DRAFT

Particulate Matter CEMS Demonstration

Volume I: DuPont, Inc. Experimental Station On-Site Incinerator, Wilmington, DE

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1.0 INTRODUCTION

The U.S. Environmental Protection Agency (EPA) currently regulates the burning of hazardous waste in incinerators under 40 CFR Part 264/265, Subpart O and in boilers and industrial furnaces under 40 CFR Part 266, Subpart H. The Agency proposed revised regulations applicable to these hazardous waste combustion (HWC) devices. These rules are scheduled to be promulgated in 1998. Included in the proposed regulations are draft performance specifications for particulate matter (PM) continuous emissions monitoring systems (CEMS), and requirements for their use. In support of these proposed monitoring requirements, EPA tested PM CEMS to determine their performance characteristics and ascertain what data quality objectives are required for this type of monitoring. The tests included an extended-period durability test.

To indicate compliance with a PM standard, EPA in the past has relied on the continuous monitoring of a surrogate for PM, opacity, or operating parameter limits on parameters which affect PM emissions established during an emissions test. Both approaches are described, below.

A continuous opacity monitor (COM) is used to demonstrate compliance with a separately-enforceable opacity limit approximately aligned with, or near, the PM emission limit. However, using a COM as a surrogate for PM has a serious limitation for certain sources within the scope of the proposed HWC rule: poor correlation between opacity and PM at PM concentrations near the proposed PM emission limits ranging from 35 to 69 mg/dscm (at 7% O_2). EPA recognizes three inherent problems with the opacity/PM approach:

1) The stability of any opacity/PM correlation is strongly dependent on particle characteristics, such as size distribution, density, and composition, and conditions in the stack, such as the presence of entrained water and interferents (smoke and condensible salts) in the flue gas;

2) The detection level of COMs is typically reached at PM concentrations of about 45 mg/dscm (@7% O_2), which is above or slightly below the proposed standards; and

3) PM itself is often a surrogate for metal hazardous air pollutants (HAPs). The more distant the final surrogate is from a direct measure of a HAP, the worse the correlation is between the final surrogate (i.e., opacity) and a HAP (metals).

Relative to point 2, above, facilities often desire the detection limit to be one-tenth of the emission limit. This gives sufficient warning of how emissions are changing before the emission limit is approached, and allows the facility, based on CEMS readings, to change operations, as necessary, to be in compliance. It is clear that COMs will not give this type of data.

Operating parameter limits are established during an emissions test designed to verify that a source can meet the applicable limit(s) while the operational effectiveness, relative to the system's ability to control that HAP or surrogate, of the combustion or process device and the air pollution control system (APCS) is minimized. These operating parameter limits often become separately enforceable conditions which are part of a facility's permit. However, using operating parameter limits as a surrogate for PM has a serious limitation: while the test used to establish these limits are worst-case for operational effectiveness, other, often intangible operating conditions are unknown or not characterizable[1]. In addition, operating parameters are again surrogates for PM, a standard which itself is a surrogate. This is not desirable for reasons just described.

If possible, EPA desires a quantitative, continuous measure of PM concentrations rather than relying on a surrogate for PM. Based on surveys and preliminary testing, EPA has recently determined that PM CEMS are commercially available. These PM CEMS rely on developing a correlation between the PM CEMS' output and manual method measurements. Therefore, EPA proposed the use of CEMS for compliance with the HWC PM standards based on the availability of

[1] For example, the tests are often performed under worst-case operating conditions, but best-case maintenance conditions.

these newer technologies. EPA also proposed a PM CEMS Performance Specification based on the International Standards organization (ISO) specification 10155 and EPA's experience at that time of what level of performance a PM CEMS could achieve. This draft performance specification is subject to revision based on new data obtained prior to the promulgation of the final HWC MACT rule.

This report documents the results from a nine month program demonstrating the performance and reliability of the PM CEMS. The results of previous tests at a hazardous waste incinerator and a cement kiln are also briefly discussed. The prescreening phase of the demonstration program was conducted in August 1996, with CEMS installations being completed in September. The initial calibration relation test was performed in one week periods each month from December 1996 through March 1997. A second calibration was conducted in April 1997. In addition, four monthly response calibration audit (RCA) tests were performed. As will be discussed later in this report, a few of the CEMS were not able to produce data due to operational difficulties during periods in October and November. The nine-month demonstration program ended in May 1997.

1.1 Demonstration Program Goal and Course of Development

Summary

EPA has performed a progressive series of interrelated steps leading to, and setting the stage for, this PM CEMS demonstration program. These assertive, iterative and parallel efforts consisted of the following PM CEMS-related tasks:

- A worldwide technology survey,
- A trip to Europe to determine how CEMS are used there,
- Two preliminary tests, one at a hazardous waste incinerator and another at a cement kiln,
- Development of performance specifications and QA requirements,
- Modification of the PM reference method,

- Invitation/participation of several PM CEMS vendors, and
- Selection of a suitable test site.

Goal

Although EPA-approved CEMS technologies for monitoring gaseous criteria pollutants (such as CO, SO_2, and NO_x) in real-time have been commercially available in the United States for more than two decades, there has been no such technologies for PM. This technology gap had created a shortcoming or a barrier in EPA's authority to develop and enforce a *direct, real-time, quantitative* compliance assurance monitoring (CAM) strategy for industries with PM emission standards. Alternatively, in past EPA regulations *indirect, surrogate* PM monitoring approaches were developed and practiced as a continuous CAM for PM. It is the goal of this program to demonstrate that PM CEMS can provide for a *direct, real-time, quantitative* CAM for PM applicable to HWC facilities, thereby replacing and overcoming the deficiency of indirect surrogate monitoring approaches.

Worldwide Survey and European Trip

In support of the proposed rule requiring PM CEMS for HWC facilities, EPA in 1993 surveyed the state-of-the-art of CEMS technologies for PM worldwide This survey drew primarily upon direct communications with vendors and developers, product literature, and test results. Several PM CEMS technologies were identified as being commercially available in the sense that several hundred PM CEMS installations exist worldwide, many of which use PM CEMS as a continuous CAM method in other countries. None of these devices had received EPA approval as a CAM method for PM, however, because:

1) EPA was not aware of the commercial availability of PM CEMS;

2) EPA had theoretical concerns regarding the generation and behavior of PM as it pertains to the direct measure of PM in a stack; and

3) EPA had not addressed how such a monitor could be implemented[2].

The worldwide survey revealed that PM CEMS are used formally as a CAM method in Germany and other countries, and that the Germans had taken the initial lead in the development, certification, and application of PM CEMS worldwide. This information led to a 1994 EPA-sponsored trip to Germany to determine the Germans' experience, their certification procedure, and the PM CEMS use in practice as a CAM method. The findings from the trip indicated that the Germans' use of PM CEMS is based on a practical engineering philosophy. In Germany, measures are taken to establish their calibration *(i.e.*, to define the statistical relationship between the CEMS output and PM concentration on a source-specific basis) and to assure their accuracy/precision and reliability through suitable laboratory experiments, long-term calibration tests, certification strategies, and performance specifications. For well-controlled emission sources, their experience indicated that PM CEMS can be calibrated with manual reference methods to achieve a statistically reliable, practical, and enforceable calibration relation.

These findings alleviated EPA's concerns about PM CEMS by:

1) Determining that commercially available devices could be used as a PM CEMS[3];
2) Finding that many of the theoretical concerns that exist are not realized when a PM CEMS is calibrated on a source-specific basis; and
3) Realizing that PM CEMS could not be implemented using gaseous HAP CEMS as a model, but could be implemented if a new, site specific calibration and implementation strategy were used.

Preliminary Tests and Performance Specifications

[2] In other words, how does one develop the equivalent to a calibration gas for PM which all sources can use when the physical characteristics of PM which affect PM CEMS response vary from source to source?

[3] Previously in this country, these monitors were sold and used for non-regulatory purposes, such as bag-leak detectors.

With this information, EPA modeled/adapted the German practice and philosophy by developing EPA experience and confidence in the utility of PM CEMS. As initial steps, in 1995 EPA sponsored two preliminary test projects to begin the process of becoming familiar with and evaluating available PM CEMS technologies. The first test was conducted at the Rollins Environmental Services Bridgeport hazardous waste incinerator and lasted less than one month in duration. Here, the PM CEMS were located downstream of a pilot scale wet electrostatic precipitator (exhausting a saturated flue gas containing water droplets). These PM CEMS represented three types of technologies: light-scattering, time dependent optical transmission, and beta gauge. The other preliminary test was conducted on the exhaust of the Lafarge Corporation hazardous waste burning cement kiln in Fredonia, Kansas, using two light-scattering PM CEMS technologies. This test lasted slightly less than five months. Each of these two test projects were successful in that EPA gained practical and technical experience with evaluating PM CEMS on HWC facilities and developing data/protocols to certify their performances. Although useful, the results of these tests indicated the need for additional demonstration and data from a long-term test program at a source which is a *reasonable worst-case* test for PM CEMS based on the expected PM characteristics at the facility.

Parallel to these preliminary tests, EPA developed draft Performance Specification 11 and the QA requirements for PM CEMS. These were modeled after the current EPA specifications for gaseous CEMS, along with the German protocol, the International Organization for Standardization (ISO) International Standard 10155, and the data obtained from the preliminary tests. Included in the performance specifications and QA requirements are the data acceptance criteria and protocols for conducting the initial calibration test and subsequent calibration audits. In general terms, the initial proposed calibration test consists of at least 15 reference method measurements over the expected range of facility operations and PM emission levels. The CEMS responses are compared to the PM reference method measurements and a calibration relation is developed. For facilities producing PM with highly variable properties (from burning a wide variety of waste or fuels), EPA proposed that a facility use multiple calibration relations for CEMS technologies sensitive to changes

in PM properties (such as light-scattering CEMS) to encompass the expected range of operations[4]. Following the initial calibration, it was proposed that an absolute calibration audit (ACA) would be performed every three months and a relative calibration audit (RCA) be performed every 18 months (30 months for small on-site incinerators). Based on the success of the demonstration, the Agency is considering less frequent audits. If the RCA manual method data lied outside the bounds of the tolerance interval calculated from the initial calibration data, a new initial calibration test would be required. Details of the calibration and audit procedures used in this program are discussed later in Section 2.

Site Selection

The next step in advancing this effort was to select a HWC facility, which under its normal range of operating conditions would present a reasonable worst-case exhaust stream to challenge multiple PM CEMS technologies in a long-term test program. For the purpose of demonstrating the capabilities and limitations of the CEMS, a worst-case exhaust stream would consist of high moisture (i.e., more than 20%), PM levels in the range of the proposed emission limit, and PM with a wide variation in properties (such as composition, particle size distribution, density, shape, color). Such a facility would burn a wide variety of waste streams (such as a corporate or commercial incinerator), and be equipped with PM APCDs. EPA reviewed the HWC emissions database for candidate facilities based on these considerations. After candidate facilities were identified, practical considerations were taken into account. These practical considerations include: sampling and CEMS installation access, adequate space, the availability of necessary facilities (electricity, compressed air, etc.), and the willingness of the facility to cooperate and accommodate the tests (*i.e.*, alter process conditions and emission control device performance over a range of normal operations).

[4] As mentioned in the first CEMS NODA (62 FR 13776, March 21, 1997), EPA foresaw problems implementing this type of approach. For instance, how does a facility know what calibrations it needs and when to use a given calibration? For these reasons, EPA (twice) established one calibration representing the entire operating range of the demonstration test facility without regard to how PM characteristics affect the bias or statistics of the correlation curve. This will cause more variability in CEMS output and, thereby, maximize the effects that PM characteristics have on the bias and statistics of the calibration curve. For this reason, EPA now believes a facility will not need multiple calibration curves since this variable has been accounted for in the data used to establish the final performance specifications.

A corporate incinerator site, presenting a reasonable worst-case challenge to the CEMS, was selected and agreed to participate. The rationale for why a corporate incinerator is a reasonable worst-case is described in section 1.2.1 of this report. A description of the test site is presented in another section.

PM CEMS Vendors Participation

As the site selection process occurred, EPA published a notice in the Federal Register soliciting technical information from PM CEMS vendors willing to participate in a long-term demonstration program. Six PM CEMS vendors from various locations in North America and Europe provided this information and agreed to participate in the program. Beyond certifying their accuracy and precision, EPA clarified in the proposal and subsequent agreements that each PM CEMS must be commercially available and sufficiently developed for certification of its continuous, reliable, and virtually automated operation. To ensure this, several additional prerequisites were established, including:

1. *Commercially available with evidence of more than 100 in-stack installations worldwide*. This ensures the credibility of the monitor as a compliance tool by reflecting that the monitors are sufficiently developed and manufactured for a large business market.

2. *Sufficiently developed to produce data more than 90% of the time*. This requirement shows that the complete monitoring system is robust and reliable enough to operate nearly all of the time. This would include provisions to withstand the harsh conditions of the gas stream produced by a facility burning hazardous waste throughout all four seasons of the year.

3. *Adequately designed to calibrate at zero and span level*. This criterion shows the monitor can ensure its readings are reasonably accurate on a frequent basis. It is not practical or acceptable to remove the monitor from service and take it to another location for a frequent

check of its calibration.

4. *Amply documented with description and schematics for use*. This criterion involves the need for written communication and specification on how to install, use, and perform simple and routine maintenance on the monitor. It ensures that a complete package of technical information (wiring schematics, drawings, figures, tables, specifications, and numerous pages of text on operating principles, maintenance, and troubleshooting) is provided by the vendor to support the continued use of the product.

5. *Operationally independent with completely self-contained equipment*. This criterion requires that the monitoring system meet EPA's definition of a "Continuous Emissions Monitoring System," as defined in 40 CFR 60.2. The monitor must be able to operate in a self-governing and automated manner. It must not reply on other equipment or human intervention to sample, analyze, or transmit a permanent record of emissions to a data storage device.

6. *Reasonably accurate readings produced in units of the regulations (mg/m^3).* This requires the monitors to produce PM concentration results in terms of an emissions concentration. These results could then be integrated with auxiliary data to correct the measurements to standard conditions for temperature, moisture, and oxygen.

All vendors completing this program adequately showed that their monitor can meet these prerequisites. Beta gauges did not meet 90% availability criteria.

1.2 Demonstration Program

These previous efforts led to a long-term test program designed to demonstrate whether advanced-technology CEMS actually *provide a viable measure of PM levels under reasonable worst-case conditions*. Specifically, the purpose of this study is:

- To identify and resolve implementation issues surrounding any PM CEMS requirement for the upcoming HWC final rule,

- To define the "worst" performance level one might expect at HWCs from these instruments, and

- To acquire data to determine whether a PM CEMS should be required for compliance with any HWC PM standard.

The focus of this study is the appropriateness of PM CEMS at HWCs, as defined in the proposed rule. Other source categories and standards were not the focus of this study and, thereby, the appropriateness of PM CEMS at other sources complying with numerically different PM standards is not addressed. The following material first discusses the rationale for the test site selection and then summarizes the achievements of the demonstration program and issues the public has raised regarding the use of PM CEMS.

1.2.1 *Site Selection Rationale*

Hazardous waste burning incinerators represent as close to a worst-case scenario as possible, relative to other HWCs, because they can generate particulate matter with a wide variation in physical properties and concentration.

Many corporate or commercial incinerators burn a wide variety of waste as their primary feedstreams. (For the purposes of this discussion, a "corporate" incinerator is one which, like a commercial incinerator, accepts wastes from a variety of sites, but only wastes from other sites within the company. "On-site" incinerators accept wastes only from the site in which it is located and not from other sites.) The broad range of feedstock has the potential to produce PM with a wider variation in physical properties (*i.e.*, shape, size, and color) and concentrations than other HWC facility types: on-site incinerators, cement kilns (CKs), and LWAKs. A wide variation in physical

properties and concentrations of PM would result in a worst-case test since some PM CEMS are known to be sensitive to changes in physical properties and concentration of PM. From an implementation perspective, this wide variation is worst-case because it causes calibration testing, calibration auditing testing, and the task of maintaining calibrations more difficult. A worse-case facility also raises probability that the demonstration would fail because it is determined that any PM CEMS requirement is not implementable due to the rigorousness of the test site. On-site incinerators typically burn fewer waste types than corporate or commercial incinerators, leading to a more consistent PM composition and concentration relative to incinerators which burn more types of wastes. CKs and LWAKs characteristically feed PM-rich process ingredients. Consequently, much of the PM emitted by CKs and LWAKs is process dust, which is more consistent than the PM emitted from other HWCs. As a result, on-site incinerators, CKs, and LWAKs do not represent a worst-case source for this program because they are likely to produce a more uniform PM than those from corporate and commercial incinerators.

1.2.2 *Achievements and Apparent Limitations of the Demonstration Program*

Another key consideration in this demonstration program centers on whether the potential exists for varying facility operations over a wide range of process conditions during the program *(i.e.*, typical as well as worse-case PM CEMS scenario) . EPA believes that this consideration was achieved, since:

- A wide variety of burnable and aqueous wastes were fed;
- Normal operations were experienced in a random, non-reproducible format;
- Different APC operating conditions and performance levels were achieved;
- The PM concentrations were varied from 5 to 100 mg/dscm;
- The PM was analyzed and it contained at least 15 different elements;
- The PM was electrostatically-charged, a potential worst-case PM condition; and
- Testing covered all four seasons, addressing weather/seasonal concerns with long-term reliability.

In addition, the fact this testing was performed prior to promulgation of the proposed PM CEMS requirements enabled EPA to study and resolve key data quality issues, including:

- Identification and subsequent treatment of outliers;
- Definition of and improvement in reference method accuracy and precision; and
- Development of new reference method data quality objectives.

Based on the results to date, these issues were resolved.

1.3 Program Overview

The CEMS demonstration program was performed to verify that at least one, and preferably more, PM CEMS have acceptable performance, even at a reasonable worst case facility, and determine what that "worst" acceptable performance level is. The program included two phases: 1) calibration tests to compare and evaluate results from each of the CEMS with the manual EPA reference method, and 2) endurance tests for nine months to examine CEMS performance relative to stability of their calibration relation and the reliability of their continuous operation. The demonstration test involved installing the CEMS and carrying out testing prescribed in the performance specifications just as if a facility were buying and using the CEMS for compliance purposes. CEMS performance in all the areas covered by the proposed performance specifications and data quality objectives were evaluated. In addition, the maintenance record and data availability of each CEMS was compiled and evaluated.

Based on proposals received by EPA in response to an announcement and request for proposals that appeared in the Federal Register, six PM CEMS were selected to participate in the demonstration. The participating CEMS vendors and their technologies, are listed as follows:

- Monitor Labs, representing Verewa GmbH - Beta technology;

- Environnement USA, representing Emissions SA (ESA) - Beta technology;
- Durag, Inc.- Light-scattering technology;
- Environmental Systems Corporation (ESC) - Light-scattering technology;
- Lisle-Metrix Ltd., representing Sigrist - Light-scattering technology; and
- Jonas, Inc. - Impaction-energy technology.

Descriptions on each of the CEMS are given in Chapter 3.

The overall scope of the PM CEMS demonstration included prescreening measurements for PM, HCl, and particle size distribution; development and laboratory testing of a Modified Method 5 for low PM loading measurements; and field demonstration of the PM CEMS. The main elements are summarized below.

- *Site selection:* The incinerator at the Dupont Experimental Station in Wilmington, Delaware, was selected for the PM CEMS demonstration based on reasons described in section 1.2.1 of this report.

- *Prescreening measurements:* Before the installation of the PM CEMS, testing was conducted as part of the facility characterization and permitting campaign which followed the installation of an electrodynamic venturi (EDV) system at the facility. An analysis of this data is included in this report.

- *Method 5 Modification*: Method 5 was not originally designed in the early 1970s for measuring low PM concentration measurements near or below the 35 to 69 mg/dscm range being considered for HWCs, particularly in cases when extraction and recovery of the filter can be difficult. Results from preliminary demonstration testing carried out by EPA/OSW revealed that the accuracy and precision of Method 5 measurements at low PM levels is one of the factors limiting exact CEMS calibration. Therefore, a modified manual method designed to provide improved precision at low PM loadings was developed, demonstrated,

and used to calibrate the CEMS. The modified design incorporates a light weight filter holder assembly that can be weighed before and after sampling without disassembling it to recover the filter. This assembly replaces the conventional filter housing used in Method 5. The proposed Method 5 procedural modification is thus very slight; it merely eliminates the filter recovery step. Nevertheless, this modification has potential to improve its accuracy and precision at low PM levels.

- *Demonstration testing of the CEMS:* The draft data quality objectives require RCAs every 1-1/2 years and quarterly checks of calibration error (absolute calibration audits, or ACAs). During the endurance test, RCAs and ACAs were performed monthly. In addition, the reliability and maintenance requirements of the CEMS was documented. The elements of the endurance test included:

  - Monthly RCAs (comparison to reference method measurements);
  - Monthly ACAs;
  - Continuous recording of CEMS data for nine months;
  - Documentation of daily calibration and zero checks;
  - Documentation of all performed maintenance/adjustments; and
  - Documentation of all periods of data non-availability.

- *Applicability of Proposed Performance Specifications*: Another important aspect of the demonstration was to evaluate the proposed performance specifications and data quality objectives themselves. In some instances, EPA found the requirements to be unworkable. Others were found to be workable, but not at the performance level observed at worst-case facilities. All deviations in the demonstration test from those procedural requirements are noted. This is important because the performance specifications and data quality objectives were drafted with the understanding that revisions to them would be necessary after EPA obtained first-hand information concerning the performance capabilities of these CEMS at the "worst-case" site and how the CEMS should be implemented. In instances

where the specifications and objectives were modified from the proposed draft requirements, the appropriate issues and the rationale for modifying the draft requirements are identified.

1.4 Description of Facility and Monitors

1.4.1 *General Facility Description*

The site selected for the PM CEMS demonstration is the incinerator at the Dupont Experimental Station in Wilmington, DE. The rationale for this site's selection is as follows:

1) An incinerator was preferred for two general reasons:

- Many incinerators burn a wide variety of waste as their primary feedstream. This has a higher potential, compared to other HW-burning facility types, to produce PM with a wide variation in characteristics (composition, size distribution, shape, and color), representing a worst-case challenge for PM CEMS; and

- Incinerators generally have well-controlled PM emissions, which allow testing at levels approaching the proposed emission limits.

2) The particular incinerator facility was chosen for the following reasons:

- Preliminary measurements show that PM emissions generally range from around 8 to 90 mg/dscm (0.003 to 0.04 gr/dscf) at 7% O_2, depending on how the facility is operated.

- The facility is willing to host the demonstration, allow the necessary CEMS installations to be made, provide ample access, space, and sample location criteria,

and vary operating conditions and waste streams as required to perform the calibration of the CEMS.

The incinerator facility has undergone recent equipment upgrades; the following is a general description of its current design.

A Nichols Monohearth incinerator is used as the primary combustion chamber. Waste is fed to this combustion chamber using three separate means: 1) a ram feeder for solid waste, 2) a cylindrical chute for batched waste material, and 3) a Trane Thermal liquid waste and No. 2 fuel oil burner. The primary combustor exhausts to a secondary combustion chamber (afterburner) where No. 2 fuel oil is fed using a Trane Thermal burner. This afterburner chamber discharges to a spray dryer where the elevated temperature exhaust gases dry the scrubber liquid to remove dissolved and suspended solids previously collected by the wet scrubber system. Some PM is removed by the spray dryer; recycling the scrubber water back into the gas stream serves as another source of PM as does the waste feedstreams. The exhaust gas from the spray dryer discharges to a cyclone where additional PM is removed from the gas stream. The exhaust gas from the cyclone discharges to a reverse jet gas cooler/condenser, which reduces the gas temperature to the dew point. The reverse jet gas cooler/condenser discharges into a variable throat venturi scrubber which is used to remove PM and acid gases. The venturi discharges into a spray absorber where a soda ash neutralized scrubbing solution is used to absorb acid gases. The gas is subcooled in the absorber by the use of the cooling tower water spray before exhausting through a chevron-type mist eliminator. After this, the gas is further treated by a set of electrodynamic venturis (EDVs), which is used to remove fine PM and the metals that condense as a result of the gas subcooling. The gas then passes through a set of centrifugal droplet separators, it is then drawn through the induced draft fan and a series of steam heat coils, and it is exhausted out the stack.

1.4.2 *General Description of CEMS Technologies*

Five PM CEMS have produced results of PM emissions concurrent with the modified M5 trains. Three of the CEMS use an optical-based technology (Sigrist, Durag, and Environmental Systems Corp.) while two use a beta attenuation-based technology (Verewa and Environment USA). Both beta monitors and the Sigrist monitor employ an extractive, heated sampling system to deliver a sample to a particulate-measuring sensor external from the stack. The other two optical systems use an in-situ sampling/measurement approach. A sixth monitor has been installed, but the vendor later decided to no longer participate in the test program.

Light-Scattering CEMS. The light-scattering technologies can be configured as either in-situ or extractive systems. The three monitors infer particulate concentration in the stack by measuring the amount of light scattered by the particulate in either the forward or backward direction. Various types of light sources (halogen, infrared, and incandescent) are being used to generate a beam with a known wavelength. A light sensor or photometer appropriately positioned in either the forward or backward direction measures the amount of scattered light. Each CEMS is designed with an air-purge system to minimize PM buildup on the optics. Each monitor adjusts and compensates the detector's signal for interferences, such as stray light and PM accumulation on its optics. Also, each CEMS has an automatic zero and calibration check performed daily. The instruments' responses are proportional to the "dry" PM concentration for a given set of PM characteristics (composition, density, size distribution, index of refraction) and provide detection levels near 0.5 to 1.0 mg/m^3. Each individual instrument undergoes a factory calibration to ensure the same response for a given set of PM conditions, so a monitor can be replaced with an identical model without the need for re-calibration. However, since the instrument response is dependent on PM characteristics, a site-specific calibration is generally required to ensure or adjust instrument response. These CEMS produce nearly continuous output. Each of the three CEMS are installed on more than 100 stacks worldwide.

Beta Gauges. Each of the two beta instruments uses a heated sampling line to obtain and deliver an isokinetic or a close-to-isokinetic sample which is collected on a filter roll. The

sampling flowrate and duration is programmable, though the optimal sampling duration depends on PM loading. After the sampling period is completed, some form of probe purge is performed to entrain any PM deposit onto the filter. Analysis of the filters begins with determining the beta transmission through each blank filter spot before sampling begins. After a batch sample is collected over the sampling period, an automatic filter indexing mechanism moves the loaded filter position spot to a location between the carbon-14 beta source and a detector. Analysis of the filter takes about 2 minutes. The difference between the two analyses is representative of the PM mass collected on the filter. Thus, the response of the instrument is relatively independent of the PM characteristics. These CEMS produce results concurrent with the sampling period and in units of PM concentration. Each beta gauge CEMS are installed on more than 100 stacks worldwide.

Acoustic Energy. In this technique shock waves caused by the impact of particles with a probe inserted into the gas flow are used to measure particle loading. The device counts the number of impacts and measures the energy of each impact. This information, coupled with knowledge of the gas velocity, allows calculation of the particle mass and thus concentration. However, correction for the flow pattern is included in the instrument's response. Since the probe inherently distorts the localized flow pattern, changes in flow velocity or particle size distribution will, in principle, alter the instrument's response. Since the instrument response is dependent on PM characteristics, a site-specific calibration is expected to be required to ensure or adjust instrument response. This CEMS produces very frequent signals on a nearly continuous basis. This vendor has not yet presented any evidence that this technology is used for a PM air emission compliance application.

The primary contacts for each of the participating CEMS vendors are :

- Mr. Richard Hooper of Monitor Labs, representing Verewa;
- Mr. Mousa Zada of Altech of Environnement USA, representing Emissions SA;
- Mr. Thomas Kurzawski of Durag, Inc.;

- Mr. Robert Nuspliger of Environmental Systems Corporation;
- Mr. T. J. Medland of Lisle-Metrix Ltd., representing Sigrist; and
- Mr. Ravi Mathur of Jonas, Inc.

2.0 TEST PROGRAM RESULTS

This section of the report provides the results of the PM CEMS demonstration test program. It also explains how the tests were conducted and how the data were evaluated during the PM CEMS demonstration program at the Dupont Experimental Station incinerator. A test which establishes the correlation between the CEMS outputs and the reference method is called the calibration. Subsequent tests to determine whether that calibration is still valid are referred to as response calibration audits (RCAs).

Two (2) calibrations were performed under a similarly wide variety of facility operating conditions. The first calibration was performed during one-week periods in each of the four (4) months between December 1996 and March 1997. These tests established the initial calibration relation between the PM CEMS and the reference method. Due to suggestions from the public, a second calibration test was conducted in April 1997 to evaluate the stability of the respective PM CEMS calibrations. In addition, another test was performed in May 1997 to serve as a RCA and another means for determining the validity of the calibration relations over time. The RCA test served a two-fold purpose: 1) to determine the acceptability of the RCA data relative to the two calibration relation test results, and 2) as additional supporting data for each PM CEMS into forming an overall or cumulative database which consisted of all acceptable data. Experimental tests from September through November 1996 were performed with these data utilized only as additional points of comparison in the RCA evaluations; however, these data were not incorporated into the cumulative data set because of their variation and questionable credibility produced from trial and error experiments with reference methods procedures during the initial phase of the program. The evaluation protocols used were those found in the proposed PS 11 for PM CEMS and Appendix F - Procedure 2, which will contain the quality control procedures governing PM CEMS that have been rewritten to replace Appendix to Subpart EEE. All tests were conducted under normal operating conditions with the ordinary mixture of waste types and consisted of comparing CEMS outputs to concurrently run, paired proposed Method 5i (M5i) measurements as the reference method.

Results from the calibration tests are presented in the following material, preceded with summaries of the Draft PS 11 test protocol, treatment of outlier and acceptable M5i data, and facility operations during testing.

2.1 Proposed Performance Specifications Calibration Testing

Draft Performance Specification 11 (Draft PS 11) was developed and proposed by EPA to establish the framework for certifying PM CEMS in future regulations governing their formal use on HWC facilities. This specification was used to evaluate the acceptability of PM CEMS following their installation and soon thereafter. Foremost in the Draft PS 11 is site-specific testing of PM CEMS response to initially calibrate and certify performance. Such calibration tests are composed of three (3) main elements : 1) operate the facility across the complete range of facility PM emissions and operating conditions, 2) conduct sets of PM CEMS and manual reference method measurements simultaneously, and 3) perform these tests at three (3) or more PM concentrations for a total of 15 measurements. The validated range of the data developed in the calibration relation test is restricted to the range of the PM loadings used in developing the relation. If any changes in facility conditions would alter PM emission properties significantly (*e.g.*, changes in emission controls, flue gas additives, feedstreams, or fuels), then a new calibration relation test would be required. Since the validity of the calibration relation may be affected by significant changes in PM properties, such as its composition, density, index of refraction, and size distribution, continued validity of the PM CEMS calibration relation would be evaluated with respect to these changes on a site-specific basis.

Because there are no available synthesized means of challenging and certifying PM CEMS performance in actual use across its intended range (*e.g.*, protocol gas cylinders with low, mid, and high concentrations), it is necessary to change and control process conditions for developing the range of PM emission levels for calibration tests. Draft PS 11 stipulates that calibration relation testing be carried out by making simultaneous CEMS and the manual reference method measurements at three (3) or more PM concentrations. The PM concentrations need to be distributed from the normal low to the highest available and include at least one (1) intermediate level. Three (3) or more

measurement sets would be obtained at each PM concentration level. The different PM concentration levels would be developed by varying operating conditions as much as the process allows within the normal operating range and permit conditions. This means that, at certain facilities, it would be necessary to vary waste, ash, and/or metal feed rates in order to develop a range of PM emission levels over which the calibration is conducted. Alternatively, PM emissions may also be varied by adjusting the performance of one (1) or more of the PM control devices. It is recommended that the CEMS be calibrated for PM levels ranging from a minimum level to a level twice the (proposed) emission standard, as this would provide the most accurate measurement for, and the smallest confidence and tolerance intervals on, the calibration relation at the emission standard. If it is not possible/practical to develop PM loadings at twice the standard, then it is recommended that at least six (6) measurement sets be performed at the maximum PM level possible to optimize the accuracy and certainty of the calibration relation at the maximum PM level.

At recurring, fixed-time intervals (*e.g*., initially proposed to be every 18 months for all but small, on-site incinerators) following the calibration, a RCA test would be conducted to evaluate whether the calibration is still valid. The RCA tests are composed of the same three (3) elements as the calibration with the following stipulations and exceptions: 1) the facility should be operated across its normal PM emission range, and assuring that all measurement sets are collected within the same range as the calibration, and 2) a minimum of *12* measurements are required[5]. It is necessary to duplicate the same range of PM loadings as in the calibration relation test to evaluate and potentially maintain the validated PM CEMS calibration relation performance for that same range. If the RCA data pass the acceptance criteria, then the calibration is still valid and no additional testing is required. Conversely, if the data acceptance criteria are not achieved with the RCA data, then the calibration is no longer valid and a new calibration must be obtained. For these cases, the RCA data could be combined with the 15 calibration measurements provided that the resulting calibration meets the statistical requirements of the performance specification.

[5] Though, as mentioned in the first CEMS NODA, as few as nine good runs may be used for the RCA evaluation if the remaining tests are reported, but not included in the RCA data set, because they fail facility or method QA/QC. Commenters to the first CEMS NODA seem to agree that only good data should be used.

Another important aspect in this demonstration program is the evaluation, and revision as necessary, of the Draft PS 11 requirements themselves. These performance specifications were drafted with the understanding that some revisions in the structure or language would become necessary based on discovery in this initial attempt to implement Draft PS 11. Based on careful review of PM CEMS performance achieved during this program and in response to public comments, it was decided to modify two of three data acceptance criteria to tighter levels than originally included in Draft PS 11. The confidence interval and tolerance interval are now proposed at the same level as specified in the International Organization for Standardization (ISO) Method 10155. Following are the original and new revised data acceptance criteria in Draft PS 11:

Version	Correlation Coefficient	Confidence Interval %	Tolerance Interval %
Original	> 0.90	<20	<35
Revised	> 0.90	<10	<25

Details and explanations on the data acceptance criteria and other stipulations in Draft PS 11 for each type of calibration test are presented in context in Section 2.3 (Facility Operation), Section 2.4 (Calibration Relation Results), and Section 2.5 (RCA Test Results). The revised Draft PS 11 is contained in the Appendix.

2.2 Reference Method Protocol and Treatment of its Outlier Data

The following material explains the fundamental importance, the measures taken, and the treatment of Outlier Data of the PM reference method results for this program.

2.2.1 *Reference Method Protocol for the Demonstration Program*

Before testing began, the quality of the data produced by the reference method for this national demonstration program was recognized as one of the most critical factors in evaluating

performance of the PM CEMS. Given that the reference method was pivotal in calibrating as well as evaluating the PM CEMS, measures were implemented to modify, measure, and improve data quality. In response to this recognition, the following measures were taken:

1) Modify M5 to improve its accuracy/precision at low PM levels,
2) Conduct paired simultaneous modified M5 measurements, and
3) Experiment and use feedback to optimize the modified M5 measurements.

As mentioned in Section 1 and further described in Section 3.2, the filter handling steps in assembly and recovery represent the areas producing the most uncertainty in M5 at low concentrations. To improve its accuracy and precision at low PM levels, the standard M5 filter and filter holder combination was scaled down to allow both to be weighed before and after sampling without direct handling of the filter itself. To evaluate the effectiveness of this modification before its use in this program, EPA required that the precision of the modified method be determined. This was performed in a two-fold experimental test involving laboratory and field measurements. The results of these tests showed that the precision for all the measurements was within M5's reported precision of 10%. A detailed account of the experiment is contained in the Appendix. Hereafter, this modification to M5 for improving low PM measurements will be referred to as Method 5i (M5i).

Data produced from M5i during the PM CEMS demonstration program concurred with the data obtained in the previous laboratory and field experiment. With filter weight gains ranging from 5 to 25 mg, the demonstration program results likewise showed that M5i had greater sensitivity and lower variability in measuring low PM concentrations than the standard M5.

Regarding the second measure, paired M5i measurements were also taken to calculate the relative standard deviation. This provided the basis for evaluating any uncertainty of the M5i data. This was considered necessary since M5i will serve as the standard measure for the correlation of the CEMS. This test program substantiates two important points learned by other groups such as TUV in Germany as well: (a) the exactness of the PM CEMS calibration comes back to any uncertainty in

the reference method, and (b) the uncertainty in the reference method must be less than in the CEMS.

And for the third measure, during the initial phase of the program experiments were tried to investigate and minimize the variability of the data produced by M5i. By improving the previous "bottleneck" producing the most uncertainty in the standard M5, it was recognized that the next level of potential "bottlenecks" in M5i needed to be investigated and minimized. These trial and error experiments conducted during the initial phase of the program from September through November lead to the following conclusions:

- Surgical gloves must be used at all times when handling the filter holder assemblies; repetitive handling without protection against transfer of natural oils produced variability.

- The filter holder must be isolated from any external sources of contamination; during pre- and post-test operations secured glass plugs on both ends of the filter assembly are required, just as petri dishes are for the standard M5.

- Tarable Teflon beakers need to be used with the probe rinses to ensure accurate weighings.

- Static charge can lead to significant variations in the weighing procedures. Allowances to neutralize static charge need to be implemented.

As an integral part of the investigation, the paired train measure added further value by giving a unique form of feedback on the data quality produced from M5i results. This feedback contributed to the project team's ability to produce higher quality data as the program progressed. But, as a result of variation and questionable credibility of the data produced from the trial and error experiments, it was considered necessary to limit the use of the M5i data, obtained from the initial phase of the program (*i.e.*, September through November tests), to RCA evaluations. In addition, the availability of paired M5i data also allowed Outlier Data to be identified and treated, which is

discussed below.

2.2.2 *Discussion of Outlier Data*

The behavior of results in the database developed in this program shows variations in some of the reference method results that are not readily explainable. The data produced during these tests show variations between the paired (identical, simultaneously operated, but differentially located) M5i sampling trains (1) typically ranging from 2% to 30%, but (2) occasionally being 35% or greater.

The first type of variation (*i.e.*, paired M5i train data with variations less than 30%) is considered statistically acceptable since they are within three (3) times the reported 10% precision (standard deviation) of the reference method [2]. They are explainable since they are within the normal certainty of the method as employed, considering the potential contribution from spatial and temporal variations in the PM loading profile obtainable from separate traversing with paired trains. However, the second type (paired M5 train data with variations greater than 35%) cannot be explained on the basis of the relative uncertainty of the reference method. The term outlier is commonly used to describe an usually high or low value from an individual measurement in the data. In a practical sense, Outlier Data are expected to occur on up to 10% of the data in any series of individual measurements due to a variety of reasons. Due to this frequency and recognition that incorrect conclusions are likely if Outlier Data are included, it is standard practice in statistical analyses of a database (as in this program) to:

1. Screen data for Outlier Data,
2. Eliminate Outlier Data prior to data analysis, and
3. Identify Outlier Data due to unusual conditions of measurement.

The appearance of Outlier Data in the database raised the following questions: (1) how are Outlier Data identified, and (2) how should they be treated once identified? The first question was addressed by looking at the different statistical approaches used to determine if there is statistical

significance to the difference in measured values. If there is, then the datum point can be labeled as an outlier. To determine the statistical significance, it was decided that a student T-test approach[6] would be used for the type of database being developed.

Approaches for identifying Outlier Data were investigated, but some (*i.e.*, statistical and paired-train Outlier Data) were discarded during the course of this program. One other approach (the RSD approach) remains under consideration and was used for this evaluation. Each approach for treating Outlier Data is discussed below.

Statistical Outlier Data

Statistical evaluation of data produced in the initial experimental phase of the program (data which has since been discarded) was performed to determine the extent of correlation of individual data points with the calibration relation. The standard deviation between each actual data point and the regression line of the calibration relation was determined. This evaluation indicated that the exact same three (3) individual data points fell outside the tolerance limits determined by the regression analysis and could be considered Outlier Data (*i.e.*, more than 3 standard deviations) for each of the CEMS. Removal of these standard deviation Outlier Data improved the correlations and was initially justified based on the circumstances in which the different CEMS technologies independently indicated the exact same three (3) data points[7] as Outlier Data. However, this approach for identifying Outlier Data (referred to as *statistical Outlier Data* in the earlier draft reports) created controversy due to its weak scientific basis and its poor precedent for future calibrations to be performed by industry with presumably only one (1) CEMS technology. As a result, this approach has been discarded.

Paired-Train Outlier Data

[6] See "Quality Assurance Handbook for Air Pollution Measurement Systems - Vol. III Stationary Source Specific Methods", EPA 600/4-77-077b.

[7] The three conditions were runs 3, 6R2, and 8; these runs were included in the experimental test data from the initial program phase.

Another means for treating Outlier Data, this one being performed prior to evaluating the correlation between the CEMS and reference method data, was once employed during an earlier draft report. Data were eliminated from the Draft PS 11 statistical treatment based on the following general approach: (1) if one of the paired trains produced an abnormal result, then both results from that condition were discarded and not just the apparently abnormal point, and (2) if both trains produce results in agreement and within the precision of the method, then both are considered acceptable. This approach, referred to as the paired-train approach, was only applied *qualitatively* as a basis for disregarding data. This approach also has been abandoned.

Relative Standard Deviation Outlier Data

Finally, a *quantitative* way of identifying Outlier Data was identified: (1) if the paired reference method data does not agree within the precision of the reference method, then the paired data are suspect and should be thrown out, and (2) if both trains produce results within the reported precision, then both data are considered acceptable. The precision of Method 5 reported from collaborative testing for PM levels from about 80 to 250 mg/dscm (uncorrected for O_2) is reported to be approximately 10%.[3] A normal statistical approach for identifying Outlier Data in a large database is to remove data with standard deviations greater than three (3) around a mean or a regression line. Since the paired data sets are a small database, this approach for identifying Outlier Data is based on removal of paired-train data that do not agree within three (3) times the relative standard deviation (RSD) of Method 5, or greater than 30% RSD. This means that the paired-train results must pass a data quality objective with a RSD less than 30% to be considered acceptable for inclusion in the calibration database. The two following equations were used in calculating RSD values:

Equation 1

$$SD = \sqrt{\frac{n\Sigma y^2 - (\Sigma y)^2}{n^2}}$$

Equation 2

$$RSD = \frac{SD}{M} X\ 100\%$$

where : SD = Standard deviation,

n = Number of samples = 2,

y = Difference in concentration results between the paired trains, and

M = Mean paired-train concentration.

Using this approach, the following RSD Outlier Data were identified in the acceptable data:

- 4 of the 9 conditions (Nos. 31, 33, 35, and 39) in December,
- 2 of the 10 conditions (Nos. 41 and 42) in January,
- 1 of the 12 conditions (No. 61) in February,
- None of the 12 conditions in March,
- 2 of the 17 conditions (Nos. 75 and 81) in April,
- None of the 12 conditions in May, and
- For a total of 9 Outlier Data from an overall set of 72 paired runs.

In addition to exploring alternate means of treating Outlier Data, the overall scope of this program includes consideration for development of new data quality criteria for M5i beyond the normal reference method criteria. This consideration would provide protection against other forms of Outlier Data or anomalies that are prone to occur if the reference method is not carefully performed by experienced personnel. An example of such an anomaly is when the sampling probe nozzle is brushed against the inner stack wall or sampling port, erroneously increasing the amount of PM collected in the nozzle/probe, and then reported. Provisions are being considered for establishing or recommending new data quality criteria involving sampling train partitioning as an extension and use of the lower precision achievable with Method 5i. Since precision in M5i results is necessary for calibration of PM CEMS, it would appear logical to expect comparable precision in terms of the RSDs, with the historical site-specific relationship between two key components (*i.e.*,

probe rinse and filter weight gains) forming the end result.

2.3 Facility Operation Summary

The incinerator operated in a manner to maintain the facility at or below the permitted levels and to accommodate the calibration relation tests as much as possible. The PM CEMS calibration tests for this demonstration program were conducted in accordance with Draft PS 11 protocol and within the terms of the agreement with the site facility. Given these constraints and goals, the calibration tests were conducted under a wide variety of incinerator waste feedstream and air pollution control (APC) conditions across the facility's normal PM emission range. Keep in mind that the rationale for selection of this test site was to present a worst-case challenge to the PM CEMS due to its inherent diversity of operating conditions potentially affecting PM CEMS performance. This aspect of diversity was realized since there were several deliberate and inadvertent changes with respect to facility operating conditions during the calibration test periods. The facility conditions that changed due to seasonal and normal operating variations include:

1) No constraints or reproducibility on the wide variety of waste feedstreams,
2) Variations in equipment operating and maintenance conditions, and
3) Measurable variations in the stack gas conditions in terms of PM concentration and composition, temperature, moisture, diluent concentration, and gas flow rate.

2.3.1 *Facility Operation During the Two Calibration Relation Tests*

Two (2) calibration relation tests were performed under a similarly wide variety of facility operating conditions. These operating conditions covered the full range of operations at the facility, which in turn caused changes in PM properties and emission levels. The calibration testing in December through March was intended to establish the (initial and only) calibration relation for each CEMS relative to the reference method. As experience was gained, data quality improved, and as a result of comments received from the first CEMS NODA, it was decided that a second calibration

relation test be conducted in April to evaluate the stability of the PM CEMS relations. The calibration relation tests were again performed in accordance with Draft PS 11.

