623	-0.4%	1582	-1.8%	1578	-1.9%	-0.1%
	2550	2544	-0.2%					
TECO	0	24	0.8%	24	0.8%	33	1.1%	0.3%
(ppm NO)	908	913	0.2%					
0-3000 ppm	1635	1637	0.1%	1655	0.7%	1589	-1.5%	-2.2%
	2550	2568	0.6%					
Horiba	0.0	-0.7	-0.7%	1.7	1.7%	4.9	4.9%	3.2%
(ppm THC)	29.9	30.2	0.3%					
0-100 ppm	60.0	60.9	0.9%	60.0	-0.0%	62.7	2.7%	2.7%
	89.4	89.6	0.2%					
Stage 1	0	-14	-0.3%	-14	-0.3%	-115	-2.3%	-2.0%
(ppm CO2)	833	888	1.1%	888	1.1%			
0-5000 ppm	1510	1618	2.2%	1618	2.2%			
	2750	2708	-0.8%	2708	-0.8%	2644	-2.1%	-1.3%
Stage 2	0	-3	-0.3%	-3	-0.3%	-43	-4.3%	-3.9%
(ppm CO2)	299	310	1.1%	310	1.1%			
0-1000 ppm	551	538	-1.3%	538	-1.3%	531	-2.0%	-0.7%
	833	837	0.4%	837	0.4%			
Diluent	0	-3	-0.3%	-3	-0.3%	20	2.0%	2.2%
(ppm CO2)	299	308	0.9%	308	0.9%			
0-1000 ppm	551	549	-0.2%	549	-0.2%	529	-2.2%	-2.0%
	833	834	0.1%	834	0.1%			
Forward	0.00	-0.24	-0.5%	-0.24	-0.5%	1.64	3.3%	3.8%
(ppm NOx)	15.10	17.89	5.6%	17.89	5.6%			
0-50 ppm	27.50							
	42.50	41.50	-2.0%	41.50	-2.0%			
Rearward	0.00	0.08	0.2%	0.08	0.2%	-0.17	-0.3%	-0.5%
(ppm NOx)	15.10	15.55	0.9%	15.55	0.9%			
0-50 ppm	27.50	28.06	1.1%	28.06	1.1%	25.72	-3.6%	-4.7%
	42.50	42.73	0.5%	42.73	0.5%			

PRE-TEST AND POST-TEST CALIBRATION SUMMARY

Source Description: 1995 Freightliner Century with 1998 Detroit Diesel Series 60 Engine   Date: 03/08/00

Test Number: 4h0-3

Monitor	Slope	Intercept
Stage 1 CO2	ERR	ERR
Stage 2 CO2	ERR	ERR
Diluent CO2	ERR	ERR
Forward NOx	ERR	ERR
Rearward NOx	ERR	ERR

Monitor	Slope	Intercept
Horiba O2	1.007	-0.139
Horiba CO2	1.015	0.086
Horiba CO	1.033	-39.573
Siemens CO	1.011	19.492
Horiba NOx	1.018	6.561
TECO NOx	1.037	-29.323
Horiba THC	NA	NA

Monitor (Units) Range	Gas Tag Value	----- Direct Calibration ----- Monitor Reading	% Error	-- Pre-Test Cal Check -- Monitor Response	% Error	-- Post-Test Cal Check -- Monitor Response	% Error	% Drift
Horiba	0.00	-0.17	-1.1%	0.04	0.3%	0.23	1.6%	1.3%
(% O2)	7.50	7.66	1.1%					
0-15%	13.70	13.83	0.9%	13.69	-0.1%	13.79	0.6%	0.7%
	21.04	20.94	-0.7%					
Horiba	0.00	-0.10	-0.6%	-0.09	-0.5%	-0.08	-0.5%	0.0%
(% CO2)	4.81	4.90	0.6%					
0-16%	8.70	8.82	0.8%	8.72	0.1%	8.25	-2.8%	-3.0%
	13.50	13.55	0.3%					
Horiba	0	22	0.2%	38	0.4%	39	0.4%	0.0%
(ppm CO)	3000	2929	-0.7%					
0-10000 ppm	5450	5351	-1.0%	5306	-1.4%	5321	-1.3%	0.1%
	8510	8428	-0.8%					
Siemens	0	-9	-0.9%	-14	-1.4%	-24	-2.4%	-1.0%
(ppm CO)	302	307	0.5%					
0-1000 ppm	607	612	0.5%					
	938	935	-0.3%	915	-2.3%	903	-3.5%	-1.2%
Horiba	0	-10	-0.3%	-5	-0.2%	-8	-0.3%	-0.1%
(ppm NOx)	908	913	0.2%					
0-3000 ppm	1635	1697	2.1%					
	2550	2538	-0.4%	2518	-1.1%	2479	-2.4%	-1.3%
TECO	0	27	0.9%	30	1.0%	27	0.9%	-0.1%
(ppm NO)	908	938	1.0%					
0-3000 ppm	1635	1627	-0.3%					
	2550	2539	-0.4%	2548	-0.1%	2426	-4.1%	-4.1%
Horiba	0.0	-0.1	-0.1%	4.8	4.8%	5.7	5.7%	0.9%
(ppm THC)	29.9	30.2	0.3%					
0-100 ppm	60.0	60.7	0.7%	60.5	0.5%	68.5	8.5%	7.9%
	89.4	89.1	-0.3%					
Stage 1	0							
(ppm CO2)	833							
0-5000 ppm	1510							
	2750							
Stage 2	0							
(ppm CO2)	299							
0-1000 ppm	551							
	833							
Diluent	0	-7	-0.7%	-7	-0.7%			
(ppm CO2)	299							
0-1000 ppm	551							
	833							
Forward	0.00							
(ppm NOx)	15.10							
0-50 ppm	27.50							
	42.50							
Rearward	0.00							
(ppm NOx)	15.10							
0-50 ppm	27.50							
	42.50							

PRE-TEST AND POST-TEST CALIBRATION SUMMARY

Source Description: 1995 Freightliner Century with 1998 Detroit Diesel Series 60 Engine   Date: 03/09/00

Test Number: 4h0-4

Monitor	Slope	Intercept
Stage 1 CO2	0.998	61.369
Stage 2 CO2	0.979	20.789
Diluent CO2	0.981	-17.089
Forward NOx	ERR	ERR
Rearward NOx	ERR	ERR

Monitor	Slope	Intercept
Horiba O2	1.016	-0.082
Horiba CO2	0.997	0.073
Horiba CO	1.036	-52.444
Siemens CO	1.026	17.151
Horiba NOx	1.041	-5.488
TECO NOx	NA	NA
Horiba THC	1.022	-4.642

Monitor (Units) Range	Gas Tag Value	----- Direct Calibration ----- Monitor Reading	% Error	-- Pre-Test Cal Check -- Monitor Response	% Error	-- Post-Test Cal Check -- Monitor Response	% Error	% Drift
Horiba	0.00	0.33	2.2%	0.16	1.0%	0.00	0.0%	-1.0%
(% O2)	7.50	7.65	1.0%					
0-15%	13.70	13.81	0.7%	13.68	-0.1%	13.44	-1.7%	-1.6%
	21.04	20.83	-1.4%					
Horiba	0.00	0.00	0.0%	-0.10	-0.6%	-0.05	-0.3%	0.3%
(% CO2)	4.81	4.84	0.2%					
0-16%	8.70	8.66	-0.3%	8.70	-0.0%	8.60	-0.6%	-0.6%
	13.50	13.30	-1.2%					
Horiba	0	38	0.4%	17	0.2%	84	0.8%	0.7%
(ppm CO)	3000	2927	-0.7%					
0-10000 ppm	5450	5351	-1.0%	5326	-1.2%	5295	-1.6%	-0.3%
	8510	8509	-0.0%					
Siemens	0	-5	-0.5%	-6	-0.6%	-27	-2.7%	-2.1%
(ppm CO)	302	321	2.0%					
0-1000 ppm	607	616	0.9%					
	938	944	0.6%	897	-4.1%	898	-4.0%	0.1%
Horiba	0	-6	-0.2%	-7	-0.2%	17	0.6%	0.8%
(ppm NOx)	908	910	0.1%					
0-3000 ppm	1635	1681	1.5%					
	2550	2520	-1.0%	2412	-4.6%	2499	-1.7%	2.9%
TECO	0	25	0.8%	24	0.8%	35	1.2%	0.4%
(ppm NO)	908	895	-0.4%					
0-3000 ppm	1635	1766	4.4%					
	2550	2525	-0.8%	2472	-2.6%	2739	6.3%	8.9%
Horiba	0.0	-0.9	-0.9%	4.8	4.8%	4.3	4.3%	-0.5%
(ppm THC)	29.9	30.4	0.5%					
0-100 ppm	60.0	61.6	1.6%	62.6	2.6%	63.9	3.9%	1.3%
	89.4	90.0	0.6%					
Stage 1	0	-13	-0.3%	-13	-0.3%	-110	-2.2%	-1.9%
(ppm CO2)	833	856	0.5%	856	0.5%			
0-5000 ppm	1510	1638	2.6%	1638	2.6%			
	2750	2747	-0.1%	2747	-0.1%	2641	-2.2%	-2.1%
Stage 2	0	-1	-0.1%	-1	-0.1%	-41	-4.1%	-4.0%
(ppm CO2)	299	308	0.9%	308	0.9%			
0-1000 ppm	551	550	-0.1%	550	-0.1%	533	-1.8%	-1.7%
	833	837	0.4%	837	0.4%			
Diluent	0	-7	-0.7%	-7	-0.7%	42	4.2%	4.9%
(ppm CO2)	299	308	0.9%	308	0.9%			
0-1000 ppm	551	562	1.1%	562	1.1%	597	4.6%	3.5%
	833	829	-0.4%	829	-0.4%			
Forward	0.00	1.97	3.9%	1.97	3.9%	2.07	4.1%	0.2%
(ppm NOx)	15.10							
0-50 ppm	27.50							
	42.50							
Rearward	0.00	-0.19	-0.4%	-0.19	-0.4%	-0.66	-1.3%	-0.9%
(ppm NOx)	15.10							
0-50 ppm	27.50	28.03	1.1%	28.03	1.1%			
	42.50	42.55	0.1%	42.55	0.1%			