Facility Operation During First Calibration Relation Test

The calibration relation testing for this demonstration required an attempt to generate wide variations in PM emission properties (such as composition, size distribution, density, and color), PM emission concentration levels, and in flue gas conditions (such as temperature, moisture, diluent concentration, and gas flow rate). Table 2-1 presents the matrix of planned test conditions. For characterizing PM CEMS performance under normal operations, testing was conducted under as-found facility operations during one-week periods from December to March. To collect data over the incinerator's entire range of PM emissions, it was necessary to continue until high PM levels were produced in March. Six (6) types of fuels and/or wastes in at least nine (9) different combinations were fed to the incinerator over three (3) EDV power settings for a total of 36 test conditions. The six (6) waste/fuel types fed to the primary combustion chamber were:

1) Fuel oil;

2) Solids (including shredded paper, animal bedding, and office/laboratory waste);

3) High-chlorinated solvents (*e.g.*, *ortho*-dichlorobenzene, carbon tetrachloride);

4) A mixture of low- and/or non-chlorinated solvents (*e.g.*, acetone, acetonitrile, butanol, diethylamine, dimethylacetamide, ethyl acetate, hexane, hexamethylenediamine, hydroxyethylidene, isopropanol, methanol, methylene chloride, methyl ethyl ketone, toluene, or xylene);

5) Paint pigments (containing water, resins, and solvents); and

6) Jugs (containing non-, low-, or high-chlorinated solvents).

PM-related process data from the plant records were collected to document the range of plant operation covered during calibration testing. These data were also collected to allow evaluation

of operating condition effects on PM emission levels or CEMS performance. Waste availability determined the order and accounted for the random sequence of the test conditions.

PM-related APC equipment performance was not deliberately varied except for the EDV power levels. The EDV power was adjusted with a programmable logic controller for three (3) set points: 0.2 - 0.3 kW for the low power, 1.0 kW for the mid-power, and 2.0 kW for the high power conditions. Another key, but not-so-controllable, variable affecting PM emission characteristics is the contribution from solids in the recycled scrubber water injected into the spray dryer. The incinerator's elevated temperature exhaust gas evaporates the recycled scrubber water injected into the spray dryer for removal of dissolved and suspended solids collected by the wet scrubbers. Metals, salts, fly ash, and unreacted soda ash (sodium carbonate for pH control) make up the dissolved and suspended solids carried in the scrubber water ultimately removed as dry PM material in the spray dryer and cyclone. Since a hysteresis effect tends to occur from the scrubber water solids, its contribution of PM emissions is not subject to direct, immediate control of affecting PM emission levels. And because of their fixed design configurations, none of the PM-related performance parameters of the spray dryer, cyclone, or venturi scrubber could be deliberately varied.

A general summary of the facility operating data for each condition in the first calibration relation testing is presented in Table 2-2. Records with a more detailed account of the facility operating data during testing are included in the Appendix.

Facility Operation During Second Calibration Relation Test

The second calibration relation test was conducted in a manner similar to, but not exactly duplicative of, the first one. The general nature of the incinerator operating conditions and waste feed combinations of the first calibration relation test was similar to the second test. Comparison

of the waste/fuel type combinations fed between the first and second tests are shown in the following:

First Calibration

1) Mixed solvents and solids
2) Chlorinated solvents and solids
3) Mixed solvents, solids, jugs, pigments
4) Mixed solvents
5) Mixed and chlorinated solvents
6) Mixed solvents, solids, jugs
7) Mixed solvents, solids, jugs
8) Chlorinated solvents, solids, jugs
9) Fuel oil and solids

Second Calibration

1) Mixed solvents and solids
2) Mixed solvents, chlorinated solvents and solids
3) Mixed solvents, solids, jugs, and pigments
4) Mixed solvents
5) Mixed and chlorinated solvents
6) Mixed solvents, solids, and pigments

However, the PM emission range of the second calibration relation test was lower than the first test. This probably was the result of greater PM removal from higher EDV power levels: 1.0 kW for the low power, 2.0 kW for the mid-power, and 3.0 kW for the high power conditions. Though the intent was to simulate waste-feed types and PM emission loadings, there were at least three (3) other factors that precluded exact duplication of facility operating conditions and PM emission levels:

1) The normally wide variety of wastes and feedstream combinations meant the exact same feed materials were not available;

2) The hysteresis effect of recycling scrubber water back to the spray dryer meant that the amount and type of PM evaporated from the scrubber water could not be reproduced; and

3) Incinerator operational constraints.

Recall that this particular facility was chosen because it treats a very broad assortment of waste feedstocks, most in small quantities. While this is desirable from a worst-case PM CEMS challenge

standpoint, these aspects did not allow reproducing the identical feed, operating conditions, and PM emissions that were obtained in the first calibration tests. Table 2-2 also presents a general summary of the operating data for each condition in the second calibration relation testing with a more detailed account of the facility data included in the Appendix.

2.3.1 *Facility Operation During RCA Testing*

The final monthly test in May 1997 was considered a RCA and performed under as-found facility conditions to represent normal day-to-day operations. No attempts were made to control the waste-feed streams for this test, although EDV power set points were adjusted to three (3) different levels: 1.0 kW for the low power, 1.5 kW for the mid-power, and 3.0 kW for the high power conditions. Similar to the calibration tests, the normal variety of waste feedstreams were added during the May monthly test. The feedstreams included the same types of waste streams as in the calibration tests along with additional types, combinations, and/or relative feed rate distributions of solids, mixed solvents, chlorinated solvents, jugs, pigments, and fuel oil. Likewise the changes in EDV power settings gives the same appearance of a similarly irregular pattern overlaying the feedstream diversity. This heterogeneous array of feedstreams and EDV power levels reflect a random configuration of test conditions portraying usual day-to-day operations. Table 2-2 also presents a general summary of the operating data for each condition in the May test. A more detailed account of the facility data is included in the Appendix.

Facility operations during the September through November 1996 tests also reflected incinerator conditions, waste feedstreams, and EDV power levels similar to the calibration tests.

Despite the merits cited, the monthly tests were not always performed in strict accordance with the Draft Appendix F - Procedure 2 requirements for RCA tests.[8] The structure and results of

[8] One aspect of the test was to ascertain the achievability of the Draft PS 11 and data quality objectives themselves. As a result, some improvements in the approach were made as EPA learned how to better conduct the tests. This includes EPA's decision to have 12 tests represent an RCA, the decision that an RCA is to be conducted under "normal" operations over the same PM emission range as the calibration test, and the current proposed specification

these tests did not completely meet one of the following two important criteria for RCA tests: either 1) operating the facility across the same PM emission range as the calibration test, or 2) testing at three or more different PM concentrations for a minimum of twelve (12) measurement sets. However, combinations of two/three months or the overall collection of monthly tests do meet the RCA testing criteria.

2.3.2 *Summary of Facility Operation Over the Test Program*

Facility operation over the test program is summarized by the following achievements:

- Under reasonable worst case (as-found, normal day-to-day) HWC facility operations,
- Consisting of various conditions with waste feeds, APC performance, PM, and flue gas,
- Across a 9-month and 4-seasonal period, and
- During a total of two (2) calibration relation tests and four (4) RCA tests.

In regard to trends, there were measurable variations in the stack gas conditions in terms of temperature, moisture, diluent concentration, and gas flow rate. These seasonal trends and typical variations, coupled with ordinary day-to-day operations, attest that the facility conditions over the course of the test program indeed were representative of regular operations at a HWC incinerator.

2.4 CEMS Calibration Relation Test Results

The scope of this subsection focuses on the results produced during the first and second calibration tests in relation to Draft PS 11. These results form the basis on which each CEMS calibration is established and then evaluated in terms of the three data acceptance criteria specified in the revised Draft PS 11. The results from the two calibration relation tests are independently

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levels. Obviously since the approach was updated as the program progressed, the RCA tests themselves might not *exactly* conform to what was proposed. This reflects the evolutionary nature of these tests.

calculated and evaluated, and then any similarities/differences between the two (2) sets of results are characterized. All data are presented, but the Draft PS 11 statistical evaluations are performed on only acceptable data meeting the QA objectives. Clarifications are included to account for the rationale and the details involving treatment of data.

Two (2) calibration relation tests were performed under a similarly wide variety of facility operating conditions to establish the correlation between the reference method and the output of each respective monitors. The calibration test in December through March was intended to establish the (initial and only) calibration for each CEMS relative to the reference method. Due to a narrow range of PM produced in the December through February tests, four (4) separate periods were needed to complete the first calibration. A second calibration test was conducted the following April to evaluate the reproducibility of the data quality produced not only from the PM CEMS but also from the reference method. Both calibration tests were conducted largely in agreement with Draft PS 11 consisting of these main elements:

1) The facility operated across its normal PM emission range and beyond/near the highest proposed PM emission standard (69 mg/dscm);

2) Sets of PM CEMS and manual reference method measurements were simultaneously obtained; and

3) These tests were performed at three (3) or more PM concentrations for a minimum of 15 measurement sets.

Exceptions/deviations in meeting the above criteria included:

1) The range of acceptable data for the ESA Beta monitor only rose to about 80% of the

proposed 69 mg/dscm standard in the first calibration test,[9]

2) The automatic internal span calibration check recorded on the DAS failed to meet the specification limit for the Durag monitor throughout the second calibration relation tests, resulting in its test data to be considered invalid,[10]

3) The range of PM emissions, and of the monitors' responses, only rose to about 80% of the proposed 69 mg/dscm standard in the second calibration relation test.

Reference Method 5 PM Results. Both sets of the calibration relation results of the M5i measurements for each train are shown in Table 2-3 with the PM concentration results expressed in actual and dry standard units along with their respective temperature and moisture content values. The average PM concentration and RSD results are also presented in Table 2-3. All supporting data and records are contained in the Appendix. The PM results produced from M5i ranged from about 5 to 75 mg/dscm at 7% O_2 and from about 5 to 55 mg/dscm at 7% O_2 during the first and second calibrations, respectively. Results are reasonably distributed across the range of PM concentrations developed in both the first and second calibration relation tests. All runs produced results with RSDs less than 30% except for 7 of the 43 runs in the first calibration and 2 of the 17 runs in the second calibration that were considered Outlier Data. Most of the weight gain was associated with the filter catch, as there was generally 5 to 25 mg weight gain on the filters and 0.5 to 4 mg weight gain from the front-half probe rinses.

CEMS PM Results. Results produced from each CEMS for each test condition during the

[9] Due to setup for a lower PM range up to 50 mg/acm, the ESA monitor produced over range flagged data for the three highest PM runs (Nos. 65, 66, and 67) in the second calibration test. The monitor is equipped to measure PM up to 4,000 mg/acm, but was adjusted for measuring the normal facility levels below 50 mg/acm, which caused point 1 to occur.

[10] The automatic span calibration checks for the Durag monitor showed deviations from the reference value up to 8% during the March calibration relation tests, which caused point 2 to occur.

calibrations are presented in Table 2-4. These were developed from averaging the 1-minute CEMS records collected on the data logger for the corresponding M5 sampling times, excluding the times during port changes. Data from the ESA and Verewa Beta monitors were offset corresponding to their response times.

Careful review of each CEMS data was also performed. This involved checking data recorded by the data acquisition system (DAS) relative to corresponding Method 5 sampling times along with consideration of respective response time offsets for the two (2) Beta monitors. Since several CEMS were undergoing PM calibration testing as a set of individual monitors (and not just one), the policy was to proceed with testing even though one (1) or more of the CEMS were not operating properly or experiencing internal calibration. Records and DAS data were also examined to determine if each CEMS was functioning properly, calibrating within specifications, or going through an internal automatic calibration, during the test period. Although this type of check is obvious and straightforward for one (1) CEMS of a proven and familiar technology, it is not necessarily so for multiple CEMS which are undergoing demonstration and consequently represent not-so-familiar technology.

The CEMS data review showed that there were calibration test periods in which the monitors produced invalid data during a portion of or throughout the entire run. For a run to be considered acceptable, a criterion for a minimum time of 80% data availability for each test condition was developed. This means that if any of the CEMS was out of commission (*i.e.*, not operating properly or experiencing internal calibration) for more than 20% of the total testing period, the CEMS data for that run was considered invalid. The one minute-average data recorded by the DAS was applied as the basis of the data availability percentage calculation for the test periods.

As a result of the QA audit, it was determined that the following four (4) CEMS were not operating properly, producing suspect data, or were experiencing calibration during the following test conditions in the calibration tests:

CEMS	Test Month: Run Number	Rationale
ESA	January : 48	Data were outside the set range (footnote 6).
	March : 65, 66, 67	Data were outside the set range (footnote 6).
	April : 83, 87, 88	Change in velocity, unable to maintain isokinetic sampling.
	May : 98	Change in velocity, unable to maintain isokinetic sampling.
Verewa	January : 41, 42, 44, 49	Off-line due to a mechanical failure.
	May : 91, 92, 93	Off-line due to a mechanical failure.
Durag	January : 42	Monitor in zero mode.
	March : 62 to 73	Internal span calibration check failure.
Sigrist	May : 92, 93	Off-line due to blower failure.

DRAFT PS 11 Calibrations. The statistical calculations for the two (2) calibration tests were carried out according to the equations and definitions in Draft PS 11 for the correlation coefficient, confidence interval, and tolerance interval. These involved performing a regression analysis on the correlations between paired set of CEMS and M5i data over corresponding time periods. Depending on the measuring conditions experienced by the individual monitors, the PM CEMS data are correlated with the corresponding M5i results presented in either actual in-stack (mg/actual cubic meter (acm) or dry standard concentration units (mg/dscm).[11] Three (3) mathematical approaches are available for evaluation to determine which approach provides the best fit to the calibration data. These approaches include:

- Linear relation,
- Quadratic relation, and

[11] For example, the three (3) light-scattering monitors and the ESA Beta monitors perform their analysis under actual in-stack conditions, and thus produce PM concentration data proportional to that reference; whereas, the Verewa measures the sample gas volume under dry conditions and then calculates the PM concentration to a (dry) standard reference temperature.

- Logarithmic relation.

A linear calibration relation is calculated by performing a linear least squares regression. The CEMS data are taken as the *x* values and the reference method data as the *y* values. A linear calibration relation, which gives the predicted PM concentration, *y'*, based on the CEMS response *x*, is given by:

$$y' = a*x + b$$

where :

a = slope of the linear regression line, and

b = y intercept.

A quadratic calibration relation is calculated by performing a second-order least squares regression. Similarly, the CEMS data are taken as the *x* values and the reference method data as the *y* values. A quadratic calibration relation, which gives the predicted PM concentration, *y'*, based on the CEMS response *x*, is given by:

$$y' = b_2*x^2 + b_1*x + b_0$$

where :

b_2 = coefficient for the first term of the quadratic equation,

b_1 = coefficient for the second term of the quadratic equation, and

b_0 = y intercept.

A logarithmic calibration relation is calculated by substituting $x = \log x$, and then by performing a linear least squares regression on the logarithmic values of *x*. The log of the CEMS data are taken as the *x* values and the reference method data as the *y* values. A logarithmic calibration relation, which gives the predicted PM concentration, *y'*, based on the log *x* of the CEMS response *x*, is given by:

$$y' = a_3*(log\ x) + b_3$$

where :

a_3 = slope of the linear regression line for *log x*, and

b_3 = y intercept.

The rationale and benefits of applying a logarithmic relation to fitting certain calibration data are discussed in the context of performing the PS 11 statistical evaluation in the following subsection.

Following this, the 95% confidence interval for the regression relation is computed, as is a tolerance interval, which predicts the bounds of 75% of the population of the manual method data with 95% confidence. Both intervals would normally be calculated at the emission limit, but for this program, both intervals are determined at each of the three (3) proposed emission limit levels (*i.e.*, 69, 50, and 34 mg/dscm @ 7% O_2). The equations provided in Draft PS 11 were put on a spreadsheet, while values for t_f, v_f, and u_n' were automatically inserted from Table I in Draft PS 11; for the logarithmic correlations, the series of equations to calculate the confidence and tolerance intervals were performed by substituting x = log x in the linear calibration relation equations. In essence, the confidence interval predicts the bounds in which one would expect any calibration line to lie, with 95% confidence, if other CEMS and manual method data from the same population as those observed during the calibration test were used. The tolerance interval bounds the region within which one would expect 75% of other manual method and CEMS data to fall, with 95% confidence, based on the CEMS and manual method measurements observed during the calibration.

Before discussing the calibration results, two clarifications are in order concerning the methodology of the CEMS performance evaluations applied in this program and those relevant to future certifications performed by industry. First, for the purpose of this demonstration program, there is a total of seven (7) data acceptance criteria used to evaluate CEMS performance. These are:

a) the correlation coefficient (at one level, as it is calculated independent of emission limits),

b) three (3) confidence interval measures (at each of three proposed emission limits), and

c) three (3) tolerance interval measures (at each of three proposed emission limits).

In future CEMS certifications performed by industry, there would only be three (3) acceptance criteria. For the second clarification, since the calibration range, or its regression equation, did not always reach each of the three (3) proposed limits, then the maxima of the calibration or the regression equation is applicable and used as the reference emission value upon which the evaluation of the confidence and tolerance intervals is performed. This procedure would also be applicable in future CEMS certifications.

First and Second Calibration Relation Results Based on Linear Fit Approach

The first calibration test results of the Draft PS 11 *linear relation* statistical calculations are presented in Table 2-5 for all five (5) CEMS. Table 2-5 lists the revised Draft PS 11 data acceptance criteria for the correlation coefficient, confidence interval, and tolerance interval as well as presents the results of these criteria relative to the three (3) proposed PM emission limits for each of the two (2) calibrations for each monitor. For the first calibration relation data set, each of the five (5) CEMS, with one minor exception, produced data meeting the revised PS 11 criteria at all three (3) proposed PM emission limits based on a *linear approach* for fitting data: correlation coefficient criterion of greater than 0.90, confidence interval less than 10%, and tolerance interval less than 25%. Despite meeting six of the seven criteria, the Sigrist did not achieve the tolerance interval measure at the lowest emission standard. Note that although the Durag produced acceptable data over 95% of the time, it was not operating properly, according to its self-calibration span check report, during the March calibration tests with the highest measured PM levels. Consequently, it reflects a more narrow range over which the initial calibration was performed. Figures 2-1 through 2-5 then graphically illustrate the linear regression lines for each set of calibration data pertaining to the ESA, Verewa, Durag, ESC, and Sigrist monitors, respectively.

The second calibration test results of the Draft PS 11 *linear relation* statistical calculations are also presented in Table 2-5 for all five (5) CEMS. For the second calibration relation data set,

the same four (4) CEMS (ESA, Verewa, Durag, and ESC) produced data which met all seven (7) of the PS 11 criteria applied in this program. The Sigrist monitor met five of the seven criteria, but did not produce data meeting the confidence interval at the 50 mg/dscm standard or at the maximum of the calibration range. Figures 2-1 through 2-5 also show graphical representations of the second calibration's linear regression line for the ESA, Verewa, Durag, ESC, and Sigrist monitors, respectively.

Review of the comparison between the two (2) calibration relation *linear* regression lines and their corresponding equations in Figures 2-1 through 2-5 give insight into three important aspects of these two (2) calibration relation tests:

1) Reproducibility, or stability, of CEMS performance in terms of the equations defining their linear relationship with M5i measured results;

2) Reproducibility in data quality associated with the M5i results produced in the first and second calibration tests, and

3) If there is non-reproducibility between the two (2) linear regression lines in a linear fit approach, then further actions are necessary to examine either potential causal factors (*e.g.*, test procedures, sampling location, change in PM properties) or non-linear approaches in fitting CEMS data reproducibly with M5i measured results.

For the first point on CEMS performance, the equations defining the *linear* regression of each calibration would agree despite differences in time and test operating conditions if a) the calibration relationship were stable over time, b) insensitive to changes in PM properties, and c) insensitive to differences in PM range over which the calibration was performed. Comparison of the slopes of the linear equations is considered to be the definitive measure in this comparison, since all y-intercepts in the equations have nominal values of 5 (mg/acm or mg/dscm) or less. The tabulated data below presents a comparison of the two calibration *linear* equations' slopes for each CEMS. Relative to

a linear fit approach, this comparison shows agreement within 4% for the two (2) Beta monitors and within 7% for the Durag light-scattering monitor. This level of agreement reflects acceptability of subsequently applying a linear regression for the ESA, Verewa, and Durag monitors over time, over their respective PM ranges, and over these operating conditions (variations in waste feedstreams, PM properties, and flue gas conditions).

CEMS	First Calibration Slope	Second Calibration Slope	% Difference[12]
ESA	0.824	0.766	3.6
Verewa	1.343	1.430	3.1
Durag	0.421	0.366	6.9
ESC	0.357	0.448	11.3
Sigrist	0.199	0.313	22.2

Regarding the second aspect on M5i results, duplication in the data quality from the M5i results between the two (2) calibration tests is reflected, given nearly identical reproducibility in performance with three independently operating CEMS, with nearly identical correlation coefficients, confidence intervals, and tolerance intervals. Since a high degree of correlation and reproducibility is indirectly confirmed from data produced by three (3) of the CEMS using a linear fit approach, this establishes that duplication in the data quality from the M5 results occurred between the two (2) calibrations.

Relative to the third point on the non-reproducibility from a linear fit approach, it is consistent with Draft PS 11 and ISO 10155 protocols to evaluate alternative non-linear calibration relation and identify one which best fits the data. Since the possibility of M5i-related causal factors is eliminated and the 11 to 22% variation in the ESC and Sigrist linear regression line slopes is unacceptable, other testing-related factors for non-reproducibility or non-linear approaches for finding a best fit approach need to be investigated. Discussion of the investigation regarding other factors and non-linear

[12] Percent Difference in slope = $|s_i - s_{AVG}]/s_{AVG}$ x 100%.

approaches follow.

Further Investigation Into Linear Fit Approach for Light-scattering CEMS

The results of further analysis to address the effect of the calibration range on the regression line slopes developed from the two (2) calibrations for the ESC and Sigrist light-scattering CEMS are presented in Table 2-6. Recall that the initial calibration traversed a higher range than the second calibration, as the highest PM levels measured in the program occurred in March. Further analysis indicates a profound effect of the range over which calibrations are performed and clearly demonstrate the criticality of high-end PM data. This effect is shown in Table 2-6 which indicates stability (< 2% difference) between the two (2) calibrations for the Beta and light-scattering CEMS as the March data are commonly included in both calibrations (see Column A/D). This is due to the slope-setting nature of the end-point data on defining the regression line with scatter in the low-end PM data. However, even by rearranging the March data with the second calibration data set instead of the first, there is still an unacceptable 22% and 34% variation in the ESC and Sigrist linear regression slopes, respectively, between the two (2) "rearranged" calibrations (see Column C/D). In summary, this analysis on the effect of the calibration range does suggest the importance of high-end PM data but does not explain why the ESC and Sigrist light-scattering CEMS produce dissimilar linear regression lines for the two (2) original and rearranged calibrations data sets, whereas the Beta monitors do (see Columns A/B and C/D).

Evaluation of Non-linear Fitting Approaches For Light-scattering CEMS

Since linear regressions do not provide a suitable fit for the ESC and Sigrist light-scattering CEMS, still further analysis is warranted to evaluate whether non-linear approaches are applicable in defining the same, reproducible relationship for both sets of calibration data. Following are such analyses assessing the fit between the two (2) calibration sets with a quadratic relation and then a logarithmic relation.

A *quadratic* regression was developed using a least-squares approach for determining the coefficients in a second-order equation for the ESC and Sigrist light-scattering CEMS. Figures 2-6 and 2-7 graphically illustrate the quadratic regressions fitting each of the two (2) calibrations for the ESC and Sigrist CEMS, respectively. As seen in both figures, quadratic regressions may fit the individual calibration data adequately, but produce 1) two dissimilar equations for each calibration, and 2) equations with inadmissible characteristics in that there is a range of data with a positive slope followed by a negative slope. The first point reflects the same non-reproducibility shortcoming associated with the linear regression approach, while the second point depicts the monitors as not being monotonic (*i.e.*, producing two different responses for the same PM concentration). As a result of each of these limitations, the quadratic regressions do not provide usable fits for the ESC and Sigrist light-scattering CEMS calibration data obtained from the test site facility.

A *logarithmic* regression was developed using a least-squares approach for the ESC and Sigrist light-scattering CEMS. This was accomplished by using the exact same equations as in the *linear* regression but with substitution of log x (base 10) values for the x values (x values = CEMS readings). Figures 2-8 and 2-9 graphically illustrate the *logarithmic* regressions fitting each of the two calibrations for the ESC and Sigrist CEMS, respectively. As seen in these two figures, *logarithmic* regressions not only fit the data very well, but produce 1) two near-identical equations for each calibration (agreement within about 2%), and 2) equations with admissible characteristics. The first point reflects a solution to the non-reproducibility barrier associated with the linear and quadratic regressions, and the second point depicts the monitors being monotonic (*i.e.*, producing one unique response for each PM concentration).

Because of the acceptable fit of the logarithmic regressions, the remaining statistical calculations for the Draft PS 11 data acceptance criteria were performed on the two (2) calibration data sets for the ESC and Sigrist light-scattering CEMS. This was likewise accomplished by using the exact same equations as in Draft PS 11 for *linear* calibration relations but with substitution of $\log_{10} x$ values for the x values. Table 2- 7 presents the results for the Draft PS 11 data acceptance criteria based on logarithmic regressions. These same results are graphically illustrated in Figures 2-8

and 2-9 for the ESC and in Figures 2-10 and 2-11 for the Sigrist for each of the two (2) calibrations, respectively. The results produced by the ESC meet all three (3) revised PS 11 data acceptance criteria at all three (3) levels near/at the proposed PM limits for both calibrations. The Sigrist-produced results meeting six (6) of the seven (7) criteria in the first calibration, but only met four (4) of the seven (7) criteria during the second calibration.

These data indicate that the logarithmic performance of the ESC and Sigrist light-scattering CEMS is attributable to a shift to a smaller particle size distribution (PSD) as PM concentrations increase. This is logically explained by the following:

1. The amount of light scattered is proportional to the surface area of the particles;

2. For a matrix of any PM concentration, there is a given surface area for a given PSD and a given amount of light scattered;

3. As PM concentration changes with the same PSD, then the amount of light scattered is linearly proportional with incremental changes in PM concentration;

4. A PM matrix with a smaller PSD will produce higher incremental changes in light scattered relative to the same given change in PM concentration for a larger PSD PM matrix;

5. For the case when PM concentration increases with an accompanying shift to a smaller PSD, then the relative amount of light scattered per unit of PM concentration increases;

6. Conversely, for the case when PM concentration increases with an accompanying shift to a larger PSD, then the relative amount of light scattered per unit of PM concentration decreases;

7. At the facility tested, it is believed that elevated PM stack concentrations were associated with a shift to a smaller PSD, caused either by a) reduced collection performance of the polishing APC device on small sized PM, and/or b) higher concentrations of small sized PM penetrating the venturi scrubber and the polishing APC device.

The PSD data of the facility's PM emissions produced during the test program show a high concentration of small particles (< 2.0 microns) with a mean particle size of about 0.5 microns and about 85% of the PM less than 2.0 microns (see Section 2.6.7 for more discussion on PSD results).

Such a high concentration of small-sized PM is consistent with facility-measured PSD data and other data on similarly equipped facilities with a venturi scrubber. This should not be construed as a conflict with other data supplied by light-scattering vendors on *other industries and APC technologies with accompanying particle size distributions.* These other data show that the regression correlation is linear for PM concentrations up to (about) 100 mg/acm, and that the nature of the regression changes to a quadratic relation at that point. Since this has been demonstrated that this "break" in the relation is related to the behavior of the APC as well as the PSD, these data do not conflict. Rather they show results that are relative to the process and APC configurations tested. Further, they substantiate the fact that this "break" can be anticipated to shift based on the process and APC configuration being evaluated. Thus, it is expected that linear and quadratic fits are applicable for other types of APC technologies on HWC facilities as well.

2.5 CEMS RCA Test Results

This section focuses on the results produced from these demonstration tests in relation to RCA criteria specified in revised Draft PS 11. RCA tests are used to determine whether the calibration is still valid, *i.e.*, whether CEMS performance varied over time. Due to the non-reproducibility of waste feedstreams, the monthly tests also furnish a measure of evaluating CEMS reproducibility despite variations in PM properties and flue gas conditions. Results from monthly testing as well as the overall collection of test results are independently calculated and evaluated based on RCA criteria relative to each of the two (2) calibrations. Subsequent RCA measurements comparing CEMS responses to reference method data are considered consistent with the current calibration relation if at least 75% of them fall within a tolerance level of 25% calculated at the PM emission standard. All data are presented, but the RCA evaluations are performed on only acceptable data meeting the QA objectives. Clarifications are made when data are not used in the RCA evaluations.

Recall that most of the individual monthly RCAs were *not* performed in strict accordance with all Appendix F - Procedure 2 requirements. This was due to the developmental nature and learning

process involved as well as the lack of influence to override normal operations in controlling waste feedstreams and the range of PM concentration for calibration test purposes. The structure and results of most monthly tests did *not* meet the following two (2) RCA test requirements:

1) The facility was operated across its normal PM emission range with assurance that all measurement sets are collected within the same range as in the calibration test, and

2) Testing was not performed at three (3) or more PM concentrations and at least 12 measurements were not always taken. Some earlier monthly tests only contained nine or ten conditions and many did not consist of three (3) or more PM stack concentrations, as was the case in the calibration relation test.

However, data produced in each monthly test does address the key issue of CEMS reproducibility performance over time, and the overall set of monthly data collectively meet the RCA criteria. The collective body of test results also serve an additional purpose of providing supporting data for each PM CEMS by forming an overall cumulative database. This cumulative database includes all valid test data, including the May monthly test results and the two calibrations, but without the September through November data.

Reference Method 5 PM Results. All M5i measurements from the May test for each train are shown in Table 2-3 with the PM results expressed in actual and dry standard units and in their respective temperature and moisture values. The average PM and RSD results are also presented in Table 2-3. The supporting data and records are contained in the Appendix. The PM results produced from M5i ranged from about: 5 to 75 mg/dscm at 7% O_2 for all the tests from December to April, 5 to 45 mg/dscm at 7% O_2 for the May test, and 10 to 100 mg/dscm at 7% O_2 for the September through November tests. Many of these results were concentrated in the low range. The test runs with RSD Outlier Data were specified earlier, as there were no Outlier Data in the May test.

CEMS PM Results. Results produced from each CEMS for each test condition during the monthly

tests are presented in Table 2-4. CEMS data from each run were carefully reviewed to ensure the CEMS was properly operating during a given run. From CEMS data review, it was determined that certain monitors were not operating properly, producing suspect data, or were experiencing calibration during the test conditions as specified earlier.

Evaluation of RCA Results. The RCA results are compared to the calibrations to determine if the calibration is still valid. If at least 75% of the manual method data collected during an RCA fall within the 25% tolerance intervals, then the calibration is still considered valid. If less than 75% of the data fall within the tolerance interval, then the calibration is considered no longer valid and a recalibration is necessary.

The following explanation, along with the accompanying tables and figures, illustrates the revised Appendix F - Procedure 2 procedure and principles to evaluate acceptability of the subsequent RCA data relative to the calibration relation.[13] First, a figure is produced showing the calibration relation regression line based on the calibration data and the tolerance intervals set at ±25% of the PM emission standard. The tolerance interval bounds an area on the graph, ±25% of the numerical emission limit from the calibration regression line on the y-axis, traversing across the calibration range (from the lowest to the highest CEMS output reading of the calibration) on the x-axis. Second, the paired CEMS/M5i values from the RCA tests are plotted and overlaid onto the figure just described. Finally, the number of points that are visually apparent to be inside the tolerance intervals are counted. For data points falling on the tolerance interval boundary line, it will be necessary to numerically determine whether the RCA data are within the boundaries by calculating the tolerance interval value and comparing it to the coordinates of the specific RCA data point on the line. If at least 75% of a minimum of the twelve RCA points fall within the tolerance interval and the calibration range boundaries, then the calibration relation is considered to still be valid. Because there are three proposed PM emission limits, RCA evaluations in this program are performed at each of these limits

[13] This revised RCA evaluation procedure is based on the calibration relation regression line and the +/- 25% tolerance interval criteria, but is *independent* of the tolerance interval calculated from the calibration test; as such, it is distinct from, and not to be confused with, the data-dependent tolerance interval approach used in the calibration relation evaluation.

where applicable. Since the calibration range, or its regression equation, did not always reach each of the three (3) proposed limits, then the maxima of the calibration or the regression equation is applicable and used as the reference emission value upon which the RCA evaluation is performed. The following material applies and illustrates the procedure and principles of the RCA evaluation just described. This procedure would be applicable in future CEMS RCA evaluations.

In this program, the stability of the initial calibration relation (December to March data) is assessed by using the remaining data (collected in April, May, and September through November tests) in the RCA evaluation for each CEMS. Similarly, the stability of the second calibration data (April) is judged by using all the remaining data collected in December to March, May, and September through November. The RCA evaluations are illustrated in the following figures for the designated CEMS and monthly calibration tests:

Figure No.	CEMS	RCA Evaluation
2-12	ESA	Initial Calibration on remaining data
2-13	ESA	Second Calibration on remaining data
2-14	Verewa	Initial Calibration on remaining data
2-15	Verewa	Second Calibration on remaining data
2-16	Durag	Initial Calibration on remaining data
2-17	Durag	Second Calibration on remaining data
2-18	ESC	Initial Calibration on remaining data
2-19	ESC	Second Calibration on remaining data
2-20	Sigrist	Initial Calibration on remaining data
2-21	Sigrist	Second Calibration on remaining data

Results from the RCA evaluations for each calibration relative to the 25% tolerance intervals at each of the three (3) proposed emission limits are presented in Table 2-8. Data within the calibration range represents valid data applicable for the RCA evaluation; data outside the range are shown on the respective figures but excluded from evaluation. Each monitor produced data meeting

the RCA criterion (*i.e.*, at least 75% falling within +/- 25 of the proposed emission limits or maxima if the emission limit is not reached) relative to each of the two (2) calibrations for the applicable emission limits with only one (1) exception: the Verewa's initial calibration at the proposed emission limit of 34 mg/dscm at 7% O_2.

These results clearly demonstrate that each monitor produced acceptable data meeting the minimum 75% RCA criterion relative to each calibration at the applicable emission limit levels with only one (1) exception. This is another firm indication of the reproducibility of these CEMS for continuous monitoring of PM emissions and compliance.

2.6 Supporting Data

There are seven (7) other information areas supporting the credibility and use of CEMS for continuously monitoring PM emissions. The first six (6) areas are derived from data collected in this demonstration program. The seventh stems from the two (2) preliminary test projects which evaluated the feasibility of PM CEMS.

2.6.1 *Cumulative Database*

All CEMS/M5i test data produced in this program were incorporated into one (1) set to form a cumulative database for each monitor. Although the original Draft PS 11 protocol and data acceptance criteria were not intended to apply to such a database, a multiple calibration relation test requirement (*e.g.*, 2 or 3 tests) is emerging for CEMS with measurement technologies sensitive to changes in PM properties (*e.g.*, light-scattering monitors). As a result, it is considered necessary and consistent with the revised PS 11 protocol and criteria to combine all the results from this program in a PS 11 format to evaluate the overall reproducibility of the PM CEMS data. The form of the calibration relation producing the best fit was used; namely a linear relation for the ESA, Verewa, and Durag and a logarithmic relation for the ESC and Sigrist. The results of the PS 11 evaluation in

terms of the data acceptance criteria for the cumulative databases are presented in Table 2-9 and summarized below. The PS 11 statistical evaluation results show, for each of these three (3) monitors, that the:

- Correlation coefficients are uniform and only vary from 0.93 to 0.95,
- Confidence intervals are < 8%, and
- Tolerance intervals are < 25%.

Cumulative Database Summary

CEMS	Correlation Coefficient	Maximum Confidence Interval (%)	Maximum Tolerance Interval (%)
ESA	0.94	5.9	19
Verewa	0.94	6.4	22
Durag	0.95	6.5	17
ESC	0.95	6.6	22
Sigrist	0.93	6.6	25

Each of the five (5) CEMS produced results for the cumulative databases meeting the revised PS 11 data acceptance criteria. Figures 2-22, 2-23, 2-24, 2-25, and 2-26 graphically illustrate the calibration relation regression equation, confidence interval, and tolerance interval for the cumulative database for the ESA, Verewa, Durag, ESC, and Sigrist, respectively. Included in Table 2-9 are measures indicating the relative stability in the regression equation slopes between the cumulative data sets and the individual calibrations. Keep in mind that the regression equations are the definitive means of relating CEMS response to PM concentrations. Again, more strong evidence of the reproducibility of the CEMS calibration relations is produced to support continuous monitoring of PM emissions and compliance.

2.6.2 *Scanning Electron Microscope Results*

The M5i filters were analyzed initially for a qualitative assessment of the collected PM and then another set of filters were analyzed on a more quantitative basis.

2.6.2.1 Initial Analyses

Each of the filters utilized in the September and October calibration tests were analyzed by a scanning electron microscope (SEM) to provide a general assay or survey of the collected PM. Results from the SEM analysis showed that the material covering the filter was predominately NaCl. Other metals or minerals found on the filters in measurable amounts were Fe, S, and Al. Analysis of blank filters showed the composition to be (in descending order) Si, Al, Ca, O, and Mg.

Following SEM analysis, a photomicrograph was taken of a select portion of each filter which appeared to represent most of the particles collected by the filter. The photographs reveal a variety of shapes (discrete spheres and cubes, along with flakes and other irregular forms) and sizes (from sub-micron to > 100 micron) of PM.

In addition, Energy-Dispersive X-ray (EDX) was performed on the various particles on each filter. Results from the EDX analysis showed that there were at least 12 other metals and minerals found and identified composing the wide variety of PM collected on the filters, including K, Zn, Pb, Si, Cu, P, Ba, I, Ag, Cr, Ti, and Ni.

In summary, these analyses clearly show that the PM covering the filter consisted of a layer of NaCl with an additional 15 different elements exhibiting an assortment of physical shapes, sizes, and, to a lesser extent, colors. The SEM and CEMS data demonstrate that even in upset conditions the PM properties did not change enough, or if individual properties were altered there was a corresponding offset in a such a way not to bias results over the CEMS calibration range.

2.6.2.2 Additional Method 5 Filter Analysis Data

A second series of analyses was performed on wedges of selected filter samples that were utilized in the November monthly calibration tests. Though similar to the first series of analyses which provided a general assay with qualitative results, the purpose of the second set of analyses was to produce semi-quantitative results of the relative amounts of the elements (excluding oxygen) found in the spectral analysis of the collected PM on the filter samples.

This second series of analyses consisted of SEM, EDS, and Advanced Image Analysis (AIA) with two (2) photomicrographs of each sample analyzed. The samples were prepared for analysis by slicing a pie wedge corresponding to about 1/5 of the total filter area and mounting the wedge on a carbon planchet with carbon paint. Imaging occurred at a magnification of 100x at 20 kilovolts. The SEM/EDS automated imaging program analyzed each wedge sample for up to 15 elements and produced high resolution X-ray maps for each element detected. This innovative analytical technique produced:

- Semi-quantitative data of the relative amounts of the elements found,
- Photomicrographs at 100x of the field examined, and
- A second series of photomicrographs displaying respective distributions of each element found.

The semi-quantitative results of these analyses are presented in Table 2-10. These data illustrate that roughly 70 to 80% of the PM material collected on the filter wedge samples was NaCl with minor and varying relative amounts of Al (1 to 12%), P (0 to 1%), S (3 to 8%), K (4 to 15%), Ca (1 to 9%), and Fe (0 to 2%). The issue of homogeneity of elemental composition and distribution on the wedge samples was addressed by performing repetitive analyses on different fields of the same wedge and different wedges from the same filter. Three (3) fields were examined on single wedges from three (3) different filters: 1) blank filter, 2) Run # TB-25, and 3) Run # TA-30. The results from the replicate analyses are also shown in Table 2-13 which reveal that no significant difference were found for any of the elements on different fields of the same wedge. One (1) filter (Run #TA-28) was divided into five (5) wedges with no significant differences found from repetitive analyses from these

different wedges of the same filter.

The second series of photomicrographs (included in the Appendix) displaying respective distributions of each element found also provides convincing support to homogeneous distribution of a) elements within the collected PM, and b) collected PM on the filter. Without exception, these photomicrographs illustrate uniform distributions of each element on each of the wedges and fields of the filter samples. The particle size data presented and discussed later in Section 2.6.6 also lends support to homogeneous distribution of a) elements within the collected PM, and b) collected PM on the filter. In combination, this convincing evidence of homogeneity of PM and small particle size (mean particle size of 0.5 microns) is also connected with, and tends to diffuse (along with the high correlation between CEMS/Method 5 data), the issue of collecting representative PM concentration data from single-point PM CEMS sampling.

2.6.3 *Comparison of Like-technology Measurement Data*

Before testing began, the quality of Method 5 produced data was recognized as one of the most limiting factors in calibrating and evaluating PM CEMS measurement performance. Given that the behavior of results in this program shows variability in Method 5i results and in Method 5i-dependent CEMS correlations, measures to look at CEMS data quality independent from Method 5i is in order. This alleviates only evaluating CEMS data relative to Method 5i, allowing focus on CEMS data quality. The following comparisons of like-technology measurements utilize data produced from December through May.

To achieve this end, comparison of like-technology CEMS measurement data is presented in Figures 2-27 and 2-28. Figure 2-27 shows the comparison of data produced from the two like-technology Beta CEMS during this program. In this figure, the ESA data and the Verewa data are plotted against each other by comparing available data from each of these two (2) CEMS results for each run. Recall that the two (2) Beta monitors produce data on a different reference: the ESA measures PM concentration on a wet basis whereas the Verewa measures on a dry basis. In order

to make a comparison on a consistent basis, the Verewa (dry basis) concentration data were converted to a wet basis and then plotted in Figure 2-27 with the ESA data. The correlation coefficient of the regression line depicting the comparison of the two (2) Beta monitors is 0.94.

Figure 2-28 shows the comparison of data produced from the three (3) like-technology light-scattering CEMS during the program. In this figure, the (back scattering) Durag and (front scattering) Sigrist data are plotted relative to the (back scattering) ESC data. The upper regression line presents the ratio of the ESC/Durag data with a correlation coefficient of 0.99, while the lower line is for the ESC/Sigrist with the same correlation coefficient of 0.99. Although similar, each of the three (3) light-scattering CEMS possess uniquely different design and operating features and sampled at separate locations in this program. The high correlation coefficient values add further support to the sensitivity and credibility of light-scattering CEMS technology.

Similarly, Method 5i data produced during the program is plotted against itself by comparing Train A versus Train B results in Figure 2-29. The regression line presents the ratio of Train A/Train B data with a correlation coefficient of 0.96. Even though Train A and B were exact duplicates in design and operation (except for the time difference in traverse sampling), their correlation coefficient was slightly lower than the three (3) light-scattering CEMS.

2.6.4 *1996 Trial Burn M5/CEMS Data Evaluation*

A trial burn consisting of three (3) replicate runs at each of two (2) test conditions for a total of six (6) runs was conducted at the Dupont Experimental Station in September 1996. The trial burn was conducted by Midwest Research Institute from September 12 - 16, 1996. Of particular interest here are the PM measurements and results. Although performed to evaluate the incinerator's performance relative to RCRA permit requirements, both Dupont and EPA were interested in evaluating the trial burn results with available Method 5/PM CEMS data collected during the trial burn in context with similar data during the 9-month demonstration program. This interest was driven by the following set of circumstances:

1. Two (2) different types of synthetic wastes, one (1) with a highly-chlorinated solvent and the other spiked with multiple metals typical for this purpose of testing, were fed during the trial burn and represent still additional variations to the wide variety of wastes employed throughout the demonstration program;

2. Another organization, different from the one conducting the CEMS demonstration, was responsible for producing Method 5 data for the trial burn without any involvement in PM CEMS data collection;

3. Conventional Method 5 equipment and recovery procedures were employed with a sampling period of two (2) hours (longer than the demonstration program); and

4. Two (2) of the PM CEMS had been installed recently and were operating automatically without any assistance from any party, including the vendors or EER during the trial burn period.

Consistent with the methodology practiced in the demonstration program, the trial burn PM concentrations measured by the conventional Method 5 equipment/procedure were calculated to represent actual in-stack conditions. Table 2-11 presents the stack gas conditions and PM concentration results for each of the six (6) trial burn runs. Table 2-12 presents the average values over the corresponding Method 5 sampling periods for the Durag and ESC monitors for each of the six (6) trial burn runs.

The trial burn Method 5/PM CEMS data were considered and evaluated as RCA data and plotted onto the cumulative calibration relation graphs. As shown in Figures 2-30 and 2-31, respectively; the Durag and ESC trial burn data track closely to their cumulative calibration regression equations; also all six (6) Method 5/PM CEMS data points clearly fall within the 25% tolerance intervals at the three proposed emission limits for both monitors. Based on this evaluation, the trial burn Method 5/PM CEMS data are shown to be statistically consistent and reliable with results

produced during the demonstration program from another organization using a slightly different methodology. Table 2-13 presents the results of this RCA evaluation using the trial burn data.