PRE-TEST AND POST-TEST CALIBRATION SUMMARY

Source Description: 1995 Freightliner Century with 1998 Detroit Diesel Series 60 Engine   Date: 03/10/00

Test Number: 4h-rtp2

Monitor	Slope	Intercept
Stage 1 CO2	0.984	18.027
Stage 2 CO2	1.002	-3.579
Diluent CO2	0.963	3.234
Forward NOx	ERR	ERR
Rearward NOx	ERR	ERR

Monitor	Slope	Intercept
Horiba O2	1.002	0.170
Horiba CO2	0.985	-0.032
Horiba CO	1.016	-45.514
Siemens CO	0.967	39.904
Horiba NOx	1.008	-7.384
TECO NOx	0.993	-30.706
Horiba THC	1.015	-4.410

Monitor		----- Direct Calibration -----		-- Pre-Test Cal Check --		-- Post-Test Cal Check --		
(Units) Range	Gas Tag Value	Monitor Reading	% Error	Monitor Response	% Error	Monitor Response	% Error	% Drift
Horiba	0.00	0.09	0.6%	-0.21	-1.4%	-0.13	-0.9%	0.5%
(% O2)	7.50	7.71	1.4%					
0-15%	13.70		NA					
	21.04	20.86	-1.2%	20.93	-0.7%	20.74	-2.0%	-1.2%
Horiba	0.00	0.01	0.1%	0.04	0.2%	0.03	0.2%	-0.1%
(% CO2)	4.81	4.96	0.9%					
0-16%	8.70	8.80	0.6%	8.97	1.7%	8.77	0.4%	-1.2%
	13.50	13.47	-0.2%					
Horiba	0	35	0.3%	81	0.8%	9	0.1%	-0.7%
(ppm CO)	3000	2965	-0.3%					
0-10000 ppm	5450	5384	-0.7%	5374	-0.8%	5446	-0.0%	0.7%
	8510	8493	-0.2%					
Siemens	0	-1	-0.1%	-34	-3.4%	-49	-4.9%	-1.5%
(ppm CO)	302	302	0.1%					
0-1000 ppm	607	615	0.8%	605	-0.2%	568	-3.9%	-3.7%
	938	931	-0.7%					
Horiba	0	-1	-0.0%	-8	-0.3%	23	0.8%	1.1%
(ppm NOx)	908	897	-0.4%					
0-3000 ppm	1635	1695	2.0%	1619	-0.5%	1639	0.1%	0.7%
	2550	2524	-0.9%					
TECO	0	22	0.7%	28	0.9%	34	1.1%	0.2%
(ppm NO)	908	945	1.2%					
0-3000 ppm	1635	1714	2.6%	1679	1.5%	1674	1.3%	-0.2%
	2550	2558	0.3%					
Horiba	0.0	-0.2	-0.2%	4.0	4.0%	4.7	4.7%	0.7%
(ppm THC)	29.9	30.4	0.5%					
0-100 ppm	60.0	60.8	0.8%	64.3	4.3%	62.7	2.7%	-1.6%
	89.4	90.0	0.6%					
Stage 1	0	-16	-0.3%	-16	-0.3%	-20	-0.4%	-0.1%
(ppm CO2)	833	805	-0.6%	805	-0.6%			
0-5000 ppm	1510	1512	0.0%	1512	0.0%	1519	0.2%	0.1%
	2750							
Stage 2	0	-12	-1.2%	-12	-1.2%	19	1.9%	3.2%
(ppm CO2)	299	301	0.2%	301	0.2%			
0-1000 ppm	551	547	-0.4%	547	-0.4%	560	0.9%	1.3%
	833	836	0.3%	836	0.3%			
Diluent	0	-5	-0.5%	-5	-0.5%	-1	-0.1%	0.4%
(ppm CO2)	299	293	-0.6%	293	-0.6%			
0-1000 ppm	551	542	-0.9%	542	-0.9%	596	4.5%	5.4%
	833	828	-0.5%	828	-0.5%			
Forward	0.00					1.68	3.4%	3.4%
(ppm NOx)	15.10							
0-50 ppm	27.50							
	42.50							
Rearward	0.00					-2.18	-4.4%	-4.4%
(ppm NOx)	15.10							
0-50 ppm	27.50							
	42.50							

PRE-TEST AND POST-TEST CALIBRATION SUMMARY

Source Description: 1995 Freightliner Century with 1998 Detroit Diesel Series 60 Engine   Date: 03/14/00

Test Number: 4h-rtp3

Monitor	Slope	Intercept
Stage 1 CO2	1.001	34.068
Stage 2 CO2	NA	NA
Diluent CO2	1.009	0.000
Forward NOx	NA	NA
Rearward NOx	1.012	-0.101

Monitor	Slope	Intercept
Horiba O2	0.999	-0.082
Horiba CO2	0.985	-0.028
Horiba CO	1.044	-18.847
Siemens CO	1.019	16.115
Horiba NOx	1.045	-16.693
TECO NOx	NA	NA
Horiba THC	1.033	-2.019

Monitor (Units) Range	Gas Tag Value	----- Direct Calibration ----- Monitor Reading	% Error	-- Pre-Test Cal Check -- Monitor Response	% Error	-- Post-Test Cal Check -- Monitor Response	% Error	% Drift
Horiba	0.00	-0.01	-0.1%	0.07	0.5%	0.09	0.6%	0.1%
(% O2)	7.50	7.69	1.3%					
0-15%	13.70		NA					
	21.04	20.85	-1.3%	21.12	0.6%	21.16	0.8%	0.3%
Horiba	0.00	-0.01	-0.0%	0.00	0.0%	0.05	0.3%	0.3%
(% CO2)	4.81	4.95	0.9%					
0-16%	8.70	8.80	0.6%	8.73	0.2%	9.00	1.9%	1.7%
	13.50	13.30	-1.2%					
Horiba	0	-9	-0.1%	19	0.2%	17	0.2%	-0.0%
(ppm CO)	3000	2914	-0.9%					
0-10000 ppm	5450	5363	-0.9%	5182	-2.7%	5293	-1.6%	1.1%
	8510	8517	0.1%					
Siemens	0	4	0.4%	-5	-0.5%	-26	-2.6%	-2.1%
(ppm CO)	302	318	1.6%					
0-1000 ppm	607	624	1.7%					
	938	929	-0.9%	920	-1.8%	889	-4.9%	-3.1%
Horiba	0	-1	-0.0%	4	0.1%	28	0.9%	0.8%
(ppm NOx)	908	920	0.4%					
0-3000 ppm	1635	1706	2.4%					
	2550	2547	-0.1%	2483	-2.2%	2428	-4.1%	-1.8%
TECO	0	18	0.6%	23	0.8%	96	3.2%	2.4%
(ppm NO)	908	955	1.6%					
0-3000 ppm	1635	1729	3.1%					
	2550	2572	0.7%	2665	3.8%	2864	10.5%	6.6%
Horiba	0.0	-0.4	-0.4%	0.7	0.7%	3.2	3.2%	2.5%
(ppm THC)	29.9	30.5	0.6%					
0-100 ppm	60.0	61.3	1.3%	60.5	0.5%	59.5	-0.5%	-1.1%
	89.4	89.0	-0.4%					
Stage 1	0	-14	-0.3%	-14	-0.3%	-54	-1.1%	-0.8%
(ppm CO2)	833	800	-0.7%	800	-0.7%			
0-5000 ppm	1510	1507	-0.1%	1507	-0.1%	1441	-1.4%	-1.3%
	2750							
Stage 2	0	-4	-0.4%	-4	-0.4%	-51	-5.1%	-4.7%
(ppm CO2)	299	306	0.7%	306	0.7%			
0-1000 ppm	551	550	-0.1%	550	-0.1%	549	-0.2%	-0.1%
	833	833	0.0%	833	0.0%			
Diluent	0	-7	-0.7%	-7	-0.7%	7	0.7%	1.3%
(ppm CO2)	299	306	0.7%	306	0.7%			
0-1000 ppm	551	552	0.1%	552	0.1%	540	-1.1%	-1.2%
	833	836	0.3%	836	0.3%			
Forward	0.00	-0.42	-0.8%	-0.42	-0.8%	0.11	0.2%	1.1%
(ppm NOx)	15.10	15.66	1.1%	15.66	1.1%			
0-50 ppm	27.50	28.07	1.1%			24.22	-6.6%	48.4%
	42.50	42.86	0.7%	42.86	0.7%			
Rearward	0.00	-0.04	-0.1%	-0.04	-0.1%	0.24	0.5%	0.6%
(ppm NOx)	15.10	15.72	1.2%	15.72	1.2%			
0-50 ppm	27.50	28.15	1.3%	28.15	1.3%	26.37	-2.3%	-3.6%
	42.50	42.70	0.4%	42.70	0.4%			

PRE-TEST AND POST-TEST CALIBRATION SUMMARY

Source Description: 1995 Freightliner Century with 1998 Detroit Diesel Series 60 Engine   Date: 03/15/00

Test Number: 4h-rtp3

Monitor	Slope	Intercept
Stage 1 CO2	0.978	87.744
Stage 2 CO2	NA	NA
Diluent CO2	NA	NA
Forward NOx	NA	NA
Rearward NOx	ERR	ERR

Monitor	Slope	Intercept
Horiba O2	1.019	-0.083
Horiba CO2	0.976	-0.023
Horiba CO	1.035	-80.019
Siemens CO	1.005	34.609
Horiba NOx	1.015	8.776
TECO NOx	NA	NA
Horiba THC	1.021	-2.843

Monitor (Units) Range	Gas Tag Value	----- Direct Calibration ----- Monitor Reading	% Error	-- Pre-Test Cal Check -- Monitor Response	% Error	-- Post-Test Cal Check -- Monitor Response	% Error	% Drift
Horiba	0.00	0.05	0.3%	0.11	0.7%	0.06	0.4%	-0.3%
(% O2)	7.50	7.69	1.2%					
0-15%	13.70		NA					
	21.04	20.84	-1.3%	20.77	-1.8%	20.71	-2.2%	-0.4%
Horiba	0.00	0.01	0.0%	0.01	0.1%	0.04	0.2%	0.2%
(% CO2)	4.81	5.00	1.2%					
0-16%	8.70	8.90	1.2%	8.88	1.1%	9.00	1.9%	0.8%
	13.50	13.55	0.3%					
Horiba	0	32	0.3%	62	0.6%	93	0.9%	0.3%
(ppm CO)	3000	2985	-0.2%					
0-10000 ppm	5450	5444	-0.1%	5341	-1.1%	5348	-1.0%	0.1%
	8510	8542	0.3%					
Siemens	0	-5	-0.5%	-19	-1.9%	-50	-5.0%	-3.1%
(ppm CO)	302	307	0.5%					
0-1000 ppm	607	609	0.2%					
	938	934	-0.4%	901	-3.7%	896	-4.2%	-0.6%
Horiba	0	-10	-0.3%	-11	-0.4%	-6	-0.2%	0.2%
(ppm NOx)	908	941	1.1%					
0-3000 ppm	1635	1738	3.4%					
	2550	2549	-0.0%	2488	-2.1%	2518	-1.1%	1.0%
TECO	0	21	0.7%	21	0.7%	28	0.9%	0.2%
(ppm NO)	908	942	1.1%					
0-3000 ppm	1635	1776	4.7%					
	2550	2568	0.6%	2616	2.2%	2842	9.7%	7.5%
Horiba	0.0	-0.1	-0.1%	0.8	0.8%	4.8	4.8%	4.0%
(ppm THC)	29.9	31.0	1.1%					
0-100 ppm	60.0	61.6	1.6%	61.4	1.4%	61.6	1.6%	0.2%
	89.4	89.2	-0.2%					
Stage 1	0	-13	-0.3%	-13	-0.3%	-166	-3.3%	-3.1%
(ppm CO2)	833	798	-0.7%	798	-0.7%			
0-5000 ppm	1510	1494	-0.3%	1494	-0.3%	1414	-1.9%	-1.6%
	2750							
Stage 2	0	-7	-0.7%	-7	-0.7%	-118	-11.8%	-11.1%
(ppm CO2)	299	293	-0.6%	293	-0.6%			
0-1000 ppm	551	541	-1.0%	541	-1.0%	419	-13.2%	-12.2%
	833	828	-0.5%	828	-0.5%			
Diluent	0	-7	-0.7%	-7	-0.7%	-2	-0.2%	0.5%
(ppm CO2)	299	298	-0.1%	298	-0.1%			
0-1000 ppm	551	542	-0.9%	542	-0.9%	443	-10.8%	-9.9%
	833	829	-0.4%	829	-0.4%			
Forward	0.00	-0.19	-0.4%	-0.19	-0.4%	0.23	0.5%	0.8%
(ppm NOx)	15.10	15.55	0.9%	15.55	0.9%			
0-50 ppm	27.50	28.39	1.8%			0.00	-55.0%	0.0%
	42.50	42.44	-0.1%	42.44	-0.1%			
Rearward	0.00	-0.30	-0.6%	-0.30	-0.6%	-0.32	-0.6%	-0.0%
(ppm NOx)	15.10	15.60	1.0%	15.60	1.0%			
0-50 ppm	27.50	28.10	1.2%		-55.0%	-0.34	-55.7%	-0.7%
	42.50	42.01	-1.0%	42.01	-1.0%			

PRE-TEST AND POST-TEST CALIBRATION SUMMARY

Source Description: 1990 Kenworth with rebuilt Detroit Diesel Series 60 Engine   Date: 9-26/27-00

Test Number: 5F3&6a

Monitor	Slope	Intercept
Stage 1 CO2	NA	NA
Stage 2 CO2	NA	NA
PM Diluent CO	1.003	11.111
Forward NOx	0.964	0.155
Rearward NOx	0.986	-0.029

Monitor	Slope	Intercept
Horiba O2	1.014	0.052
Horiba CO2	1.032	-0.108
Horiba CO	1.022	-79.770
Siemens CO	1.021	7.666
Horiba NOx	0.994	-7.135
TECO NOx	0.991	-2.468
Horiba THC	NA	NA

Monitor (Units) Range	Gas Tag Value	----- Direct Calibration ----- Monitor Reading	% Error	-- Pre-Test Cal Check -- Monitor Response	% Error	-- Post-Test Cal Check -- Monitor Response	% Error	% Drift
Horiba	0.00	-0.09	-0.3%	-0.04	-0.1%	-0.07	-0.3%	-0.1%
(% O2)	7.50	7.53	0.1%					
0-25%	13.70	13.95	1.0%	13.72	0.1%	13.21	-2.0%	-2.0%
	20.88	20.88	-0.0%					
Horiba	0.00	0.10	0.6%	0.10	0.6%	0.11	0.7%	0.1%
(% CO2)	4.81	4.87	0.4%					
0-16%	8.71	8.73	0.1%	8.73	0.1%	8.36	-2.2%	-2.3%
	13.50		NA					
Horiba	0	58	0.6%	66	0.7%	90	0.9%	0.2%
(ppm CO)	3000	2962	-0.4%					
0-10000 ppm	5600	5616	0.2%	5629	0.3%	5486	-1.1%	-1.4%
	8510		NA					
Siemens	0.0	-5.0	-0.5%	-0.5	-0.0%	-14.5	-1.5%	-1.4%
(ppm CO)	303.0	319.1	1.6%					
0-1000 ppm	600.0	608.0	0.8%	591.9	-0.8%	568.2	-3.2%	-2.4%
	902.0	907.0	0.5%					
Horiba	0	1.5	0.0%	3	0.1%	12	0.4%	0.3%
(ppm NOx)	903	954.8	1.7%					
0-3000 ppm	1672	1676.1	0.1%	1648	-0.8%	1731	2.0%	2.8%
	2547	2554.1	0.2%					
TECO	0	7.3	0.2%	-1	-0.0%	6	0.2%	0.2%
(ppm NO)	903	873.3	-1.0%					
0-3000 ppm	1674	1668.5	-0.2%	1754	2.7%	1630	-1.5%	-4.1%
	2548	2542.1	-0.2%					
Horiba	0.00	0.78	0.8%	0.68	0.7%	-6.54	-6.5%	-7.2%
(ppm THC)	30.60	30.18	-0.4%					
0-100 ppm	60.00	60.64	0.6%					
	91.20	92.09	0.9%	88.57	-2.6%	82.03	-9.2%	-6.5%
Stage 1	0.00	-8.85	-0.3%	-8.85	-0.3%	-47.61	-1.6%	-1.3%
(ppm CO2)	851.00	927.12	2.5%	927.12	2.5%			
0-3000 ppm	1510.00		NA					
	2770.00	2768.25	-0.1%	2768.25	-0.1%	2329.10	-14.7%	-14.6%
Stage 2	0.00	0.61	0.1%	0.61	0.1%	-67.57	-6.8%	-6.8%
(ppm CO2)	300.00	302.86	0.3%	302.86	0.3%			
0-1000 ppm	551.00	553.16	0.2%	553.16	0.2%			
	851.00	854.19	0.3%	854.19	0.3%	789.12	-6.2%	-6.5%
Diluent	0.00	-2.69	-0.3%	-2.69	-0.3%	-19.47	-1.9%	-1.7%
(ppm CO2)	300.00	310.06	1.0%	310.06	1.0%			
0-1000 ppm	551.00	556.21	0.5%	556.21	0.5%			
	851.00	854.98	0.4%	854.98	0.4%	819.82	-3.1%	-3.5%
Forward	0.10	-0.17	-0.5%	-0.17	-0.5%	-0.15	-0.5%	0.0%
(ppm NOx)	15.10	16.04	1.9%	16.04	1.9%			
0-50 ppm	27.30	27.65	0.7%	27.65	0.7%	28.67	2.7%	1.0%
	43.50		NA					
Rearward	0.10	-0.15	-0.5%	-0.15	-0.5%	0.21	0.2%	0.4%
(ppm NOx)	15.10	16.05	1.9%	16.05	1.9%			
0-50 ppm	27.30	27.26	-0.1%	27.26	-0.1%	28.17	1.7%	0.9%
	43.50		NA					

PRE-TEST AND POST-TEST CALIBRATION SUMMARY

Source Description: 1990 Kenworth with rebuilt Detroit Diesel Series 60 Engine   Date: 9-27-00

Test Number: 5F3&6b

Monitor	Slope	Intercept
Stage 1 CO2	NA	NA
Stage 2 CO2	NA	NA
PM Diluent CO	1.002	-5.229
Forward NOx	0.964	0.155
Rearward NOx	0.986	-0.029

Monitor	Slope	Intercept
Horiba O2	1.013	0.064
Horiba CO2	1.030	-0.115
Horiba CO	1.022	-96.003
Siemens CO	1.003	15.611
Horiba NOx	0.985	-8.226
TECO NOx	1.007	-5.751
Horiba THC	0.986	-3.274