2.6.5 *Particle Size Data*

Since a change in particle size is one of the key parameters known to influence the response of light-scattering PM CEMS, measurements were conducted to document and characterize the particle size distribution (PSD) of the PM emissions at the stack sampling location. This was accomplished by using an eleven-stage University of Washington Mark V cascade impactor following Method 201A during the last monthly calibration test in May. An Anderson Preseparator cyclone was attached to the impactor to provide a 90° sampling nozzle orientation relative to the horizontal-positioned probe. Sampling flow rates were maintained near 0.4 actual cubic feet per minute and the impactor was located at a single-point about one (1) foot underneath the plane, and out of the way, of the Method 5 trains. Sampling times for these relatively low PM concentrations were 2 - 3 hours in order to obtain a weighable sample (> 0.5 mg) on most stages. Consequently, the PSD runs were conducted concurrently with, but over a longer period than, the paired Method 5 sampling runs. Since the sampling duration of each of the last three (3) PSD runs was concurrent with more than one (1) M5i run, no direct correlation between PSD data and PM concentration can be made.

Results for each of the six (6) PSD runs are summarized and presented in Table 2-14. Comparison of the total PM concentrations produced by the PSD and Method 5 trains are shown for each run to range from about 45% to 80% with an overall average near 60%. Based on an assumed particle density of 1.0 g/cc, the average particle size diameter on a weight basis is on the order of 0.5 microns with the majority of PM less than 1.0 micron. The bottom part of Table 2-14 shows that the PSD varied across a range of nearly 65 to 85% of the PM being less than 1.0 micron and 70 to 95% being less than 2.0 microns. More detailed information on the PSD procedures and results are included in the Appendix.

2.6.6 *Rollins and Lafarge PM CEMS Results*

Rollins Preliminary PM CEMS Feasibility Assessment

The Rollins project was used as a preliminary test site to evaluate the feasibility of PM CEMS and to answer the underlying critical questions: Can particulate emissions be controlled down to about 15 mg/dscm (or 0.005 gr/dscf) by additional air pollution control (APC) equipment such as a wet electrostatic precipitator (WESP), and do the current CEMS allow for measurement in this low range and under saturated moisture conditions? For the first question, a pilot scale WESP was installed on a slipstream withdrawn downstream of a well-controlled commercial hazardous waste incinerator. Regarding the second, three (3) monitors were installed at the outlet of the WESP: the BHA Group CPM 1000, the Sick Optic-Electronic RM200, and the Emissions SA Beta 5M.

Two (2) of the three (3) phases of testing conducted at the Rollins facility in Bridgeport, NJ, pertained directly to the PM CEMS testing. During the second phase of tests, the PM CEMS were tested under three (3) WESP voltage levels: off, low voltage (46, 48, and 52 kV), and high voltage (52 to 53 kV). Three (3) runs were made at each voltage level; each run had paired trains. After the completion of Phase 2 there was a 2½ week interval. Then Phase 3 was conducted to quantify any drift or errors.

PM concentrations measured by the conventional Method 5 are reported in actual in-stack conditions for temperature, moisture, and pressure. Table 2-15 presents the stack gas conditions and PM concentrations for each run. The CEMS were operated simultaneously and continuously during the manual M5 testing periods. Responses were averaged for the duration of the Method 5 runs, excluding port changes. The CEMS averages are presented in Table 2-16.

Each monitor experienced problems, mostly attributable to the project team's learning process: the optical CEMS were not equipped to measure dry PM without a heated sample line, and the Beta monitor would have benefited from a longer sampling time to measure PM at these low levels. The slip stream entering and leaving the WESP was at saturated moisture conditions. When

the sample ports were opened to insert and traverse the M5 trains, the influx of cold air (3°C) into the negative-pressure duct further increased the concentration of liquid aerosols. The optical monitors (BHA and Sick) are sensitive to liquid aerosols as well as to dry particulate when making in-situ measurements. In lower particulate levels, the liquid aerosols interfered with their ability to measure small variations in dry PM. The Beta 5M was configured with a 2-minute sampling time, as this limited its detection limit at low PM concentrations. The high collection performance of the WESP only resulted in three (3) runs with concentrations above 16 mg/Acm, as the remaining 10 were less than 3 mg/Acm. Unfortunately, no comparison between the Beta 5M and the manual method was possible.

Data from Phases 2 and 3 were combined for treatment. By strict definition, the calibration data set does not meet two key Draft PS 11 requirements. First, there were only 12 runs with complete data; 15 are required for a PS 11 calibration relation test. Second, the runs must be uniformly distributed over at least three or more PM concentrations. The Rollins data represents only two (2) levels with three (3) runs at a high level and ten (10) at a low PM level. Table 2-17 presents the statistical results. Despite the limitations and problems just described, the optical monitors did show a high correlation coefficient but did not produce acceptably tight confidence and tolerance intervals. Continuous data from the optical monitors also track each other. The results obtained suggest, along with reported experience in Europe, that with a heated sample line and use of M5i an optical device can be calibrated at this facility and meet Draft PS 11 for particulate monitors. Phase 3, the check on stability of the calibration, was inconclusive due to low levels of PM concentrations.

Lafarge Preliminary PM CEMS Feasibility Assessment

The Lafarge test site in Fredonia, KS was chosen as another evaluation of PM CEMS and the Draft PS 11 criteria. The facility manufactures cement from raw materials in a two-phase wet process kiln. The PM CEMS consisted of two (2) light-scattering monitors: the ESC P5A and the Sick RM200. The Method 5 sampling and the CEMS sampling occurred in the main duct between an Electrostatic Precipitator (ESP) and an induced draft (ID) fan. The test involved triplicate testing at

three (3) different ESP power settings ranging from 55 to 140 KW; each run had paired trains. Additional calibration checks were conducted using the same testing format at 5- and 10-week intervals following the initial calibration.

During the initial part of the calibration test performed in May 1995, the manual method results from Train A were very erratic. Inspection of the filters revealed the presence of contamination by extremely large size particulate (some as large as 1 mm in diameter). It was determined that these particles were accumulated particulate or pieces of the duct wall. For the purposes of calibrating the CEMS, the data from Train A were discarded. Additional sets of manual method measurements were made in June 1995 to complete the calibration test. During these tests erratic results were also produced from one of the two (2) trains, this time from Train B, and again due to large size particulate contaminations. For this second part of the calibration test, the Train B results were disregarded. Subsequent measurements in July 1995 were performed to serve as RCA-type tests. All Method 5 stack conditions and PM concentrations are presented in Table 2-18. Calibration 2 once again showed erratic.

The acceptable Method 5 data were reported in actual stack gas temperature, moisture, and pressure conditions. The CEMS were operated simultaneously and continuously during the manual testing. Responses were averaged for the duration of the manual method runs. All CEMS run averages are presented in Table 2-19.

The ESC P5A calibration test produced encouraging but inadequate results in terms of meeting the revised Draft PS 11 criteria. Likewise, the RCA test results were somewhat favorable but inadequate to meet the requirements.

The Sick RM200 was removed and serviced prior to the second part of calibration testing in June; the response function of the instrument may have changed. Service was necessary due to deposition and significant buildup of PM material on the surface of the instrument exposed to the flue gas, which eventually obstructed the optics of the instrument. This problem occurred because the

purge air, used to keep the optics clean, was not heated, resulting in cooling of the face plate and condensation. Unfortunately, since the Sick RM200 does include an optional system for heating the purge air, buildup occurred again between the calibration test in June and the RCA test in July. This time the instrument was not removed. A further deterioration in the response from the Sick RM200 resulted. All statistical data is presented in Table 2-17 along with the Rollins data.

There was a concerted effort to achieve an appropriate test matrix and distribution over three PM levels at each calibration. However, results of the calibration test do not reflect the current performance specifications. A PS 11 calibration requires 15 runs distributed over at least three (3) levels. These Lafarge series of calibrations exemplify the difficulty in correlating two (2) simultaneous Method 5 trains. The monitors performed well in the calibration tests, but both experienced a decreased correlation to PM concentrations in the RCA-type test. The Sick RM200 problems can be attributed to the heated, purge-air system.

2.7 Assessment of PM CEMS Cost and Data Availability

2.7.1 *Preliminary Cost Assessment*

This material deals with the preliminary assessment of the capital and annual costs of PM CEMS. The objective here is to provide a rough (order of magnitude) initial basis in developing estimated cost information for EPA's consideration of requiring PM CEMS at HWC facilities. This discussion covers two areas concerning CEMS: 1) identification of the major cost-related assumptions, and 2) technology-specific cost estimates based on these assumptions.

This preliminary cost assessment is based on the revised EPA/EMTIC CEMS cost model along with experience gained in the demonstration program. This computerized model provides estimated costs for the overall cost of ownership reflecting all expenses involved in procurement, installation, operation, maintenance, and calibration for all types of CEMS. It is currently being adapted for PM CEMS and EPA is in the process of revising and preparing a user's manual for the

cost model.

Cost-related factors and assumptions developed from the demonstration program are listed below in the order presented in the EMTIC cost model. Experience and data obtained from PM CEMS use in the program are applied as the premise for assessing cost-related factors and assumptions in estimating their ownership cost. The list only identifies the assumptions made by EER. Some of these assumptions are specific to the particular technology type, while others are generically applicable to any type of PM CEMS.

Technology- specific costs are estimated from the EMTIC model and presented in Table 2-20 for each of the three (3) general types PM CEMS in the demonstration program. These include purchase cost supplied by the vendors. For the four (4) foreign vendors, the purchase value was based on the exchange rate of their respective currency with U.S. dollars at the point in time of submittal and are subject to change. Annualized cost range from about $30,000 to $46,000 with the following assumptions.

List of Cost Assumptions

EMTIC No.	Topic	Comment / Assumption
4 C.	Data acquisition	$20,000 for either purchase of data acquisition system or programming cost for use of existing PC software
4 F.	Monitor cost	See cost table
5 E.	Installation	1-day for in-situ light-scattering with all preparations made. 2-days for extractive light-scattering and Beta units with all preparations made. $20,000 for installation, equally divided for labor and ODC
6 E.b.	Calibration test	44 hours for plant technician; 130 hours for test technicians; One test for Beta monitors; Three tests for light-scattering Monitors.

6 F.	Test Report	8 hours for consultant professional 16 hours for test technicians
8 A.	Daily check	1/4 hour for optical monitors ½ hour for Beta monitors
8 B.	Weekly check	Nothing extra needed for optical monitors 1 hour for Beta monitors
8 C.	Quarterly check	3 hours for optical monitors 3 hours for Beta monitors
9.	RCA test	Multiplied actual total by 0.2 to account for assumed 5 year period of testing frequency
10.	Quarterly ACA	Multiplied actual total by 4 to account for assumed 4 times per year testing frequency
----	Auxiliary data	No costs for oxygen, temperature, pressure, or moisture monitoring to convert PM CEMS data into units of the standard (*e.g.*, mg/dscm @ 7% oxygen)
----	Redundancy	Redundant in-situ light scattering monitor included; Other two options included predictive emission monitoring system for backup capability.
----	Service	Spare parts and service are available throughout the U.S.
----	Testing	Contractors are efficient in calibration evaluation
----	Monetary	7% interest over a 10 year period

2.7.2 *Preliminary Assessment of Data Availability*

Beyond accuracy/precision, EPA is also interested in assuring that CEMS performance is suitable for continuous, reliable, and virtually automatic operation. Most are reliable enough that only a daily spot check of data and equipment is needed to assure proper operation and internal-calibration. Below is a summary of how the continuous data were collected and treated to derive data

availability for each monitor. More detailed information on the specific servicing events to maintain each CEMS over the program is presented in the Appendix.

The 'minute data' for each PM monitor were collected and saved in a spreadsheet format. The data for each monitor were then stored in monthly files. Data availability was assessed by determining the times in which the PM CEMS were and were not producing valid data. All flags and/or numbers were counted and recorded and a percentage calculated for each day, although some flags were excluded from the data availability calculation. The specific flags that were excluded or ignored from the percent data availability calculation with the reasoning for exclusion are:

'C' or 'calibration':	The calibration function is a normal operation flag.
'Z' or 'incinerator down':	Data availability is normally not judged during these periods.
'Y' or 'low velocity':	This flag indicates times when the incinerator was being brought down. At this time, the facility is operating under its start-up, shut-down, or malfunction plan, a time when data availability is not counted.

However, there were five (5) types of specific flags that reflected invalid data periods, and time periods with these flagged data were included in the availability calculation. These are:

'B' for bad,
'M' for maintenance,
'O' for over range,
'P' for power failure (<0.5% counted), and
'D' for disabled (<0.5% counted).

For each monitor, the daily calculated percent availability was linked to a spreadsheet and a chart was generated from this data. Consideration was given to the fact that a technician responsible for maintaining the monitors was only on-site every two (2) weeks and not available every day for

servicing the monitors. Because of this, it was reasonable to estimate the amount of down-time associated to correct a given problem (as if a technician were available) and to ignore the reported down-time. Likewise for startups following an incinerator outage, CEMS were not penalized for down-time because a technician was not available to initiate its startup.

The overall average data availability over the course of the program is illustrated in Figures 2-32 through 2-36 for the ESA, Verewa, Durag, ESC, and Sigrist, respectively. The overall average data availability percentage is presented below for each respective monitor.

Average Percent Data Availability

ESA - 85.3%
Verewa - 74%
Durag - 99.9% (% IN CALIBRATION MODE - 4.1%)
ESC - 99.2% (% IN CALIBRATION MODE - 0.3%)
Sigrist - 99.7%

2.8 Summary and Conclusions

The national PM CEMS program is completed and can be summarized by the following demonstrated achievements:

- CEMS were operated under reasonable worst case (as-found, normal day-to-day) HWC facility operations,
- Operations consisted of varying conditions with waste feeds, APC performance, PM, and flue gas,
- Operations spanned a 9-month/4-seasonal period of endurance/duty testing with five (5) commercial CEMS,
- Over 100 pairs of M5/CEMS test sets were performed, and
- A total of two (2) calibration relation tests and four (4) RCA tests were performed.

The key results and conclusions are:

- In relation to the revised Draft PS 11 acceptance criteria for the correlation coefficient, confidence interval, and tolerance interval:

  - Four (4) of the five (5) PM CEMS met each criteria at three (3) emission levels for the initial calibration,
  - Four (4) of the five (5) PM CEMS met each criteria at three (3) emission levels for the second calibration,
  - While the fifth PM CEMS met 10 of the 14 criteria for both calibrations; and
  - All five (5) PM CEMS met each criteria at three (3) emission levels relative to the cumulative database.

- All five (5) PM CEMS produced accurate/precise/stable data meeting Appendix F - Procedure 2 acceptance criteria for the 25% tolerance interval requirements at three (3) emission levels in the RCA tests,

- Four (4) of the five (5) PM CEMS produced reliable data available from 85% to 99% of the time while the fifth produced reliable data available 74% of the time,

- Each of the five (5) CEMS vendors have unique features and approaches for PM monitoring,

- Both the light-scattering and Beta CEMS technologies can meet the revised Draft PS 11 criteria, and

- The CEMS produce data as reproducible as the new reference method, M5i.

The demonstration tests showed that more than one calibration may be necessary to determine what type of calibration curve fit best characterizes the correlation between CEMS response and PM concentration. Because of the need to develop a calibration curve representative for each particular

type of HWC facility/APC system, the following strategy may be appropriate to ensure that the calibration curve facilities develop adequately corresponds to measured PM concentrations:

- Perform the initial calibration test and develop a correlation by the Performance Test Date (within six months of the compliance date). For CEMS with measurement technologies insensitive to changes in PM properties (*e.g.*, Beta-gauge), this would be the only calibration test required.

- For CEMS with measurement technologies sensitive to PM property changes (*e.g.*, light-scattering), perform a second calibration test three (3) months after the first calibration (8 to 9 months after the compliance date). Compare the results of the two (2) calibrations to determine what type of fit best correlates with measured PM concentrations. The calibration relation for the facility is one comprised of both sets of calibration data.

- Have these same facilities perform a third calibration test three (3) months after the second calibration (11 to 12 months after the compliance date). Compare the third calibration relation to the first two. If this calibration relation confirms the findings of the original two (2) calibrations, then this is the last calibration test to be performed. The final calibration relation for the facility is one comprised of all three (3) sets of calibration data.

- If the third calibration shows some fit other than the one originally determined best correlates CEMS response to PM emission concentrations, then a fourth calibration test must be performed three (3) months after the third. This process of performing additional calibration test continues until the facility can determine what fit best correlates CEMS output to PM concentrations. The final calibration relation will comprise all calibration data obtained.

TABLE 2-1. MATRIX OF CALIBRATION RELATION CONDITIONS

EDV Power Set Point		
Low	**Medium**	**High**
Fuel oil only	**Fuel oil only**	**Fuel oil only**
Solids	**Solids**	**Solids**
Chlorinated solvents +	**Chlorinated solvents +**	**Chlorinated solvents +**
Mixed solvents + solids	**Mixed solvents + solids**	**Solvents mix + solids,**
Mixed solvents, solids, paint	**Mixed solvents, solids, paint**	**Mixed solvents, solids, paint**

TABLE 2.2. PROCESS DATA FROM SEPTEMBER MONTHLY TEST

DATE		9/25/96	9/25/96	9/25/96
TIME	1st half	11:09 - 11:39	14:02 - 14:32	16:34 - 17:04
	2nd half	12:04 - 12:34	14:47 - 15:17	17:16 - 17:46
	NET SAMPLE TIME (minutes)	60	60	48
TEST	RUN NUMBER	10	11	2
CONDITIONS	WASTE FEEDS	mix solv	mix solv	mix solv, solids
	EDV POWER SET POINT (kw)	0.3	0.4	0.6
DATE		9/26/97	9/26/97	9/26/97
TIME	1st half	09:56 - 10:20	13:51 - 14:15	16:31 - 16:49
	2nd half	11:48 - 12:12	14:37 - 15:01	17:18 - 17:36
	NET SAMPLE TIME (minutes)	48	48	36
TEST	RUN NUMBER	11-R1	3	10-R1
CONDITIONS	WASTE FEEDS	mix solv	mix solv, jugs	mix solv, jugs, solids
	EDV POWER	0.3	0.3 / off	0.5
DATE		9/27/96	9/27/96	9/27/96
TIME	1st half	09:02 - 09:26	11:05 - 11:23	13:03 - 13:21
	2nd half	09:45 - 10:09	11:37 - 11:55	13:47 - 14:05
	NET SAMPLE TIME (minutes)	48	36	36
TEST	RUN NUMBER	8	9	15
CONDITIONS	WASTE FEEDS	solids	solids	solv, pigments
	EDV POWER SET POINT (kw)	0.5	0.3	0.3
DATE		9/27/96		
TIME	1st half	15:03 - 15:27		
	2nd half	15:39 - 16:03		
	NET SAMPLE TIME (minutes)	48		
TEST	RUN NUMBER	14		
CONDITIONS	WASTE FEEDS	solv, pigments		
	EDV POWER	0.4		

TABLE 2.2 (CONT.). PROCESS DATA FROM OCTOBER MONTHLY TEST

DATE		10/15/96	10/15/96	10/16/96
TIME	1st half	14:02 - 14:20	16:10 - 16:28	12:44 - 12:56
	2nd half	14:32 - 14:50	16:41 - 16:59	13:04 - 13:16
	NET SAMPLE TIME (minutes)	36	36	24
TEST	RUN NUMBER	4	5	6
CONDITIONS	WASTE FEEDS	pigments	solvents	solvents
	EDV POWER SET POINT (kw)	1	0.6	0.3
DATE		10/17/96	10/17/96	10/17/96
TIME	1st half	08:37 - 08:49	10:15 - 10:24	11:57 - 12:06
	2nd half	09:01 - 09:13	10:38 - 10:47	12:19 - 12:28
	NET SAMPLE TIME (minutes)	24	18	18
TEST	RUN NUMBER	6-R1	6-R2	16
CONDITIONS	WASTE FEEDS	solvents, oil, solids	solvents, oil, solids	oil, solids
	EDV POWER	0.3	0.3	0.8
DATE		10/17/96	10/17/96	10/17/96
TIME	1st half	14:15 - 14:24	15:10 - 15:19	17:06 - 17:15
	2nd half	14:31 - 14:40	16:18 - 16:27	17:23 - 17:32
	NET SAMPLE TIME (minutes)	18	18	18
TEST	RUN NUMBER	17	18	19
CONDITIONS	WASTE FEEDS	oil, solids	oil, solids	solvents, solids
	EDV POWER SET POINT (kw)	0.7	0.7	1.1
DATE		10/18/96	10/18/96	
TIME	1st half	10:15 - 10:33	13:16 - 13:40	
	2nd half	10:47 - 11:05	13:54 - 14:18	
	NET SAMPLE TIME (minutes)	36	48	
TEST	RUN NUMBER	20	21	
CONDITIONS	WASTE FEEDS	oil	oil	
	EDV POWER	0.7	0.7	

TABLE 2.2 (CONT.). PROCESS DATA FROM NOVEMBER MONTHLY TEST

DATE		**11/12/96**	**11/12/96**	**11/12/96**
TIME	**1st half**	**12:44 - 13:02**	**14:12 - 14:30**	**15:59 - 16:17**
	2nd half	**13:12 - 13:30**	**14:37 - 14:55**	**16:26 - 16:44**
	NET SAMPLE TIME (minutes)	**36**	**36**	**36**
TEST	**RUN NUMBER**	**22**	**23**	**24**
CONDITIONS	**WASTE FEEDS**	**oil**	**oil, jugs, solids**	**oil, jugs, solids**
	EDV POWER SET POINT (kw)	**1.1**	**1.1**	**1.1**
DATE		**11/13/96**	**11/13/96**	**11/13/96**
TIME	**1st half**	**08:44 - 09:08**	**10:24 - 10:48**	**12:09 - 12:33**
	2nd half	**09:15 - 09:39**	**10:55 - 11:19**	**12:42 - 13:06**
	NET SAMPLE TIME (minutes)	**48**	**48**	**48**
TEST	**RUN NUMBER**	**25**	**26**	**27**
CONDITIONS	**WASTE FEEDS**	**solvents, jugs, solids**	**solvents, jugs, solids**	**oil, jugs, solids**
	EDV POWER SET POINT (kw)	**0.7**	**0.7**	**0.7**
DATE		**11/13/96**	**11/13/96**	**11/14/96**
TIME	**1st half**	**15:11 - 15:29**	**16:38 - 16:56**	**15:42 - 16:00**
	2nd half	**15:37 - 15:55**	**17:04 - 17:22**	**16:09 - 16:27**
	NET SAMPLE TIME (minutes)	**36**	**36**	**36**
TEST	**RUN NUMBER**	**28**	**29**	**30**
CONDITIONS	**WASTE FEEDS**	**solvents, jugs, solids**	**oil**	**oil, jugs, solids**
	EDV POWER SET POINT (kw)	**0.3**	**0.3**	**0.3**

TABLE 2-2 (CONT.). PROCESS DATA FROM DECEMBER MONTHLY TEST

DATE		12/17/96	12/17/96	12/17/96
TIME	1st half	11:40 - 12:04	13:51 - 14:15	15:46 - 16:10
	2nd half	12:20 - 12:44	14:22 - 14:46	16:17 - 16:41
	NET SAMPLE TIME (minutes)	48	48	48
TEST	RUN NUMBER	31	32	33
CONDITIONS	WASTE FEEDS	unrecorded	unrecorded	unrecorded
	EDV POWER SET POINT (kw)	0.2	0.2	0.2
DATE		12/18/96	12/18/96	12/18/96
TIME	1st half	08:52 - 09:16	10:28 - 10:52	12:05 - 12:29
	2nd half	09:22 - 09:46	10:56 - 11:20	12:34 - 12:58
	NET SAMPLE TIME (minutes)	48	48	48
TEST	RUN NUMBER	34	35	36
CONDITIONS	WASTE FEEDS	oil, solids	oil, solids	oil, solids
	EDV POWER SET POINT (kw)	0.2	0.7	0.3
DATE		12/18/96	12/18/96	12/18/96
TIME	1st half	13:36 - 14:00	15:00 - 15:24	16:35 - 16:59
	2nd half	14:04 - 14:28	15:28 - 15:52	17:03 - 17:27
	NET SAMPLE TIME (minutes)	48	48	48
TEST	RUN NUMBER	37	38	39
CONDITIONS	WASTE FEEDS	oil, solids	oil, solids	oil, solids
	EDV POWER SET POINT (kw)	0.7	0.2	0.2

TABLE 2-2 (CONT.). PROCESS DATA FROM JANUARY MONTHLY TEST

DATE		1/15/97	1/15/97	1/15/97
TIME	1st half	09:25 - 09:49	11:47 - 12:11	14:57 - 15:21
	2nd half	10:14 - 10:38	12:57 - 13:21	15:28 - 15:52
	NET SAMPLE TIME (minutes)	48	48	48
TEST	RUN NUMBER	40	41	42
CONDITIONS	WASTE FEEDS	oil, jugs	oil, jugs, solids	oil, solids
	EDV POWER SET POINT (kw)	1.5	1.0	1.0
DATE		1/16/97	1/16/97	1/16/97
TIME	1st half	12:25 - 12:49	13:40 - 14:04	15:00 - 15:24
	2nd half	12:55 - 13:19	14:10 - 14:34	15:40 - 16:04
	NET SAMPLE TIME (minutes)	48	48	48
TEST	RUN NUMBER	43	44	45
CONDITIONS	WASTE FEEDS	chlor solv, solids	chlor solv, jugs, solids	chlor solv, solids
	EDV POWER SET POINT (kw)	1.0	1.0	1.0
DATE		1/16/97	1/17/97	1/17/97
TIME	1st half	16:38 - 17:02	08:39-08:43/09:50-10:10	12:22 - 12:46
	2nd half	17:08 - 17:32	10:19 - 10:43	12:53 - 13:17
	NET SAMPLE TIME (minutes)	48	48	48
TEST	RUN NUMBER	46	47	48
CONDITIONS	WASTE FEEDS	chlor solv, oil, jugs	chlor solv, jugs, solids	chlor solv, jugs, solids
	EDV POWER SET POINT (kw)	1.0	1.0	1.0
DATE		1/17/97		
TIME	1st half	14:57 - 15:21		
	2nd half	15:46 - 16:10		
	NET SAMPLE TIME (minutes)	48		
TEST	RUN NUMBER	49		
CONDITIONS	WASTE FEEDS	chlor solvents, jugs, solids		
	EDV POWER SET POINT (kw)	1.0		

TABLE 2-2 (CONT.). PROCESS DATA FROM FEBRUARY MONTHLY TEST

DATE		2/19/97	2/19/97	2/19/97
TIME	1st half	9:45 - 10:15	11:59 -12:35	14:29 - 15:05
	2nd half	10:24 - 10:54	12:45 - 13:21	15:13 - 15:49
	NET SAMPLE TIME (minutes)	60	72	72
TEST	RUN NUMBER	50	51	52
CONDITIONS	WASTE FEEDS	oil, solids	oil, jugs, solids	oil, jugs, solids
	EDV POWER SET POINT (kw)	2.0	2.0	1.0
DATE		2/19/97	2/20/97	2/20/97
TIME	1st half	16:28 -17:04	8:30 - 9:06	10:50 - 11:26
	2nd half	17:13 - 17:49	9:13 - 9:49	11:34 - 12:10
	NET SAMPLE TIME (minutes)	72	72	72
TEST	RUN NUMBER	53	54	55
CONDITIONS	WASTE FEEDS	oil, solids	mixed solv, jugs, solids, pigment	mixed solv, jugs, solids
	EDV POWER SET POINT (kw)	1.0	1.0	1.0
DATE		2/20/97	2/20/97	2/21/97
TIME	1st half	12:59 - 13:35	15:19 - 15:55	8:33 - 9:09
	2nd half	13:46 - 14:22	16:02 - 16:38	9:15 - 9:51
	NET SAMPLE TIME (minutes)	72	72	72
TEST	RUN NUMBER	56	57	58
CONDITIONS	WASTE FEEDS	mixed solv, jugs	mixed solv, jugs,solids	mixed solv, jugs,solids
	EDV POWER SET POINT (kw)	1.0	1.0	1.0
DATE		2/21/97	2/21/97	2/21/97
TIME	1st half	10:41 - 11:17	12:33 - 13:09	14:49 - 15:25
	2nd half	11:23 - 11:59	13:45 - 14:21	15:31 - 16:07
	NET SAMPLE TIME (minutes)	72	72	72
TEST	RUN NUMBER	59	60	61
CONDITIONS	WASTE FEEDS	mixed solv, jugs,solids	mixed solv, jugs	mixed solv, solids
	EDV POWER SET POINT (kw)	1.0	1.0	1.0

TABLE 2-2 (CONT.). PROCESS DATA FROM MARCH MONTHLY TEST

DATE		3/18/97	3/18/97	3/18/97
TIME	1st half	10:55 - 11:25	13:00 - 13:30	14:56 - 15:26
	2nd half	11:32 - 12:02	13:38 - 14:08	15:32 - 16:02
	NET SAMPLE TIME (minutes)	60	60	60
TEST	RUN NUMBER	62	63	64
CONDITIONS	WASTE FEEDS	oil, jugs, solids	oil, jugs	oil, jugs,solids
	EDV POWER SET POINT (kw)	2.0	2.0	2.0
DATE		3/19/97	3/19/97	3/19/97
TIME	1st half	8:43 - 9:13	10:36 - 11:06	14:30 - 15:00
	2nd half	9:20 - 9:50	11:24 - 11:54	15:06 - 15:36
	NET SAMPLE TIME (minutes)	60	60	60
TEST	RUN NUMBER	65	66	67
CONDITIONS	WASTE FEEDS	oil, jugs,solids,pigment	mixed solv, jugs, solids, pigment	mixed solv, jugs
	EDV POWER SET POINT (kw)	2.0	1.0	1.0
DATE		3/19/97	3/20/97	3/20/97
TIME	1st half	16:56 - 17:26	9:08 - 9:38	10:49 - 11:19
	2nd half	17:30 - 18:00	9:44 - 10:14	11:29 - 11:59
	NET SAMPLE TIME (minutes)	60	60	60
TEST	RUN NUMBER	68	69	70
CONDITIONS	WASTE FEEDS	mixed solv, oil, solids	mixed solv, jugs	mixed solv, jugs, solids, pigment
	EDV POWER SET POINT (kw)	1.0	1.0	1.0
DATE		3/20/97	3/20/97	3/20/97
TIME	1st half	12:51 - 13:21	14:42 - 15:12	16:33 - 17:03
	2nd half	13:27 - 13:57	15:18 - 15:48	17:35 - 18:05
	NET SAMPLE TIME (minutes)	60	60	60
TEST	RUN NUMBER	71	72	73
CONDITIONS	WASTE FEEDS	mixed solv, solids	mixed solv, jugs,solids	mixed solv, solids
	EDV POWER SET POINT (kw)	1.0	1.0	1.0

TABLE 2-2 (CONT.). PROCESS DATA FROM APRIL MONTHLY TEST

DATE		4/21/97	4/21/97	4/22/97
TIME	1st half	13:37 - 14:07	19:52 - 20:22	10:03 - 10:33
	2nd half	14:15 - 14:45	20:36 - 21:06	10:41 - 11:11
	NET SAMPLE TIME (minutes)	60	60	60
TEST	RUN NUMBER	74	75	76
CONDITIONS	WASTE FEEDS	mixed solv, jugs,solids,pigment	mixed solv, jugs,solids,pigment	mixed solv, jugs,solids,pigment
	EDV POWER SET POINT (kw)	2.0	2.0	2.0
DATE		4/22/97	4/22/97	4/23/97
TIME	1st half	12:13 - 12:43	17:32 - 18:02	9:05 - 9:35
	2nd half	12:55 - 13:25	18:08 - 18:38	9:41 - 10:11
	NET SAMPLE TIME (minutes)	60	60	60
TEST	RUN NUMBER	77	78	79
CONDITIONS	WASTE FEEDS	mixed solv, jugs,solids	oil	mixed solv,solids
	EDV POWER SET POINT (kw)	2.0	2.0	2.0
DATE		4/23/97	4/23/97	4/23/97
TIME	1st half	10:53 - 11:23	12:34 - 13:04	14:59 - 15:29
	2nd half	11:28 - 11:58	13:09 - 13:39	15:36 - 16:06
	NET SAMPLE TIME (minutes)	60	60	60
TEST	RUN NUMBER	80	81	82
CONDITIONS	WASTE FEEDS	mixed solv	mixed solv	mixed solv
	EDV POWER SET POINT (kw)	1.0	1.0	1.0
DATE		4/24/97	4/24/97	4/24/97
TIME	1st half	8:04 - 8:34	10:03 - 10:33	12:05 -12:35
	2nd half	8:40 - 9:10	10:46 - 11:16	12:43 - 13:13
	NET SAMPLE TIME (minutes)	60	60	60
TEST	RUN NUMBER	83	84	85
CONDITIONS	WASTE FEEDS	mixed solv, chlor solv, solids	mixed solv, chlor solv	mixed solv, chlor solv
	EDV POWER SET POINT (kw)	1.0	1.0	3.0

TABLE 2-2 (CONT.). PROCESS DATA FROM APRIL MONTHLY TEST

DATE		4/24/97	4/24/97	4/25/97
TIME	1st half	14:13 - 14:43	15:50 - 16:20	8:22 - 8:52
	2nd half	14:49 - 15:19	16:29 - 16:59	9:00 - 9:30
	NET SAMPLE TIME (minutes)	60	60	60
TEST	RUN NUMBER	86	87	88
CONDITIONS	WASTE FEEDS	mixed solv, chlor solv, solids	mixed solv, chlor solv	mixed solv, chlor solv
	EDV POWER SET POINT (kw)	3.0	3.0	3.0
DATE		4/25/97	4/25/97	
TIME	1st half	10:58 - 11:28	13:00 - 13:30	
	2nd half	11:34 - 12:04	13:36 - 14:06	
	NET SAMPLE TIME (minutes)	60	60	
TEST	RUN NUMBER	89	90	
CONDITIONS	WASTE FEEDS	mixed solv, chlor solv	mixed solv, chlor solv	
	EDV POWER SET POINT (kw)	1.1	1.1	

TABLE 2-2 (CONT.). PROCESS DATA FROM MAY MONTHLY TEST

DATE		5/20/97	5/20/97	5/20/97
TIME	1st half	10:12 - 10:42	13:50 - 14:20	16:36 - 17:06
	2nd half	10:49 - 11:31	14:25 - 14:55	17:15 - 17:45
	NET SAMPLE TIME (minutes)	60	60	60
TEST	RUN NUMBER	91	92	93
CONDITIONS	WASTE FEEDS	mixed solv, solids	mixed solv, solids	mixed solv
	EDV POWER SET POINT (kw)	3.0	3.0	3.0
DATE		5/21/97	5/21/97	5/22/97
TIME	1st half	13:51 - 14:21	16:07 - 16:37	9:35 - 10:20
	2nd half	14:29 - 14:59	16:45 - 17:15	10:33 - 11:18
	NET SAMPLE TIME (minutes)	60	60	90
TEST	RUN NUMBER	94	95	96
CONDITIONS	WASTE FEEDS	mixed solv, solids	mixed solv, solids, pigments, jugs	oil
	EDV POWER SET POINT (kw)	1.5	1.5	1.5
DATE		5/22/97	5/22/97	5/23/97
TIME	1st half	14:04 - 14:34	16:07 - 16:37	7:53 - 8:23
	2nd half	14:42 - 15:12	16:44 - 17:22	8:30 - 9:00
	NET SAMPLE TIME (minutes)	60	60	60
TEST	RUN NUMBER	97	98	99
CONDITIONS	WASTE FEEDS	mixed solv, solids, pigments, jugs	mixed solv, solids	mixed solv, solids, jugs
	EDV POWER SET POINT (kw)	1.5	1.5	1.5
DATE		5/23/97	5/23/97	5/23/97
TIME	1st half	9:43 - 10:13	12:03 - 12:33	13:59 - 14:29
	2nd half	10:22 - 10:52	12:45 - 13:15	14:47 - 15:17
	NET SAMPLE TIME (minutes)	60	60	60
TEST	RUN NUMBER	100	101	102
CONDITIONS	WASTE FEEDS	mixed solv, solids, pigments, jugs	mixed solv, solids, pigments, jugs	mixed solv, solids, jugs
	EDV POWER SET POINT (kw)	1.5	1.0	1.0

TABLE 2.3 SUMMARY OF METHOD 5 RUN DATA AND RSD SEPTEMBER

Run Identification	Stack Temp. °F	Moisture Content %	PM Concentration mg/dscm			PM Concentration mg/Acm		
			mg/dscm	avg	RSD %	mg/Acm	avg	RSD %
09-25-TA-10	318.3	28.9	10.28	9.11	12.8%	4.97	4.42	12.4%
09-25-TB-10	320.3	28.1	7.94			3.87		
09-25-TA-11	311.7	28.5	23.21	22.65	2.5%	11.38	11.07	2.8%
09-25-TB-11	313.3	28.9	22.09			10.75		
09-25-TA-2	314.8	28.5	27.92	20.92	33.5%	13.64	10.18	34.0%
09-25-TB--2	317.2	29.2	13.92			6.71		
09-26-TA-11-R-1	310.1	29.1	5.81	5.16	12.5%	2.84	2.54	12.0%
09-26-TB-11-R-1	312.8	28.1	4.52			2.23		
09-26-TA-10-R-1	315.7	28.5	11.53	8.67	33.0%	5.65	4.26	32.7%
09-26-TB-10-R-1	317.8	27.8	5.81			2.87		
09-26-TA-3	318.1	27.5	32.84	33.35	1.5%	16.26	16.55	1.7%
09-26-TB-3	319.8	27.1	33.87			16.83		
09-27-TA-8	310.9	28.4	13.36	12.81	4.3%	6.54	6.25	4.6%
09-27-TB-8	313.2	28.7	12.27			5.97		
09-27-TA-9	313.8	27.7	13.14	12.44	5.6%	6.47	6.14	5.4%
09-27-TB-9	315.6	27.3	11.74			5.80		
09-27-TA-15	311.8	28.9	27.09	24.12	12.3%	13.15	11.74	12.0%
09-27-TB-15	314.3	28.2	21.15			10.33		
09-27-TA-14	312.6	28.8	35.52	27.65	28.5%	17.25	13.44	28.4%
09-27-TB-14	314.0	28.6	19.78			9.62		

TABLE 2. 3 (CONT.) SUMMARY OF METHOD 5 RUN DATA AND RSD OCTOBER

Run Identification	Stack Temp. °F	Moisture Content %	PM Concentration mg/dscm			PM Concentration mg/Acm		
			mg/dscm	avg	RSD %	mg/Acm	avg	RSD %
10-15TA4	320.1	24.3	31.99	32.54	1.7%	16.55	16.90	2.1%
10-15-TB4	320.3	23.7	33.09			17.25		
10-15TA5	324.5	23.9	31.31	34.40	9.0%	16.18	17.73	8.8%
10-15TB-5	324.3	24.3	37.50			19.29		
10-16-TA-6	321.6	26.3	26.63	26.36	1.0%	13.41	13.39	0.1%
10-16-TB-6	320.7	25.1	26.10			13.38		
10-17-TA-6-R1	306.7	26.0	43.41	39.48	10.0%	22.38	20.31	10.2%
10-17-TB-6-R1	308.8	26.1	35.55			18.25		
10-17-TA-6-R2	307.2	26.6	64.30	67.28	4.4%	32.85	34.56	5.0%
10-17-TB--6-R2	309.3	25.6	70.26			36.28		
10-17-TA-16	309.0	28.8	43.93	41.65	5.5%	21.72	20.27	7.2%
10-17-TB-16	311.8	30.9	39.37			18.82		
10-17-TA-17	309.1	24.1	35.25	37.13	5.0%	18.57	19.33	3.9%
10-17-TB-17	312.2	25.5	39.00			20.09		
10-17-TA-18	308.9	27.8	27.51	34.08	19.3%	13.79	17.16	19.7%
10-17-TB-18	312.3	26.9	40.64			20.54		
10-17-TA-19	308.3	32.1	24.53	29.65	17.2%	11.57	14.35	19.4%
10-17-TB-19	312.8	28.7	34.76			17.13		
10-18-TA-20	305.5	25.1	16.55	35.49	53.4%	8.64	18.43	53.1%
10-18-TB-20	309.4	25.2	54.43			28.22		
10-18-TA-21	305.8	25.3	8.89	9.46	6.0%	4.63	4.88	5.2%
10-18-TB-21	310.9	26.0	10.03			5.14		

TABLE 2. 3 (CONT.) SUMMARY OF METHOD 5 RUN DATA AND RSD NOVEMBER

Run Identification	Stack Temp. °F	Moisture Content %	PM Concentration mg/dscm			PM Concentration mg/Acm		
			mg/dscm	avg	RSD %	mg/Acm	avg	RSD %
11-12-TA-22	303.3	21.3	26.14	28.28	7.6%	14.47	15.67	7.7%
11-12-TB-22	303.7	21.1	30.42			16.87		
11-12-TA-23	303.8	22.1	15.68	17.74	11.6%	8.59	9.69	11.4%
11-12-TB-23	305.9	22.3	19.79			10.79		
11-12-TA-24	303.8	22.8	37.92	35.19	7.8%	20.59	19.23	7.1%
11-12-TB-24	304.4	21.7	32.45			17.86		
11-13-TA-25	305.3	22.1	21.80	18.50	17.9%	12.00	10.21	17.6%
11-13-TB-25	302.8	21.9	15.20			8.42		
11-13-TA-26	302.3	22.0	17.29	19.08	9.4%	9.57	10.55	9.4%
11-13-TB-26	304.4	21.8	20.88			11.54		
11-13-TA-27	303.0	22.3	19.19	27.58	30.4%	10.57	15.19	30.4%
11-13-TB-27	304.9	22.1	35.96			19.81		
11-13-TA-28	304.5	22.8	50.01	54.36	8.0%	27.29	29.75	8.3%
11-13-TB-28	304.8	22.4	58.70			32.22		
11-13-TA-29	303.1	22.1	23.83	23.17	2.8%	13.15	12.76	3.0%
11-13-TB-29	303.6	22.4	22.51			12.37		
11-14-TA-30	257.5	22.6	8.96	15.73	43.1%	5.22	9.15	42.9%
11-14-TB-30	258.5	22.8	22.51			13.08		

TABLE 2-3 (CONT.). SUMMARY OF METHOD 5 RUN DATA AND RSD DECEMBER

Run Identification	Stack Temp. °F	Moisture Content %	PM Concentration mg/dscm mg/dscm	avg	RSD %	PM Concentration mg/Acm mg/Acm	avg	RSD %
12-17-cond-31-TA	291.7	22.7	38.97	27.65	40.9%	21.14	15.01	40.8%
12-17-cond-31-TB	293.7	22.3	16.33			8.88		
12-17-cond-32-TA	294.7	22.9	23.75	20.09	18.2%	12.81	10.91	17.4%
12-17-cond-32-TB	294.7	21.6	16.44			9.01		
12-17-cond-33-TA	295.8	22.5	84.31	56.57	49.0%	45.58	30.64	48.7%
12-17-cond-33-TB	294.6	22.1	28.84			15.70		
12-18-cond-34-TA	281.3	23.4	15.61	20.27	23.0%	8.51	11.17	23.8%
12-18-cond-34-TB	281.8	22.0	24.93			13.83		
12-18-cond-35-TA	281.1	22.2	2.56	12.42	79.3%	1.42	6.93	79.5%
12-18-cond-35-TB	279.5	21.7	22.27			12.44		
12-18-cond-36-TA	290.2	21.7	25.32	25.04	1.1%	13.95	13.78	1.2%
12-18-cond-36-TB	290.6	21.8	24.76			13.62		
12-18-cond-37-TA	283.2	22.9	33.54	30.41	10.3%	18.36	16.67	10.2%
12-18-cond-37-TB	283.7	22.6	27.27			14.98		
12-18-cond-38-TA	282.8	22.9	33.00	30.12	9.6%	18.08	16.58	9.0%
12-18-cond-38-TB	283.3	22.0	27.23			15.08		
12-18-cond-39-TA	283.8	22.6	26.49	131.13	79.8%	14.55	72.15	79.8%
12-18-cond-39-TB	284.3	22.4	235.78			129.74		

TABLE 2-3 (CONT.). SUMMARY OF METHOD 5 RUN DATA AND RSD JANUARY

Run Identification	Stack Temp. °F	Moisture Content %	PM Concentration mg/dscm			PM Concentration mg/Acm		
			mg/dscm	avg	RSD %	mg/Acm	avg	RSD %
1-15-cond-40-TB	290.4	20.4	4.67	4.67	#N/A	2.64	2.64	#N/A
1-15-cond-41-TA	291.8	20.4	0.00	2.57	100.0%	0.00	1.45	100.0%
1-15-cond-41-TB	291.0	20.4	5.14			2.90		
1-15-cond-42-TA	291.3	29.3	1.46	2.88	49.4%	0.73	1.51	51.6%
1-15-cond-42-TB	292.3	25.0	4.30			2.29		
1-16-cond-43-TA	292.8	21.1	12.17	12.17	#N/A	6.66	6.66	#N/A
1-16-cond-44-TA	292.5	20.7	10.94	10.94	#N/A	6.01	6.01	#N/A
1-16-cond-45-TA	291.2	20.7	5.48	5.48	#N/A	3.02	3.02	#N/A
1-16-cond-46-TA	291.4	21.0	7.57	7.57	#N/A	4.15	4.15	#N/A
1-17-cond-47-TA	286.7	16.1	10.23	12.37	17.3%	6.08	7.33	17.1%
1-17-cond-47-TB	288.8	16.2	14.51			8.58		
1-17-cond-48-TA	284.4	18.3	15.55	20.49	24.1%	9.02	11.96	24.6%
1-17-cond-48-TB	286.3	17.2	25.42			14.91		
1-17-cond-49-TA	287.2	19.2	20.61	19.84	3.9%	11.77	11.31	4.1%
1-17-cond-49-TB	287.7	19.5	19.07			10.84		