Monitor		----- Direct Calibration -----		-- Pre-Test Cal Check --		-- Post-Test Cal Check --		
Monitor (Units) Range	Gas Tag Value	Monitor Reading	% Error	Monitor Response	% Error	Monitor Response	% Error	% Drift
Horiba	0.00	-0.09	-0.3%	-0.07	-0.3%	-0.06	-0.2%	0.0%
(% O2)	7.50	7.53	0.1%					
0-25%	13.70	13.95	1.0%	13.21	-2.0%	13.70	-0.0%	2.0%
	20.88	20.88	-0.0%					
Horiba	0.00	0.10	0.6%	0.11	0.7%	0.11	0.7%	0.0%
(% CO2)	4.81	4.87	0.4%					
0-16%	8.71	8.73	0.1%	8.36	-2.2%	8.77	0.4%	2.6%
	13.50		NA					
Horiba	0	58	0.6%	90	0.9%	98	1.0%	0.1%
(ppm CO)	3000	2962	-0.4%					
0-10000 ppm	5600	5616	0.2%	5486	-1.1%	5663	0.6%	1.8%
	8510		NA					
Siemens	0.0	-5.0	-0.5%	-14.5	-1.5%	-16.6	-1.7%	-0.2%
(ppm CO)	303.0	319.1	1.6%					
0-1000 ppm	600.0	608.0	0.8%	568.2	-3.2%	597.0	-0.3%	2.9%
	902.0	907.0	0.5%					
Horiba	0	1.5	0.0%	12	0.4%	5	0.2%	-0.2%
(ppm NOx)	903	954.8	1.7%					
0-3000 ppm	1672	1676.1	0.1%	1731	2.0%	1680	0.3%	-1.7%
	2547	2554.1	0.2%					
TECO	0	7.3	0.2%	6	0.2%	6	0.2%	0.0%
(ppm NO)	903	873.3	-1.0%					
0-3000 ppm	1674	1668.5	-0.2%	1630	-1.5%	1707	1.1%	2.6%
	2548	2542.1	-0.2%					
Horiba	0.00	-0.20	-0.2%	3.81	3.8%	2.83	2.8%	-1.0%
(ppm THC)	30.60	29.79	-0.8%					
0-100 ppm	60.00	61.04	1.0%					
	91.20	91.70	0.5%	96.19	5.0%	95.41	4.2%	-0.8%
Stage 1	0.00	-1.83	-0.1%	-1.83	-0.1%	49.44	1.6%	1.7%
(ppm CO2)	851.00	906.68	1.9%	906.68	1.9%			
0-3000 ppm	1510.00		NA					
	2770.00	2770.39	0.0%	2770.39	0.0%	3305.05	17.8%	17.8%
Stage 2	0.00	2.14	0.2%	2.14	0.2%	38.02	3.8%	3.6%
(ppm CO2)	300.00	320.01	2.0%	320.01	2.0%			
0-1000 ppm	551.00	570.92	2.0%	570.92	2.0%			
	851.00	854.49	0.3%	854.49	0.3%	935.73	8.5%	8.1%
Diluent	0.00	-2.69	-0.3%	-2.69	-0.3%	13.12	1.3%	1.6%
(ppm CO2)	300.00	310.06	1.0%	310.06	1.0%			
0-1000 ppm	551.00	556.21	0.5%	556.21	0.5%			
	851.00	854.98	0.4%	854.98	0.4%	853.94	0.3%	-0.1%
Forward	0.10	-0.17	-0.5%	-0.17	-0.5%	-0.15	-0.5%	0.0%
(ppm NOx)	15.10	16.04	1.9%	16.04	1.9%			
0-50 ppm	27.30	27.65	0.7%	27.65	0.7%	28.67	2.7%	1.0%
	43.50		NA					
Rearward	0.10	-0.15	-0.5%	-0.15	-0.5%	0.21	0.2%	0.4%
(ppm NOx)	15.10	16.05	1.9%	16.05	1.9%			
0-50 ppm	27.30	27.26	-0.1%	27.26	-0.1%	28.17	1.7%	0.9%
	43.50		NA					

PRE-TEST AND POST-TEST CALIBRATION SUMMARY

Source Description: 1990 Kenworth with rebuilt Detroit Diesel Series 60 Engine Date: 9-27-00

Test Number: 5H3&6

Monitor	Slope	Intercept
Stage 1 CO2	1.018	35.900
Stage 2 CO2	0.998	1.705
PM Diluent CO	0.994	-4.065
Forward NOx	0.947	0.143
Rearward NOx	0.976	-0.205

Monitor	Slope	Intercept
Horiba O2	0.999	0.072
Horiba CO2	1.004	-0.111
Horiba CO	1.005	-99.539
Siemens CO	0.991	13.492
Horiba NOx	1.002	-5.871
TECO NOx	0.980	-4.449
Horiba THC	0.972	-2.184

Monitor (Units) Range	Gas Tag Value	----- Direct Calibration ----- Monitor Reading	% Error	-- Pre-Test Cal Check -- Monitor Response	% Error	-- Post-Test Cal Check -- Monitor Response	% Error	% Drift
Horiba	0.00	-0.09	-0.3%	-0.06	-0.2%	-0.08	-0.3%	-0.1%
(% O2)	7.50	7.53	0.1%					
0-25%	13.70	13.95	1.0%	13.70	-0.0%	13.58	-0.5%	-0.5%
	20.88	20.88	-0.0%					
Horiba	0.00	0.10	0.6%	0.11	0.7%	0.11	0.7%	-0.0%
(% CO2)	4.81	4.87	0.4%					
0-16%	8.71	8.73	0.1%	8.77	0.4%	8.80	0.5%	0.1%
	13.50		NA					
Horiba	0	58	0.6%	98	1.0%	100	1.0%	0.0%
(ppm CO)	3000	2962	-0.4%					
0-10000 ppm	5600	5616	0.2%	5663	0.6%	5676	0.8%	0.1%
	8510		NA					
Siemens	0.0	-5.0	-0.5%	-16.6	-1.7%	-10.6	-1.1%	0.6%
(ppm CO)	303.0	319.1	1.6%					
0-1000 ppm	600.0	608.0	0.8%	597.0	-0.3%	586.3	-1.4%	-1.1%
	902.0	907.0	0.5%					
Horiba	0	1.5	0.0%	5	0.2%	7	0.2%	0.1%
(ppm NOx)	903	954.8	1.7%					
0-3000 ppm	1672	1676.1	0.1%	1680	0.3%	1669	-0.1%	-0.4%
	2547	2554.1	0.2%					
TECO	0	7.3	0.2%	6	0.2%	3	0.1%	-0.1%
(ppm NO)	903	873.3	-1.0%					
0-3000 ppm	1674	1668.5	-0.2%	1707	1.1%	1719	1.5%	0.4%
	2548	2542.1	-0.2%					
Horiba	0.00	-0.20	-0.2%	3.52	3.5%	0.98	1.0%	-2.5%
(ppm THC)	30.60	28.71	-1.9%					
0-100 ppm	60.00	60.84	0.8%					
	91.20	91.89	0.7%	96.19	5.0%	95.90	4.7%	-0.3%
Stage 1	0.00	4.58	0.2%	4.58	0.2%	-75.07	-2.5%	-2.7%
(ppm CO2)	851.00	925.90	2.5%	925.90	2.5%			
0-3000 ppm	1510.00		NA					
	2770.00	2723.69	-1.5%	2723.69	-1.5%	2645.26	-4.2%	-2.6%
Stage 2	0.00	7.81	0.8%	7.81	0.8%	-11.23	-1.1%	-1.9%
(ppm CO2)	300.00	313.54	1.4%	313.54	1.4%			
0-1000 ppm	551.00	563.29	1.2%	563.29	1.2%			
	851.00	856.87	0.6%	856.87	0.6%	845.64	-0.5%	-1.1%
Diluent	0.00	-2.69	-0.3%	13.12	1.3%	-4.94	-0.5%	-1.8%
(ppm CO2)	300.00	310.06	1.0%					
0-1000 ppm	551.00	556.21	0.5%					
	851.00	854.98	0.4%	853.94	0.3%	866.46	1.5%	1.3%
Forward	0.10	-0.17	-0.5%	-0.15	-0.5%	-0.15	-0.5%	0.0%
(ppm NOx)	15.10	16.04	1.9%					
0-50 ppm	27.30	27.65	0.7%	28.67	2.7%	28.67	2.7%	0.0%
	43.50		NA					
Rearward	0.10	-0.15	-0.5%	0.21	0.2%	0.21	0.2%	0.0%
(ppm NOx)	15.10	16.05	1.9%					
0-50 ppm	27.30	27.26	-0.1%	28.17	1.7%	28.17	1.7%	0.0%
	43.50		NA					

PRE-TEST AND POST-TEST CALIBRATION SUMMARY

Source Description: 1990 Kenworth with rebuilt Detroit Diesel Series 60 Engine   Date: 9-27-00

Test Number: 5H3&6b

Monitor	Slope	Intercept
Stage 1 CO2	1.000	42.095
Stage 2 CO2	0.976	21.510
PM Diluent CO	0.989	0.815
Forward NOx	0.991	0.126
Rearward NOx	1.015	-0.139

Monitor	Slope	Intercept
Horiba O2	0.982	0.095
Horiba CO2	1.005	-0.106
Horiba CO	1.011	-101.527
Siemens CO	0.998	14.250
Horiba NOx	1.030	-6.183
TECO NOx	1.024	-3.151
Horiba THC	0.999	-2.001

Monitor (Units) Range	Gas Tag Value	----- Direct Calibration ----- Monitor Reading	% Error	-- Pre-Test Cal Check -- Monitor Response	% Error	-- Post-Test Cal Check -- Monitor Response	% Error	% Drift
Horiba	0.00	-0.10	-0.4%	-0.09	-0.3%	-0.11	-0.4%	-0.1%
(% O2)	7.50	7.67	0.7%					
0-25%	13.70	13.90	0.8%	13.86	0.6%	13.85	0.6%	-0.0%
	20.88	20.91	0.1%					
Horiba	0.00	0.11	0.7%	0.10	0.6%	0.11	0.7%	0.0%
(% CO2)	4.81	4.92	0.7%					
0-16%	8.71	8.76	0.3%	8.78	0.4%	8.76	0.3%	-0.1%
	13.50		NA					
Horiba	0	1	0.0%	71	0.7%	130	1.3%	0.6%
(ppm CO)	3000	2962	-0.4%					
0-10000 ppm	5600	5614	0.1%	5632	0.3%	5651	0.5%	0.2%
	8510		NA					
Siemens	0.0	-1.7	-0.2%	-9.5	-1.0%	-19.0	-1.9%	-1.0%
(ppm CO)	303.0	307.3	0.4%					
0-1000 ppm	600.0	592.7	-0.7%	588.1	-1.2%	586.1	-1.4%	-0.2%
	902.0	898.4	-0.4%					
Horiba	0	1.5	0.0%	7	0.2%	5	0.2%	-0.0%
(ppm NOx)	903	954.8	1.7%					
0-3000 ppm	1672	1676.1	0.1%	1666	-0.2%	1594	-2.6%	-2.4%
	2547	2554.1	0.2%					
TECO	0	4.1	0.1%	4	0.1%	2	0.1%	-0.1%
(ppm NO)	903	888.9	-0.5%					
0-3000 ppm	1674	1640.6	-1.1%	1627	-1.6%	1648	-0.9%	0.7%
	2548	2550.9	0.1%					
Horiba	0.00	-0.88	-0.9%	-0.78	-0.8%	4.79	4.8%	5.6%
(ppm THC)	30.60	30.86	0.3%					
0-100 ppm	60.00	61.43	1.4%					
	91.20	91.31	0.1%	90.72	-0.5%	95.80	4.6%	5.1%
Stage 1	0.00	-7.32	-0.2%	-7.32	-0.2%	-76.90	-2.6%	-2.3%
(ppm CO2)	851.00	917.05	2.2%	917.05	2.2%			
0-3000 ppm	1510.00		NA					
	2770.00	2723.69	-1.5%	2723.69	-1.5%	2734.68	-1.2%	0.4%
Stage 2	0.00	-5.55	-0.6%	-5.55	-0.6%	-38.51	-3.9%	-3.3%
(ppm CO2)	300.00	295.04	-0.5%	295.04	-0.5%			
0-1000 ppm	551.00	544.13	-0.7%	544.13	-0.7%			
	851.00	844.60	-0.6%	844.60	-0.6%	854.74	0.4%	1.0%
Diluent	0.00	-4.09	-0.4%	-4.09	-0.4%	2.44	0.2%	0.7%
(ppm CO2)	300.00	296.94	-0.3%	296.94	-0.3%			
0-1000 ppm	551.00	534.12	-1.7%	534.12	-1.7%			
	851.00	843.81	-0.7%	843.81	-0.7%	876.04	2.5%	3.2%
Forward	0.10	-0.40	-1.0%	-0.40	-1.0%	0.14	0.1%	0.5%
(ppm NOx)	15.10	15.80	1.4%	15.80	1.4%			
0-50 ppm	27.30	27.14	-0.3%	27.14	-0.3%	27.70	0.8%	0.6%
	43.50		NA					
Rearward	0.10	-0.06	-0.3%	-0.06	-0.3%	0.34	0.5%	0.4%
(ppm NOx)	15.10	15.96	1.7%	15.96	1.7%			
0-50 ppm	27.30	27.15	-0.3%	27.15	-0.3%	26.93	-0.7%	-0.2%
	43.50		NA					

PRE-TEST AND POST-TEST CALIBRATION SUMMARY

Source Description: 1990 Kenworth with rebuilt Detroit Diesel Series 60 Engine

Date: 9-27/28-00

Test Number: 5E3&6

Monitor	Slope	Intercept
Stage 1 CO2	NA	NA
Stage 2 CO2	0.967	33.599
PM Diluent CO	0.987	13.311
Forward NOx	0.969	-0.019
Rearward NOx	1.021	-0.304

Monitor	Slope	Intercept
Horiba O2	0.981	0.090
Horiba CO2	1.007	-0.106
Horiba CO	1.011	-106.672
Siemens CO	0.992	18.960
Horiba NOx	1.068	-5.160
TECO NOx	1.012	-1.927
Horiba THC	1.003	-4.604

Monitor (Units) Range	Gas Tag Value	Direct Calibration Monitor Reading	Direct Calibration % Error	Pre-Test Cal Check Monitor Response	Pre-Test Cal Check % Error	Post-Test Cal Check Monitor Response	Post-Test Cal Check % Error	% Drift
Horiba	0.00	-0.10	-0.4%	-0.11	-0.4%	-0.08	-0.3%	0.1%
(% O2)	7.50	7.67	0.7%					
0-25%	13.70	13.90	0.8%	13.85	0.6%	13.89	0.8%	0.1%
	20.88	20.91	0.1%					
Horiba	0.00	0.11	0.7%	0.11	0.7%	0.10	0.6%	-0.0%
(% CO2)	4.81	4.92	0.7%					
0-16%	8.71	8.76	0.3%	8.76	0.3%	8.75	0.2%	-0.1%
	13.50		NA					
Horiba	0	1	0.0%	130	1.3%	81	0.8%	-0.5%
(ppm CO)	3000	2962	-0.4%					
0-10000 ppm	5600	5614	0.1%	5651	0.5%	5639	0.4%	-0.1%
	8510		NA					
Siemens	0.0	-1.7	-0.2%	-19.0	-1.9%	-19.2	-1.9%	-0.0%
(ppm CO)	303.0	307.3	0.4%					
0-1000 ppm	600.0	592.7	-0.7%	586.1	-1.4%	584.8	-1.5%	-0.1%
	902.0	898.4	-0.4%					
Horiba	0	ERR	ERR	5	0.2%	4	0.1%	-0.0%
(ppm NOx)	903	ERR	ERR					
0-3000 ppm	1672	ERR	ERR	1594	-2.6%	1548	-4.1%	-1.5%
	2547	ERR	ERR					
TECO	0	4.1	0.1%	2	0.1%	2	0.1%	-0.0%
(ppm NO)	903	888.9	-0.5%					
0-3000 ppm	1674	1640.6	-1.1%	1648	-0.9%	1664	-0.3%	0.5%
	2548	2550.9	0.1%					
Horiba	0.00	-0.88	-0.9%	4.79	4.8%	4.39	4.4%	-0.4%
(ppm THC)	30.60	30.86	0.3%					
0-100 ppm	60.00	61.43	1.4%					
	91.20	91.31	0.1%	95.80	4.6%	95.21	4.0%	-0.6%
Stage 1	0.00	-7.32	-0.2%	-76.90	-2.6%	-94.60	-3.2%	-0.6%
(ppm CO2)	851.00	917.05	2.2%					
0-3000 ppm	1510.00		NA					
	2770.00	2723.69	-1.5%	2734.68	-1.2%	2524.72	-8.2%	-7.0%
Stage 2	0.00	-5.55	-0.6%	-38.51	-3.9%	-31.01	-3.1%	0.8%
(ppm CO2)	300.00	295.04	-0.5%					
0-1000 ppm	551.00	544.13	-0.7%					
	851.00	844.60	-0.6%	854.74	0.4%	836.55	-1.4%	-1.8%
Diluent	0.00	-4.09	-0.4%	2.44	0.2%	-29.42	-2.9%	-3.2%
(ppm CO2)	300.00	296.94	-0.3%					
0-1000 ppm	551.00	534.12	-1.7%					
	851.00	843.81	-0.7%	876.04	2.5%	821.78	-2.9%	-5.4%
Forward	0.10	-0.40	-1.0%	0.14	0.1%	-0.10	-0.4%	-0.2%
(ppm NOx)	15.10	15.80	1.4%					
0-50 ppm	27.30	27.14	-0.3%	27.70	0.8%	28.70	2.8%	1.0%
	43.50		NA					
Rearward	0.10	-0.06	-0.3%	0.34	0.5%	0.26	0.3%	-0.1%
(ppm NOx)	15.10	15.96	1.7%					
0-50 ppm	27.30	27.15	-0.3%	26.93	-0.7%	27.14	-0.3%	0.2%
	43.50		NA					

PRE-TEST AND POST-TEST CALIBRATION SUMMARY

Source Description: 1990 Kenworth with rebuilt Detroit Diesel Series 60 Engine   Date: 10/10/00

Test Number: 5F0C

Monitor	Slope	Intercept
Stage 1 CO2	NA	NA
Stage 2 CO2	NA	NA
PM Diluent CO	1.008	-0.154
Forward NOx	0.985	-0.022
Rearward NOx	1.035	-0.081

Monitor	Slope	Intercept
Horiba O2	1.008	-0.005
Horiba CO2	0.977	-0.088
Horiba CO	0.989	-65.787
Siemens CO	0.989	4.589
Horiba NOx	1.084	-3.334
TECO NOx	1.028	-3.916
Horiba THC	0.978	-1.528