TABLE 2-3 (CONT.). SUMMARY OF METHOD 5 RUN DATA AND RSD FEBRUARY

Run Identification	Stack Temp. °F	Moisture Content %	PM Concentration mg/dscm mg/dscm	avg	RSD %	PM Concentration mg/Acm mg/Acm	avg	RSD %
2-19-97-50-ta	296.9	22.9	5.45	5.75	5.2%	2.94	3.10	5.2%
2-19-97-50-tb	298.2	22.7	6.04			3.27		
2-19-97-51-ta	298.4	23.0	3.44	4.09	16.0%	1.85	2.21	16.2%
2-19-97-51-tb	297.3	22.6	4.74			2.57		
2-19-97-52-ta	298.3	22.4	10.51	10.09	4.1%	5.70	5.49	3.8%
2-19-97-52-tb	296.3	22.1	9.68			5.28		
2-19-97-53-ta	301.3	22.8	6.24	6.65	6.1%	3.36	3.58	6.3%
2-19-97-53-tb	300.2	22.5	7.05			3.81		
2-20-97-54-ta	296.5	22.9	13.01	12.79	1.8%	7.09	6.95	2.1%
2-20-97-54-tb	295.3	23.5	12.56			6.81		
2-20-97-55-ta	296.8	23.0	10.79	9.76	10.6%	5.88	5.33	10.3%
2-20-97-55-tb	295.9	22.6	8.72			4.78		
2-20-97-56-ta	296.1	22.3	10.81	12.17	11.2%	5.94	6.69	11.2%
2-20-97-56-tb	296.2	22.3	13.54			7.45		
2-20-97-57-ta	295.9	22.6	11.11	12.03	7.7%	6.08	6.59	7.7%
2-20-97-57-tb	295.8	22.6	12.95			7.10		
2-21-97-58-ta	289.9	22.5	13.55	12.73	6.4%	7.41	6.98	6.1%
2-21-97-58-tb	293.1	21.6	11.91			6.56		
2-21-97-59-ta	296.4	21.8	12.02	11.90	1.1%	6.57	6.50	1.1%
2-21-97-59-tb	295.8	21.9	11.77			6.43		
2-21-97-60-ta	297.8	22.0	11.20	8.73	28.3%	6.10	4.76	28.3%
2-21-97-60-tb	296.6	22.0	6.27			3.41		
2-21-97-61-ta	297.9	22.4	12.37	8.32	48.6%	6.70	4.51	48.5%
2-21-97-61-tb	296.7	22.2	4.28			2.32		

TABLE 2-3 (CONT.). SUMMARY OF METHOD 5 RUN DATA AND RSD MARCH

Run Identification	Stack Temp. °F	Moisture Content %	PM Concentration mg/dscm mg/dscm	avg	RSD %	PM Concentration mg/Acm mg/Acm	avg	RSD %
3-18-97-62-ta	291.8	16.8	16.18	16.50	1.9%	9.56	9.78	2.2%
3-18-97-62-tb	293.9	16.0	16.81			10.00		
3-18-97-63-ta	292.8	17.0	16.47	17.32	4.9%	9.70	10.22	5.1%
3-18-97-63-tb	294.1	16.5	18.18			10.74		
3-18-97-64-ta	291.8	17.5	19.85	18.43	7.7%	11.63	10.83	7.3%
3-18-97-64-tb	292.9	16.8	17.01			10.04		
3-19-97-65-ta	289.3	17.3	33.59	31.98	5.0%	19.74	18.82	4.9%
3-19-97-65-tb	291.1	16.9	30.37			17.89		
3-19-97-66-ta	291.9	17.3	51.05	49.09	4.0%	29.91	29.03	3.0%
3-19-97-66-tb	291.3	15.7	47.12			28.14		
3-19-97-67-ta	291.8	17.0	50.32	49.07	2.5%	29.57	28.89	2.4%
3-19-97-67-tb	293.4	16.5	47.82			28.21		
3-19-97-68-ta	293.9	16.3	14.83	15.22	2.6%	8.77	8.98	2.4%
3-19-97-68-tb	296.1	16.3	15.61			9.20		
3-20-97-69-ta	279.5	15.0	38.37	37.18	3.2%	23.25	22.36	4.0%
3-20-97-69-tb	291.7	14.9	35.99			21.48		
3-20-97-70-ta	291.6	13.6	28.13	26.27	7.1%	17.05	15.94	6.9%
3-20-97-70-tb	291.9	13.3	24.42			14.84		
3-20-97-71-ta	291.3	13.7	#N/A	33.26	0.0%	#N/A	20.18	0.0%
3-20-97-71-tb	292.0	13.4	33.26			20.18		
3-20-97-72-ta	293.7	13.9	23.81	22.82	4.3%	14.34	13.76	4.2%
3-20-97-72-tb	293.5	13.6	21.83			13.19		
3-20-97-73-ta	290.8	13.6	5.99	6.33	5.2%	3.64	3.84	5.3%
3-20-97-73-tb	291.7	13.4	6.66			4.04		

TABLE 2-3 (CONT.). SUMMARY OF METHOD 5 RUN DATA AND RSD APRIL

Run Identification	Stack Temp. °F	Moisture Content %	PM Concentration mg/dscm			PM Concentration mg/Acm		
			mg/dscm	avg	RSD %	mg/Acm	avg	RSD %
74-TA	291.8	21.6	33.47	33.99	1.5%	18.35	18.66	1.6%
74-TB	292.6	21.4	34.50			18.96		
75-TA	292.5	21.7	3.91	16.24	75.9%	2.14	8.89	76.0%
75-TB	293.3	21.6	28.58			15.65		
76-TA	291.3	21.2	29.21	30.81	5.2%	16.05	16.92	5.1%
76-TB	293.4	21.0	32.41			17.79		
77-TA	291.9	21.8	36.14	35.44	2.0%	19.69	19.33	1.9%
77-TB	292.6	21.6	34.74			18.97		
78-TA	285.3	17.0	10.16	11.90	14.6%	5.93	6.95	14.6%
78-TB	287.3	16.7	13.64			7.96		
79-TA	296.1	22.3	12.01	12.66	5.1%	6.46	6.81	5.1%
79-TB	297.7	22.1	13.31			7.16		
80-TA	299.3	21.0	16.25	15.44	5.2%	8.85	8.35	6.0%
80-TB	301.4	22.1	14.64			7.85		
81-TA	300.8	21.0	13.69	19.68	30.5%	7.45	10.66	30.1%
81-TB	302.1	21.4	25.68			13.86		
82-TA	298.2	20.8	22.77	22.51	1.1%	12.45	12.32	1.0%
82-TB	300.2	20.5	22.26			12.19		
83-TA	289.3	22.1	23.20	22.23	4.4%	12.63	12.07	4.6%
83-TB	292.0	22.3	21.26			11.51		
84-TA	299.1	21.3	10.69	9.34	14.5%	5.80	5.07	14.3%
84-TB	300.8	21.0	7.99			4.35		
85-TA	296.3	21.6	11.71	11.64	0.6%	6.36	6.32	0.7%
85-TB	298.8	21.4	11.56			6.27		
86-TA	292.6	21.8	15.33	14.97	2.4%	8.34	8.15	2.4%
86-TB	294.5	21.5	14.61			7.96		
87-TA	298.2	21.3	8.52	8.30	2.7%	4.63	4.51	2.8%
87-TB	300.6	21.2	8.08			4.38		
88-TA	300.6	30.0	6.86	7.11	3.5%	3.34	3.46	3.4%
88-TB	302.7	29.9	7.36			3.58		
89-TA	301.1	30.7	11.36	10.34	9.9%	5.47	4.99	9.7%
89-TB	303.1	30.2	9.32			4.51		
90-TA	300.8	30.2	10.37	10.11	2.6%	5.03	4.91	2.5%
90-TB	303.5	29.9	9.85			4.79		

TABLE 2-3 (CONT.). SUMMARY OF METHOD 5 RUN DATA AND RSD MAY

Run Identification	Stack Temp. °F	Moisture Content %	PM Concentration mg/dscm			PM Concentration mg/acm		
			mg/dscm	avg	RSD %	mg/Acm	avg	RSD %
91-TA	288.8	21.9	14.21	13.80	3.0%	7.79	7.57	2.9%
91-TB	291.8	21.5	13.39			7.35		
92-TA	290.4	21.4	10.90	10.49	3.9%	6.00	5.78	3.7%
92-TB	291.9	21.0	10.08			5.57		
93-TA	289.6	21.3	8.03	8.11	1.0%	4.43	4.48	1.1%
93-TB	291.8	21.0	8.19			4.53		
94-TA	289.2	22.0	19.76	18.92	4.4%	10.88	10.43	4.3%
94-TB	290.8	21.7	18.09			9.98		
95-TA	288.8	21.8	19.21	18.72	2.6%	10.62	10.36	2.5%
95-TB	290.0	21.4	18.24			10.11		
96-TA	275.1	10.6	4.56	4.47	1.9%	2.94	2.87	2.1%
96-TB	278.0	10.7	4.38			2.81		
97-TA	290.3	21.5	9.34	9.54	2.1%	5.18	5.29	2.2%
97-TB	289.9	21.4	9.74			5.41		
98-TA	291.2	21.8	10.83	10.52	2.9%	5.98	5.81	2.9%
98-TB	291.3	21.7	10.21			5.64		
99-TA	289.6	21.9	14.48	14.75	1.8%	8.02	8.16	1.7%
99-TB	291.9	21.8	15.02			8.30		
100-TA	290.8	21.9	16.88	17.31	2.5%	9.34	9.58	2.5%
100-TB	292.9	21.6	17.75			9.83		
101-TA	288.7	21.5	30.16	30.60	1.4%	16.82	17.05	1.3%
101-TB	293.0	21.2	31.04			17.27		
102-TA	290.2	21.1	22.19	21.80	1.8%	12.42	12.16	2.1%
102-TB	292.8	21.2	21.40			11.91		

TABLE 2-4. CEMS PM RESULTS

	Mth 5 comments	Run #	ESA	VEREWA	DURAG	ESCP5	SIGRIST
September		RUN #10	7.44	10.50	15.33	13.23	13.95
		RUN #11	'O'	20.35	25.98	23.17	23.60
	RSD	RUN #2	4.20	5.14	7.09	5.91	2.88
	Traceability	RUN #11-R	10.06	32.05	44.09	42.58	51.14
	RSD	RUN #10-R	7.88	12.75	19.17	18.48	18.93
		RUN #3	'O'	19.65	12.29	12.18	8.01
		RUN #8	'O'	14.38	14.75	13.02	10.99
		RUN #9	9.82	13.44	16.77	15.79	15.57
		RUN #15	'O'	24.35	29.76	27.31	31.78
		RUN #14	'O'	23.61	27.58	24.74	27.20
October		RUN #4	'B'	'B'	39.29	33.42	35.08
		RUN #5	'B'	'B'	42.79	36.00	38.10
		RUN #6	'B'	'B'	36.87	31.34	36.31
		RUN #6-R1	'B'	'B'	45.10	40.21	50.58
		RUN #6-R2	'B'	'B'	49.99	45.22	56.72
		RUN #16	'B'	'B'	61.33	55.84	70.92
		RUN #17	'B'	'B'	59.36	54.42	66.31
	Traceability	RUN #18	'B'	'B'	45.62	42.71	47.84
		RUN #19	'B'	'B'	32.01	29.49	30.16
	RSD	RUN #20	'B'	'B'	17.73	15.48	14.19
		RUN #21	'B'	'B'	12.23	9.17	7.01
November		RUN #22	'B'	'B'	9.08	12.02	10.58
		RUN #23	'B'	'B'	12.67	14.36	14.52
		RUN #24	'B'	'B'	33.32	17.92	19.53
		RUN #25	'B'	'B'	'C'	11.58	11.86
		RUN #26	'B'	'B'	25.26	12.20	11.70
	RSD	RUN #27	'B'	'B'	'C' & 'S'	13.00	12.78
		RUN #28	'B'	'B'	'D'	25.62	32.00
		RUN #29	'B'	'B'	23.74	11.83	14.43
	RSD	RUN #30	'B'	'B'	11.18	13.61	14.98

TABLE 2-4. (CONT.) CEMS PM RESULTS

December	RSD	RUN #31	26.41	38.13	43.61	40.73	48.21
		RUN #32	14.14	19.48	17.73	18.48	16.74
	RSD	RUN #33	15.17	19.09	17.34	17.87	16.66
		RUN #34	15.53	21.68	21.26	21.85	21.34
	RSD	RUN #35	16.68	22.07	25.66	25.63	25.41
		RUN #36	16.61	25.86	27.73	27.10	28.83
		RUN #37	19.36	24.93	33.07	31.54	34.06
		RUN #38	19.70	30.73	33.93	32.33	34.35
	RSD	RUN #39	17.38	25.19	27.66	26.68	28.24
January		RUN #40	7.01	10.40	4.25	8.35	7.03
	RSD	RUN #41	5.74	'S'	5.24	7.60	5.73
	RSD	RUN #42	3.18	'S'	'D'	4.95	2.96
		RUN #43	12.92	12.86	15.07	15.83	16.75
		RUN #44	8.47	'S'	9.72	11.95	11.55
		RUN #45	6.33	11.37	5.59	8.43	6.91
		RUN #46	6.70	11.27	7.05	9.59	8.63
		RUN #47	9.14	13.05	13.50	13.81	15.91
		RUN #48	'O'	20.12	24.04	21.48	28.53
		RUN #49	21.33	'S'	32.11	27.64	38.48
February		RUN #50	4.30	8.63	3.35	7.08	4.54
		RUN #51	3.13	5.17	2.05	6.15	3.29
		RUN #52	5.98	9.11	5.41	8.92	6.78
		RUN #53	4.08	7.55	5.33	8.77	6.16
		RUN #54	9.85	13.64	16.77	17.10	17.94
		RUN #55	7.76	12.73	12.71	13.58	12.53
		RUN #56	7.10	11.66	12.88	14.14	12.46
		RUN #57	8.35	13.75	14.75	15.28	13.90
		RUN #58	9.41	14.76	13.28	13.92	13.39
		RUN #59	9.72	13.66	13.15	14.00	13.68
		RUN #60	9.97	15.49	14.01	15.09	14.14
	RSD	RUN #61	7.10	10.20	9.03	11.56	8.95

TABLE 2-4. (CONT.) CEMS PM RESULTS

March		RUN #62	15.77	15.83	'H'	17.43	18.83
		RUN #63	15.74	15.96	'H'	21.63	24.23
		RUN #64	15.81	15.69	'H'	18.56	20.24
		RUN #65	'O'	24.19	'H'	48.53	73.87
		RUN #66	'O'	39.07	'H'	82.25	140.75
		RUN #67	'O'	41.62	'H'	83.04	132.11
		RUN #68	10.16	13.24	'H'	21.20	25.48
		RUN #69	26.41	29.65	'H'	60.00	95.30
		RUN #70	16.77	20.84	'H'	32.08	40.59
		RUN #71	21.18	25.20	'H'	43.05	58.07
		RUN #72	12.98	17.72	'H'	30.51	35.23
		RUN #73	3.95	8.12	'H'	12.45	9.39
April		RUN #74	21.01	22.49	46.18	39.24	47.43
	RSD	RUN #75	22.29	25.35	42.09	36.79	46.10
		RUN #76	21.16	23.56	41.55	36.14	43.27
		RUN #77	25.47	26.23	52.52	44.22	60.73
		RUN #78	7.35	5.86	11.54	11.17	8.00
		RUN #79	5.62	8.15	10.23	10.39	10.14
		RUN #80	9.34	14.07	16.38	15.40	17.86
	RSD	RUN #81	6.61	9.19	12.02	11.35	11.22
		RUN #82	14.03	18.13	26.75	23.57	27.83
		RUN #83	'F'	17.58	23.11	20.68	20.44
		RUN #84	5.24	8.63	10.98	10.42	10.63
		RUN #85	7.93	11.14	13.52	12.37	11.95
		RUN #86	9.56	13.81	17.86	15.87	16.88
		RUN #87	'F'	8.18	10.58	10.11	9.66
		RUN #88	'F'	7.51	9.74	9.26	8.33
		RUN #89	6.47	11.29	14.00	12.55	14.98
		RUN #90	6.78	10.11	14.36	12.54	15.09

TABLE 2-4. (CONT.) CEMS PM RESULTS

May	RUN #91	9.39	'S'	13.87	12.62	13.86
	RUN #92	5.79	'S'	9.92	8.40	'S'
	RUN #93	4.75	'S'	7.44	6.47	'S'
	RUN #94	13.55	13.56	25.81	21.94	25.75
	RUN #95	14.23	13.62	28.87	24.47	27.97
	RUN #96	1.57	2.41	1.48	4.25	2.19
	RUN #97	5.85	6.49	6.46	7.61	6.81
	RUN #98	'F'	8.01	7.65	8.56	8.20
	RUN #99	11.23	11.17	10.27	11.59	13.07
	RUN #100	11.92	11.19	15.19	15.50	19.21
	RUN #101	21.66	20.44	30.60	27.80	36.14
	RUN #102	15.13	14.43	21.74	19.81	24.34

LEGEND

O-Over range
B-Off line due to a mechanical failure
C-Cal Mode
D-Zero Mode
M-Maintenance / Failure
F-Disconnected sample line
S-Servicing
E-Change in velocity unable to sample at iso
H-Excessive span check values

TABLE 2-5. RESULTS OF LINEAR CALIBRATION RELATION

CEM	CALIBRATION SERIES		Proposed Emission Limits	PERFORMANCE CRITERIA	Correlation Coefficient	Confidence Interval	Tolerance Interval	
			mg/dscm @7% O2 (mg/Acm)	Revised PS 11	> 0.90	< 10 %	< 25 %	
ESA	Initial Calibration							
			max of cal. (20.97)		0.927	9.4%	15.8%	
			limit_50 (18.65)			8.8%	17.1%	
	slope =	0.824	limit_34 (12.68)			7.3%	23.7%	
	Second Calibration							
			max of cal. (20.48)		0.985	7.1%	11.0%	
			limit_50 (18.1)			6.6%	11.7%	
	slope =	0.766	limit_34 (12.31)			5.7%	15.5%	
			mg/dscm @7% O2 (mg/dscm)					
VEREWA	Initial Calibration							
			limit_69 (46)			6.1%	10.6%	
			limit_50 (33.33)		0.968	5.3%	13.9%	
	slope =	1.343	limit_34 (22.67)			5.1%	20.0%	
	Second Calibration							
			max of cal. (34.92)		0.961	9.8%	15.7%	
			limit_50 (33.33)			9.6%	16.4%	
	slope =	1.430	limit_34 (22.67)			8.0%	21.7%	
			mg/dscm @7% O2 (mg/Acm)					
DURAG	Initial Calibration							
			max of cal. (15.5)		0.952	8.2%	14.4%	
	slope =	0.421	limit_34 (12.44)			7.2%	17.2%	
	Second Calibration							
			max of cal. (20.7)		0.972	8.7%	13.3%	
			limit_50 (18.1)			8.1%	13.8%	
	slope =	0.366	limit_34 (12.31)			6.9%	18.8%	
ESC	Initial Calibration							
			limit_69 (25.73)		0.966	6.1%	11.1%	
			limit_50 (18.65)			5.3%	14.7%	
	slope =	0.357	limit_34 (12.68)			5.2%	21.2%	
	Second Calibration							
			max of cal. (20.59)		0.978	7.8%	12.0%	
			limit_50 (18.1)			7.3%	12.4%	
	slope =	0.448	limit_34 (12.31)			6.2%	16.9%	
SIGRIST	Initial Calibration							
			limit_69 (25.73)		0.936	8.5%	15.3%	
			limit_50 (18.65)			7.4%	19.9%	
	slope =	0.199	limit_34 (12.68)			7.1%	28.7%	A
	Second Calibration							
			max of cal. (21.52)		0.951	12.0% A	17.0%	
			limit_50 (18.1)			10.9% A	18.2%	
	slope =	0.313	limit_34 (12.31)			9.2%	24.9%	

LEGEND
A-Above performance specification criteria
Max of Cal. - PM Concentration Predicted by the Calibration Relation and the Maximum CEMS value

TABLE 2-6. CALIBRATION RANGE EFFECTS ON LINEAR REGRESSIONS

CEMS	Slopes of Linear Regression				Percent Difference in Slopes			
	A	B	C	D	A/B	C/D	A/D	B/C
ESA	0.824	0.766	0.740	0.793	3.6%	3.5%	1.9%	1.7%
VEREWA	1.343	1.430	1.151	1.307	3.1%	6.3%	1.4%	10.8%
ESC	0.357	0.448	0.536	0.343	11.3%	21.9%	2.1%	8.9%
SIGRIST	0.199	0.313	0.389	0.193	22.2%	33.7%	1.6%	10.8%

LEGEND

A-Initial Calibration Original (December - March)
B-Calibration 2 Original (April)
C-Initial Calibration Rearranged (December - February)
D-Calibration 2 Rearranged (April + March)

Percent Difference: $[x_i - x_{ave}] / x_{ave}$

ESA was out of range 25% of March
This table does not apply to the DURAG.
Excessive DURAG span check values in March produced unacceptable data during the entire March series.

TABLE 2-7. RESULTS OF ESC AND SIGRIST LOGARITHMIC CALIBRATION RELATIONS

CEM	CALIBRATION SERIES	Proposed Emission Limits	PERFORMANCE CRITERIA			
			Correlation Coefficient	Confidence Interval	Tolerance Interval	
		mg/dscm @7% O2 (mg/Acm)	Revised PS 11	> 0.90	< 10 %	< 25 %	
ESC	Initial Cal. (Dec-March)						
		max of cal. (25.63)		0.966	6.0%	11.1%	
		limit_50 (18.65)			5.3%	14.6%	
	slope = 23.76	limit_34 (12.68)			5.2%	21.0%	
	Cal. 2 (April)						
		max of cal. (19.11)		0.982	6.6%	10.8%	
		limit_50 (18.1)			6.4%	11.0%	
	slope = 22.85	limit_34 (12.31)			5.5%	15.1%	
SIGRIST	Initial Cal. (Dec-March)						
		max of cal. (25)		0.948	7.5%	14.0%	
		limit_50 (18.65)			6.6%	18.0%	
	slope = 17.04	limit_34 (12.68)			6.4%	25.9%	A
	Cal. 2 (April)						
		max of cal. (18.97)		0.942	12.3% A	19.5%	
		limit_50 (18.1)			11.9% A	20.5%	
	slope = 17.89	limit_34 (12.31)			10.0%	27.0%	A

LEGEND

A-Above performance specification criteria
Max of Cal. - PM Concentration Predicted by the Calibration Relation and the Maximum CEMS value

TABLE 2-8. SUMMARY OF RCA EVALUATIONS RESULTS

		Tolerance Interval Fractions / Percentages @ Proposed Emission Limits								
LINEAR FIT	RCA Evaluations	25% @69mg/dscm or 25% max of cal.			25% @50mg/dscm or 25% max of cal.			25% @34mg/dscm		
ESA	A	24/24	100%	D	24/24	100%		24/24	100 %	
	B	36/37	97%	D	36/37	97%		32/37	86%	
VEREWA	A	29/30	97%		26/30	87%		20/30	67%	E
	B	42/44	95%	D	42/44	95%		34/44	77%	
DURAG	A	F	F		35/37	95%	D	33/37	89%	
	C	40/43	93%	D	40/43	93%		38/43	88%	

		Tolerance Interval Fractions / Percentages @ Proposed Emission Limits								
LOGARITHMIC FIT	RCA Evaluations	25% @69mg/dscm or 25% max of cal.			25% @50mg/dscm			25% @34mg/dscm		
ESC	A	42/48	88%	D	40/48	83%		36/48	75%	
	B	48/54	89%	D	48/54	89%		44/54	81%	
SIGRIST	A	42/47	89%	D	42/47	89%		36/47	77%	
	B	48/54	89%	D	48/54	89%		44/54	81%	

LEGEND

A-September through November, April and May RCA Evaluation on the Initial Calibration (December through March)
B-September through November, December through March and May RCA Evaluation on the Second Calibration (April)
C-September through November, December through February and May RCA Evaluation on the Second Calibration (April)

D-Calibration Range did not reach Proposed Limit, Instead Evaluated at 25% of Maximum of the Calibration
E-Did not meet 75% Criteria
F-Proposed Emission limit not evaluated because of range limitations

All PM Concentrations Corrected to 7 % O2

TABLE 2-9. SUMMARY OF CUMULATIVE CALIBRATION RESULTS

CEM	CALIBRATION SERIES	Proposed Emission Limits	PERFORMANCE CRITERIA			
				Correlation Coefficient	Confidence Interval	Tolerance Interval
		mg/dscm @7% O2 (mg/Acm)	Revised PS 11	> 0.90	< 10 %	< 25 %
ESA	Cumulative (Dec-May)					
		max of cal. (20.74)		0.944	5.9%	11.8%
	slope = 0.783	limit_50 (18.51)			5.5%	13.0%
		limit_34 (12.58)			4.5%	18.5%
		mg/dscm @7% O2 (mg/dscm)				
VEREWA	Cumulative (Dec-May)					
		limit_69 (46)		0.939	6.4%	11.8%
	slope = 1.265	limit_50 (33.33)			5.5%	15.5%
		limit_34 (22.67)			4.8%	22.4%
		mg/dscm @7% O2 (mg/Acm)				
DURAG	Cumulative (Dec,Jan,Feb,April,May)					
		max of cal. (21.63)		0.945	6.5%	10.4%
	slope = 0.376	limit_50 (18.27)			5.9%	11.9%
		limit_34 (12.42)			4.8%	16.8%
ESC	Cumulative (Dec-May)					
		max of cal. (24.4)		0.945	5.7%	11.7%
	slope = 21.17	limit_50 (18.51)			5.0%	14.9%
		limit_34 (12.58)			4.5%	21.6%
SIGRIST	Cumulative (Dec-May)					
		max of cal. (24.07)		0.929	6.6%	13.7%
	slope = 15.88	limit_50 (18.51)			5.8%	17.2%
		limit_34 (12.58)			5.2%	24.9%

LEGEND
Max of Cal. - PM Concentration Predicted by the Calibration Relation and the Maximum CEMS value

TABLE 2-10. SEM / EDS ANALYTICAL RESULTS OF FILTERS

Test ID	Na	Al	Si	P	S	Cl	K	Ca	Fe	% Su
TA-23	33.98	2.54	9.02		3.44	36.63	4.76	9.60		99.97
TB-23	37.37	1.06	3.96		3.55	42.21	6.06	5.79		100
TA-24	38.87	1.45	3.06	1.18	4.07	40.76	5.22	3.03	2.36	100
TA-25	34.33	1.54	2.16		8.88	37.18	13.85	2.06		100
TB-25	36.43	1.76	2.71		7.95	34.71	13.90	2.52		99.98
	33.65	0.99	2.76		8.35	36.80	14.88	2.57		100
	33.5	1.38	2.60		8.77	36.66	14.49	2.60		100
SD	1.7	0.4	0.1		0.4	1.2	0.5	0.0		
TA-28	33.82	1.44	5.75		4.12	48.39	5.35	1.13		100
	33.01	1.73	4.72		4.26	49.21	5.75	1.32		100
	33.98	2.05	5.46		3.96	47.95	4.89	1.71		100
	34.74	1.66	4.86		3.97	48.60	5.10	1.06		99.99
	34.39	1.38	4.93		4.38	48.49	5.27	1.18		100
SD	0.7	0.3	0.4		0.2	0.5	0.3	0.3		
TB-28	33.13		6.41		3.57	51.40	5.49			100
TA-30	42.14		5.53		6.85	36.47	5.41	3.61		100
	34.82	3.18	13.93		5.57	26.84	3.86	11.8		100
	39.18		6.2		7.82	35.73	5.28	5.78		99.99
SD	3.7		4.7		1.1	5.4	0.9	4.2		

TABLE 2-11. TRIAL BURN METHOD 5 RESULTS SUMMARY

(Trial Burn, Sept. 12-15, 1996)

Proposed Emission Limit : 69 (mg/dscm @7% O2) 33.68 (mg/ACM)

	sampling time (min)	gas volume (dscm)	% O2	Percent H2O	Stack Temp. (F)	isokinetic	stack velocity (m/s)	filter gain (mg)	probe rinse (mg)	PM level (mg/dscm)	probe rinse/total	DURAG (arbitrary units)	ESC (arbitrary units)	mg/Acm
1	120	3.067	11.4	28.5	323	100.9	12.0	46.4	9.6	18.26	17.1%	17.67	11.25	8.80
2	120	3.083	11.0	29.0	323	101.5	12.2	39.5	5.5	14.60	12.2%	17.12	9.24	6.99
3	120	3.108	12.5	29.3	323	101.7	12.3	47.5	10.9	18.79	18.7%	21.12	11.71	8.96
4	120	3.122	12.1	26.6	323	100.7	12.0	56.8	10.2	21.46	15.2%	19.65	14.19	10.62
5	120	1.998	11.9	25.2	325	98.5	11.5	33.9	6.9	20.42	16.9%	22.67	15.04	10.27
6	120	2.083	12.3	26.8	324	100.3	11.9	42.6	9.7	25.11	18.5%	29.66	20.62	12.38

Note: Absolute Stack Pressure is assumed 29.92

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TABLE 2-12. PM CEMS DATA DURING TRIAL BURN

DATE	RUN #	CEM ID	AVERAGE MGM
9/12/96	1	DURAG	17.67
		ESA	Data suspect
		ESCP5	11.25
		SIGRIST	No data
		VEREWA	Data suspect
9/13/96	2	DURAG	17.12
		ESA	Data suspect
		ESCP5	9.24
		SIGRIST	No data
		VEREWA	Data suspect
9/13/96	3	DURAG	21.12
		ESA	Data suspect
		ESCP5	11.71
		SIGRIST	No data
		VEREWA	Data suspect
9/14/96	4	DURAG	19.65
		ESA	Data suspect
		ESCP5	14.19
		SIGRIST	No data
		VEREWA	Data suspect
9/15/96	5	DURAG	22.67
		ESA	Data suspect
		ESCP5	15.04
		SIGRIST	No data
		VEREWA	Data suspect
9/15/96	6	DURAG	29.66
		ESA	Data suspect
		ESCP5	20.62
		SIGRIST	No data
		VEREWA	Data suspect

		Tolerance Interval Fractions / Percentages @ Proposed Emission Limits					
LINEAR FIT	RCA Evaluations	25% @69mg/dscm or 25% max of cal.			25% @50mg/dscm or 25% max of cal.		25% @34mg/dscm
DURAG	A	6/6	100%	C	6/6	100%	6/6 100%

		Tolerance Interval Fractions / Percentages @ Proposed Emission Limits					
LOGARITHMIC FIT	RCA Evaluations	25% @69mg/dscm or 25% max of cal.			25% @50mg/dscm		25% @34mg/dscm
ESC	B	6/6	100%	C	6/6	100%	6/6 100%

LEGEND

A-September 1996 Trial Burn RCA Evaluation on the Cumulative Calibration (Dec,Jan,Feb,April,May)
B-September 1996 Trial Burn RCA Evaluation on the Cumulative Calibration (Dec-May)
C-Calibration Range did not reach proposed limit, instead evaluated at 25% of maximum of the calibration

TABLE 2-14. SUMMARY OF PARTICLE SIZE RESULTS

PSD Data				M 5 Data				
Run #	Date	Time	PM Concentration mg/dscm	Run #	Date	Time	PM Concentration mg/dscm	PSD Conc. / %M 5 Conc.
1	5/20/97	13:30-16:00	4.81	92	5/20/97	13:50-14:55	10.49	46%
2	5/21/97	13:55-16:10	15.1	94	5/21/97	13:51-14:59	18.92	80%
3	5/22/97	10:10-12:40	3.43	96	5/22/97	09:35-11:18	4.47	77%
4	5/22/97	14:15-17:15	4.58	97	5/22/97	14:04-15:12	9.54	48%
				98	5/22/97	16:07-17:22	10.52	43%
5	5/23/97	08:30-10:30	8.47	99	5/23/97	07:53-09:00	14.75	57%
				100	5/23/97	09:43-10:52	17.31	49%
6	5/23/97	12:45-14:45	16.5	101	5/23/97	12:03-13:15	30.60	54%
				102	5/23/97	13:59-15:17	21.80	76%
								Average = 58.8%

Particle Size Run #		Particulate Matter and Monitor: Run #		% < 1 micron		% < 2 micron	
1		92	93	64%		70%	
2		94	-	77%		89%	
3		96	-	65%		72%	
4		97	98	79%		87%	
5		99	100	81%		91%	
6		101	102	84%		95%	

TABLE 2-15. ROLLINS METHOD 5 SUMMARY

Particulate Train 1														
		Run 1	Run 2	Run 3	Run 4	Run 5	Run 6	Run 7	Run 8	Run 9	Run 10	Run 11	Run 12	Run 13
Flue Gas Parameters														
Temp.	F	84	82.3	76.6	68.7	72.4	71.9	74.3	75.3	72.5	86.2	83.3	85	87.2
Pressure	in. Hg	29.86	29.76	29.81	29.04	28.89	28.89	28.94	28.94	28.94	29.69	29.69	29.6	29.6
O2	%vd	7.1	7.7	7.4	14.3	12.3	14.9	14.3	13.5	14.3	7	7.2	7.7	7.2
CO2	%vd	12.5	12.1	12.3	6.9	6.5	5.2	7.5	7.4	5.7	13.6	12.9	14.3	14
Moisture	%v	4.20%	3.80%	5.30%	1.90%	2.50%	2.30%	2.30%	2.40%	2.20%	3.10%	2.70%	3.10%	2.90%
Velocity	ft./s	29.3	29.5	26.1	28.9	33	32.8	29.1	28.4	31.6	34.8	38.9	34.5	34
Flowrate	dscf/min.	1282.8	1296.3	1131.9	1295.1	1454.0	1449.2	1280.0	1246.5	1398.9	1523.8	1719.0	1510.6	1482.0
Sample Train Parameters														
Date		1-Mar-95	1-Mar-95	1-Mar-95	2-Mar-95	4-Mar-95	4-Mar-95	3-Mar-95	3-Mar-95	3-Mar-95	22-Mar-95	22-Mar-95	23-Mar-95	23-Mar-95
Start Time	-	16:37	19:48	22:44	15:45	9:15	13:55	9:11	14:27	19:38	8:12	16:05	8:23	13:50
End Time	-	18:26	20:53	23:55	19:00	12:39	17:05	13:24	18:45	23:45	14:24	22:11	12:45	18:04
Isokinetic Rate	%	99.3	100.7	102.3	100.8	97.9	96.8	95.2	99.6	93.9	99.9	99.5	97.9	100.1
Particulate	mg/dscm at 20 C	17.3	19.5	36.42	2.3	3.3	0.8	1.07	0.86	0.92	0.52	0.53	0.86	0.57
	mg/Acm	16.05	18.17	33.81	2.19	3.08	0.75	1.00	0.80	0.86	0.48	0.50	0.80	0.53

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TABLE 2-15 (CONT.). ROLLINS METHOD 5 SUMMARY

Particulate Train 2														
		Run 1	Run 2	Run 3	Run 4	Run 5	Run 6	Run 7	Run 8	Run 9	Run 10	Run 11	Run 12	Run 13
Flue Gas Parameters														
Temp.	F	83.6	81	76.1	70.1	73.9	73.2	76	77	72	79.5	82.2	84.8	87.1
Pressure	in. Hg	29.86	29.76	29.81	29.04	28.89	28.89	28.94	28.94	28.94	29.69	29.69	29.6	29.6
O2	%vd	7.1	7.7	7.4	14.3	12.3	14.9	14.3	13.5	14.3	7	7.2	7.7	7.3
CO2	%vd	12.5	12.1	12.3	6.9	6.5	5.2	7.5	7.4	5.7	13.6	12.9	14.3	14
Moisture	%v	4.40%	3.80%	4.20%	1.90%	2.30%	2.50%	2.30%	2.60%	2.20%	3.00%	2.70%	3.00%	3.10%
Velocity	ft./s	28.4	28.8	26.4	27.4	32	32.5	29.5	31.1	29.5	34.3	38.7	33.8	33.2
Flowrate	dscf/min.	1241.7	1265.4	1170.5	1225.2	1405.0	1426.0	1293.2	1354.8	1306.5	1524.1	1715.7	1478.9	1448.8
Sample Train Parameters														
Date		1-Mar-95	1-Mar-95	1-Mar-95	2-Mar-95	4-Mar-95	4-Mar-95	3-Mar-95	3-Mar-95	3-Mar-95	22-Mar-95	22-Mar-95	23-Mar-95	23-Mar-95
Start Time	-	16:37	19:49	22:45	15:45	9:34	13:56	9:11	14:27	19:38	8:12	16:07	8:37	13:52
End Time	-	18:26	20:54	23:56	19:00	12:39	17:06	13:24	18:45	23:45	14:23	22:10	12:45	18:05
Isokinetic Rate	%	101.6	100.5	101.4	105.5	104.1	99.4	97.8	92.9	100.3	100.1	99.5	100	100.3
Particulate	mg/dscm at 20 C	18.61	17.34	26.94	2.11	2.11	1.58	0.61	1.06	0.97	1.06	0.58	0.74	0.49
	mg/Acm	17.25	16.19	25.33	2.00	1.97	1.47	0.57	0.98	0.91	1.00	0.55	0.69	0.45
WESP Condition		OFF	OFF	OFF	LOW	LOW	LOW	HIGH	HIGH	HIGH	HIGH	HIGH	LOW	LOW

TABLE 2-16. ROLLINS CEMS SUMMARY

Run #	Mth 5: ave mg/Acm	RM200 Arbitrary Units	CPM1000 Arbitrary Units
1	16.65	58.94	22.22
2	17.18	46.33	31.99
3	29.57	57.79	A
4	2.09	3.50	1.44
5	2.52	2.92	4.18
6	1.11	2.03	3.48
7	0.78	1.51	2.72
8	0.89	1.77	1.79
9	0.89	1.52	2.15
10	0.74	1.58	2.11
11	0.52	B	B
12	0.74	2.94	2.02
13	0.49	2.97	2.02

LEGEND

A-Out of Range
B-Incomplete Data

TABLE 2-17 ROLLINS AND LAFARGE CALIBRATION RELATION RESULTS

Rollins

CEM	Revised PS 11	Correlation Coefficient > 0.90	Confidence Interval << 10 %	Tolerance Interval < 25 %
RM200	Cal. 1	0.953	18.5% A	A A
CPM1000	Cal. 1	0.976	14.2% A	A

Lafarge

CEM	Revised PS 11	Correlation Coefficient > 0.90	Confidence Interval < 10 %	Tolerance Interval < 25 %	Tolerance Interval Fractions / Percentages @ Proposed Emission Limits					
					25% @69mg/dscm		25% @50mg/dscm		25% @34mg/dscm	
P5A	Cal. Relation	0.792 A	16.6%	36.5% A	5/8	63%	3/8	38%	2/8	25%
	RCA									
RM200	Cal. Relation	0.512 A	30.2% A	54.9% A	0/0	#N/A	0/0	#N/A	0/0	#N/A
	RCA									

LEGEND

A-Above Performance Specification Criteria

TABLE 2-18. LAFARGE METHOD 5 SUMMARY

Calibration										
		1-1-B	1-2-B	1-3-B	1-4-B	1-5-B	1-6-B	1-7-B	1-8-B	1-9-B
Flue Gas Parameters										
Temp.	F	334	347	338	350	350	354	342	327	336
O2	%vd	7	7	7	11	11	12	12	12	12
Moisture	%v	0.307	0.33	0.34	0.3	0.34	0.35	0.29	0.29	0.31
Velocity	ft./s	39.9	40.1	40.2	39.1	39.8	39.6	40.3	40	40.1
Sample Train Parameters										
Date		3-May-95	3-May-95	3-May-95	4-May-95	4-May-95	4-May-95	5-May-95	7-May-95	7-May-95
Start Time	-	8:00	11:30	14:48	7:44	10:58	15:31	7:52	10:57	14:13
End Time	-	10:48	13:36	16:51	9:39	13:45	17:12	10:43	12:53	15:58
Particulate	mg/dscm at 20 C	75.9	48.9	74.9	50.8	27.3	35.7	27.4	34.2	30.3
	mg/Acm	34.60	20.85	31.81	22.53	11.42	14.63	12.58	16.00	13.62
ESP Condition		LOW	LOW	LOW	MID	MID	MID	HIGH	HIGH	HIGH

		2-1-A	2-2-A	2-3-A	2-7-A	2-8-A	2-9-A	2-4-A	2-5-A	2-6-A
Flue Gas Parameters										
Temp.	F	354	371	366	345	363	345	354	347	362
O2	%vd	8	8	8	11	11	11	11	11	11
Moisture	%v	0.372	0.361	0.352	0.364	0.338	0.343	0.333	0.352	0.291
Velocity	ft./s	37.4	37.1	37	35.6	36.9	39	36.6	35.6	35.2
Sample Train Parameters										
Date		12-Jun-95	12-Jun-95	12-Jun-95	13-Jun-95	13-Jun-95	13-Jun-95	14-Jun-95	14-Jun-95	14-Jun-95
Start Time	-	8:01	10:17	13:18	8:06	10:21	13:01	8:03	10:26	13:24
End Time	-	9:52	12:44	15:07	9:57	12:13	15:29	9:55	12:20	15:17
Particulate	mg/dscm at 20 C	22	17.5	30.6	36.7	43.2	44.9	28.9	26.2	21.6
	mg/Acm	8.84	7.01	12.50	15.04	18.03	19.01	12.33	10.95	9.70
ESP Condition		HIGH	HIGH	HIGH	LOW	LOW	LOW	MID	MID	MID

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TABLE 2-18 (CONT.). LAFARGE METHOD 5 SUMMARY

RCA										
Train A										
		3-1	3-2	3-3	3-4	3-5	3-6	3-7	3-8	3-9
Flue Gas Parameters										
Temp.	F	342	342	342	335	331	344	344	345	345
O2	%vd	7	7	7	7	7	7	7	7	7
Moisture	%v	0.28	0.30	0.31	0.29	0.30	0.30	0.30	0.31	0.31
Velocity	ft./s	43.8	45.3	42.6	44.3	45.3	45.2	44.6	45.3	44.9
Sample Train Parameters										
Date		18-Jul-95	18-Jul-95	18-Jul-95	19-Jul-95	19-Jul-95	19-Jul-95	19-Jul-95	19-Jul-95	19-Jul-95
Start Time	-	14:37	17:30	9:58	9:51	12:05	14:24	17:30	19:46	23:00
End Time	-	16:37	19:25	21:48	11:34	13:38	16:08	19:04	22:11	24:33
Particulate	mg/dscm at 20 C	28.53	31.79	25.89	32.38	40.83	34.83	31.15	37.54	33.63
	mg/Acm	12.92	14.30	11.58	15.19	18.95	16.00	14.26	17.09	15.23

Train B										
		3-1	3-2	3-3	3-4	3-5	3-6	3-7	3-8	3-9
Flue Gas Parameters										
Temp.	F	343	341	341	343	339	344	342	343	342
O2	%vd	7	7	7	7	7	7	7	7	7
Moisture	%v	0.30	0.31	0.31	0.31	0.31	0.32	0.31	0.32	0.31
Velocity	ft./s	43.6	43.6	45.6	43.2	45.7	44.3	45.1	45.2	45.2
Sample Train Parameters										
Date		18-Jul-95	18-Jul-95	18-Jul-95	19-Jul-95	19-Jul-95	19-Jul-95	19-Jul-95	19-Jul-95	19-Jul-95
Start Time	-	14:42	17:31	20:39	9:53	12:05	14:24	17:30	19:42	22:57
End Time	-	16:53	19:25	22:31	11:33	13:43	16:09	19:06	22:06	24:24
Particulate	mg/dscm at 20 C	27.69	27.92	25.64	36.50	37.12	37.04	29.02	36.85	31.59
	mg/Acm	13.16	12.85	11.62	16.28	16.63	16.37	12.91	16.36	14.23

ESP Condition		HIGH	HIGH	HIGH	LOW	LOW	LOW	MID	MID	MID

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TABLE 2-19. LAFARGE CEMS SUMMARY

	Run #	Mth 5: ave mg/Acm	RM200 Arbitrary Units	P5A Arbitrary Units
Cal. 1	1-1	34.6	3.95	4.61
	1-2	20.8	3.81	4.22
	1-3	31.8	3.97	4.53
	1-4	22.5	3.38	3.83
	1-5	11.4	3.15	3.59
	1-6	14.6	3.26	3.84
	1-7	12.6	2.40	2.53
	1-8	16.0	2.58	2.96
	1-9	13.6	2.82	3.39
Cal. 2	2-1	8.8	2.46	2.62
	2-2	7.0	2.09	2.46
	2-7	15.0	4.76	4.17
	2-8	18.0	4.59	4.12
	2-9	19.0	4.68	4.25
	2-4	12.3	3.40	3.22
	2-5	11.0	3.42	3.28
	2-6	9.7	3.44	3.35
Cal. 3	3-1	13.0	1.59	2.46
	3-2	13.6	1.64	2.60
	3-3	11.6	1.60	2.51
	3-4	15.7	1.80	3.24
	3-5	17.8	1.81	3.37
	3-6	16.2	1.83	3.52
	3-7	13.6	2.02	4.45
	3-8	16.7	2.06	4.63
	3-9	14.7	1.95	4.23