Monitor		----- Direct Calibration -----		-- Pre-Test Cal Check --		-- Post-Test Cal Check --		
(Units)	Gas Tag	Monitor	%	Monitor	%	Monitor	%	%
Range	Value	Reading	Error	Response	Error	Response	Error	Drift
Horiba	0.00	-0.04	-0.2%	-0.02	-0.1%	0.03	0.1%	0.2%
(% O2)	7.50	7.54	0.2%					
0-25%	13.76	13.70	-0.2%	13.73	-0.1%	13.58	-0.7%	-0.6%
	20.88	20.81	-0.3%					
Horiba	0.00	0.08	0.5%	0.08	0.5%	0.10	0.6%	0.1%
(% CO2)	4.81	5.08	1.7%					
0-16%	8.71	9.03	2.0%	8.98	1.7%	9.03	2.0%	0.3%
	13.62	13.54	-0.5%					
Horiba	0	27	0.3%	61	0.6%	72	0.7%	0.1%
(ppm CO)	3000	3008	0.1%					
0-10000 ppm	5600	5714	1.1%	5695	0.9%	5758	1.6%	0.6%
	8600	8620	0.2%					
Siemens	0.0	8.1	0.8%	0.5	0.0%	-9.8	-1.0%	-1.0%
(ppm CO)	303.0	311.2	0.8%					
0-1000 ppm	600.0	612.4	1.2%	604.7	0.5%	599.0	-0.1%	-0.6%
	902.0	913.8	1.2%					
Horiba	0	-0.6	-0.0%	1	0.0%	6	0.2%	0.2%
(ppm NOx)	903	904.4	0.0%					
0-3000 ppm	1672	1662.0	-0.3%	1562	-3.7%	1530	-4.7%	-1.1%
	2547	2550.3	0.1%					
TECO	0	-3.2	-0.1%	-6	-0.2%	13	0.4%	0.6%
(ppm NO)	903	891.5	-0.4%					
0-3000 ppm	1674	1656.7	-0.6%	1658	-0.5%	1606	-2.3%	-1.7%
	2548	2555.6	0.3%					
Horiba	0.00	-0.10	-0.1%	0.39	0.4%	2.73	2.7%	2.3%
(ppm THC)	30.60	31.64	1.0%					
0-100 ppm	60.60	61.04	0.4%	62.70	2.1%	64.36	3.8%	1.7%
	91.20	91.21	0.0%					
Stage 1	0.00	-10.99	-0.4%	-10.99	-0.4%	45.47	1.5%	1.9%
(ppm CO2)	851.00	887.15	1.2%	887.15	1.2%			
0-3000 ppm	1510.00		NA					
	2770.00	2753.60	-0.5%	2753.60	-0.5%	3205.57	14.5%	15.1%
Stage 2	0.00	-3.42	-0.3%	-3.42	-0.3%	-56.64	-5.7%	-5.3%
(ppm CO2)	300.00	308.29	0.8%	308.29	0.8%			
0-1000 ppm	549.00	562.38	1.3%	562.38	1.3%	489.01	-6.0%	-7.3%
	851.00	862.91	1.2%	862.91	1.2%			
Diluent	0.00	-1.34	-0.1%	-1.34	-0.1%	1.65	0.2%	0.3%
(ppm CO2)	300.00	302.73	0.3%	302.73	0.3%			
0-1000 ppm	549.00	553.53	0.5%	553.53	0.5%	536.32	-1.3%	-1.7%
	851.00	850.28	-0.1%	850.28	-0.1%			
Forward	0.10	-0.15	-0.5%	-0.15	-0.5%	0.19	0.2%	0.3%
(ppm NOx)	15.10	15.85	1.5%	15.85	1.5%			
0-50 ppm	27.30	27.38	0.2%	27.38	0.2%	28.09	1.6%	0.7%
	44.70		NA					
Rearward	0.10	0.05	-0.1%	0.05	-0.1%	0.11	0.0%	0.1%
(ppm NOx)	15.10	16.05	1.9%	16.05	1.9%			
0-50 ppm	27.30	27.44	0.3%	27.44	0.3%	25.45	-3.7%	-2.0%
	44.70		NA					

PRE-TEST AND POST-TEST CALIBRATION SUMMARY

Source Description: 1990 Kenworth with rebuilt Detroit Diesel Series 60 Engine   Date: 10-10-00

Test Number: 5F0V

Monitor	Slope	Intercept
Stage 1 CO2	1.049	-5.762
Stage 2 CO2	0.995	-0.455
PM Diluent CO	1.008	-0.154
Forward NOx	0.985	-0.022
Rearward NOx	1.035	-0.081

Monitor	Slope	Intercept
Horiba O2	1.008	-0.005
Horiba CO2	0.977	-0.088
Horiba CO	0.989	-65.787
Siemens CO	0.989	4.589
Horiba NOx	1.084	-3.334
TECO NOx	1.028	-3.916
Horiba THC	0.978	-1.528

Monitor		----- Direct Calibration -----		-- Pre-Test Cal Check --		-- Post-Test Cal Check --		
Monitor (Units) Range	Gas Tag Value	Monitor Reading	% Error	Monitor Response	% Error	Monitor Response	% Error	% Drift
Horiba	0.00	-0.04	-0.2%	-0.02	-0.1%	0.03	0.1%	0.2%
(% O2)	7.50	7.54	0.2%					
0-25%	13.76	13.70	-0.2%	13.73	-0.1%	13.58	-0.7%	-0.6%
	20.88	20.81	-0.3%					
Horiba	0.00	0.08	0.5%	0.08	0.5%	0.10	0.6%	0.1%
(% CO2)	4.81	5.08	1.7%					
0-16%	8.71	9.03	2.0%	8.98	1.7%	9.03	2.0%	0.3%
	13.62	13.54	-0.5%					
Horiba	0	27	0.3%	61	0.6%	72	0.7%	0.1%
(ppm CO)	3000	3008	0.1%					
0-10000 ppm	5600	5714	1.1%	5695	0.9%	5758	1.6%	0.6%
	8600	8620	0.2%					
Siemens	0.0	8.1	0.8%	0.5	0.0%	-9.8	-1.0%	-1.0%
(ppm CO)	303.0	311.2	0.8%					
0-1000 ppm	600.0	612.4	1.2%	604.7	0.5%	599.0	-0.1%	-0.6%
	902.0	913.8	1.2%					
Horiba	0	-0.6	-0.0%	1	0.0%	6	0.2%	0.2%
(ppm NOx)	903	904.4	0.0%					
0-3000 ppm	1672	1662.0	-0.3%	1562	-3.7%	1530	-4.7%	-1.1%
	2547	2550.3	0.1%					
TECO	0	-3.2	-0.1%	-6	-0.2%	13	0.4%	0.6%
(ppm NO)	903	891.5	-0.4%					
0-3000 ppm	1674	1656.7	-0.6%	1658	-0.5%	1606	-2.3%	-1.7%
	2548	2555.6	0.3%					
Horiba	0.00	-0.10	-0.1%	0.39	0.4%	2.73	2.7%	2.3%
(ppm THC)	30.60	31.64	1.0%					
0-100 ppm	60.60	61.04	0.4%	62.70	2.1%	64.36	3.8%	1.7%
	91.20	91.21	0.0%					
Stage 1	0.00	-14.04	-0.5%	-14.04	-0.5%	25.02	0.8%	1.3%
(ppm CO2)	851.00	859.99	0.3%	859.99	0.3%	773.62	-2.6%	-2.9%
0-3000 ppm	1510.00		NA					
	2770.00	2758.79	-0.4%	2758.79	-0.4%			
Stage 2	0.00	-1.77	-0.2%	-1.77	-0.2%	2.69	0.3%	0.4%
(ppm CO2)	300.00	302.25	0.2%	302.25	0.2%			
0-1000 ppm	549.00	549.74	0.1%	549.74	0.1%	555.24	0.6%	0.5%
	851.00	859.74	0.9%	859.74	0.9%			
Diluent	0.00	-1.34	-0.1%	-1.34	-0.1%	1.65	0.2%	0.3%
(ppm CO2)	300.00	302.73	0.3%	302.73	0.3%			
0-1000 ppm	549.00	553.53	0.5%	553.53	0.5%	536.32	-1.3%	-1.7%
	851.00	850.28	-0.1%	850.28	-0.1%			
Forward	0.10	-0.15	-0.5%	-0.15	-0.5%	0.19	0.2%	0.3%
(ppm NOx)	15.10	15.85	1.5%	15.85	1.5%			
0-50 ppm	27.30	27.38	0.2%	27.38	0.2%	28.09	1.6%	0.7%
	44.70		NA					
Rearward	0.10	0.05	-0.1%	0.05	-0.1%	0.11	0.0%	0.1%
(ppm NOx)	15.10	16.05	1.9%	16.05	1.9%			
0-50 ppm	27.30	27.44	0.3%	27.44	0.3%	25.45	-3.7%	-2.0%
	44.70		NA					

PRE-TEST AND POST-TEST CALIBRATION SUMMARY

Source Description: 1990 Kenworth with rebuilt Detroit Diesel Series 60 Engine

Date: 10-11-00

Test Number: 5h0

Monitor	Slope	Intercept
Stage 1 CO2	1.006	-6.905
Stage 2 CO2	0.989	4.016
PM Diluent CO	1.006	-0.706
Forward NOx	1.018	0.129
Rearward NOx	1.018	-0.035

Monitor	Slope	Intercept
Horiba O2	0.997	-0.028
Horiba CO2	0.968	-0.092
Horiba CO	0.987	-67.077
Siemens CO	0.998	1.096
Horiba NOx	1.019	-6.272
TECO NOx	1.034	-1.363
Horiba THC	ERR	ERR

Monitor (Units) Range	Gas Tag Value	----- Direct Calibration ----- Monitor Reading	% Error	-- Pre-Test Cal Check -- Monitor Response	% Error	-- Post-Test Cal Check -- Monitor Response	% Error	% Drift
Horiba	0.00	0.02	0.1%	0.04	0.1%	0.02	0.1%	-0.1%
(% O2)	7.50	7.60	0.4%					
0-25%	13.76	13.80	0.1%	13.80	0.1%	13.85	0.4%	0.2%
	20.88	20.89	0.0%					
Horiba	0.00	0.08	0.5%	0.08	0.5%	0.11	0.7%	0.1%
(% CO2)	4.81	5.04	1.5%					
0-16%	8.71	9.04	2.1%	9.03	2.0%	9.16	2.8%	0.8%
	13.62	13.42	-1.2%					
Horiba	0	49	0.5%	35	0.3%	101	1.0%	0.7%
(ppm CO)	3000	3009	0.1%					
0-10000 ppm	5600	5730	1.3%	5732	1.3%	5747	1.5%	0.2%
	8600	8554	-0.5%					
Siemens	0.0	0.4	0.0%	4.4	0.4%	-6.6	-0.7%	-1.1%
(ppm CO)	303.0	312.9	1.0%					
0-1000 ppm	600.0	606.1	0.6%	604.6	0.5%	596.2	-0.4%	-0.8%
	902.0	909.4	0.7%					
Horiba	0	-1.2	-0.0%	2	0.1%	10	0.3%	0.3%
(ppm NOx)	903	914.1	0.4%					
0-3000 ppm	1672	1696.9	0.8%	1602	-2.3%	1691	0.6%	3.0%
	2547	2537.4	-0.3%					
TECO	0	-2.6	-0.1%	-2	-0.1%	5	0.2%	0.2%
(ppm NO)	903	878.9	-0.8%					
0-3000 ppm	1674	1645.3	-1.0%	1632	-1.4%	1609	-2.2%	-0.8%
	2548	2540.9	-0.2%					
Horiba	0.00	-0.29	-0.3%	-0.29	-0.3%	4.69	4.7%	5.0%
(ppm THC)	30.60	31.35	0.7%					
0-100 ppm	60.60	60.84	0.2%	62.40	1.8%			
	91.20	90.33	-0.9%					
Stage 1	0.00	-5.80	-0.2%	-5.80	-0.2%	19.53	0.7%	0.8%
(ppm CO2)	851.00	898.44	1.6%	898.44	1.6%			
0-3000 ppm	1510.00		NA					
	2770.00	2767.94	-0.1%	2767.94	-0.1%	2754.52	-0.5%	-0.4%
Stage 2	0.00	-2.99	-0.3%	-2.99	-0.3%	-5.13	-0.5%	-0.2%
(ppm CO2)	300.00	301.70	0.2%	301.70	0.2%			
0-1000 ppm	549.00	554.50	0.6%	554.50	0.6%	547.24	-0.2%	-0.7%
	851.00	855.10	0.4%	855.10	0.4%			
Diluent	0.00	-1.77	-0.2%	-1.77	-0.2%	3.17	0.3%	0.5%
(ppm CO2)	300.00	298.52	-0.1%	298.52	-0.1%			
0-1000 ppm	549.00	550.84	0.2%	550.84	0.2%	541.93	-0.7%	-0.9%
	851.00	842.59	-0.8%	842.59	-0.8%			
Forward	0.10	-0.29	-0.8%	-0.29	-0.8%	0.04	-0.1%	0.3%
(ppm NOx)	15.10	15.58	1.0%	15.58	1.0%			
0-50 ppm	27.30	26.92	-0.8%	26.92	-0.8%	26.45	-1.7%	-0.5%
	44.70		NA					
Rearward	0.10	0.00	-0.2%	0.00	-0.2%	0.06	-0.1%	0.1%
(ppm NOx)	15.10	15.85	1.5%	15.85	1.5%			
0-50 ppm	27.30	27.23	-0.1%	27.23	-0.1%	26.45	-1.7%	-0.8%
	44.70		NA					

PRE-TEST AND POST-TEST CALIBRATION SUMMARY

Source Description: 1990 Kenworth with rebuilt Detroit Diesel Series 60 Engine

Date: 10-12-00

Test Number: 5e0

Monitor	Slope	Intercept
Stage 1 CO2	0.928	-0.849
Stage 2 CO2	0.969	-5.088
PM Diluent CO	0.969	-8.134
Forward NOx	1.028	0.060
Rearward NOx	1.001	-0.147

Monitor	Slope	Intercept
Horiba O2	0.999	-0.040
Horiba CO2	0.972	-0.106
Horiba CO	1.002	-84.733
Siemens CO	0.986	17.822
Horiba NOx	0.996	-11.238
TECO NOx	NA	NA
Horiba THC	1.005	-3.876

Monitor		----- Direct Calibration -----		-- Pre-Test Cal Check --		-- Post-Test Cal Check --		
Monitor (Units) Range	Gas Tag Value	Monitor Reading	% Error	Monitor Response	% Error	Monitor Response	% Error	% Drift
Horiba	0.00	0.01	0.1%	0.04	0.2%	0.04	0.2%	-0.0%
(% O2)	7.50	7.66	0.6%					
0-25%	13.76	13.95	0.8%	13.88	0.5%	13.76	-0.0%	-0.5%
	20.88	20.86	-0.1%					
Horiba	0.00	0.08	0.5%	0.09	0.6%	0.13	0.8%	0.2%
(% CO2)	4.81	5.12	1.9%					
0-16%	8.71	9.07	2.2%	9.04	2.1%	9.10	2.4%	0.3%
	13.62	13.66	0.2%					
Horiba	0	35	0.3%	55	0.5%	114	1.1%	0.6%
(ppm CO)	3000	3002	0.0%					
0-10000 ppm	5600	5725	1.3%	5749	1.5%	5597	-0.0%	-1.5%
	8600	8542	-0.6%					
Siemens	0.0	-5.0	-0.5%	-12.2	-1.2%	-23.9	-2.4%	-1.2%
(ppm CO)	303.0	300.7	-0.2%					
0-1000 ppm	600.0	594.5	-0.6%	597.5	-0.2%	582.8	-1.7%	-1.5%
	902.0	899.3	-0.3%					
Horiba	0	0.6	0.0%	6	0.2%	16	0.5%	0.3%
(ppm NOx)	903	921.4	0.6%					
0-3000 ppm	1672	1664.6	-0.2%	1600	-2.4%	1779	3.6%	6.0%
	2547	2531.0	-0.5%					
TECO	0	-4.1	-0.1%	-2	-0.1%	5	0.2%	0.2%
(ppm NO)	903	886.5	-0.5%					
0-3000 ppm	1674	1651.5	-0.8%	1661	-0.4%	1501	-5.8%	-5.3%
	2548	2559.1	0.4%					
Horiba	0.00	-0.20	-0.2%	3.03	3.0%	4.69	4.7%	1.7%
(ppm THC)	30.60	30.57	-0.0%					
0-100 ppm	60.60	61.33	0.7%	64.16	3.6%	64.16	3.6%	0.0%
	91.20	90.72	-0.5%					
Stage 1	0.00	-20.45	-0.7%	-20.45	-0.7%	22.28	0.7%	1.4%
(ppm CO2)	851.00	871.89	0.7%	871.89	0.7%	963.74	3.8%	3.1%
0-3000 ppm	1510.00		NA					
	2770.00	2744.14	-0.9%	2744.14	-0.9%			
Stage 2	0.00	8.73	0.9%	8.73	0.9%	1.77	0.2%	-0.7%
(ppm CO2)	300.00	308.84	0.9%	308.84	0.9%			
0-1000 ppm	549.00	567.93	1.9%	567.93	1.9%	575.38	2.6%	0.7%
	851.00	863.16	1.2%	863.16	1.2%			
Diluent	0.00	-1.83	-0.2%	-1.83	-0.2%	18.62	1.9%	2.0%
(ppm CO2)	300.00	304.32	0.4%	304.32	0.4%			
0-1000 ppm	549.00	557.01	0.8%	557.01	0.8%	592.65	4.4%	3.6%
	851.00	847.96	-0.3%	847.96	-0.3%			
Forward	0.10	-0.30	-0.8%	-0.30	-0.8%	0.18	0.2%	0.5%
(ppm NOx)	15.10	15.48	0.8%	15.48	0.8%			
0-50 ppm	27.30	26.72	-1.2%	26.72	-1.2%	26.25	-2.1%	-0.5%
	44.70		NA					
Rearward	0.10	0.07	-0.1%	0.07	-0.1%	0.22	0.2%	0.1%
(ppm NOx)	15.10	16.03	1.9%	16.03	1.9%			
0-50 ppm	27.30	27.52	0.4%	27.52	0.4%	27.32	0.0%	-0.2%
	44.70		NA					

PRE-TEST AND POST-TEST CALIBRATION SUMMARY

Source Description: 1990 Kenworth with rebuilt Detroit Diesel Series 60 Engine   Date: 10-13-00

Test Number: ERR

Monitor	Slope	Intercept
Stage 1 CO2	NA	NA
Stage 2 CO2	NA	NA
PM Diluent CO	1.002	-8.348
Forward NOx	1.034	0.220
Rearward NOx	1.040	-0.211

Monitor	Slope	Intercept
Horiba O2	0.991	-0.028
Horiba CO2	0.965	-0.101
Horiba CO	0.986	-89.097
Siemens CO	0.995	18.158
Horiba NOx	NA	NA
TECO NOx	NA	NA
Horiba THC	NA	NA