TABLE 2-20. PM CEMS COST ESTIMATE SUMMARY
(All costs in thousands of dollars)

PM CEMS Technology with sampling and analysis characteristics	Monitor Costs ($)	Total Capital Cost ($)	Total Annual Cost ($/year)	Total Annualized Cost ($/year)
Beta-gauge CEMS with heated extractive sampling and external analysis	46	125	24	42
In-situ light-scattering CEMS	13	120	13	30
Extractive light-scattering CEMS heated with external analysis	66	175	21	46

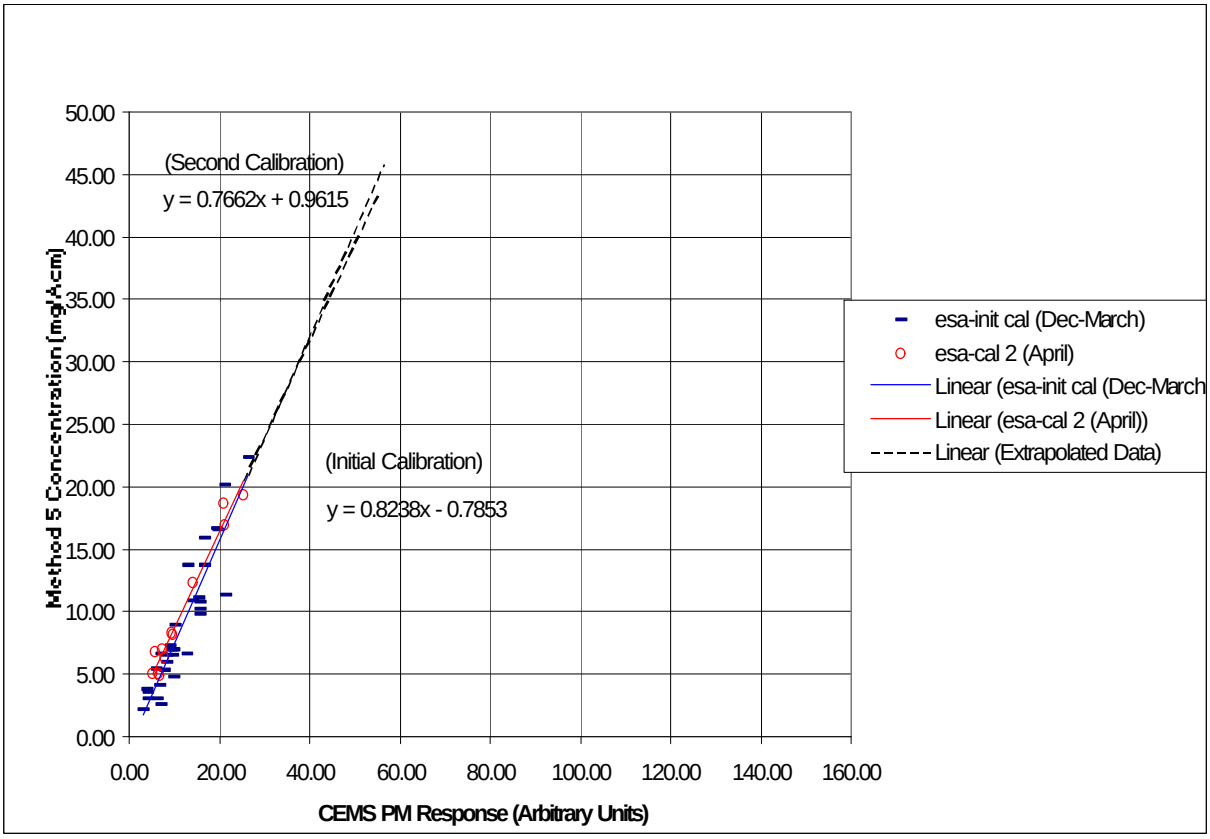


Figure 2-1. Comparison of ESA Linear Calibration Relations

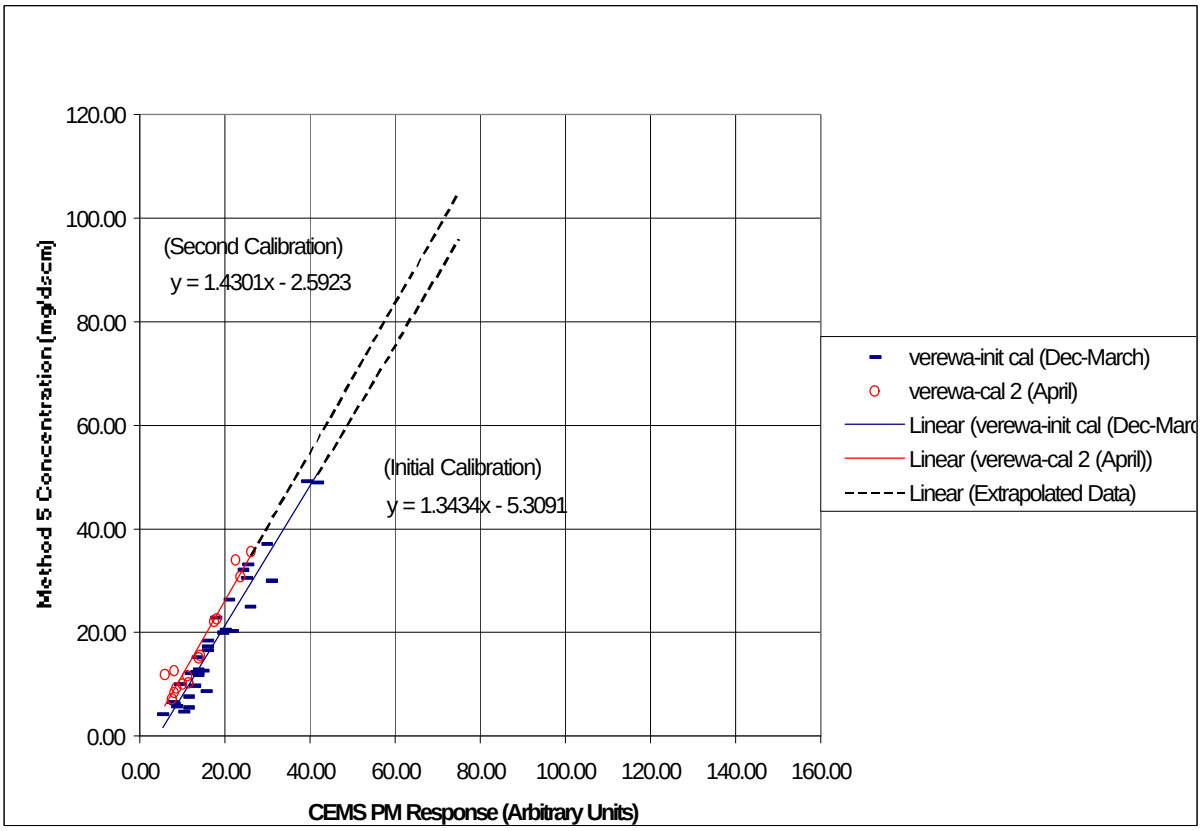


Figure 2-2. Comparison of Verewa Linear Calibration Relations

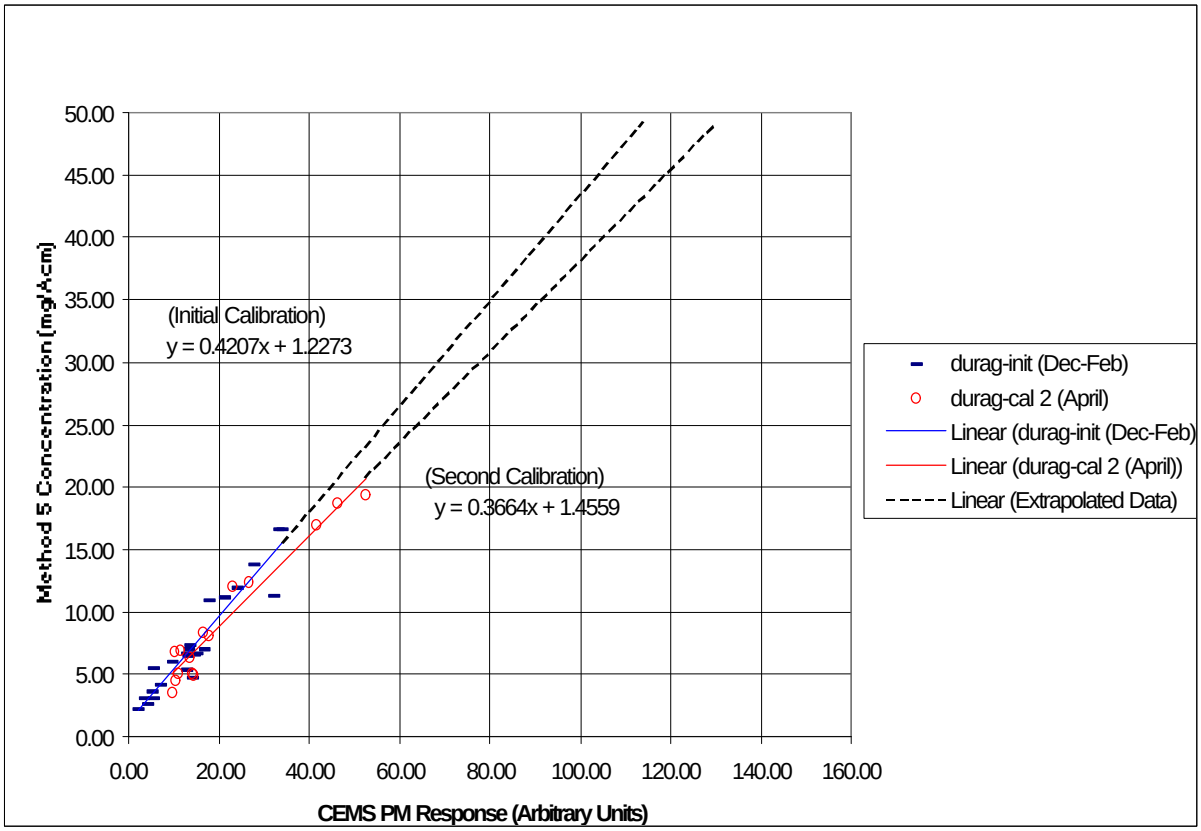


Figure 2-3. Comparison of Durag Linear Calibration Relations

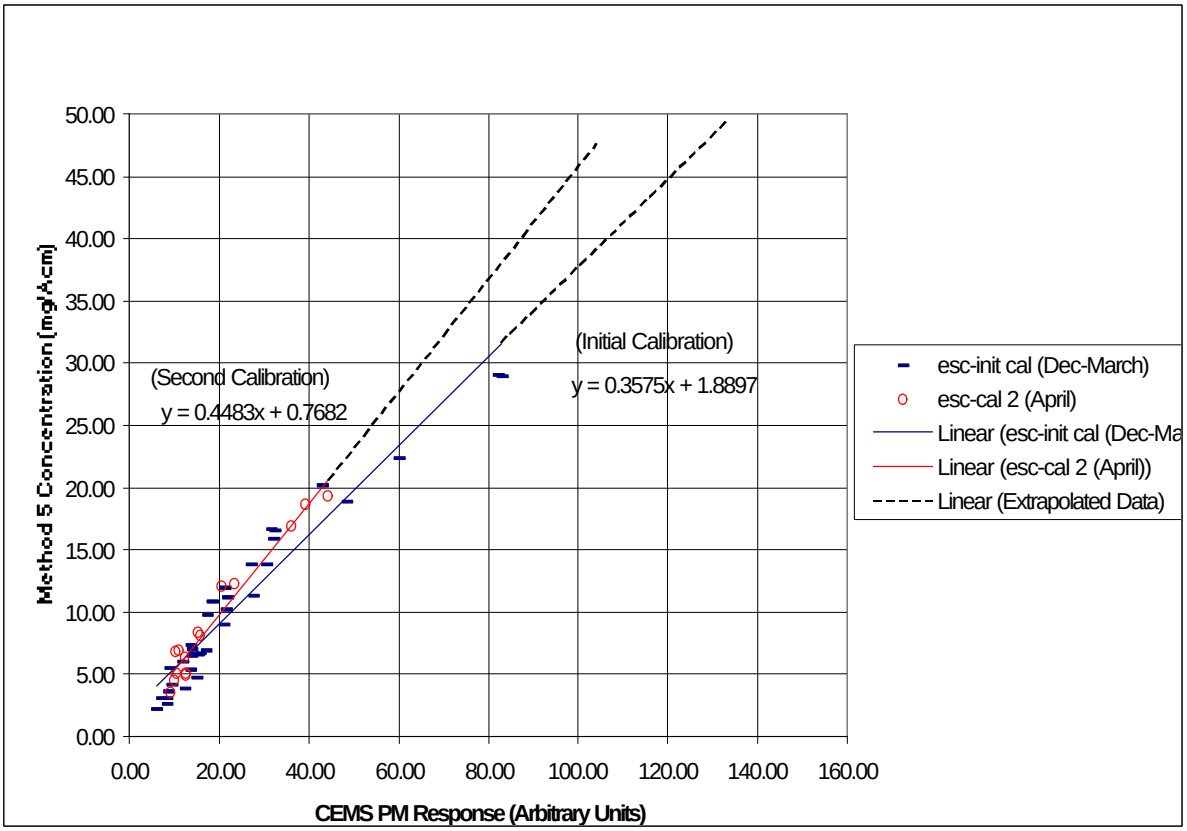


Figure 2-4. Comparison of ESC Linear Calibration Relations

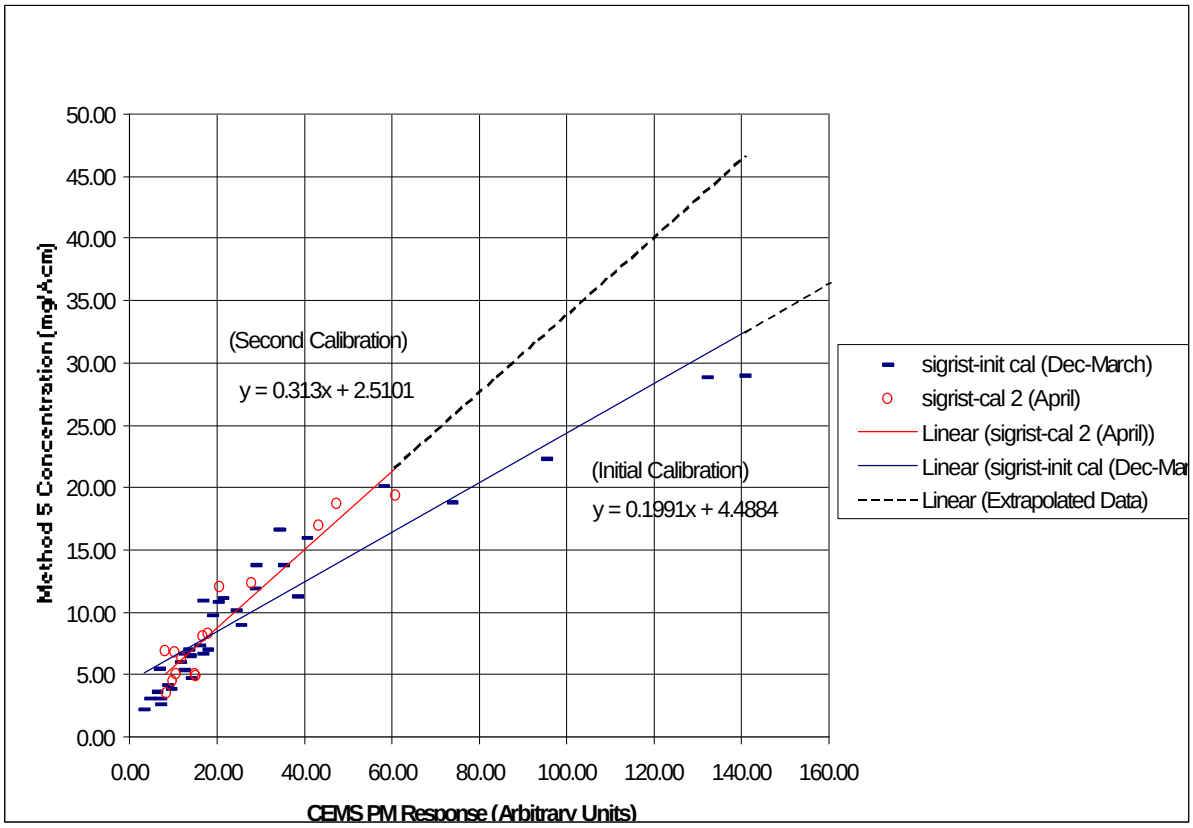


Figure 2-5. Comparison of Sigrist Linear Calibration Relations

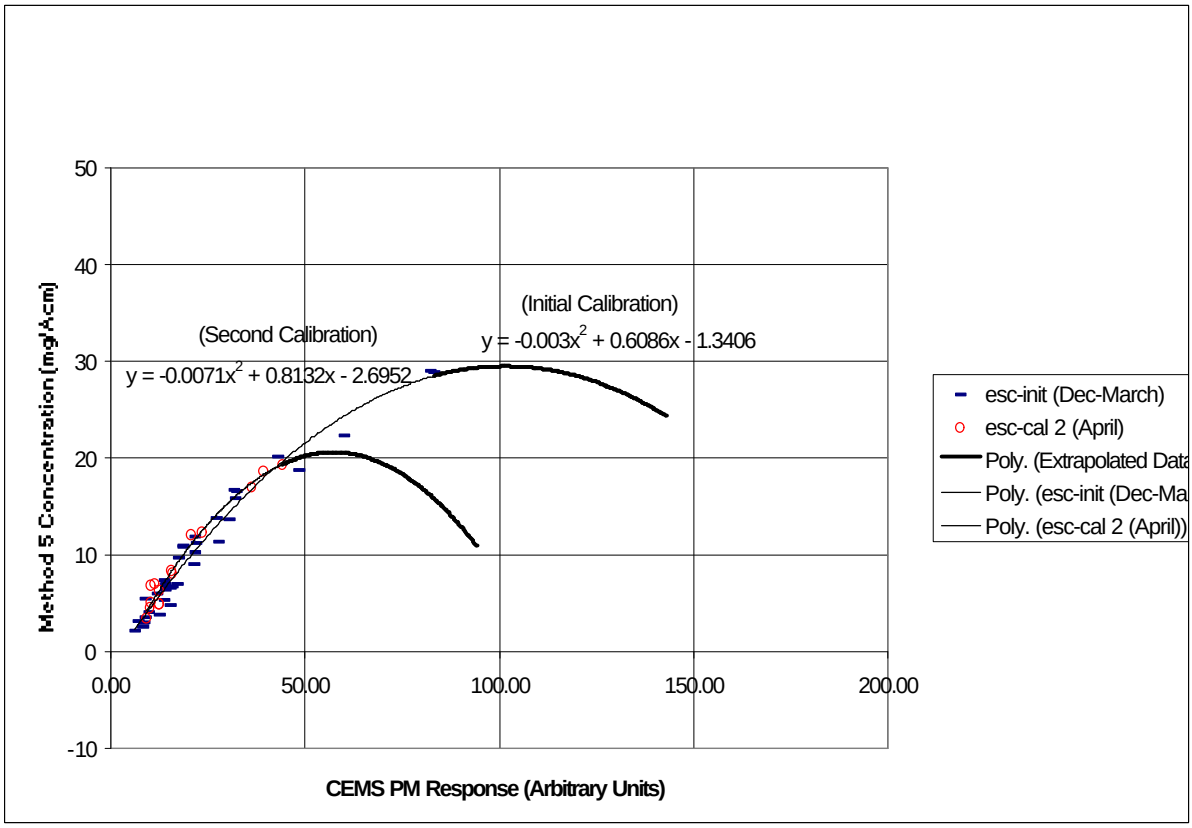


Figure 2-6. Comparison of ESC Quadratic Calibration Relations

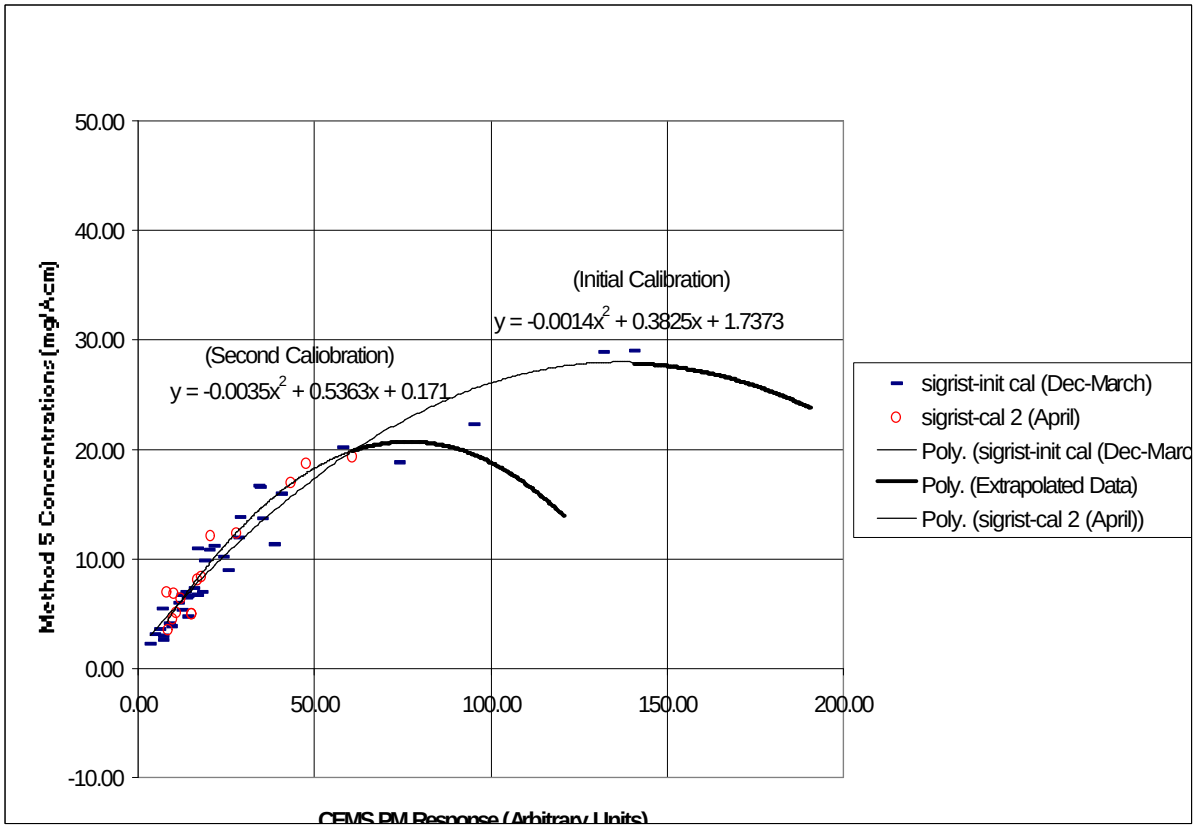


Figure 2-7. Comparison of Sigrist Quadratic Calibration Relations

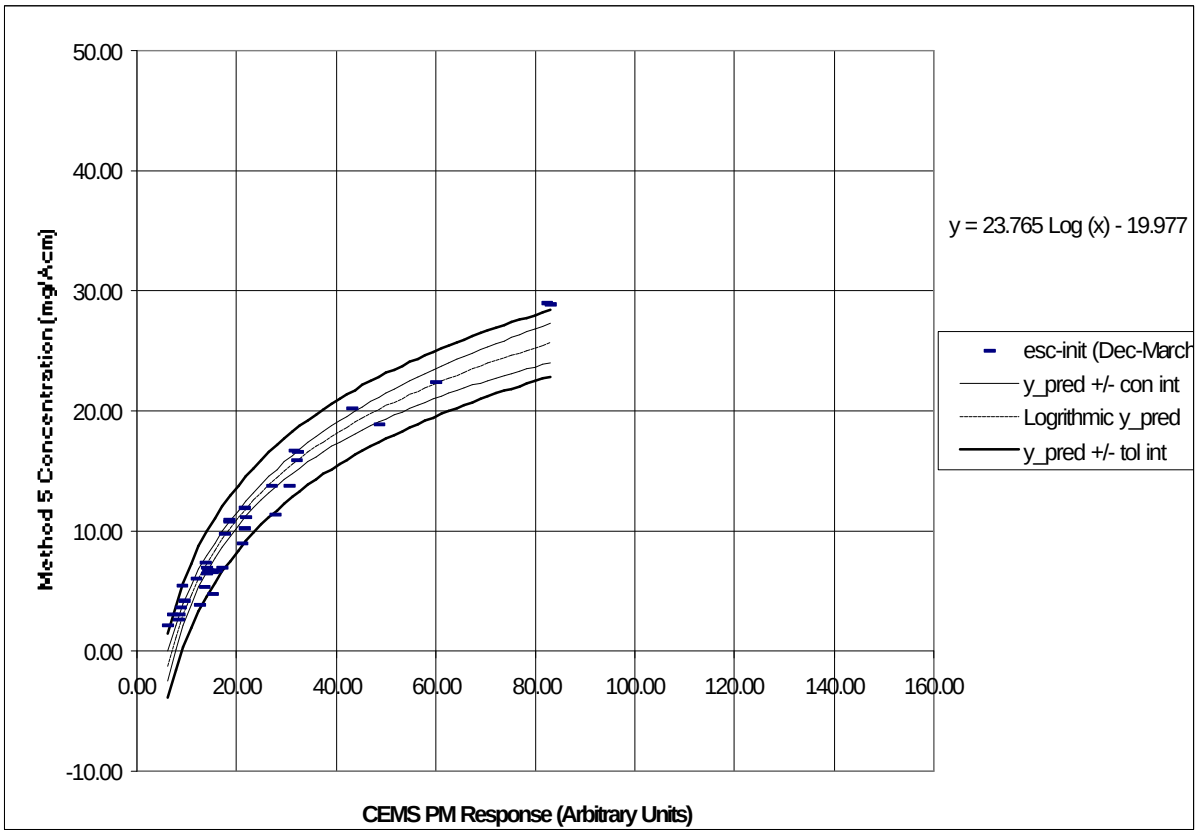


Figure 2-8. Statistical Evaluation of ESC Logarithmic Relation for Initial Calibration

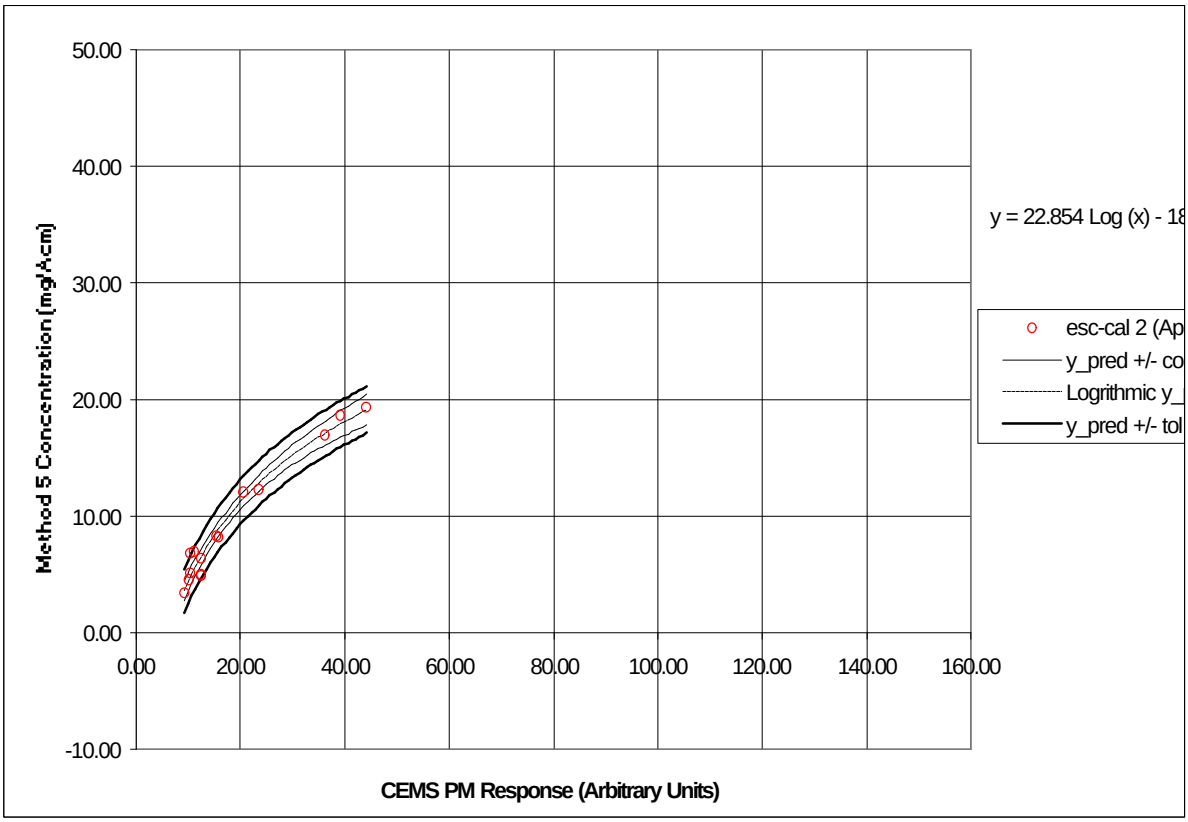


Figure 2-9. Statistical Evaluation of ESC Logarithmic Relation for Second Calibration

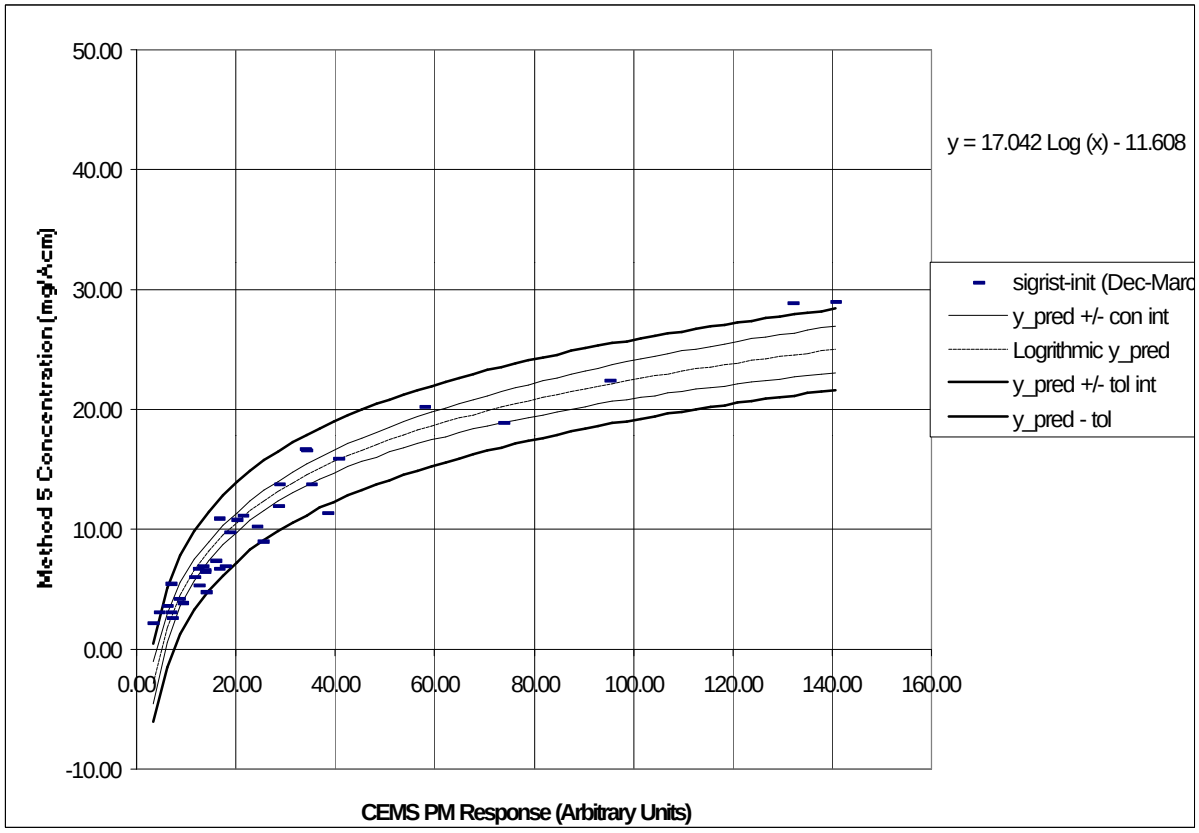


Figure 2-10. Statistical Evaluation of Sigrist Logarithmic Relation for Initial Calibration

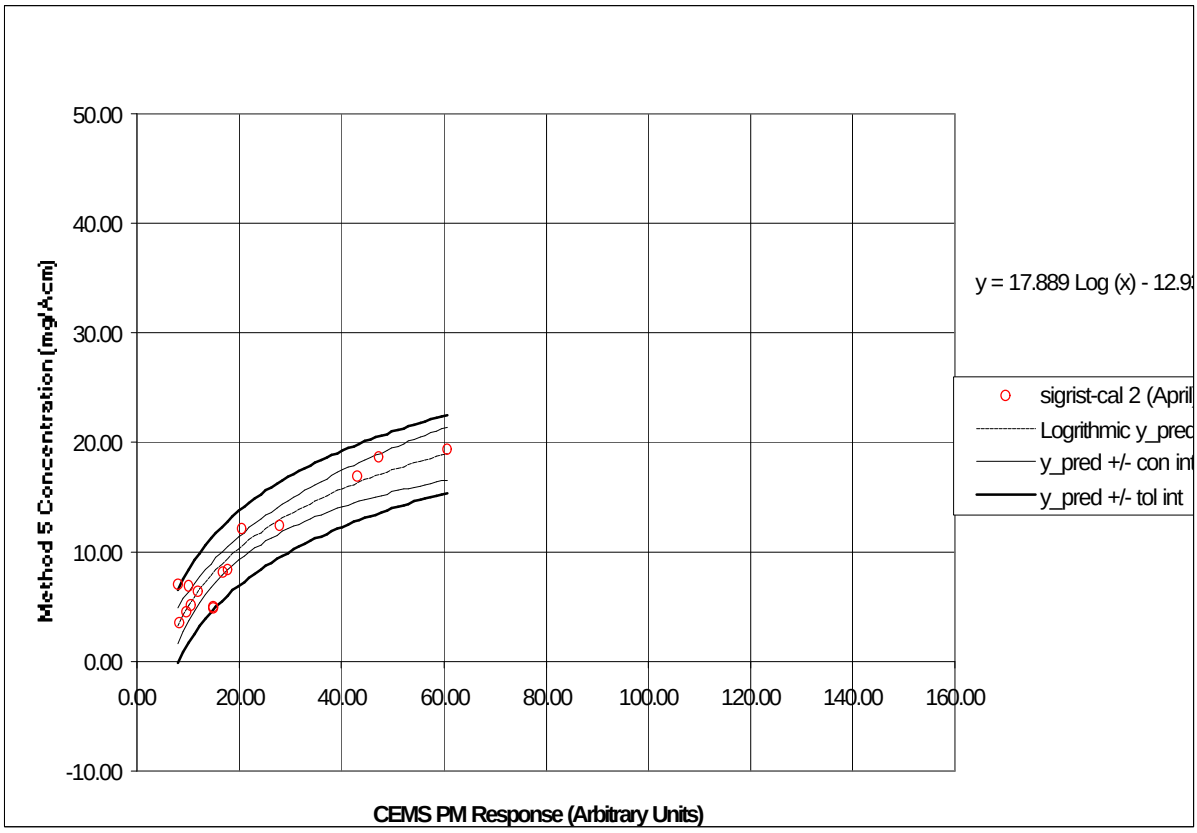


Figure 2-11.Statistical Evaluation of Sigrist Logarithmic Relation for Second Calibration

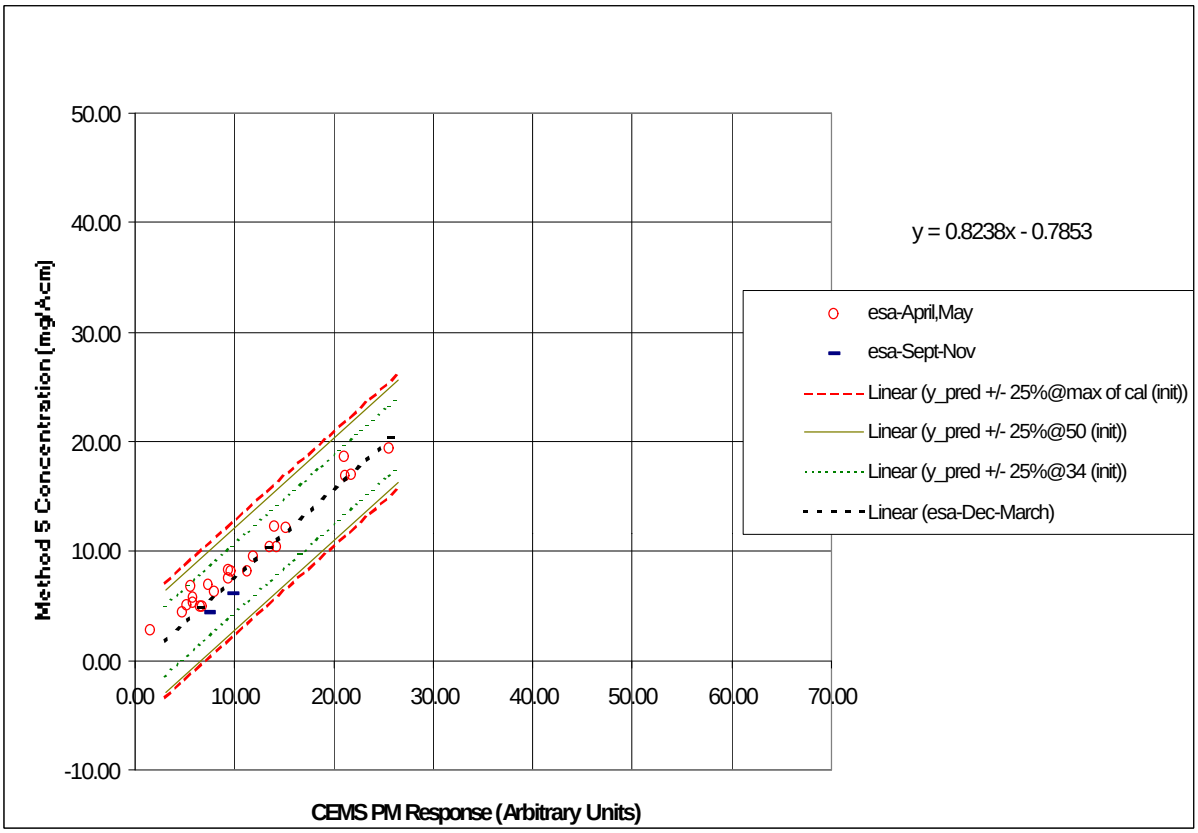


Figure 2-12. ESA RCA Evaluation of Initial Calibration

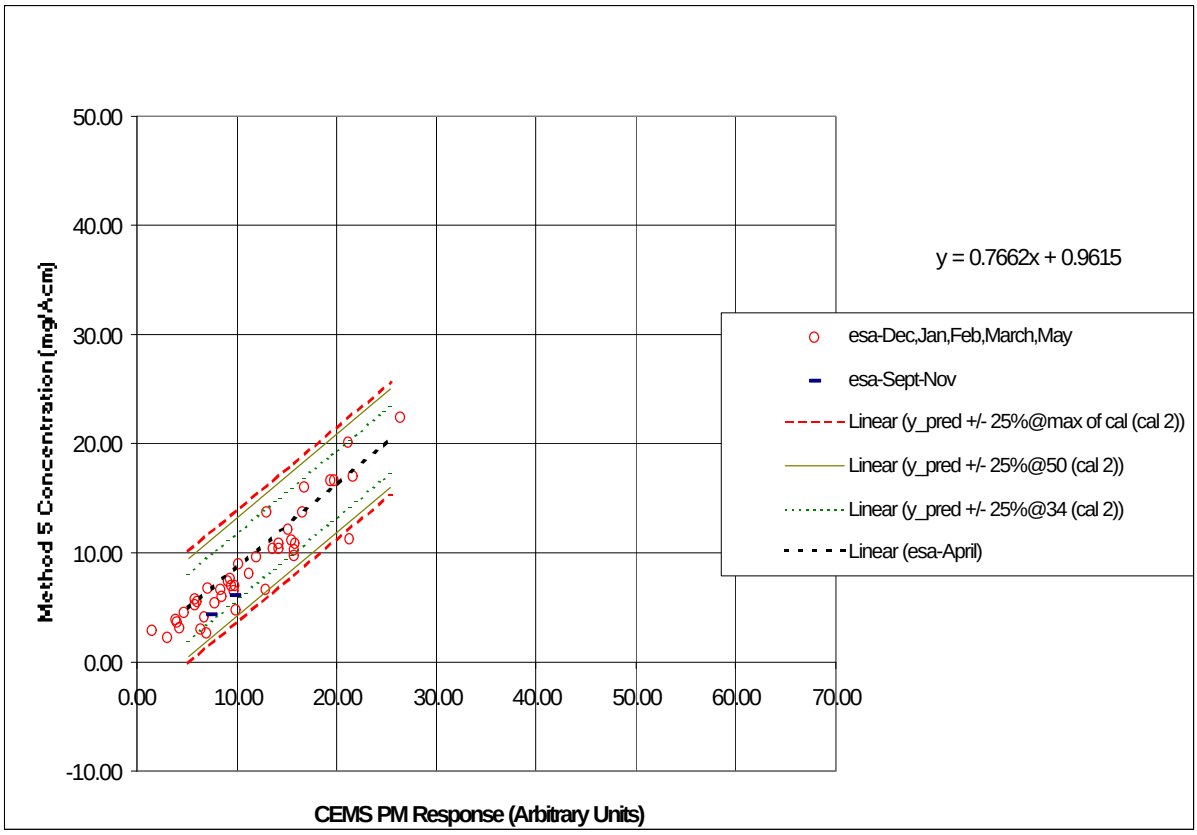


Figure 2-13. ESA RCA Evaluation of Second Calibration

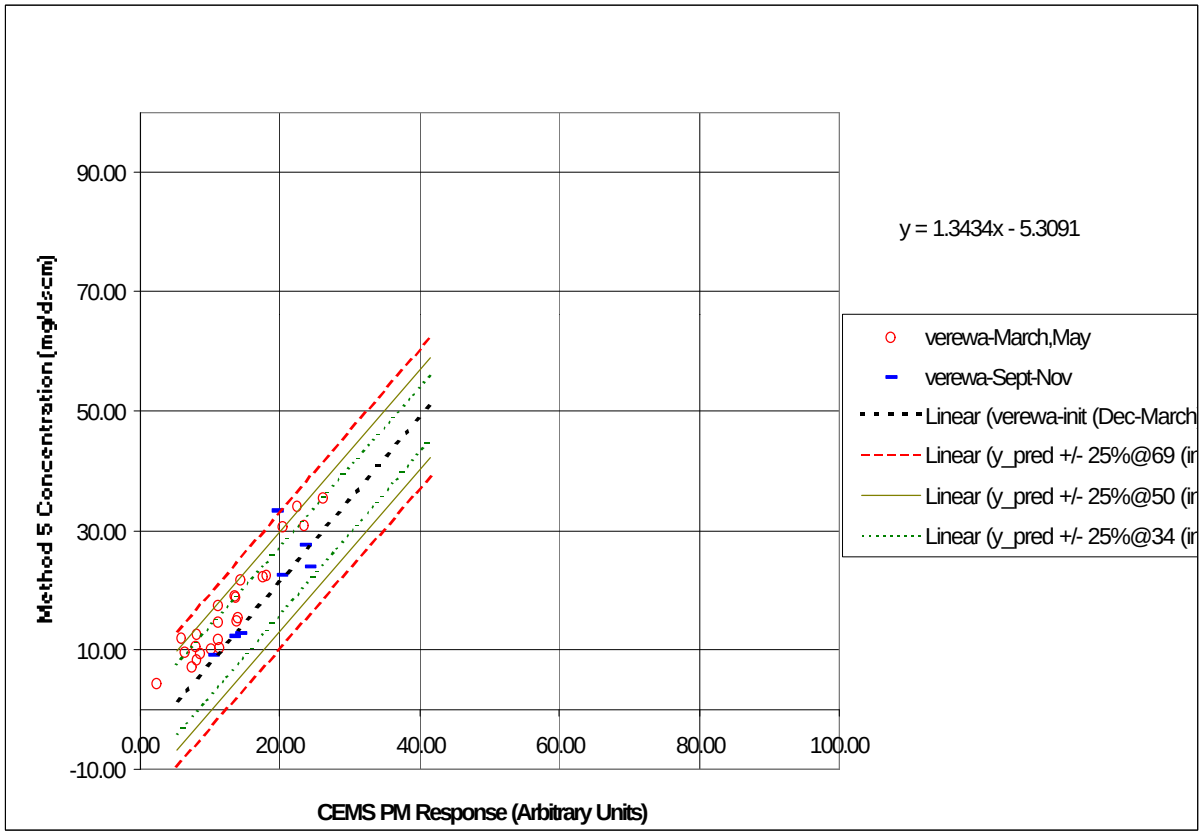


Figure 2-14. Verewa RCA Evaluation of Initial Calibration

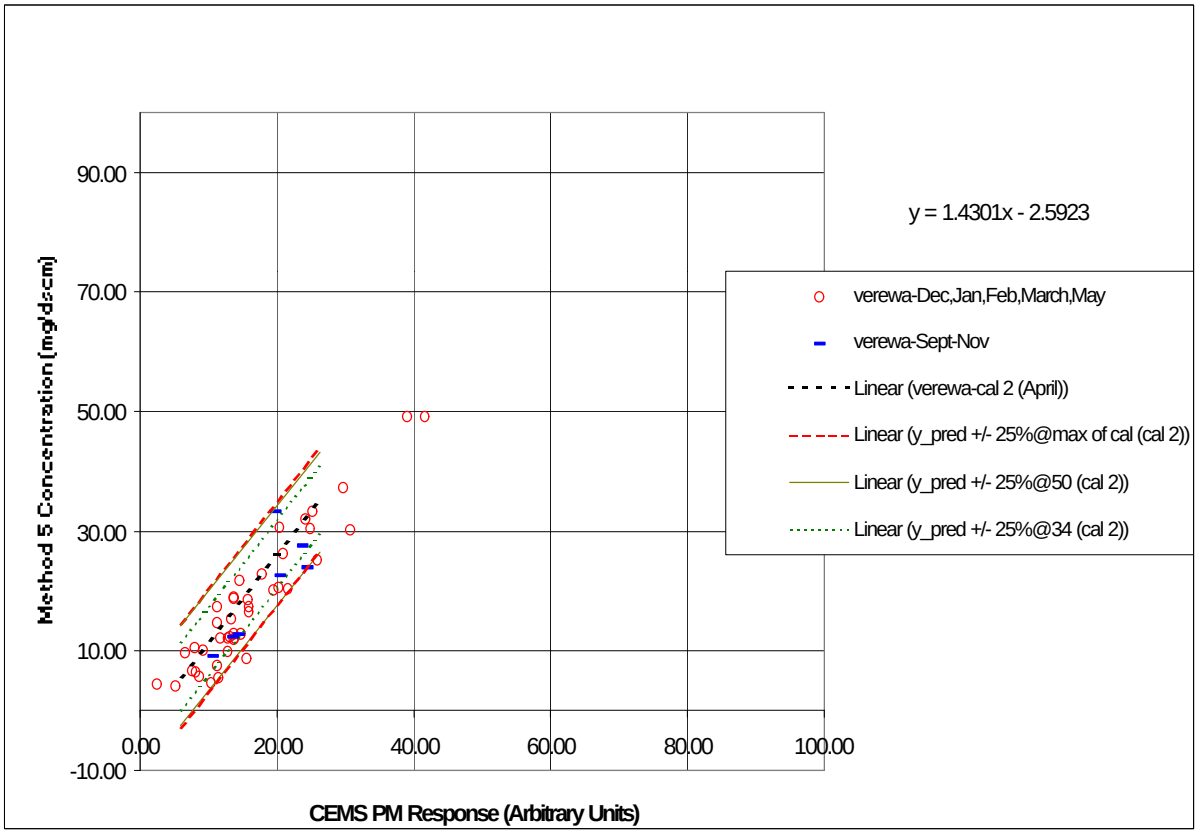


Figure 2-15. Verewa RCA Evaluation of Second Calibration

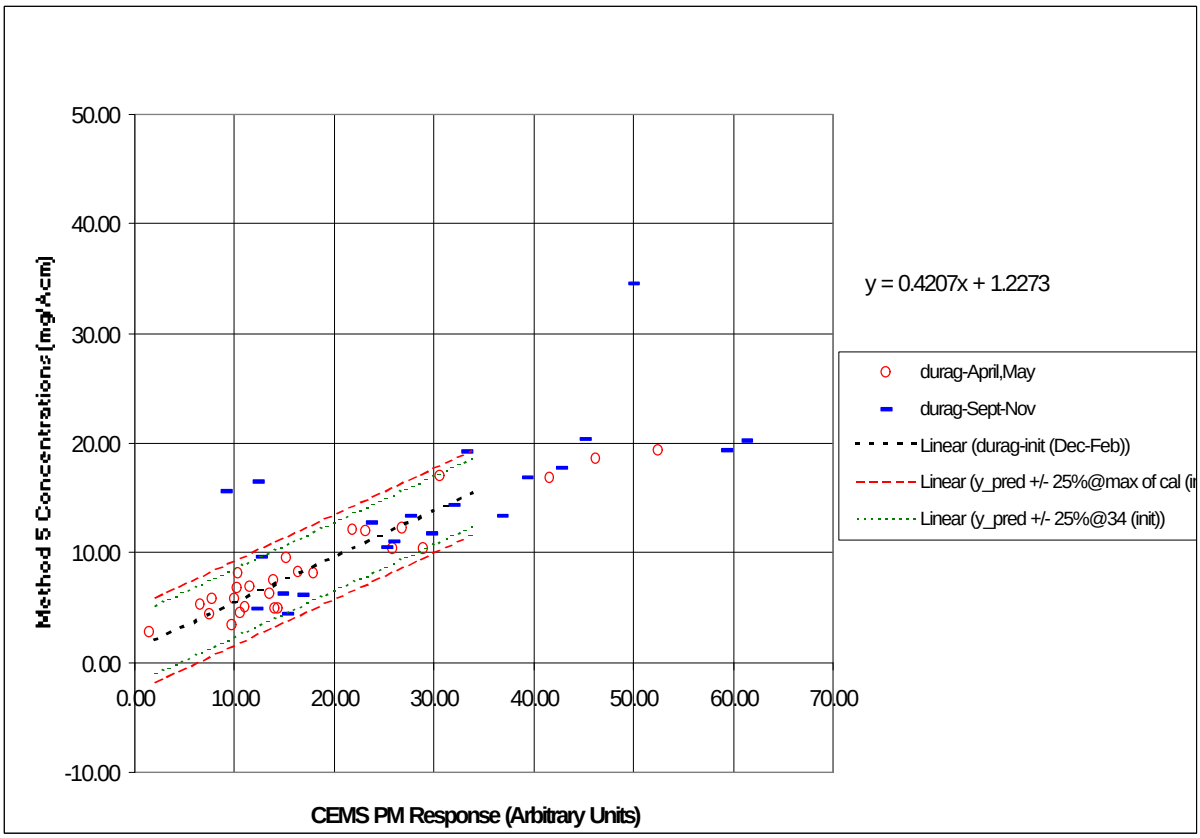


Figure 2-16. Durag RCA Evaluation of Initial Calibration

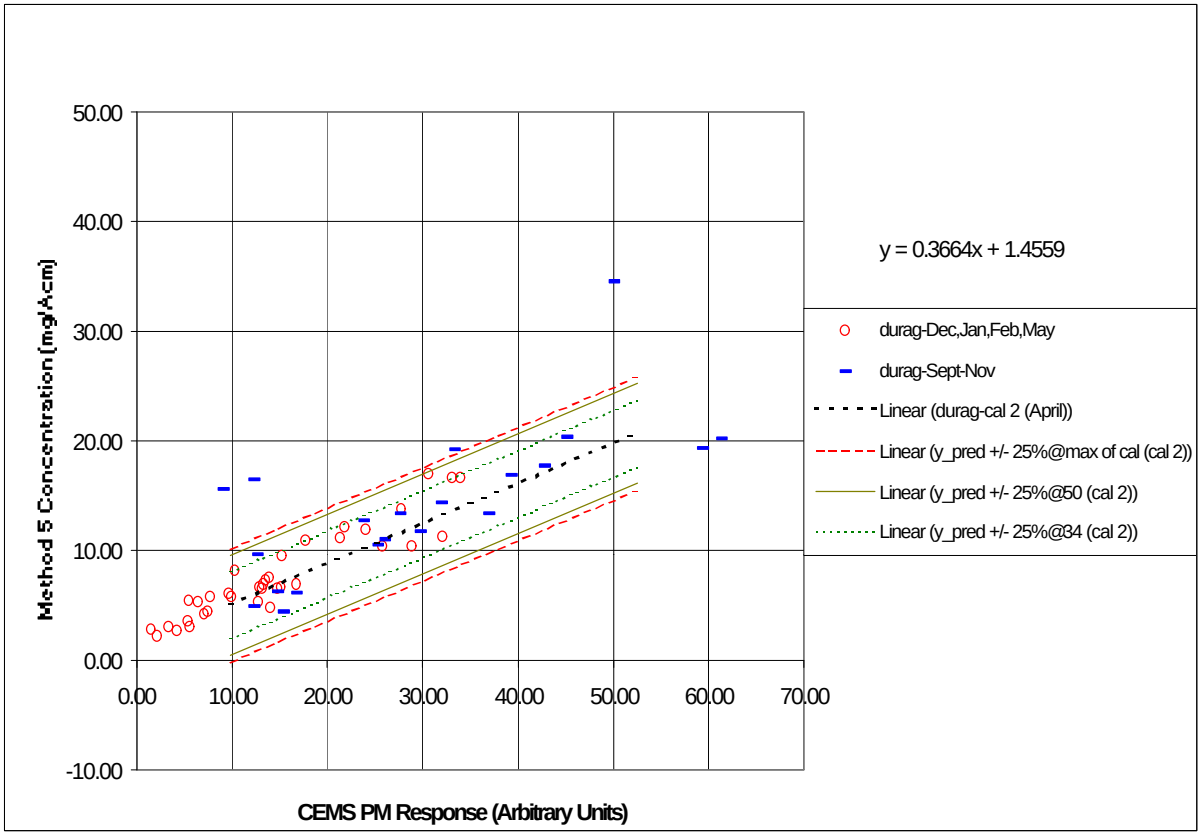


Figure 2-17. Durag RCA Evaluation of Second Calibration

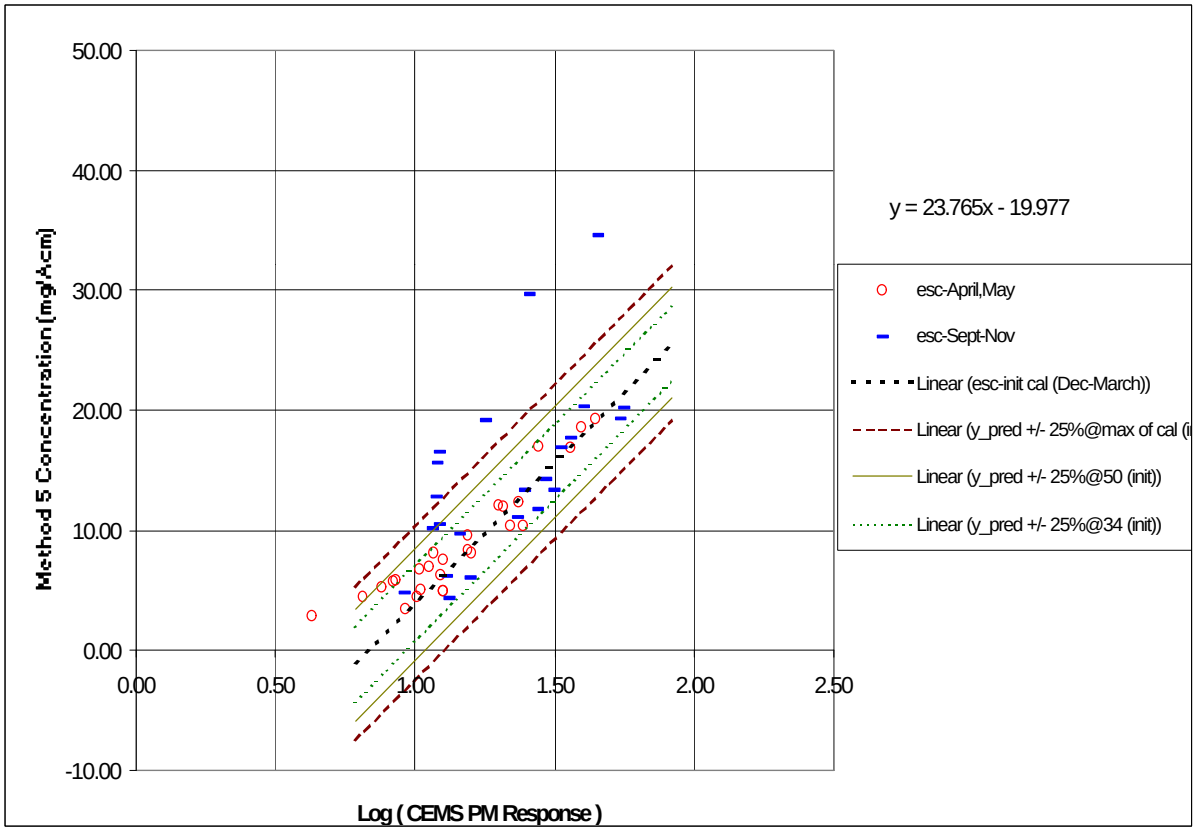


Figure 2-18. ESC RCA Evaluation of Initial Calibration

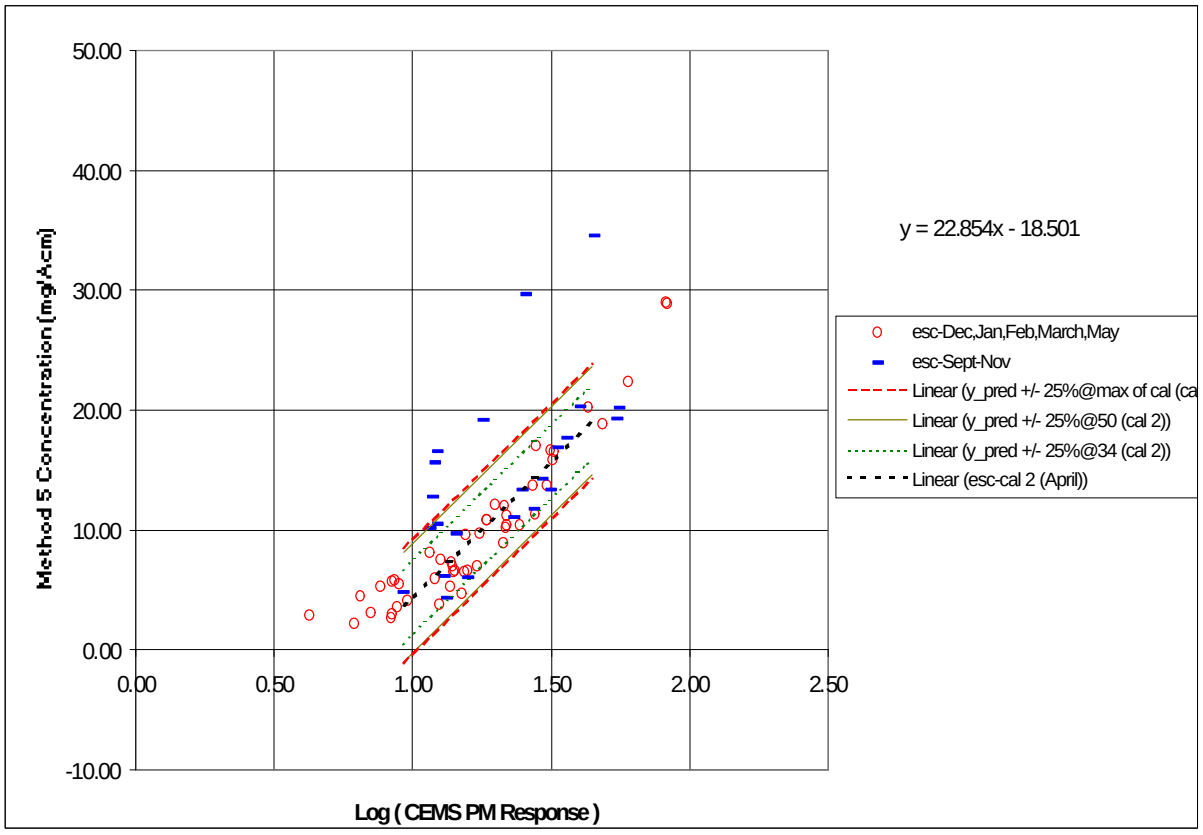


Figure 2-19. ESC RCA Evaluation of Second Calibration

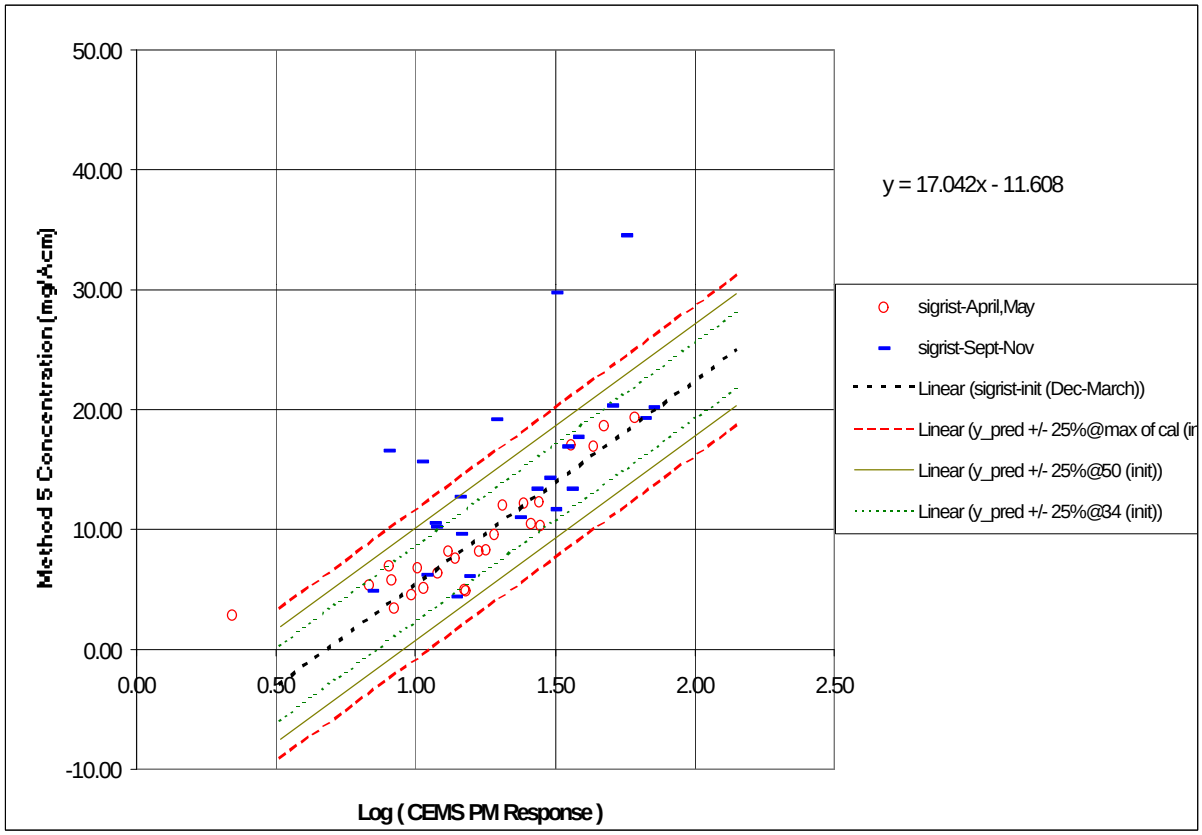


Figure 2-20. Sigrist RCA Evaluation of Initial Calibration

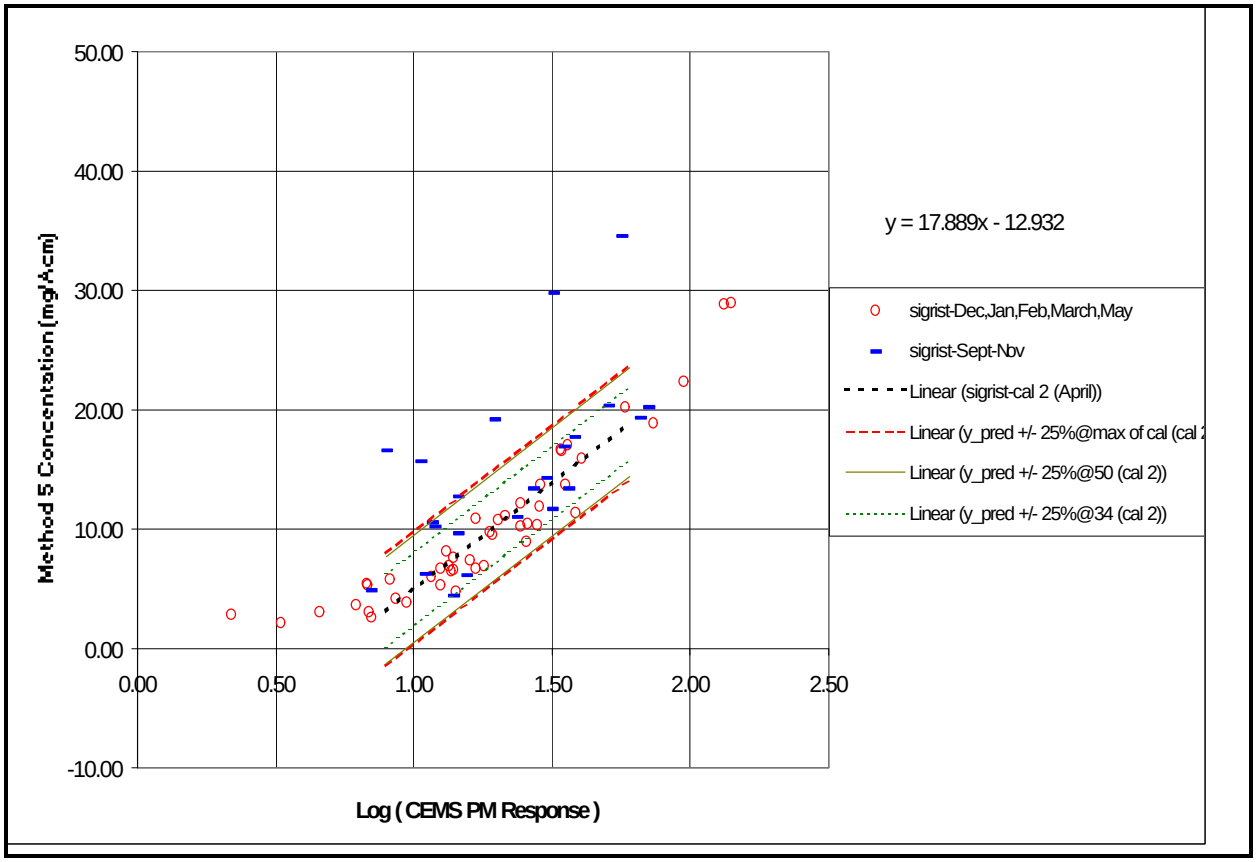


Figure 2-21. Sigrist RCA Evaluation of Second Calibration

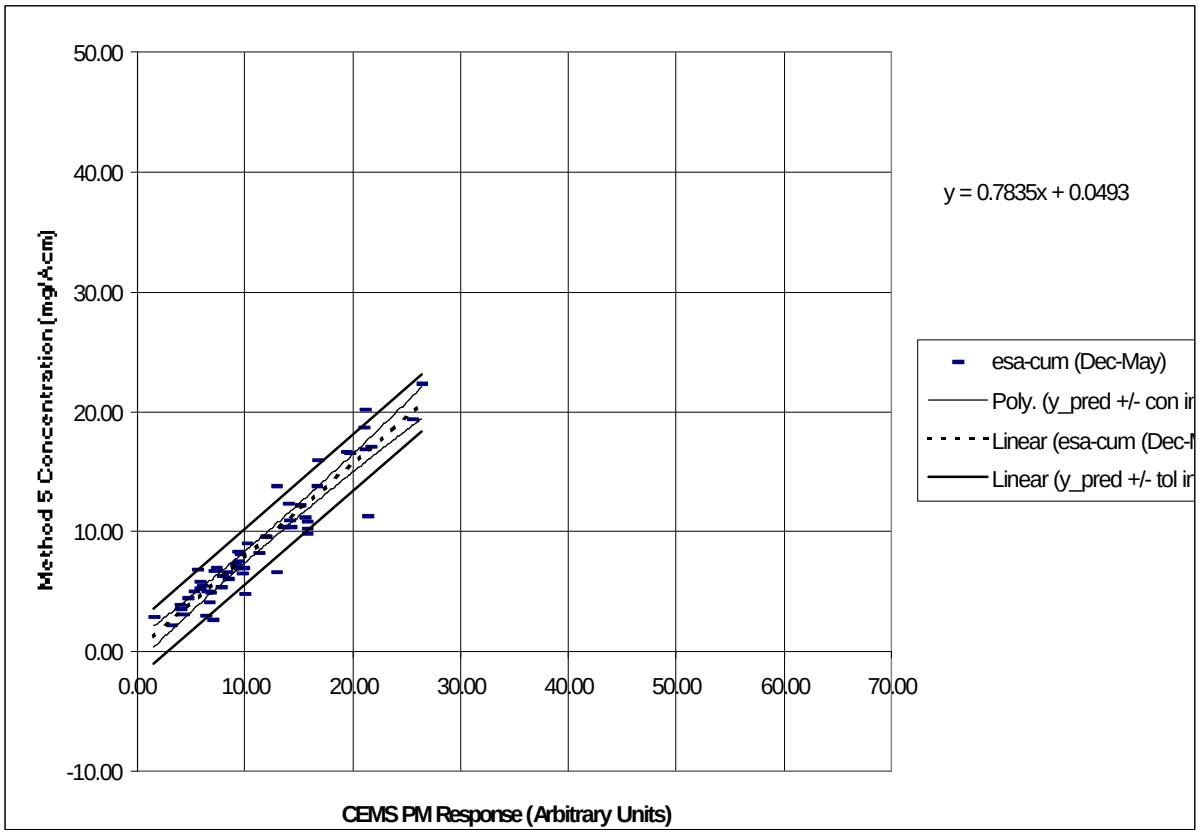


Figure 2-22. ESA Cumulative Linear Calibration Relation

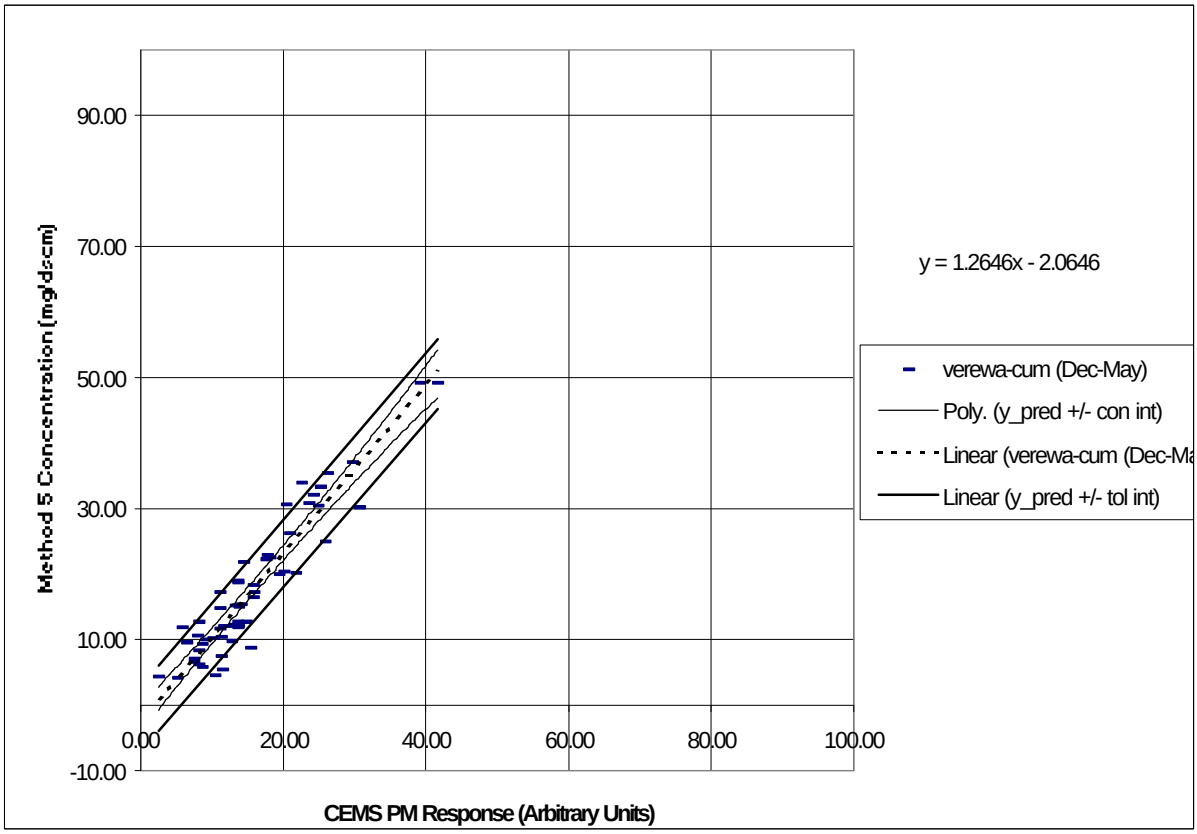


Figure 2-23. Verewa Cumulative Linear Calibration Relation

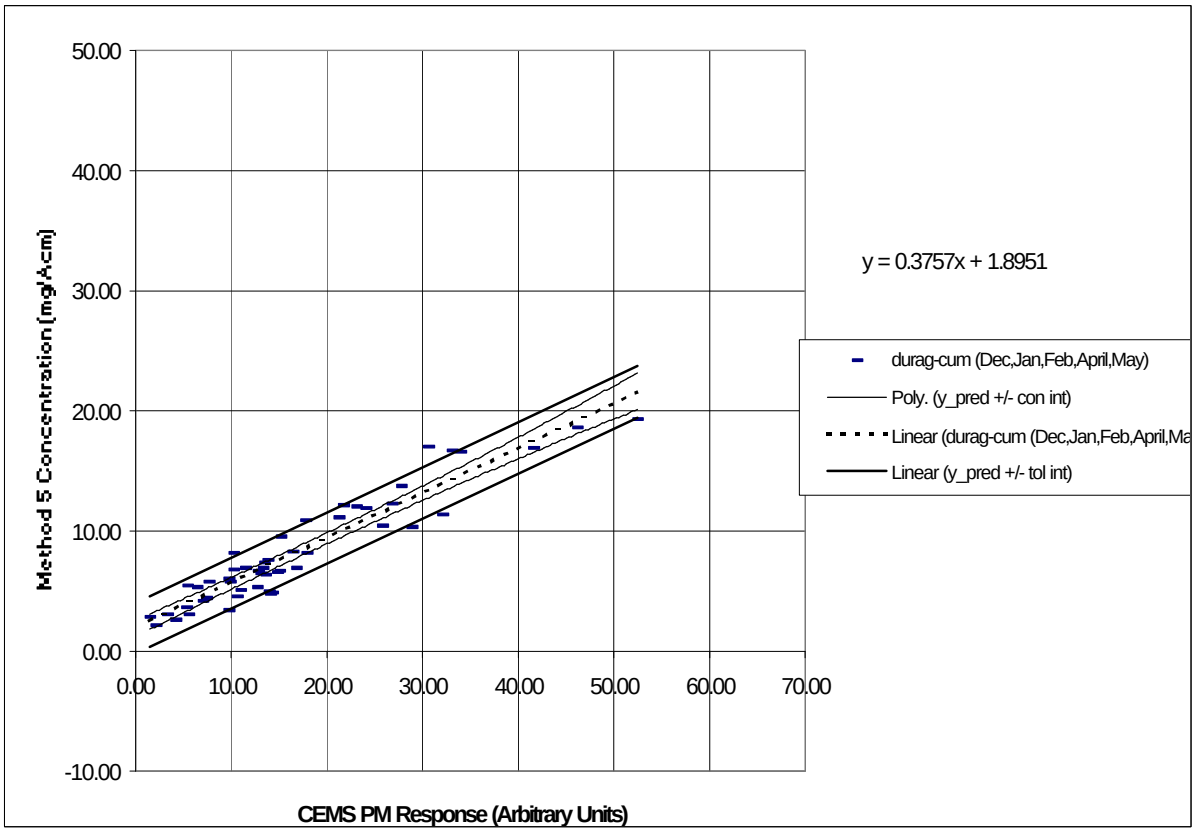


Figure 2-24. Durag Cumulative Linear Calibration Relation

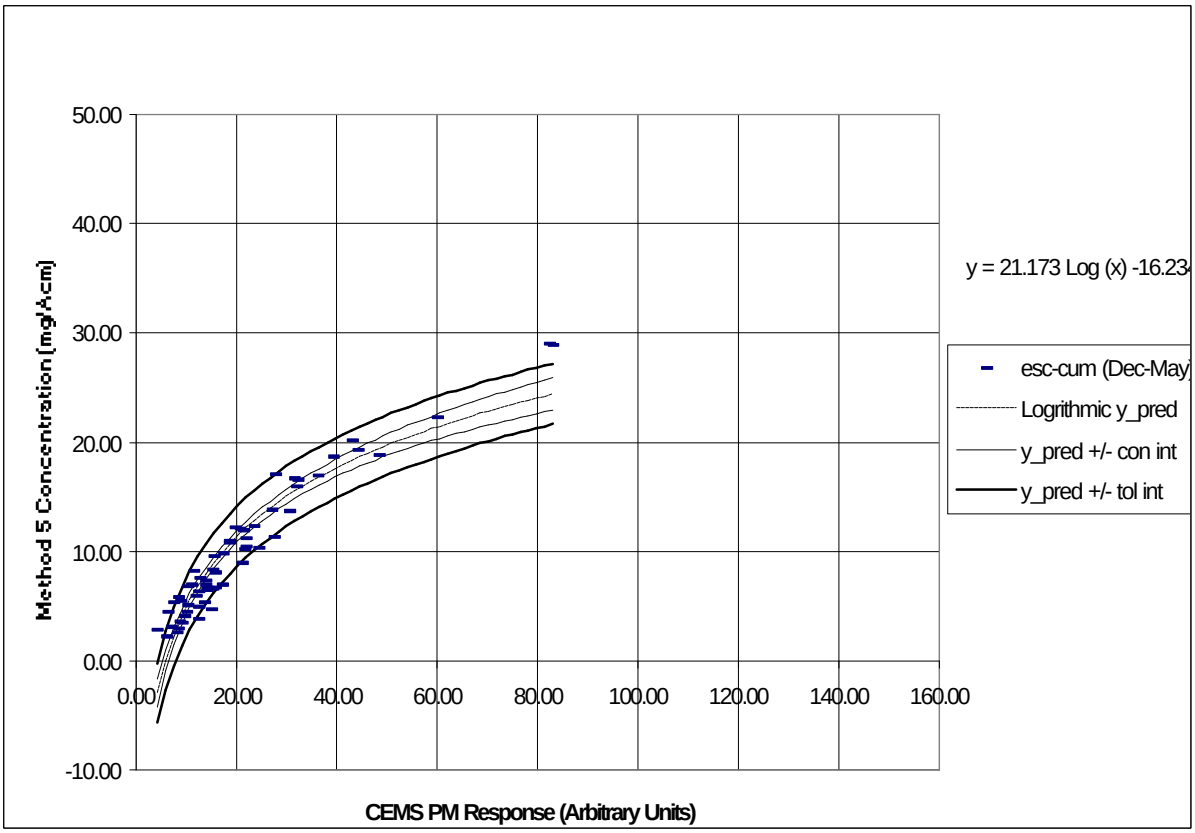


Figure 2-25. ESC Cumulative Logarithmic Calibration Relation

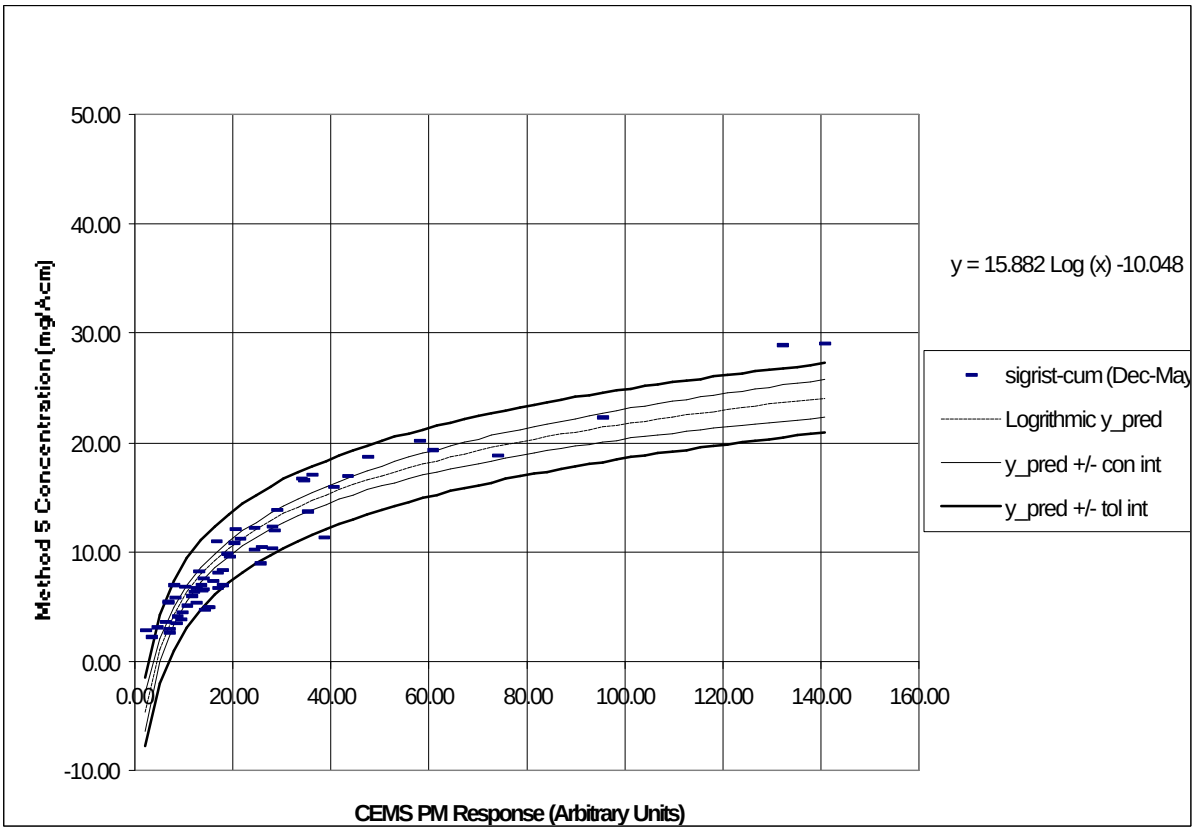


Figure 2-26. Sigrist Cumulative Logarithmic Calibration Relation

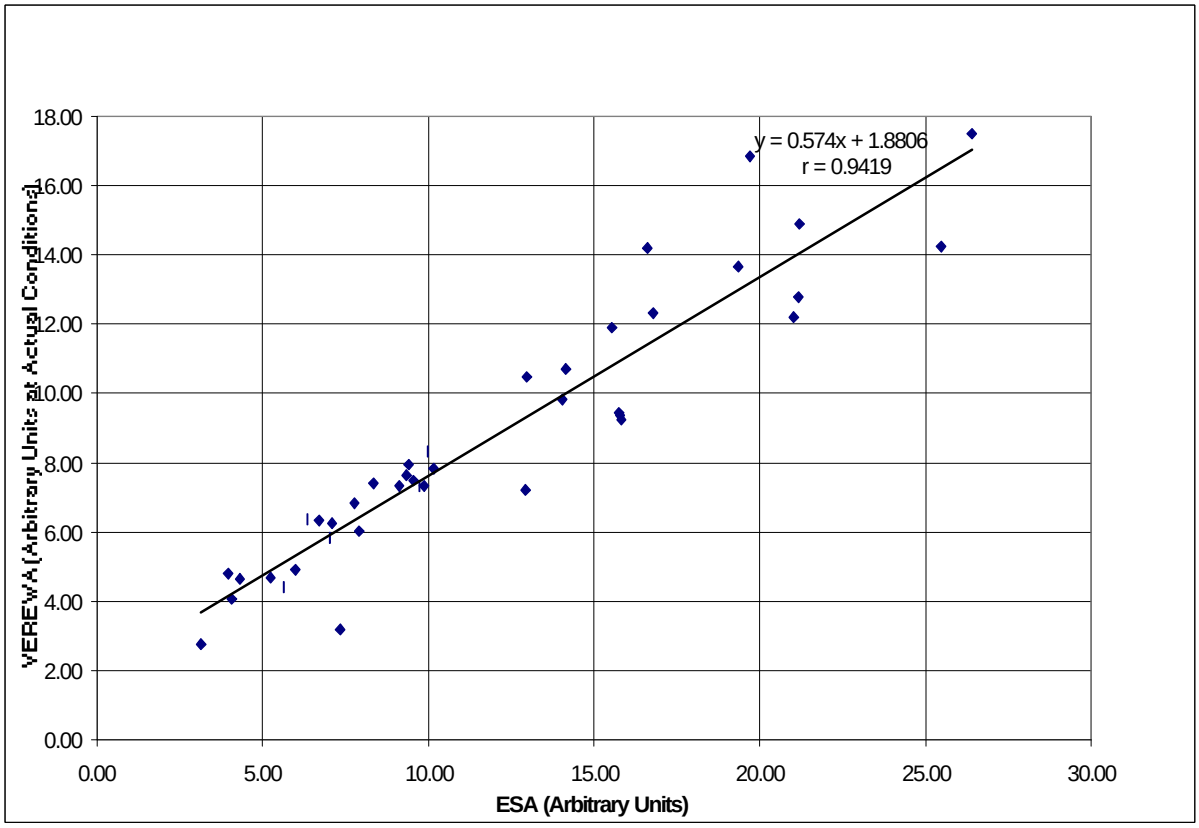


Figure 2-27. Comparison of Like-Technology, Beta CEMS

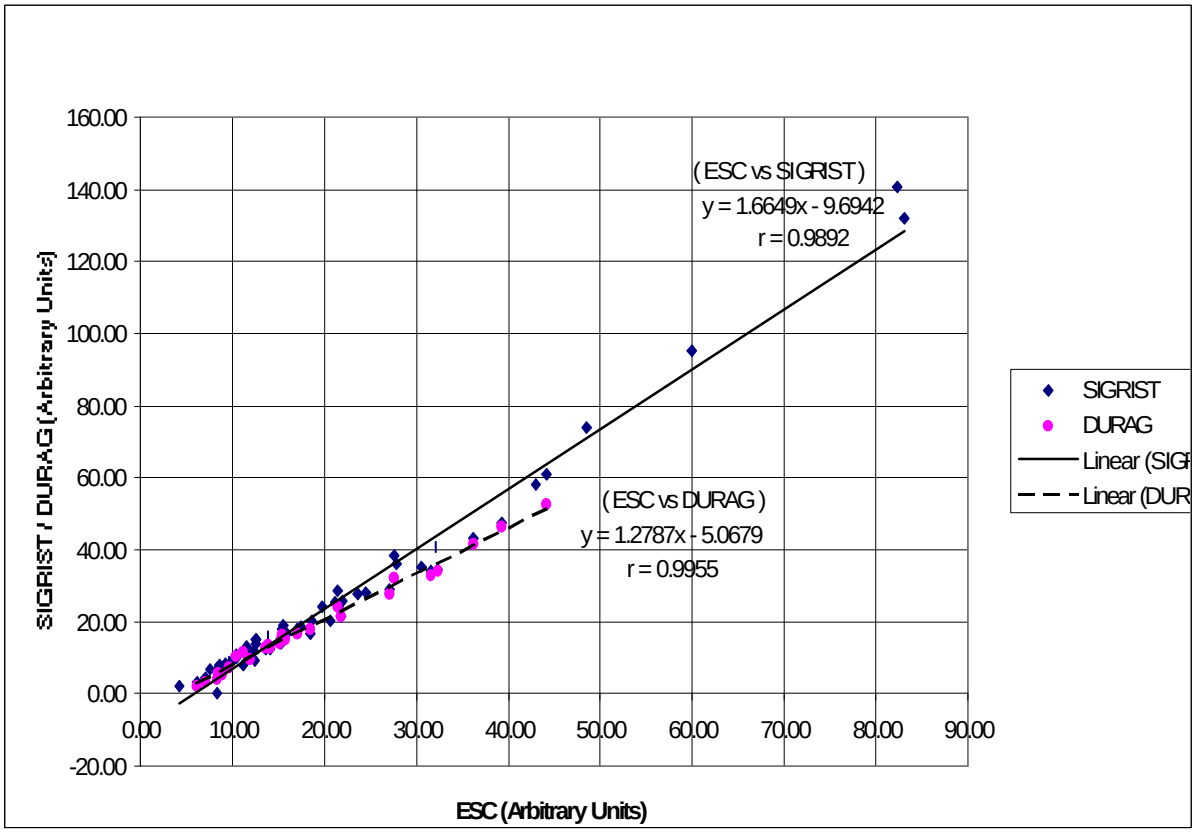


Figure 2-28. Comparison of Like-Technology, Light-Scattering CEMS

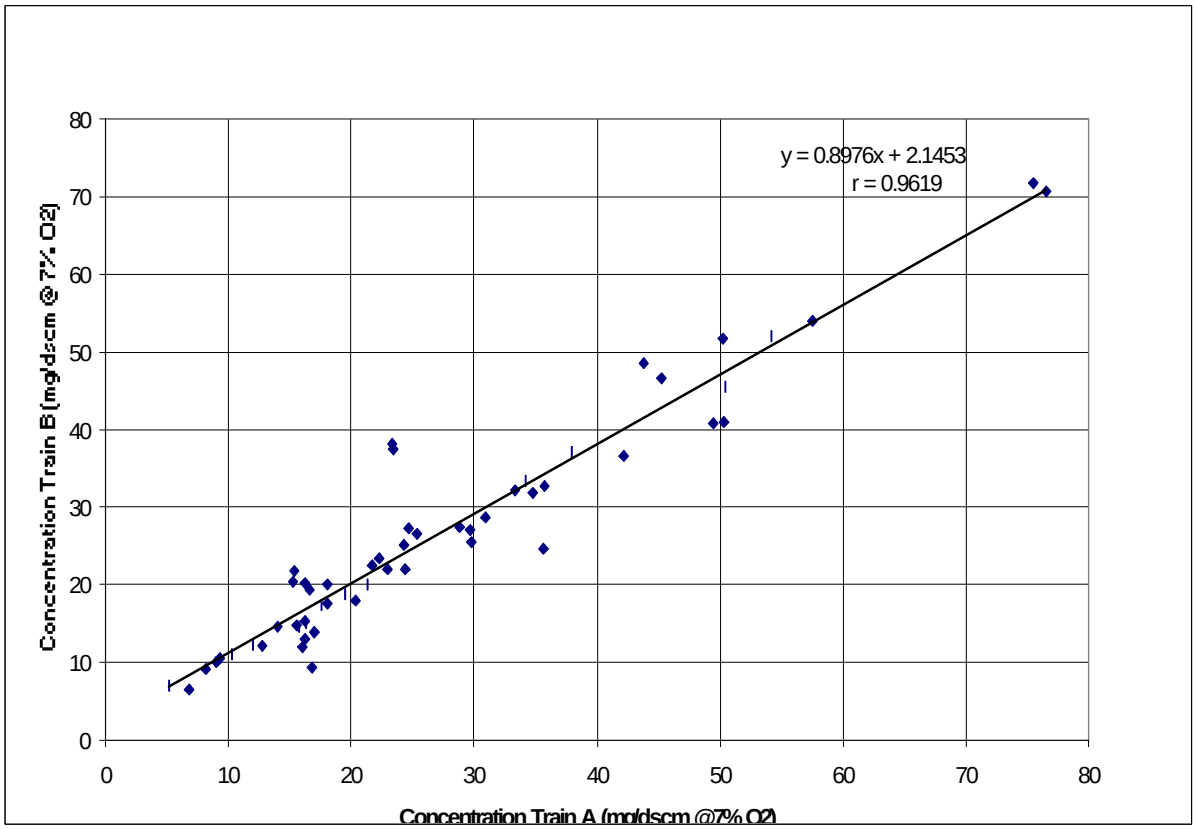


Figure 2-29. Comparison of Like-Technology, Method 5i

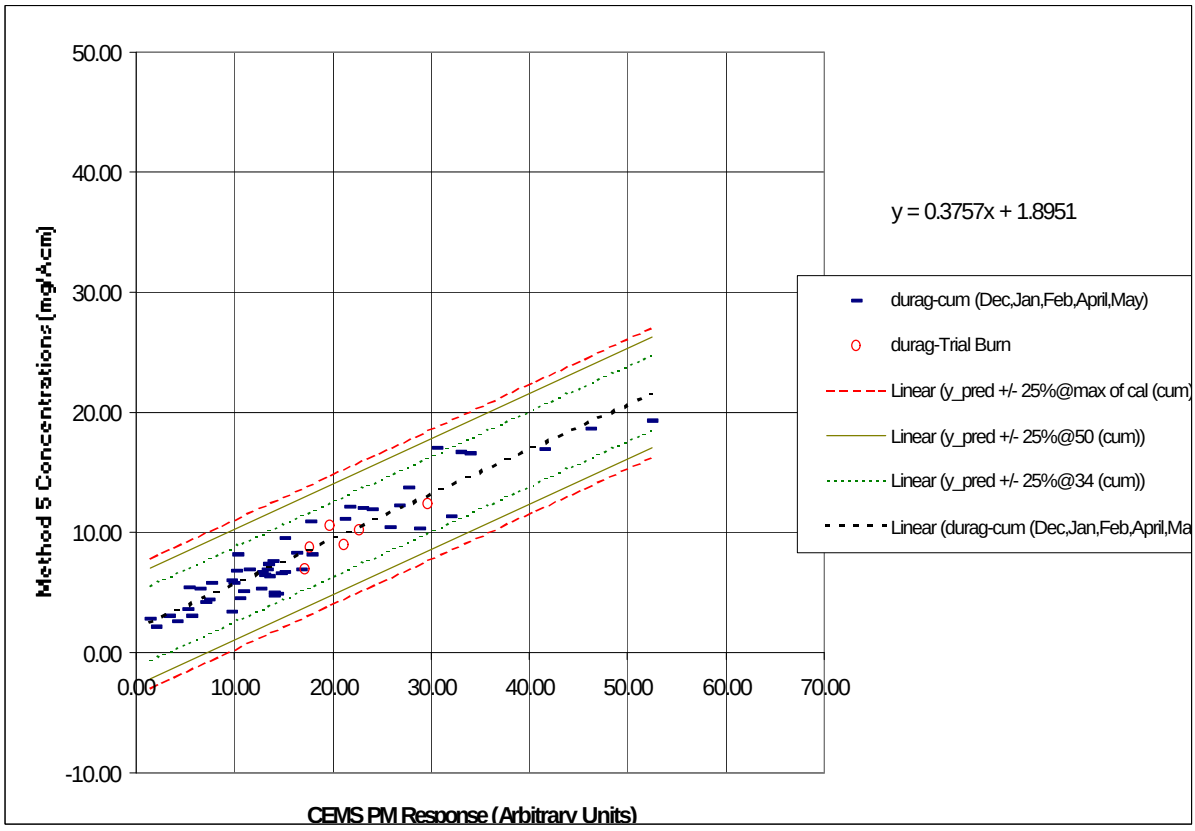


Figure 2-30. Durag RCA Evaluation of Trial Burn

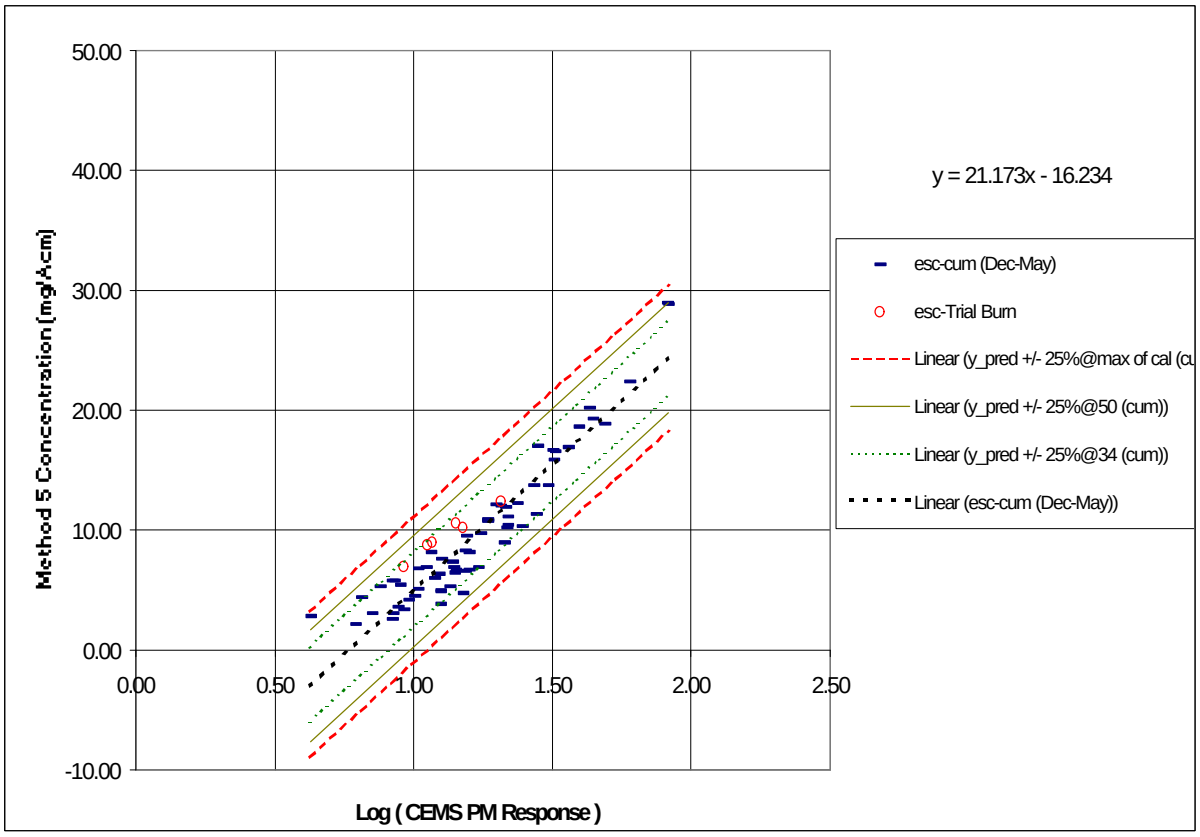


Figure 2-31. ESC RCA Evaluation of Trial Burn

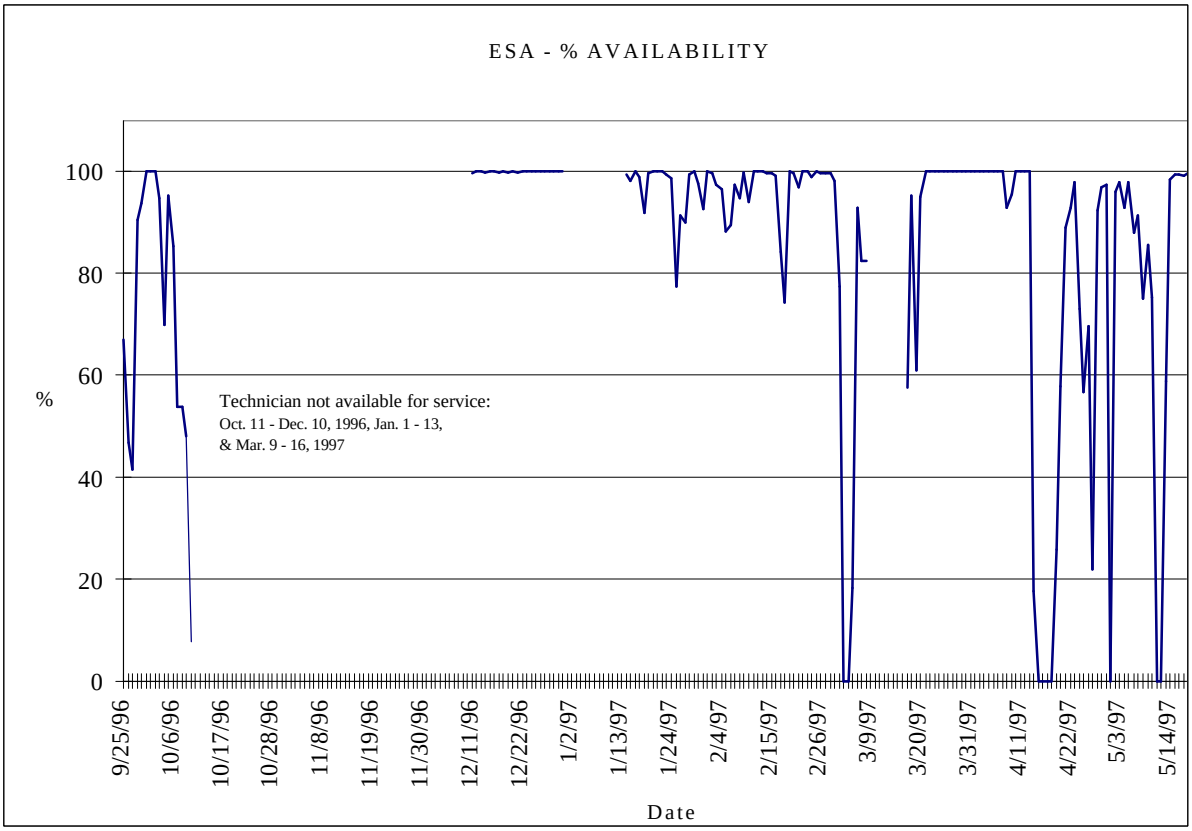


Figure 2-32. ESA Data Availability

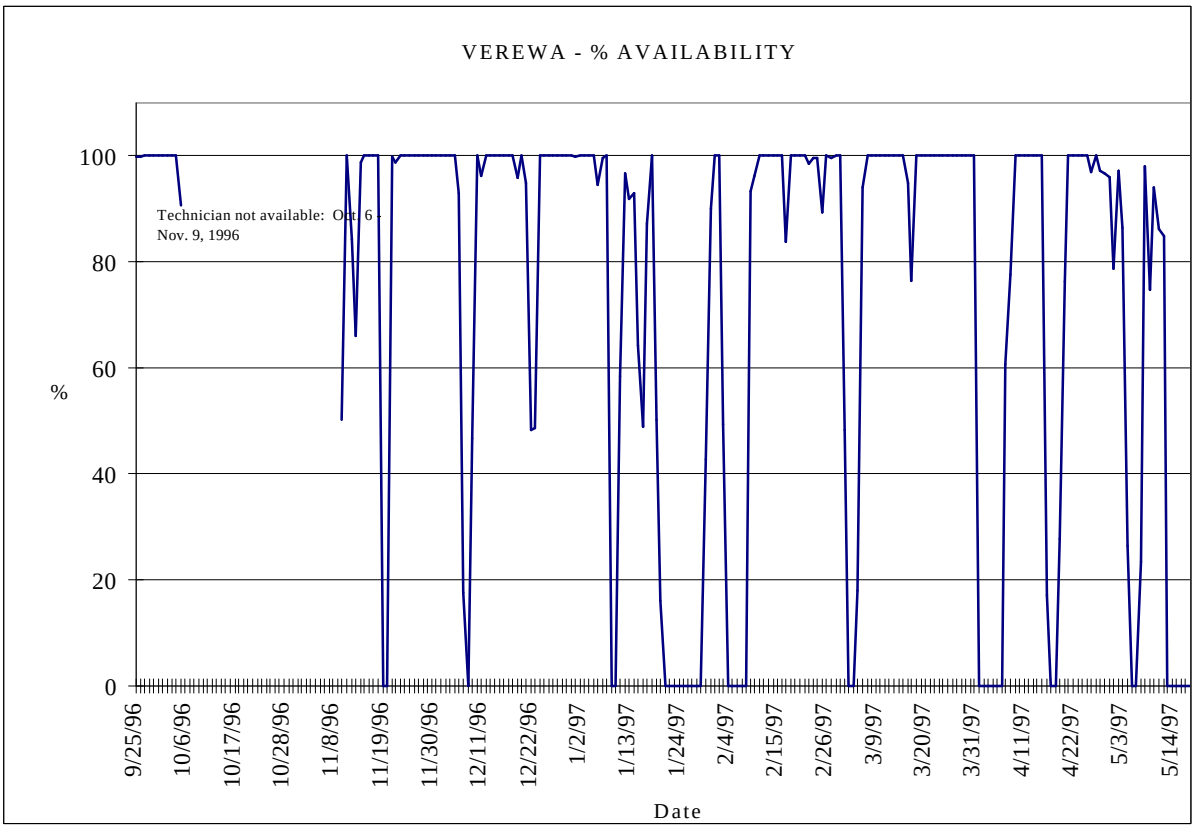


Figure 2-33. Verewa Data Availability

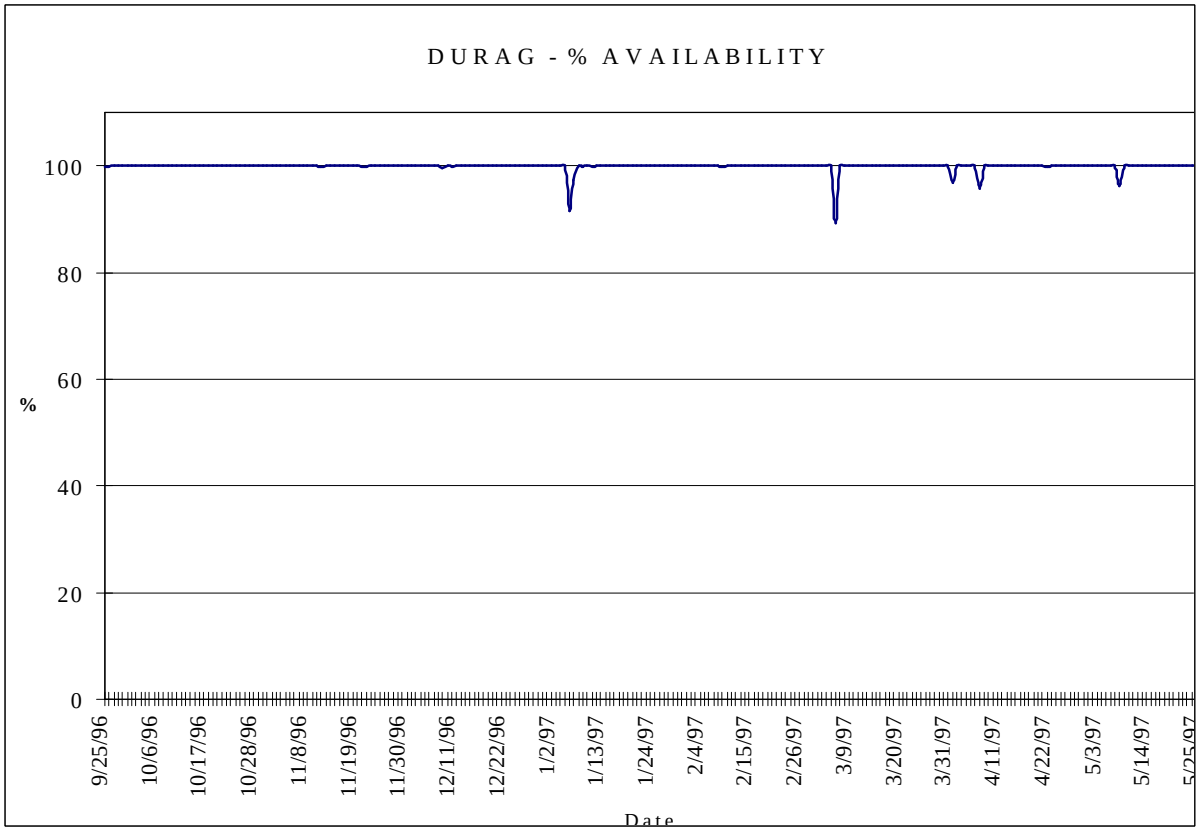


Figure 2-34. Durag Data Availability

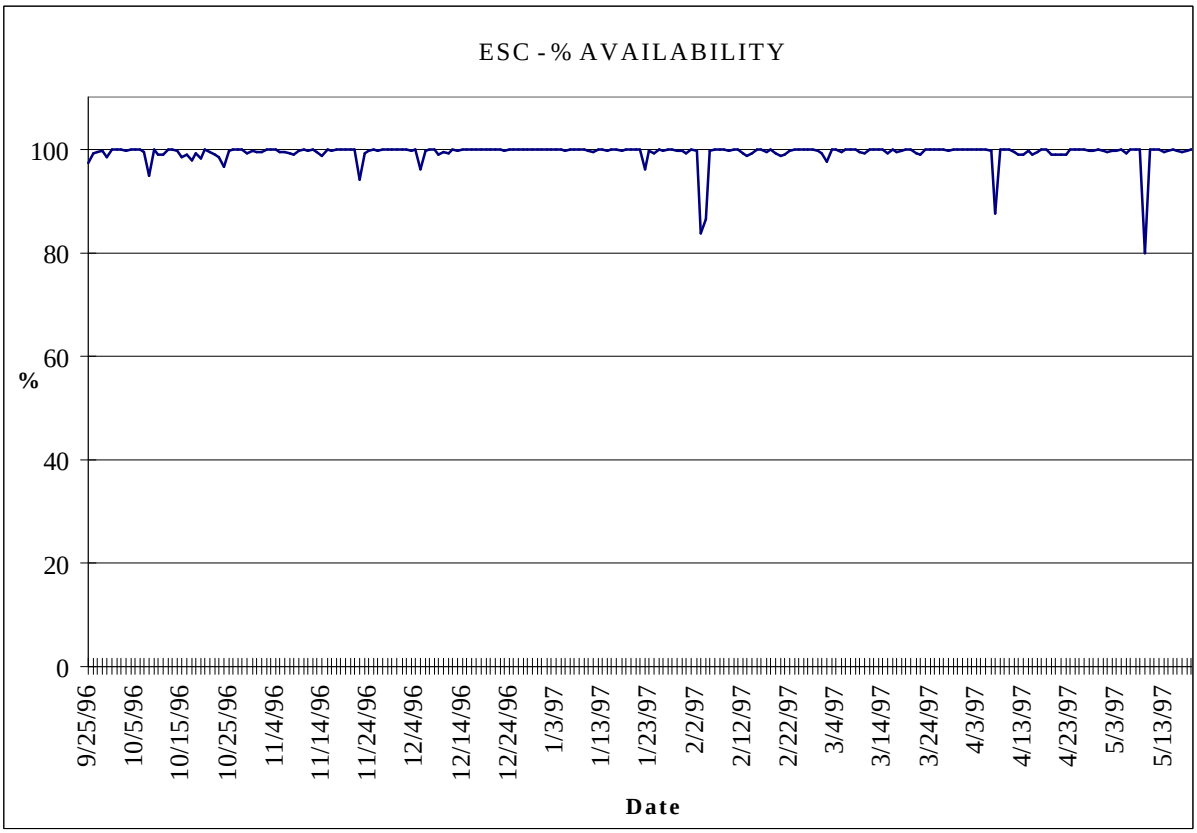


Figure 2-35. ESC Data Availability

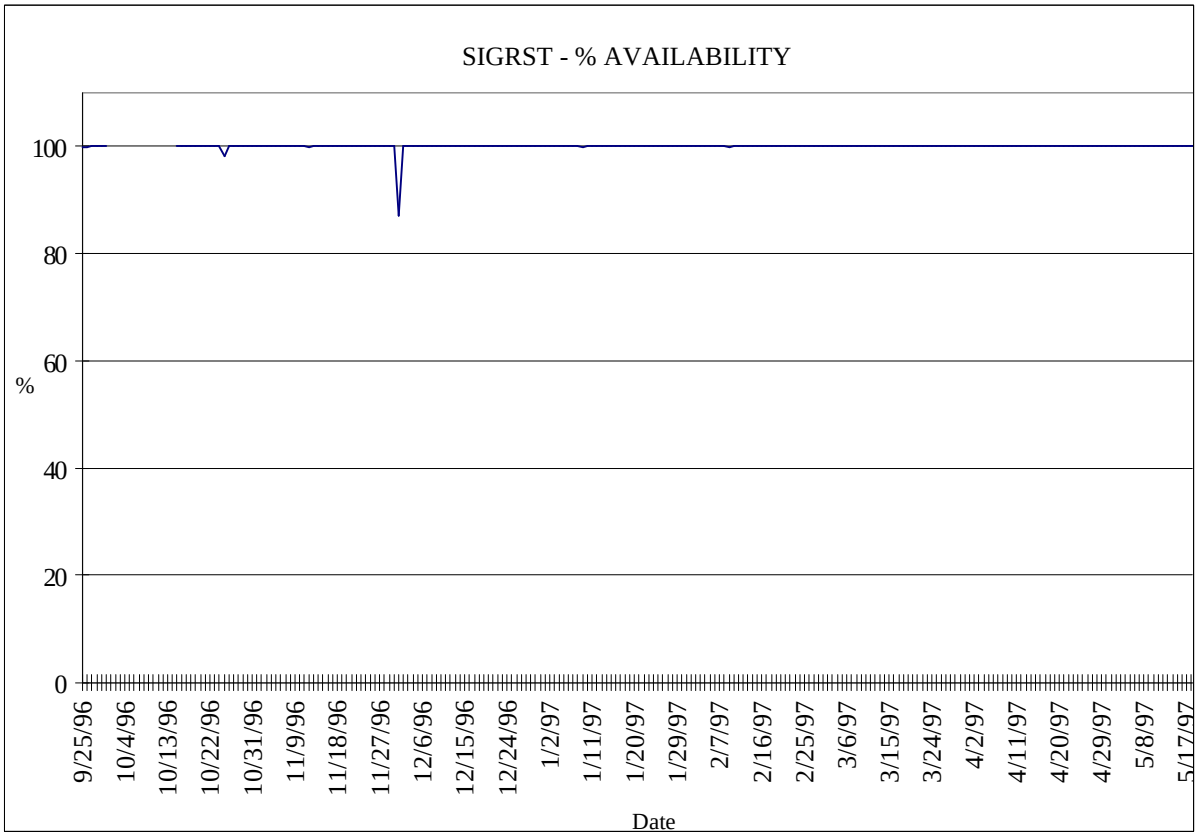


Figure 2-36. Sigrist Data Availability

3.0 TEST PROGRAM PROTOCOL

To achieve the project goals, a number of measurements at different periods were performed on the flue gas for the facility. In addition, six ports, necessary utilities, and a data acquisition system were installed to support and accommodate this PM CEMS demonstration test program. The following section discusses details of the sampling locations, the modified reference test methods performed for this program, and each of the CEMS.

Although the tests were conducted with the facility operating under normal conditions, coordination / communication with facility personnel occurred regularly. As discussed in the preceding section, the facility was operated in a manner to maintain it within permitted conditions and in an attempt to achieve a range of PM emissions that are integral to the calibration testing protocol. The matrix of plant operating conditions over which the CEMS calibration were performed was obtained by varying EDV power level set points as well as waste feedstream composition. Figure 3-1 presents a schematic of the principal components of the incinerator facility to help provide an integrated picture on the overall scope of this form of testing.