Monitor (Units) Range	Gas Tag Value	----- Direct Calibration ----- Monitor Reading	% Error	-- Pre-Test Cal Check -- Monitor Response	% Error	-- Post-Test Cal Check -- Monitor Response	% Error	% Drift
Horiba	0.00	0.03	0.1%	0.02	0.1%	0.03	0.1%	0.0%
(% O2)	7.50	7.64	0.6%					
0-25%	13.76	13.92	0.6%					
	20.88	20.84	-0.2%	21.01	0.5%	21.19	1.2%	0.7%
Horiba	0.00	0.08	0.5%	0.10	0.6%	0.11	0.7%	0.1%
(% CO2)	4.81	5.08	1.7%					
0-16%	8.71	8.98	1.7%	9.07	2.3%	9.19	3.0%	0.7%
	13.62	13.59	-0.2%					
Horiba	0	6	0.1%	71	0.7%	110	1.1%	0.4%
(ppm CO)	3000	2962	-0.4%					
0-10000 ppm	5600	5695	0.9%	5756	1.6%	5781	1.8%	0.3%
	8600	8536	-0.6%					
Siemens	0.0	-4.6	-0.5%	-7.6	-0.8%	-28.9	-2.9%	-2.1%
(ppm CO)	303.0	296.6	-0.6%					
0-1000 ppm	600.0	599.6	-0.0%	591.8	-0.8%	577.8	-2.2%	-1.4%
	902.0	897.8	-0.4%					
Horiba	0	2.6	0.1%	4	0.1%	11	0.4%	0.2%
(ppm NOx)	903	923.7	0.7%					
0-3000 ppm	1672	1674.9	0.1%	1697	0.8%	1834	5.4%	4.6%
	2547	2555.0	0.3%					
TECO	0	29.0	1.0%	1	0.0%	11	0.4%	0.3%
(ppm NO)	903	960.9	1.9%					
0-3000 ppm	1674	1635.6	-1.3%	1546	-4.3%	1513	-5.4%	-1.1%
	2548	2552.3	0.1%					
Horiba	0.00	0.49	0.5%	1.95	2.0%	-0.68	-0.7%	-2.6%
(ppm THC)	30.60	29.88	-0.7%					
0-100 ppm	60.60	62.30	1.7%	57.71	-2.9%	69.73	9.1%	12.0%
	91.20	91.99	0.8%					
Stage 1	0.00	-3.66	-0.1%	-3.66	-0.1%	44.86	1.5%	1.6%
(ppm CO2)	851.00	881.04	1.0%	881.04	1.0%			
0-3000 ppm	1510.00		NA					
	2770.00	2792.66	0.8%	2792.66	0.8%	2493.29	-9.2%	-10.0%
Stage 2	0.00	-3.36	-0.3%	-3.36	-0.3%	-88.38	-8.8%	-8.5%
(ppm CO2)	300.00	300.60	0.1%	300.60	0.1%			
0-1000 ppm	549.00	545.65	-0.3%	545.65	-0.3%	469.85	-7.9%	-7.6%
	851.00	840.52	-1.0%	840.52	-1.0%			
Diluent	0.00	-1.28	-0.1%	-1.28	-0.1%	17.94	1.8%	1.9%
(ppm CO2)	300.00	302.12	0.2%	302.12	0.2%			
0-1000 ppm	549.00	552.43	0.3%	552.43	0.3%	560.00	1.1%	0.8%
	851.00	843.44	-0.8%	843.44	-0.8%			
Forward	0.10	-0.10	-0.4%	-0.10	-0.4%	-0.32	-0.8%	-0.2%
(ppm NOx)	15.10	15.44	0.7%	15.44	0.7%			
0-50 ppm	27.30	26.60	-1.4%	26.60	-1.4%	25.81	-3.0%	-0.8%
	44.70		NA					
Rearward	0.10	-0.00	-0.2%	-0.00	-0.2%	0.41	0.6%	0.4%
(ppm NOx)	15.10	16.07	1.9%	16.07	1.9%			
0-50 ppm	27.30	27.62	0.6%	27.62	0.6%	25.30	-4.0%	-2.3%
	44.70		NA					

PRE-TEST AND POST-TEST CALIBRATION SUMMARY

Source Description: 1990 Kenworth with rebuilt Detroit Diesel Series 60 Engine Date: 10/24/00

Test Number: 5f-seq2

Monitor	Slope	Intercept
Stage 1 CO2	1.007	-37.033
Stage 2 CO2	1.028	-3.731
PM Diluent CO	1.018	-3.138
Forward NOx	1.037	0.073
Rearward NOx	ERR	ERR

Monitor	Slope	Intercept
Horiba O2	0.978	0.407
Horiba CO2	0.979	-0.121
Horiba CO	0.987	-67.738
Siemens CO	0.998	0.426
Horiba NOx	1.012	-7.262
TECO NOx	1.060	-0.932
Horiba THC	0.964	-0.188

Monitor		----- Direct Calibration -----		-- Pre-Test Cal Check --		-- Post-Test Cal Check --		
(Units) Range	Gas Tag Value	Monitor Reading	% Error	Monitor Response	% Error	Monitor Response	% Error	% Drift
Horiba	0.00	-0.45	-1.8%	-0.42	-1.7%	-0.42	-1.7%	0.0%
(% O2)	7.50	7.29	-0.8%					
0-25%	13.76	13.62	-0.5%	13.56	-0.8%	13.75	-0.0%	0.8%
	20.88	20.81	-0.3%					
Horiba	0.00	0.11	0.7%	0.11	0.7%	0.14	0.9%	0.2%
(% CO2)	4.81	4.96	0.9%					
0-16%	8.71	8.83	0.8%	8.90	1.2%	9.14	2.7%	1.5%
	13.62	13.55	-0.5%					
Horiba	0	-10	-0.1%	51	0.5%	87	0.9%	0.4%
(ppm CO)	3000	2965	-0.3%					
0-10000 ppm	5600	5654	0.5%	5702	1.0%	5788	1.9%	0.9%
	8600	8604	0.0%					
Siemens	0.0	5.1	0.5%	4.3	0.4%	-5.1	-0.5%	-0.9%
(ppm CO)	303.0	313.7	1.1%					
0-1000 ppm	600.0	604.6	0.5%	601.0	0.1%	600.5	0.0%	-0.0%
	902.0	908.4	0.6%					
Horiba	0	4.7	0.2%	8	0.3%	6	0.2%	-0.0%
(ppm NOx)	903	906.4	0.1%					
0-3000 ppm	1672	1657.0	-0.5%	1692	0.7%	1627	-1.5%	-2.2%
	2547	2557.6	0.4%					
TECO	0	-1.2	-0.0%	-4	-0.1%	6	0.2%	0.3%
(ppm NO)	903	897.7	-0.2%					
0-3000 ppm	1674	1659.1	-0.5%	1634	-1.3%	1525	-5.0%	-3.7%
	2548	2551.5	0.1%					
Horiba	0.00	-0.78	-0.8%	-1.27	-1.3%	1.66	1.7%	2.9%
(ppm THC)	30.60	29.88	-0.7%					
0-100 ppm	60.60	61.33	0.7%	61.72	1.1%	64.36	3.8%	2.6%
	91.20	90.04	-1.2%					
Stage 1	0.00	-14.34	-0.5%	-14.34	-0.5%	87.89	2.9%	3.4%
(ppm CO2)	851.00	886.84	1.2%	886.84	1.2%			
0-3000 ppm	1510.00	1633.91	4.1%	1633.91	4.1%			
	2750.00	2699.28	-1.7%	2699.28	-1.7%	2835.69	2.9%	4.5%
Stage 2	0.00	-8.61	-0.9%	-8.61	-0.9%	15.87	1.6%	2.4%
(ppm CO2)	300.00	290.83	-0.9%	290.83	-0.9%			
0-1000 ppm	549.00	559.51	1.1%	559.51	1.1%	516.36	-3.3%	-4.3%
	851.00	848.08	-0.3%	848.08	-0.3%			
Diluent	0.00	-5.86	-0.6%	-5.86	-0.6%	12.02	1.2%	1.8%
(ppm CO2)	300.00	311.40	1.1%	311.40	1.1%			
0-1000 ppm	549.00	560.42	1.1%	560.42	1.1%	524.35	-2.5%	-3.6%
	851.00	848.69	-0.2%	848.69	-0.2%			
Forward	0.10	0.05	-0.1%	0.05	-0.1%	-0.19	-0.6%	-0.2%
(ppm NOx)	15.10	15.97	1.7%	15.97	1.7%			
0-50 ppm	27.30	27.46	0.3%	27.46	0.3%	25.07	-4.5%	-2.4%
	44.70		NA					
Rearward	0.10		NA					
(ppm NOx)	15.10		NA					
0-50 ppm	27.30		NA					
	44.70		NA					

TECHNICAL REPORT DATA
(Please read Instructions on the reverse before completing)

1. REPORT NO. EPA-600/R-01-079	2.	3. RECIPIENT'S ACCESSION NO.
4. TITLE AND SUBTITLE Heavy Duty Diesel Fine Particulate Matter Emissions: Development and Application of On-road Measurement Capabilities		5. REPORT DATE October 2001
		6. PERFORMING ORGANIZATION CODE
7. AUTHORS J. Edward Brown		8. PERFORMING ORGANIZATION REPORT NO.
9. PERFORMING ORGANIZATION NAME AND ADDRESS ARCADIS Geraghty & Miller, Inc. P.O. Box 13109 Research Triangle Park, North Carolina 27709		10. PROGRAM ELEMENT NO.
		11. CONTRACT/GRANT NO. 68-C-99-201, W.A. 2-028
12. SPONSORING AGENCY NAME AND ADDRESS U. S. EPA, Office of Research and Development Air Pollution Prevention and Control Division Research Triangle Park, North Carolina 27711		13. TYPE OF REPORT AND PERIOD COVERED Final; 10/1/00 - 9/1/01
		14. SPONSORING AGENCY CODE EPA/600/13
15. SUPPLEMENTARY NOTES APPCD project officer is John S. Kinsey, Mail Drop 61, 919/541-4121.		

16. ABSTRACT The report discusses EPA's On-road Diesel Emissions Characterization Facility, which has been collecting real-world gaseous emissions data for the past 6 years. It has recently undergone extensive modifications to enhance its particulate matter (PM) measurement capabilities, with specific emphasis on fine PM or PM-2.5 (particles smaller than 2.5 micrometers in aerodynamic diameter). At present the facility's capabilities are focused on continuous sampling and analysis, using fast-responding instruments such as the Electrical Low-pressure Impactor (ELPI), the Tapered-element Oscillating Microbalance (TEOM), and a particle-bound Polycyclic Aromatic Hydrocarbon (PAH) analyzer, all of which require a dilute exhaust sample. This dilute sample has been drawn directly from the vehicle exhaust via a stack dilution system, and sampled from the ambient exhaust plume via probes in the trailer. Dilute samples have also been collected on filters for chemical and gravimetric analysis. Experimental results indicate that stack dilution sampling does not adequately represent real-world conditions as determined from initial plume sampling. Therefore, future efforts will be directed toward improved plume characterization techniques.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS		b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group	
Pollution	Analyzing		13B	
Diesel Fuels	Impactors		21D	13I
Combustion	Microbalances		21B	
Emission	Hydrocarbons		14G	07C
Particles	Plumes			
Measurement				
Sampling			14B	

18. DISTRIBUTION STATEMENT	19. SECURITY CLASS *(This Report)*	21. NO. OF PAGES 145
	20. SECURITY CLASS *(This Page)*	22. PRICE