The flue gas sampling utilized Method 5i for PM as the reference method. The reference method measurements were conducted on the stack using the two sampling ports already installed and located 90° apart. Traversing measurements were made using duplicate trains. The current port locations on the stack are easily accessible from the relatively large platform surrounding the stack. The ports were configured for performing compliance tests and meet all necessary EPA Method 1 criteria for upstream and downstream disturbances. The stack is round with a 4-ft. inner diameter. The sampling platform is located about 90 feet above ground level. The nearest flow disturbance is 9.75 diameters upstream and three (3) diameters downstream of the sampling location as shown in Figure 3-2.

A schematic of the stack configuration with the location of the Method 5 ports and the respective levels for each of the CEMS is shown in Figure 3-3. Figure 3-4 shows the traverse points

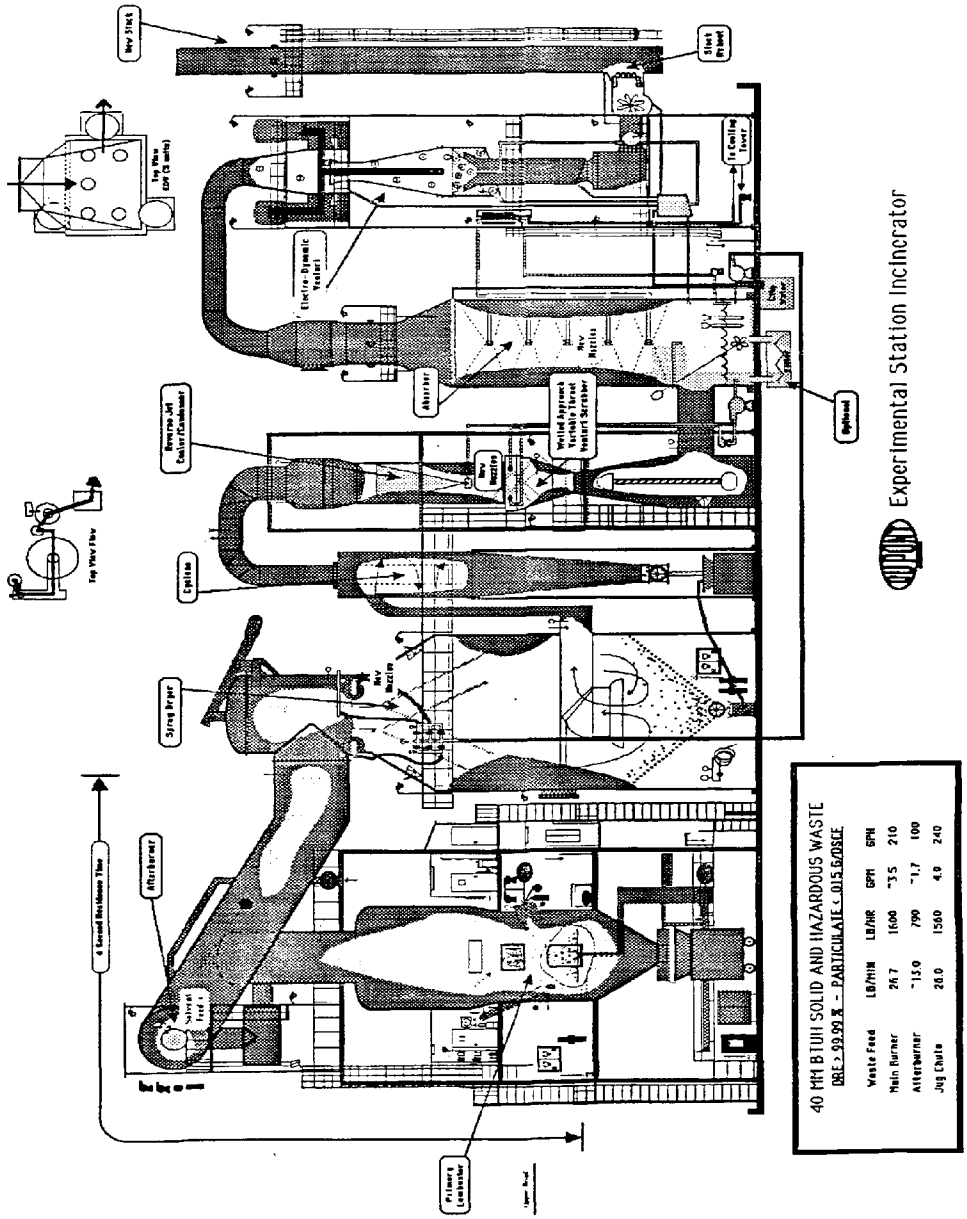


Figure 3-1. DuPont Incineration Schematic.

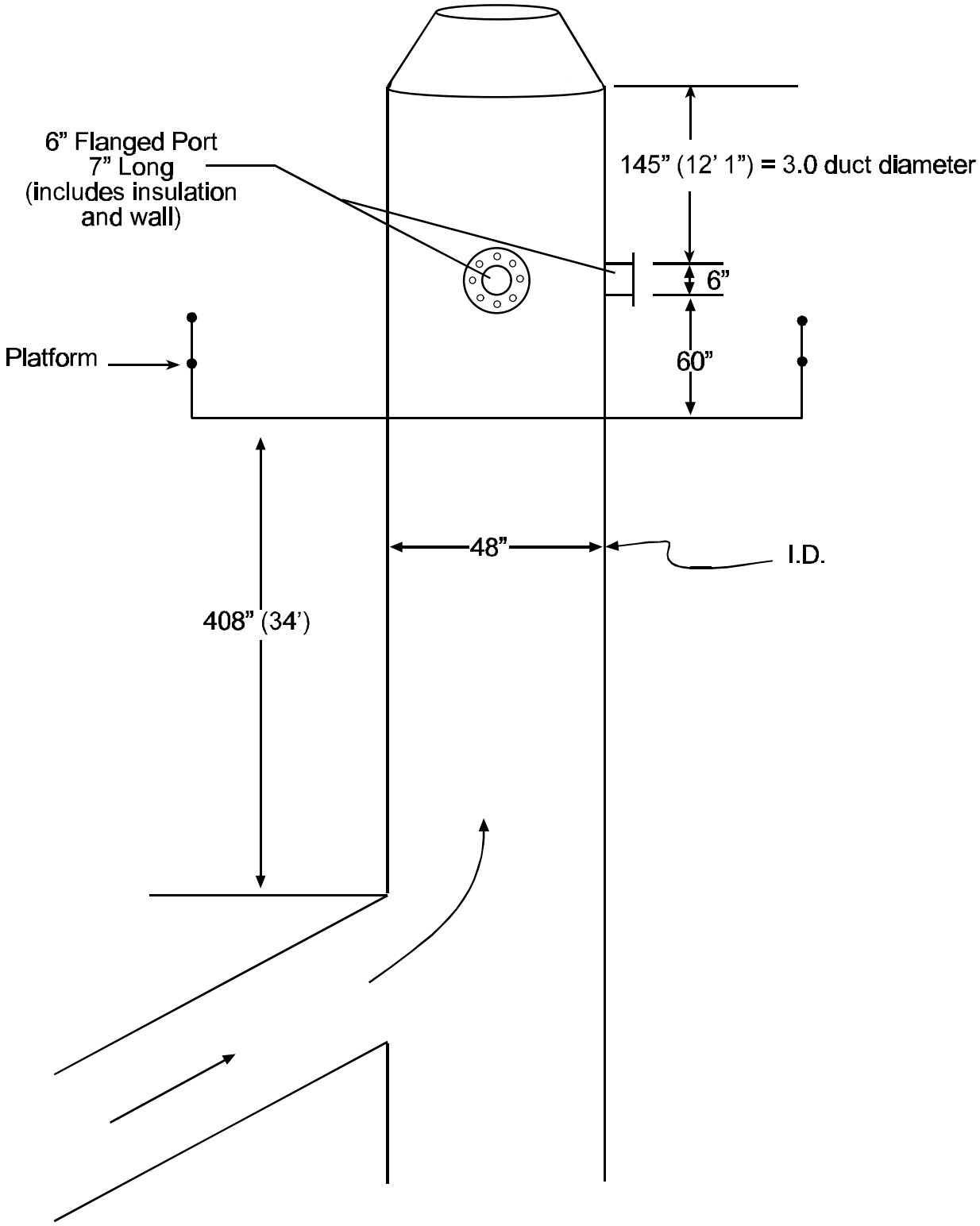


Figure 3-2. Stack diagram at Dupont Incinerator.

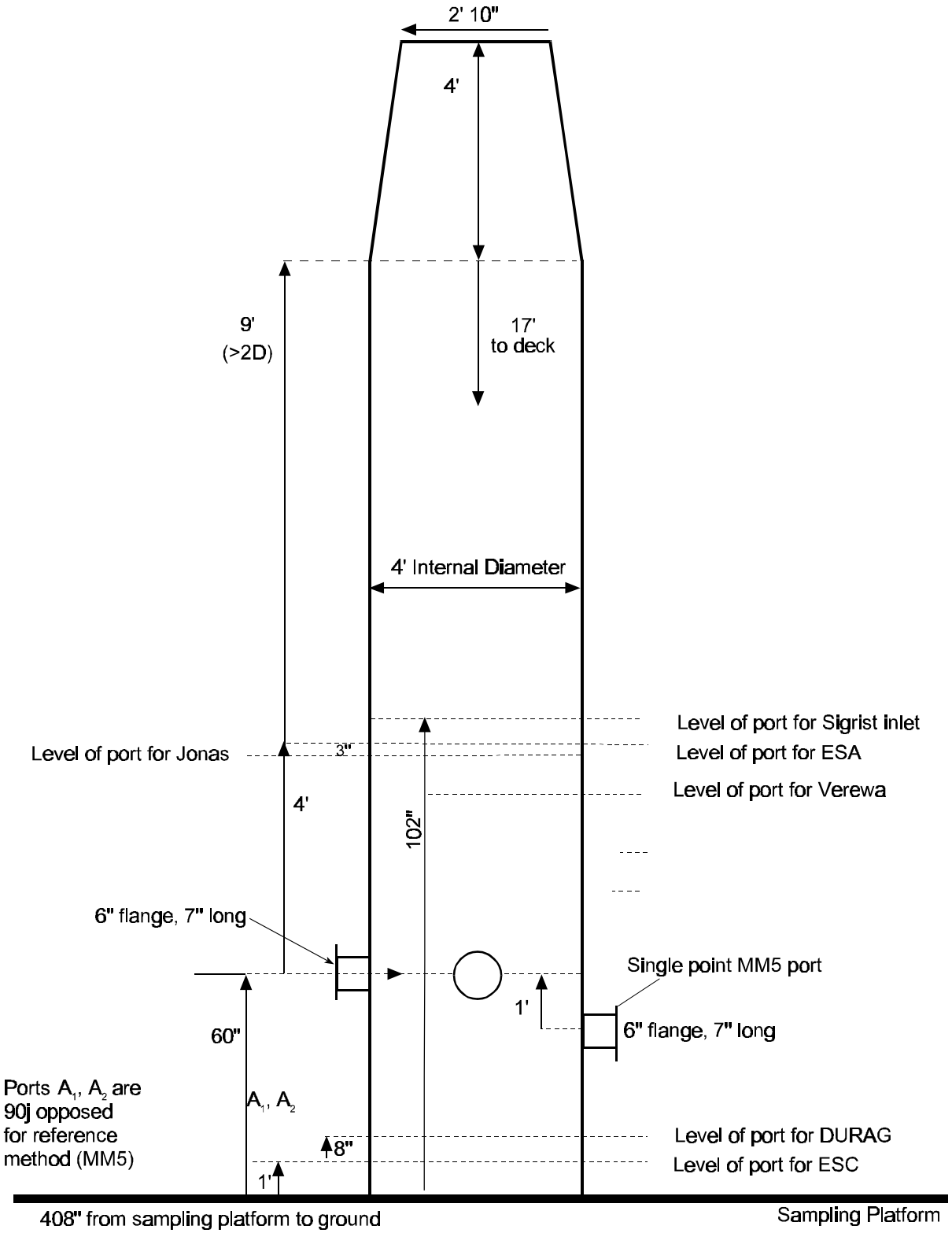
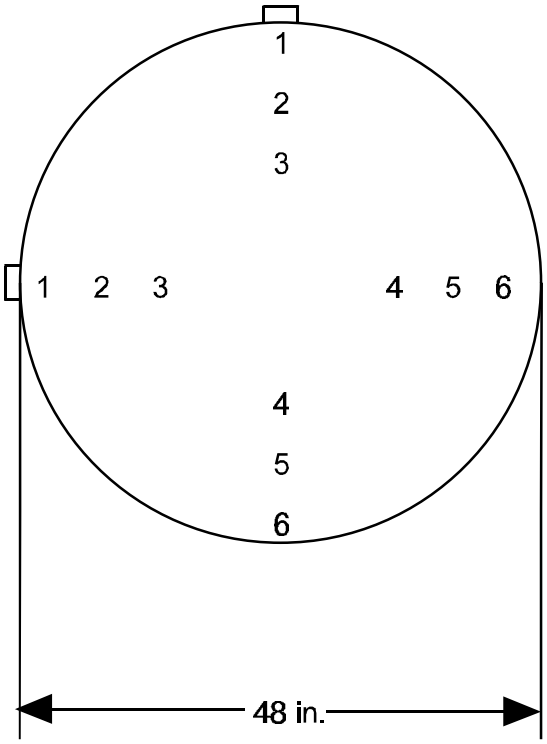


Figure 3-3. Stack schematic.



Point	Distance from wall (in.)
1	2.11
2	7.00
3	14.20
4	33.80
5	41.00
6	45.90

All measurements in inches.

Figure 3-4. Sampling port configuration and traverse points at DuPont.

that were used for the Modified Method 5 measurements. The port lengths and actual stack were measured on-site, and the appropriate adjustments to the traverse points were measured on-site, and the appropriate adjustments to the traverse points were implemented. For the course of the program, the flue gas conditions at this sampling location showed variations in the following ranges:

Temperature:	285 - 325	°F (with steam reheat)
Static pressure:	+0.2	inches of water
Flow Rate:	13,000 - 15,000	dscfm
Velocity:	10 - 12	m/sec
Moisture:	16 - 30	%
PM Loading:	5 - 100	mg/dscm at 7% O_2

3.1 Reference Method and CEMS Sampling Locations

The reference method measurements with the traversing trains were made using two pre-existing 90^0 - opposed ports, while a third port was used for the single point reference method sampling in the initial testing phase. The CEMS were located on the stack platform at ports specially installed for each CEMS. The CEMS ports were located around the stack at various, nearby levels (within 3 feet) above the plane of the reference method location. They were arranged around the stack such that no CEMS samples are directly downstream of another CEMS or the reference method trains. Figures 3-5 and 3-6 are helpful in illustrating the staggered arrangements of the sampling port locations for the reference methods and the CEMS.

3.2 Reference Method Sampling Procedures

To achieve acceptable data from this test program, detection limits need to be established and achieved. For flue gas measurements, the detection limit is a function of the analytical detection limit and the total sample collected. Depending on PM concentrations, the M5 sampling trains were

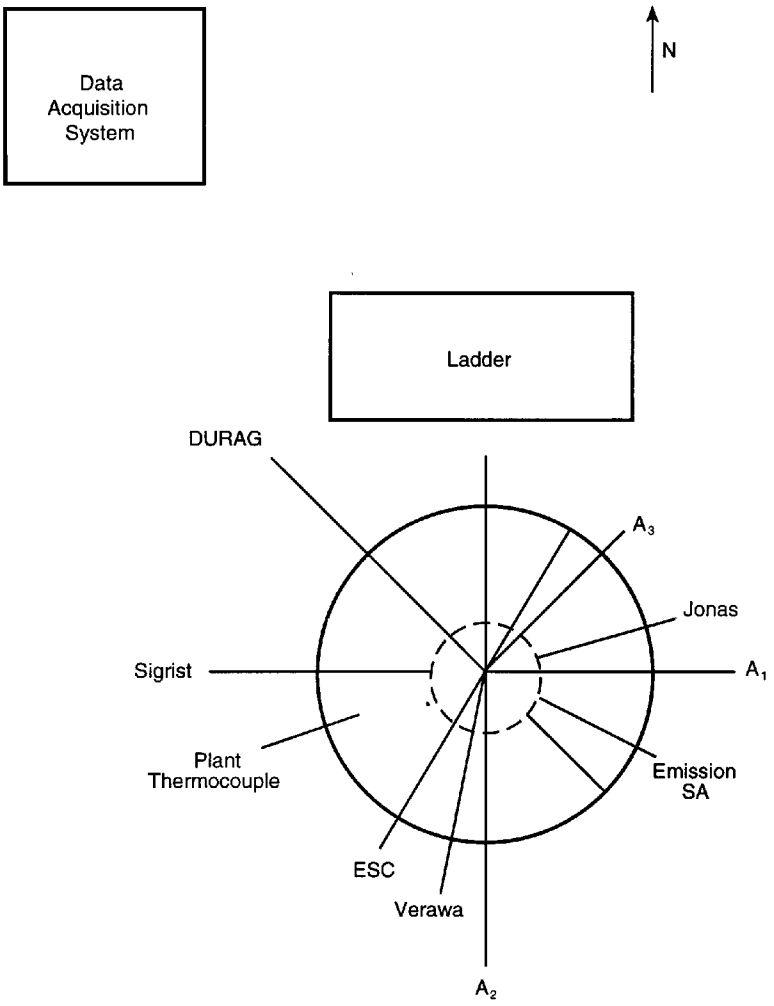


Figure 3-4. Plan view showing location of CEMS' sampling axes.

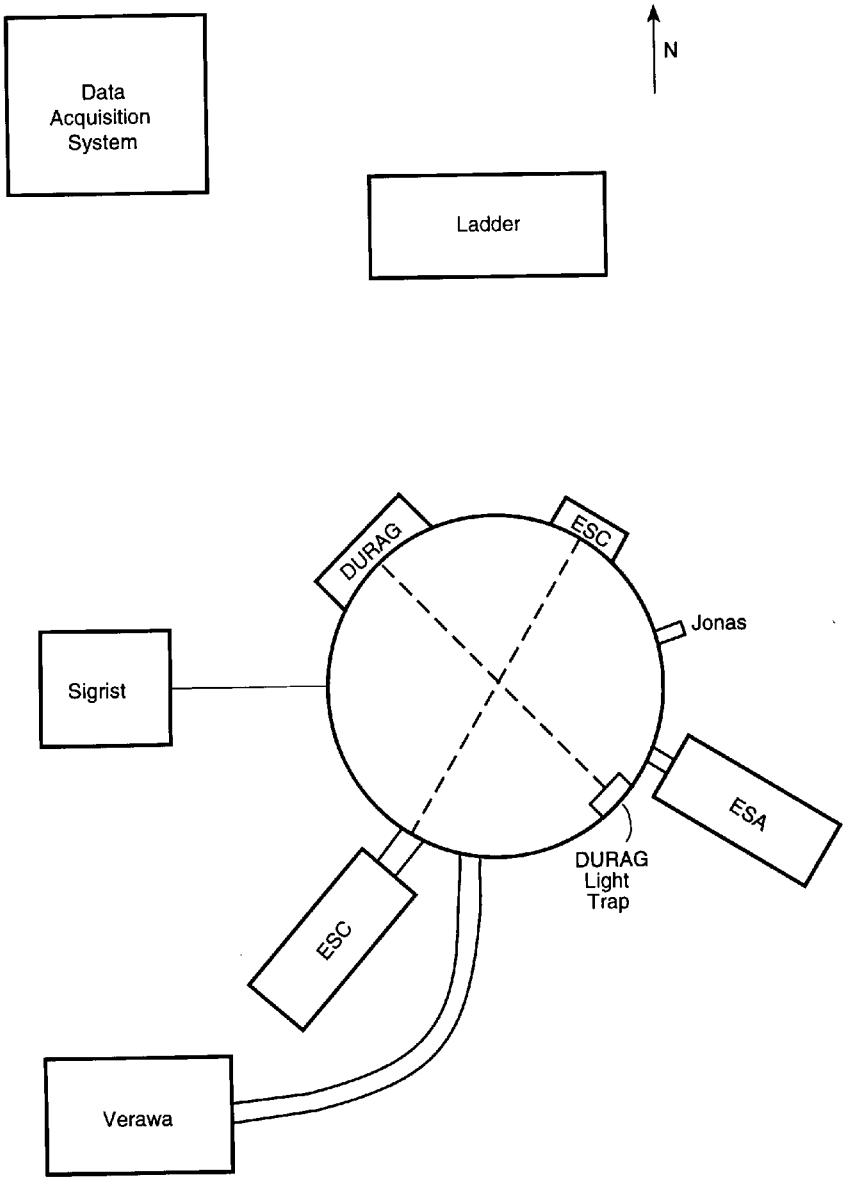


Figure 3-5. Plan view showing locations of all the monitors.

operated for 18 to 72 minutes. Details of the sample trains, sampling procedures, and recovery procedures follow.

3.2.1 *Sample Train Description and Sampling Procedures*

EPA Methods 1, 2 - Traverse Point Determination, Stack Gas Temperature, Velocity, and Volumetric Flow Rate

EPA Method 1 was used to determine the sample and velocity traverse points for velocity measurements and isokinetic sampling. With EPA Method 1, the duct or stack cross-section is divided into equal areas. A traverse point is located in the centroid of each of the resulting areas.

The minimum number of equal areas and traverse points depends on the duct diameter and length in equivalent diameters directly upstream and downstream of the sample location. Schematic layouts of the sample locations and traverse points are shown in Figure 3-2 and 3-4.

EPA Method 2 was used to determine the stack gas temperature, velocity, and volumetric flow rate. The velocity of the stack gas was determined from the density of the gas and the measurement of the average velocity head. A stainless steel sheathed Type-K thermocouple (TC) was used to measure stack temperature, while a stainless steel Type-S pitot, and an inclined manometer is used to measure stack gas velocity. To minimize mutual interference, the TC and pitot are assembled according to the method specifications. Pre-test and post-test leak checks were conducted to ensure the accuracy of the velocity measurements.

EPA Methods 3A and 4 - Stack Gas Analysis and Moisture Content Determination

EPA Method 3 was used to determine the stack gas oxygen (O_2) and carbon dioxide (CO_2) concentrations and the dry molecular weight. An integrated stack gas sample was collected from the M5 sample train and examined using an Fyrite analyzer to determine carbon dioxide and oxygen content. The dry molecular weight of the stack gas was calculated using the measured O_2 and CO_2 levels, assuming the remainder of the stack gas composition is nitrogen. Low levels (ppm range) of

CO, SO_2, NO_x, hydrocarbons, and other compounds are not significant factors in the molecular weight determination. The molecular weight and excess O_2 levels are used in velocity, isokinetic sampling rate, and pollutant emission concentration calculations.

EPA Method 4 was used to determine the moisture content of the stack gas for a pre-test determination. Moisture was determined from all M5 sampling trains during the calibration tests.

EPA Method 5 - Determination of Particulate Emissions from Stationary Sources

As directed by the Code of Federal Regulations, Method 5 applies specifically to the gravimetric determination of the emission rate of particulate matter (PM) from stationary sources. For this to be achieved, the location of the sampling points must be determined (Method 1) and the volumetric flow rate (Method 2) calculated. To calculate the volumetric flow rate, the values for carbon dioxide and oxygen contents (Method 3), and moisture content (Method 4) must be determined, per the methods discussed in the previous section.

With EPA Method 5, a gas sample is withdrawn isokinetically from the stationary source and passed through a heated glass fiber filter. The filter collects any solid PM contained in the effluent gas stream while allowing any uncombined water vapor to pass through for collection in the impinger train containing a known volume of water. The mass of the particulate is then determined by desiccating the filter and associated probe rinse. For this study, the recovery of the filter was modified to accommodate a new light-weight filter housing. The housing is designed such that the filter and the front half of the filter housing make one integral piece that can be tared as a single unit. The moisture content was determined by measuring the amount of water collected in the impingers. The volumetric flow rate of the gas stream was determined by the velocity and temperature traverse. These values were then used to calculate the particulate mass concentration. Figure 3-7 gives a schematic of the modified Method 5 sampling train.

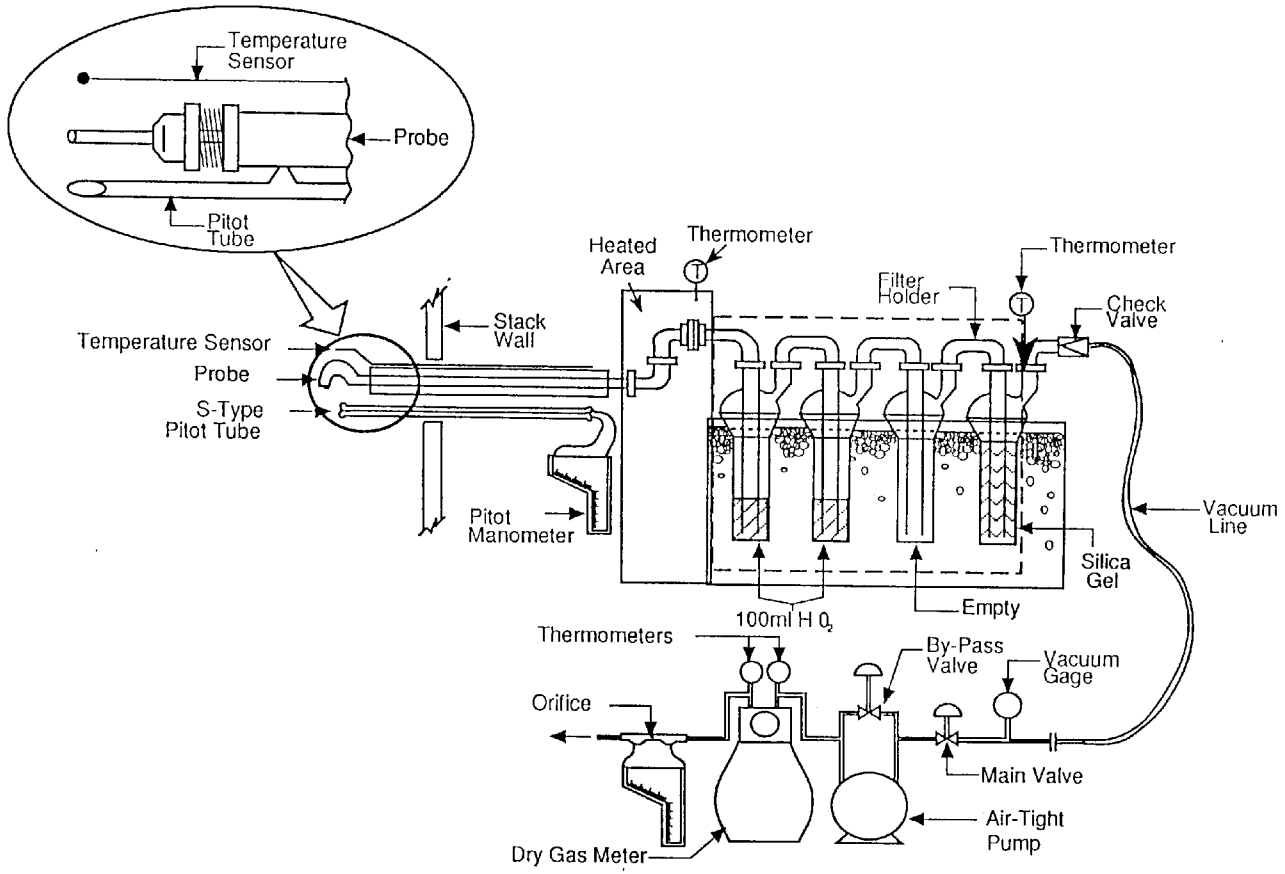


Figure 3-6. EPA Method 5 sampling train schematic.

The largest area of significant error in Method 5 testing at low PM concentrations comes from inaccuracies produced by unnecessary filter handling after pre-weighing and before final weighing. In the original Method 5 procedure, 1) filters were pre-weighed and then handled during assembly into the filter holder; 2) following sampling, filters were handled during recovery from the filter assembly, desiccated, and then weighed. As a result of this procedure, it was common for small filter pieces/fibers to be inadvertently removed/lost (after pre-taring) during filter handling in assembly and/or in recovery (before final weighing). The problem with this approach stems from filter handling after pre-weighing; it was further compounded by further handling before final weighing.

For this PM CEMS program the standard Method 5 filter and its holding assembly were replaced with a smaller (47 mm) filter and smaller holder to minimize inadvertent loss of small filter pieces in its handling during assembly and recovery. The new filter holder allows the filter to be assembled, and then pre-weighed in the low-weight assembly; following sampling, the assembly was desiccated and then weighed before disassembly -- without the filter being directly handled during pre-test and post-test activities. This approach eliminates filter handling after pre-weighing and before final weighing and, thereby, simplifies as well as improves the method.

The filter assemblies were uniquely marked with stamped, metal tags and tared, and the filters used for sampling were immediately removed and carefully transferred to a desiccator. After allowing the filter to cool and following a successful post-test leak check, the filter holder was removed from the sample oven box and the exposed ends of the probe and filter holder were immediately covered with Teflon tape. The filter holder was taken to the recovery area; the probe and impingers were immediately recovered on the stack platform. The filter was recovered by loosening the rings of the holder and separating the filter halves. The front half of the filter housing and the filter disassemble as one unit and were placed directly into a desiccator to continue cooling and allow the weight to stabilize. The average weight of these units was approximately 30 grams, allowing the pre-taring and final weighings to be performed on a micro-balance with a resolution of ±0.1 mg.

To determine stack gas moisture concentrations, each of the four impingers were individually weighed to the nearest 0.5g before and after sampling.

Sample train front half recovery was accomplished using a damp cloth or paper towel to remove any accumulated particulate from the exteriors of the nozzle and the probe. Then, the probe and nozzle were rinsed three times using acetone and a small brush. The rinsate was placed in a small pre-cleaned sample jar labeled with a unique sample log number including the run and sample train number.

Analysis of the samples for particulate catch was accomplished using a micro-balance with a resolution to 0.1 mg resolution. The filter and front half rinse were weighed after being desiccated for several hours. The acetone rinses were transferred into Teflon or glass beakers and then evaporated, desiccated and weighed separately. The samples were evaporated at 20° ± 6°C (68° ± 10°F). The samples were weighed until three successive weighings that agreed to ± 0.5 mg for the filters and ± 1.0 mg for the probe rinses were achieved. Anti-static provisions were used to minimize fluctuation in weighings. Prior to analysis the balance was calibrated using Class S weights that are traceable to a National Institute of Standards and Technology (NIST) standard.

3.2.2 *Calibration Procedures*

All equipment used in this test program was maintained and calibrated using approved procedures and EPA, American Standards Testing Material (ASTM), and/or National Institute of Standards and Technology (NIST) traceable reference equipment, where applicable. Calibrations were routinely performed on all key equipment so that required pre-test calibrations were performed prior to mobilization. During equipment preparation, the calibration records were reviewed to ensure that specified calibrations were up-to-date. The applicable equipment was also checked in the field to assure that handling and use did not affect the calibrations. Following each monthly test series, the equipment was again routinely calibrated in order to verify continuous calibration status throughout the on-site testing. If at any time during testing the operator has reason to believe a piece of equipment may no longer be in calibration due to unusual change in readings or possible damage, a recalibration was performed to verify accuracy. Equipment which required calibration included meter boxes, thermocouples, nozzles, and pitot tubes. Reference calibration procedures were followed when available, and the results properly documented and retained in a calibration log book. A discussion of the techniques used to calibrate this equipment is presented below.

Type-S Pitot Tube Calibration

The EPA has specified guidelines concerning the construction and geometry of an acceptable Type-S pitot tube. If the specified design and construction guidelines are met, a pitot tube coefficient of 0.84 can be used. Information related to the design and construction of the Type-S pitot tube is presented in detail in Section 3.1.1 of EPA Document 700/4-77/027b. Only Type-S pitot tubes meeting the required EPA specifications were used during this project. Pitot tubes were inspected and documented as meeting EPA specifications prior to the field sampling.

Sampling Nozzle Calibration

EPA Method 5 prescribes the use of stainless steel buttonhook nozzles for isokinetic particulate sampling. However, for this study glass nozzles were used. Calculation of the isokinetic sampling rate requires that the cross-sectional area of sampling nozzle be accurately and precisely known. All nozzles used for Methods 5 sampling were thoroughly cleaned, visually inspected, and calibrated according to the procedure outlined in Section 3.4.2 of EPA Document 600/4-77-027b.

Temperature Measuring Device Calibration

Accurate temperature measurements are required during emission sampling. Bimetallic stem thermometers and thermocouple temperature sensors were calibrated using the procedure described in Section 3.4.2 of EPA Document 600/4-77-027b. Each temperature sensor was calibrated at a

minimum of three points above the anticipated range of use against an NIST-traceable mercury-in-glass thermometer. All sensors were calibrated prior to field sampling.

Dry Gas Meter Calibration

Dry gas meters (DGMs) were used in the Method 5 trains to monitor the sampling gas flow rate and to measure the sample gas volume. All dry gas meters were calibrated (documented correction factor) just prior to the departure of the equipment to the field. A post-test calibration

check was performed as soon as possible after the equipment was returned to EER's shop. Pre- and post-test calibrations agreed within 5%.

Dry gas meters were calibrated using the calibration system. Prior to calibration, a positive pressure leak-check of the system was performed, using the procedure outlined in Sections 3.3.2 of EPA Document 600/4-77-27b. The system was placed under approximately 10 inches of water pressure, and a gauge oil manometer was used to determine if a pressure decrease can be detected for a one-minute period. If leaks were detected, they were eliminated before actual calibrations were performed.

After the sampling console was assembled and leak-checked, the pump was allowed to run for 15 minutes, allowing the pump and dry gas meter to warm up. The valve was then adjusted to obtain the desired flow rate. For the pre-test calibrations, data were collected at orifice manometer settings ($\triangle$ H) of 0.5, 1.0, 1.5, 2.0, 3.0, and 4.0 inches of H_2O. Gas volumes of 5 ft^3 were used for the two lower orifice settings and volumes of 10 ft^3 for the higher settings. The individual gas meter correction factors (Y_i) were calculated for each orifice setting and averaged. The method requires that each of the individual correction factors must fall within 2% of the average correction factor or the meter must be cleaned, adjusted, and recalibrated. For the post-test calibration, the meter was calibrated three times at the average orifice setting and highest vacuum used during the actual test.

Analytical Balance Calibration

Analytical balances were calibrated over the expected range of use with standard weights (NIST Class S). Measured values must agree within ± 0.1 mg for the probe rinse and filter weights, and 1.0 mg for moisture, respectively. The balances were calibrated prior to and during the field measurement program.

Field checks of balance accuracy were made daily using a set of quality control weights which have previously been weighed side-by-side with the NIST-traceable weights.

3.2.3 Data Reduction, Validation, and Reporting

Manual methods operations data were input onto computer spreadsheets each day following receipt from testing. Results of sample weighings were input onto the computer system as soon as they were available. Data were reduced and analyzed using hand-held calculator programs, computer spreadsheets, and other computer programs. The actual equations and nomenclature are shown on the calculator program data sheets and on the spreadsheets. This feature enabled operator and analyst to become familiar with the programmed computations, gave separate spot-checking of computed results by hand, and eliminated the need to show equations separately in the text.

Standardized run data forms were used for each method. All run sheets were reviewed daily by the Field Manager for evaluation of progress, completeness, and problems. Standardized computer spreadsheets were used to reduce and analyze field data. At the end of each test day, test data was input onto these spreadsheets. Lab analytical results were not available at the end of each test day, however, results were input as they became available. A standard data set, which had been verified by hand, was used to demonstrate the accuracy of the spreadsheet calculations before the test program.

For each test condition, the field data was reduced manually at the end of each test. An isokinetic ratio was then estimated at the end of each condition using an average or typical moisture value. The estimated moisture value, estimated isokinetic ratio, and all intermediate calculations were noted on the run sheet. Upon entry into the computer spreadsheet program, both the data and the program were validated by checking the estimated isokinetic ratio against the manually determined value.

Spreadsheet calculations for the various runs observed the following guidelines:

1. Isokinetic calculations for each train were conducted using the input run data from that specific run rather than from the average or other values from previous runs. Stack gas moisture content was determined using the condensed water measured in

that train; and

2. Stack temperature, velocity, and flow rate values for each sampling train were determined for each specific sampling run.

The accepted range for the isokinetic rate is 90 to 110%. All valid data had isokinetic rates were within the acceptable range.

Upon daily completion of testing, the Field Manager was responsible for preparation of a data summary which included:

- Raw data sheets;
- Calculation of isokinetic ratio for each run;
- Traverse start and stop times for each run;
- Calculation of sample volume for each run;
- Calculation of stack gas flow rate; and
- Problems encountered during sampling and/or deviations from standard procedure.

The daily data summary was submitted to the QA Coordinator. The final section of this report includes a separate QA/QC section, which summarizes any audit results from manual sampling procedures, as well as QC data collected throughout the duration of the program. The EER QA/QC Officer has reviewed the manual methods QC data and provided data quality input for this report.

3.2.4 *Sample Tracking, Shipping, Storage, and Custody Procedures*

The execution of this program included the acquisition and compilation of field data and the physical collection, handling, storage, shipping, and analysis of two types of field samples. Both acquired data and physical samples required documentation and safeguarding to maintain data and sample integrity and to ensure against loss of valuable test results. Field data, such as computer files, operator logs, and data sheets, were filled out and checked for completeness, then copied, and stored

or maintained in systematic fashion. In addition, physical samples were promptly labeled and tracked, they were handled, stored, and/or shipped using methods and observing procedure, according to M5 procedures. These steps are critical for samples since the number of physical samples was large, and many of the samples were shipped or changed hands between operations in order to conduct sample analysis. However, there were lapses in filter tracking during the initial test in September as filter numbers were not recorded accurately on the field data sheets for Conditions 2, 11 - Rerun, 10 - Rerun, and 3. Corrective action was taken by developing new and additional field recovery and test summary forms to provide redundancy in filter tracking.

The Field Manager was responsible for proper data and sample logging and custody. Run sheets, data sheets, files, and sample tracking forms were completed by each of the respective team members responsible for data acquisition, equipment operation, sample recovery, and manual data logging, except as noted above. The Test Team Leader daily checked off the completion of logging, documentation, and storage tasks lists. The sample recovery specialist was responsible for signing sample custody forms and transferring samples.

3.3 CEMS Sampling and Analysis

The CEMS sampling locations were arranged around the stack at the platform location as shown in Figures 3-3, 3-5, and 3-6. The CEMS were downstream of the reference method location, except for the Durag and ESC. Ports as required for each CEMS were installed at the locations indicated in the figures. The CEMS probes for the ESA, Verewa, Sigrist, and Jonas extended 20 inches into the stack (the same distance as the single-point M5 train). The six CEMS participating in the demonstration are described below. Additional vendor-provided information with more detailed descriptions of the CEMS are contained in the Appendix. In this section, the CEMS are briefly described with their performance specifications summarized. Table 3-1 profiles each CEMS sampling and analysis characteristics.

3.3.1 *Verewa F-904-KD Beta Gauge Monitor*

The Verewa F-904-KD continuous particulate monitor extracts a sample from the stack at

a nominal design point under close-to-isokinetic conditions. Isokinetic sampling is not actively maintained as stack flow changes. The stack sample is diluted for this application since moisture/acid-gas dew points and high pm loadings > 100 mg/dscm are feasible. The sample passes through a heated probe and sample line and then collected on a filter. The sampled gas is dried by cooling and the flow rate is measured, thus allowing reporting on a dry standard (dscm) basis. A filter tape mechanism allows long duration operation and positions the filter spot in either a "measurement" or "sample" location. In the measurement location, the attenuation of beta particles from a carbon-14 source is measured. Each filter spot location used for sampling is measured before and after sampling: The difference between these two measurements is representative of the PM mass sampled. The attenuation of the beta particles is virtually independent of the composition/properties of the PM; thus a site-specific calibration is not generally required. The F-904-KD uses a dual source/detector arrangement to allow measurement of the previous sample while acquiring the current sample. Sampling and analysis frequency is thus enforced. Zero and span calibration checks are carried out at programmable intervals. The zero check is performed by

TABLE 3-1. SUMMARY OF PM/CEMS CHARACTERISTICS

	Analysis						Sampling		
MFG	**Type**	**Detection Limit**	**Range(s)**	**Location**	**Response Time**	**Unique Features**	**Isokinetic**	**Rate**	**Heated Probe**
ESC	Back-scattering @ 180° with Infrared LED Light source	0.5 mg/am3	0-100 mg/am^3 0-500 mg/am^3 0-2,000 mg/am^3 0-10,000 mg/am^3	In-Situ	~ 1 sec.	Second reference detector for self-compensation	Not; In Situ Probe	NA	No
DURAG	Back-scattering @ 120° with Halogen light sources	0.5 mg/m^3	0-1 mg/m^3 0-50 mg/m^3 0-100 mg/m^3	In Situ	~ 1 sec.	Purge air optics cleaning; 2 light sources and 1 trap	Not; In Situ No Probe	NA	No
Sigrist	Forward-scattering @15° with Incandescent light source	0.003 mg/m^3	0-0.1 mg/m^3 0-1000 mg/m^3 DL of 10 on 0-1000 mg/m^3	External	~ 5 sec.	Purge air optics cleaning; Double-beam compensation split by oscillating mirror	Semi-ISO	1 am^3/min; large sample extracted with 35 l pm sub-sample analyzed	170°C
ESA	Beta attenuation; blank & sample analysis	0.1 mg/m^3	2-4000 mg/m^3	External	Programmable 2 min. sample ~ 6 min.	Real-time gas velocity and temperature; Close-off valve for probe cleaning with back-flushing	ISO-pitot and TC venturi for sample flow rate control; eductor instead of pump	~ 0.05 am^3/min	170/200°C (340-392°F)
Verewa (Monitor Labs)	Beta Attenuation blank & sample analysis; dual source/detectors	0.1 mg/Nm^3	10-2,000 mg/Nm^3	External	Programmable sample; 12.3 min. total: 10 min. sampling, 20 sec. tape transport	Dual light sources and detectors; Date/Time Stamp on Filter Paper; Probe breakdown; Reusable filter	Semi-ISO with dilution; rotary vane; compressor-cooler; mass flow meter for sampling flow rate control	~ 0.05 am^3/min	170/180°C
Jonas	Acoustic	To Be Determined	To be Determined	External	~ 1 sec.	Design technology	Not; in-situ	NA	No

Note: All monitors have internal zero and span calibrations performed automatically.
NA = Not Applicable.

measuring the same location on the filter tape twice in succession, without collecting a sample. The span calibration is checked using a radiation attenuator inserted into the measurement beam. For most of the test program, it took two (2) minutes for sample collection on the filter, two (2) minutes for filter analysis, and about 60 seconds for filter tape transport time. Using the dual source/detector configuration, measurements are thus reported about every 12.3 minutes in the beginning and 5 to 6 minutes at the end of this test program. These times are programmable, however, so different sample and reporting times can be obtained depending on the sample loading.

3.3.2 *Emissions SA 5M Beta Gauge Monitor*

The Emissions SA Beta 5M uses a heated sampling probe with real-time pitot and thermocouple measurements to obtain an isokinetic sample that is maintained automatically. These features are suitable for applications where moisture/acid-gas dew points are approached and/or where larger particles (>5 microns) prevail. The sample is collected on a filter, which, at the end of the sampling period, is moved using a continuous filter tape mechanism to a measurement location between a carbon 14 beta particle source and a detector. The beta transmission through each blank filter is determined before sampling begins. The sampling duration is programmable and determines the mass concentration detection limit. At high PM loadings, it must be kept small enough to prevent sampling excessive amounts of PM, and is usually set at two (2) minutes for typical applications. Analysis takes 90-120 seconds, and thus a measurement is made every six (6) minutes. At the end of each sampling period, the probe nozzle is temporarily closed, opened, and closed again in order to re-entrain any PM deposited in the probe. It is equipped with a programmable logic controller which monitors and diagnoses key sampling and analysis operations. The instrument is relatively insensitive to variations in PM composition and properties, thus a site-specific calibration is not generally required, although certification tests are normally performed.

3.3.3 *Durag DR-300 Light-scattering Monitor*

The Durag model D-R 300-40 light-scattering monitor measures the back scattered light at approximately 120° by the PM. The light beam is generated by a halogen lamp (400-700 nm)

modulated at 1.2 kHz, and the sample volume is located in a region 80 to 280 mm (centered at 150 mm) from the wall. Both the light source and the detector are located in a single unit, thus requiring only one point of access to the duct and light trap on opposite side of stack. The D-R 300-40 is designed to carry out and record automatic zero and span checks, and it provides automatic compensation for dirt on the optics even though the optics are protected by an air purge system. Stray light from surface reflections of the transmitted beam is minimized through the use of a light trap mounted on the opposite side of the duct. The D-R 300-40 is normally located directly on the duct wall, thus making an *in-situ* measurement.

For applications where moisture/acid-gas dew points are approached, a hot by-pass system is available but not provided for this demonstration.

3.3.4 *ESC P5A Light-scattering Monitor*

Environmental Systems Corporation model P5A light-scattering instrument monitors the back scattered light (180°) from an infrared light emitting diode (LED). The instrument has a roughly constant response to particles in the 0.1 to 10 micron range and a measurement range of 1 to 10,000 mg/dscm. The measuring area is located 4.5 inches from the end of a probe containing both the transmitting and receiving optics that are inserted into the flow through a standard flange. The probe is purged with its own blower, supplying air to keep the optics clean. Only one point of access and light trap to the stack is required; measurement is accomplished *in-situ* without an extractive probe. The instrument automatically carries out and records zero and span calibrations and is continuously compensated for any changes in the LED intensity due to aging or temperature changes via a second reference detector. A site-specific calibration is recommended to assure accuracy.

3.3.5 *Sigrist KTNR Light-scattering Monitor*

The Sigrist model KTNR is an extractive sampling light-scattering monitor suitable for

applications where moisture/acid-gas dew points are approached or produced. This device extracts a heated slipstream (1 m^3/min) from the stack, a small portion of which is sampled (35 liters/min) and passes through a scattered light photometer. The entire sample, including the bypass portion of the slipstream, is then returned to the duct. The sample rate is set up to be close-to-isokinetic at a normal stack flow, but isokinetic sampling is not actively maintained. Rather, a constant sample rate is maintained. The photometer measures the forward light scattered at 15° from a incandescent bulb emitting over the range 360 to 2800 nm. A double beam compensation measuring method is used in which the light path is split and the intensity of the reference path adjusted by an attenuator to equal the intensity of the measurement path. The amount of adjustment necessary is reflected in the output signal. This approach makes the output signal independent of fluctuations or aging in the optical and electronic components, including the buildup of dirt on the optics. Drift of the calibration and zero point is absent. Periodic cleaning and checks with optical filters supplied with the instrument are carried out, typically in 6 to 12 months. Measuring ranges run from 0 to 0.1 mg/dscm to 0 to 1000 mg/dscm. It is recommended that a site-specific calibration be performed to improve accuracy.

3.3.6 *Jonas, Inc.*

The Jonas Consulting Acoustic Energy PM monitor uses shock waves caused by the impact of particles with a probe inserted into the flow to measure particle loading. The device counts the number of impacts and also measures the energy of each impact. This information, coupled with knowledge of the flow velocity, allows calculation of the particle mass. Since the probe distorts the flow, changes in flow velocity and particle size distribution will, in principle, change the instrument response. However, correction for the flow pattern is included in the instrument's response.

3.3.7 *CEMS Data Acquisition System*

All the data from the CEMS instruments are collected and stored on a dedicated data acquisition system (DAS) manufactured by Environmental Systems Corp. This system includes a data logger with a personal computer and a modem for automatic downloading of data. The DAS is

housed in an air-conditioned and weather-proofed cabinet located on the stack sampling platform, as shown in Figures 3-5 and 3-6. The data logger samples each CEMS signal output (typically 4 to 20 milliamp) once per second and calculates one minute averages based on these samples. The one-minute averages are further used to produce 10- and 60-minute rolling averages. Additional channels are available for other inputs, such as stack gas temperature, O_2, and moisture.

3.4 Scanning Electron Microscope Analytical Procedure

Each filter from the September and October tests was assigned a sequential laboratory number. A wedge-shaped sample was cut from the filter and mounted on an aluminum planchet using silver paint. Each sample was analyzed using a JEOL JSM 840A Scanning Electron Microscope (SEM). The filters were scanned using Backscattered ED Electron Microscopy (BEM). A compositional image was selectively obtained using a paired semiconductor element conductor in the BEM. This form of microscopy was very useful for surveying sample surfaces prior to X-ray analysis.

A photo micrograph was taken of a selective portion of each sample which appeared to represent most of the particles collected on the filter. These photos were taken using BEM. Particles with elements of high atomic numbers produced bright images in the photomicrograph.

Energy-Dispersive X-ray (EDX) analysis was performed on the various particle types found on each sample. Electrons produced during EDX analysis emit unique and characteristic patterns of X-rays. Under analytical conditions, the number of X-rays emitted by each element reflects its concentration.

A second series of analyses was performed on wedges of selected filter samples that were utilized in the November monthly calibration tests. Though similar to the first series of analyses which provided a general assay with qualitative results, the purpose of the second set of analyses was to produce semi-quantitative results of the relative amounts of the elements (excluding oxygen) found in the spectral analysis of the collected PM on the filter samples.

This second series of analyses consisted of SEM, EDS, and Advanced Image Analysis (AIA) with two (2) photomicrographs of each sample analyzed. The samples were prepared for analysis by slicing a pie wedge corresponding to about 1/5 of the total filter area and mounting the wedge on a carbon planchet with carbon paint. Imaging occurred at a magnification of 100x at 20 kilovolts. The SEM/EDS automated imaging program analyzed each wedge sample for up to 15 elements and produced high resolution X-ray maps for each element detected. This innovative analytical technique produced:

- Semi-quantitative data of the relative amounts of the elements found,
- Photomicrographs at 100x of the field examined, and
- A second series of photomicrographs displaying respective distributions of each element found.

3.5 Process Data Acquisition

Process data are manually recorded from the facility operating system are included in the Appendix.

4.0 QUALITY ASSURANCE/QUALITY CONTROL

Quality Assurance Program

Quality assurance is an integrated system of activities which involves planning, quality control, quality assessment, reporting, and quality improvement to ensure that the test program meets standards of quality with a stated level of confidence. Quality assurance encompasses the organization within which quality control activities are performed. The QC activities which accompany testing, lab analysis and other procedures provide control of data and quantify the quality of data so that it meets the needs of the users as stated in the quality assurance objectives.

Generally, EER's QA procedures follow the guidelines in the "Quality Assurance Handbook for Air Pollution Measurement Systems," Volumes I through III. These procedures outline pre-test preparation and calibrations of sampling equipment, post-test sample handling, and post-test calibrations. Standardized, written procedures, calculator programs, and spreadsheets are used for test planning, pre-surveys, equipment checklists, preliminary calculations, data and sample collection, sample tracking, sample and data analysis, and reporting.

Test procedures were based on applicable EPA test methods. However, slight modifications of the standard Method 5 filter holder assembly and filter recovery procedure were made to improve quality of the Method 5i data. For each key measurement area, there were specific QC activities and checks to ensure that written procedures were followed during all preparation, validation, sampling, and recovery activities. There are also criteria to quantify and judge the performance of the measurements and corrective action procedures for correcting deficiencies. Prior to reporting, all data was reviewed by an independent QA auditor.

Quality Assurance Approach

The EPA has defined Categories I through IV to define the content of QA plans according

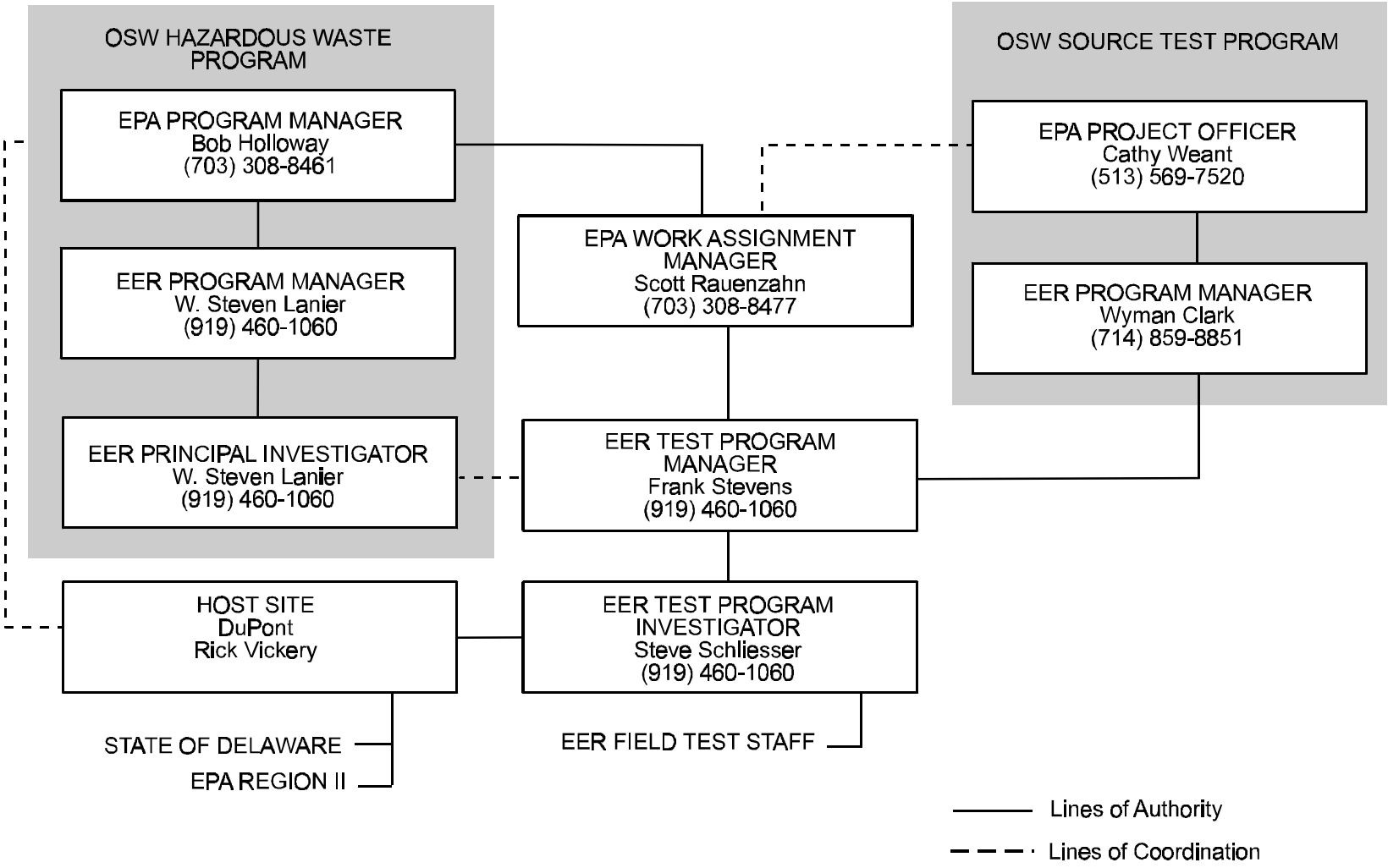


Figure 4-1. Project Organization for DuPont PM CEMS Demonstration.

to the goals of the program with which the QA plan is associated (Preparation Aids for the Development of RREL Quality Assurance Project Plans, U.S. EPA, Risk Reduction Engineering Laboratory, Cincinnati, OH, 1989). The four categories are defined as follows:

Category	Description
I	Projects for support of enforcement, compliance, or litigation. This level of QA is the highest possible for legal challenge. The cost of the QA program for this type of project is typically 20-30% of the total cost.
II	Projects for producing results used to complement (or in combination with) other projects of similar scope for rule making, regulation making, or policy making. Data quality indicators (DQIs) for completeness, representativeness, and comparability may not be easily defined. The cost of the QA program for this type of project is typically 10-30% of the total cost.
III	Projects for producing results used for engineering, technology development, feasibility studies, or preliminary assessments. QA requirements are more broadly defined, although definitive documentation of QC activities and results is still required for reports.
IV	Projects for producing results used in assessing suppositions, feasibility studies, or fundamental investigations.

The purpose of this test program was to generate data to evaluate: (1) the acceptability of commercially-available PM CEMS towards the Draft Performance Specification 11, (2) the applicability of those draft performance specifications, and (3) the acceptability of modifying Method 5 for measuring low PM emission levels. Category I QA/QC was implemented during this program. Phase I required an abbreviated form of the QA/QC required in a Category II program

since fewer samples were collected than are required to calculate the necessary DQIs.

QA/QC Organization

The QA/QC structure for this test project is shown in Figure 4-1. The Test Program Investigator was Mr. Steve Schliesser of EER. EER's Quality Assurance Officer is Mr. Jerry Cole, and EER Project QA Coordinator was Mr. Bob Zimperman. Mr. Zimperman had overall responsibility for all project QA. The QA Coordinator's activities consisted of test plan review, on-site performance and system audits, analytical system and performance audits, and reporting of all QA/QC activities and data. The efforts of the QA coordinator were designed to assure that the specific goals for precision, accuracy, and completeness were achieved. In addition, an outside independent QA consultant performed a comprehensive audit of all data produced during the tests.

4.1 Quality Assurance Objectives

Quality assurance objectives are goals for test data accuracy, precision, and completeness. Accuracy is the degree of agreement of a measurement (or average of measurements) with an accepted reference or true value. Precision is a measure of mutual agreement of replicate measurements. Completeness is a measure of the amount of valid data compared to the amount that was expected to be obtained under correct operating conditions. QA objectives should be defined for all of the critical measurements of the test program. The objectives should be based on the limitations and requirements of the test methods, where available. The quality assurance objectives for the particulate matter are: completeness of 98%; precision of a constant weighing ± 1% or ± 0.5 mg, whichever is greater; and accuracy of ± 6%.

Some of the data validation was not completed until after the testing phase ended. In this case, it may not be possible to take corrective action to meet the quality assurance objectives (for example, if the analytical laboratory irrecoverably contaminates or loses a sample). Daily records

of completeness were maintained by the EER QA Coordinator for each test method. These daily records are based on the validity of each run.

Calculation of Quality Assurance Objectives

The quality assurance objectives for precision, accuracy, and completeness will support the integrity of the data generated for each source test. Precision will be a measure of mutual agreement among individual measurements of the same property. Precision will be generally determined for each of the key measurements through either the percentage agreement between duplicate measurements or by determining the relative percent standard deviation for three or more replicate measurements. When two replicate measurements are available, then the relative standard deviation (RSD) from the mean of all the replicate values will be used to indicate precision calculated using the two equations defined in Section 2.2.2.

Accuracy, defined as the percent difference between a measurement and a reference or standard value, will be calculated by the following equation:

$$A\ (\%) = \frac{X - X_R}{X_R} * 100$$

where: A = accuracy

X = measurement

XR = reference or standard value

Completeness will be a measure of the amount of valid data obtained compared to the amount which was expected to be obtained. Completeness will be calculated by the following equation:

$$C\ (\%) = \left(\frac{D_V}{D_P} \right) * 100$$

where: C = Completeness

Dv = Quantity of valid data

Dp = Quantity of expected data

4.2 Reference Method QC

The quality assurance (QA) objectives provide a standard of quality for the various measurements to be made in this program. These objectives include criteria for precision, accuracy, and completeness. In order to quantify how well the measurements have satisfied these objectives, comprehensive internal QA/QC activities were implemented. The efforts of the internal QA coordinator are designed to assure that the specific goals for precision, accuracy, and completeness are achieved. The specific system of internal quality control (QC) procedures to establish the performance of the measurement systems is presented in this section. This system of internal checks is an integral part of the emissions characterization program.

For each key measurement area, there were specific QC activities and checks, which ensure that written procedures are followed during all preparation, validation, sampling, and recovery activities. There are also criteria used to quantify and judge the performance of the measurements and corrective action procedures for correcting deficiencies, if necessary.

Quality control is the overall system of activities whose purpose is to provide a quality product or service: for example, the routine application of procedures for obtaining prescribed standards of performance in the monitoring and measurement process. Quality assurance, on the other hand, is a system of activities whose purpose is to provide assurance that the QC system is adequate to ensure that the program goals will be achieved and that it is being implemented effectively. The program quality control system includes these features:

- Calibration procedures and schedules;

- Specific checklists and procedures for pre-test, test operation, and post-test activities for each measurement system;
- Standard pre-programmed calculation routines using hand-held calculators and computer spreadsheets;
- Blanks, spikes, duplicates, QC audit samples, and other analytical quality control procedures for each measurement system; and
- Organization and documentation of all calibration records, run, data, and calculation sheets, process logs, spreadsheet files, and printouts.

QA audits were conducted in order to ensure that the above QC activities were effectively implemented. The following sub-sections discuss QC activities ensuring data validity.

Quality control samples are used to determine QA objectives and to provide data which supports the generated data. Quality control samples include field blanks, matrix spikes, matrix spike duplicates, and laboratory control spikes.

4.2.1 *Quality Control Procedures*

This program involved sampling and analysis of the stack outlet flue gas stream. This section describes the QA/QC activities and criteria accomplished during the sampling, as well as the analytical phases of this test program.

4.2.2 *QC for Flue Gas Sampling and Analysis*

The following section discusses the QA/QC activities utilized for this program's flue gas sampling and analytical procedure.

EPA Method 1, 2, and 4 - Sample point determination, flue gas velocity, and moisture content

Sampling: The S-type pitot tube was visually inspected before sampling. Both legs of the pitot tube were leak checked before and after sampling. Proper orientation of the S-type pitot tube was maintained while making measurements. The roll and pitch axis of the S-type pitot tube is maintained at 90° to the flow. The oil manometer was leveled and zeroed before each run. The pitot tube/manometer umbilical lines were inspected before and after sampling for moisture condensate. Cyclonic or turbulent flow checks were performed prior to and after the test program. An average velocity pressure reading was recorded at each point instead of recording extreme high or low values. Reported duct dimensions were checked by measurements to determine cross-sectional duct area. If a negative gas static pressure was present, checks were made for air in leakage at ports resulting in possible flow and temperature errors (leaks were sealed if found). The stack gas temperature measuring system was checked by observing ambient temperatures prior to placement in the stack. The balance zero was checked, and rezeroed if necessary, before each weighing. Pre-test liquid volumes of impinger solutions were recorded as a check on tare weights. The balance was leveled and placed in a clean, motionless environment for weighing. The indicating silica gel was fresh for each run and periodically inspected and replaced during runs if necessary. The silica gel impinger gas temperature was maintained below 68°F. The dry gas meter is fully calibrated using an EPA-approved intermediate standard. Pre-test, port change, and post-test leak checks are completed (must be less than 0.02 cfm or 4% of the average sample rate). The gas meter was read to the thousandth of a cubic foot for the initial and final readings. The meter thermocouples were compared with ambient prior to the test run as a check on operation. Readings of the dry gas meter, meter orifice pressure (ΔH) and meter temperatures were taken at every sampling point. Accurate barometric pressures were recorded at least once a day.

Analysis: Prior to daily use, the balance was calibrated with NIST-traceable weights. The impingers were weighed to the nearest 0.5 g.

Sampling: All sampling equipment was thoroughly checked to ensure clean and operable components. The oil manometer or Magnehelic gauge used to measure pressure across the S-type pitot tube was leveled and zeroed. The pitot tubes and connecting tubing were leak checked. The temperature measurement system was visually checked for damage and operability by measuring the ambient temperature prior to each traverse. All train components were sealed with Teflon tape before train was leaked checked.

During Test: Duplicate readings of temperature and differential pressure were taken at each traverse point. Isokinetic sampling rates were maintained at each traverse point. The sample train was leak-checked between most port changes.

The probe and filter temperature were maintained at 248 (± 25)°F. The impinger outlet temperature was maintained at < 68°F. Any unusual occurrences were noted during each run on the appropriate data form.

Post-test: The Field Team Leader reviewed sampling data sheets daily after testing. Each train operator recorded final gas meter readings; performed a final leak-check at the highest observed vacuum; ensured that the Field Task Manager had the data sheets; and transported samples to recovery area.

Analysis: Method 5 QC samples collected in the field included a field train blank and field acetone blanks. Sample results were corrected for field reagent blanks only as

described in Method 5. The field train blank results are reported with the sample results.

Analysis of particulate in Method 5 samples were conducted by a microbalance with

resolution of ± 0.1 mg for weights less than 100 g. The balance was calibrated prior to analysis using NIST-traceable Class S weights. The calibration was checked using one of the Class S weights. Table 4-1 lists the QA/QC criteria for the stack gas sampling procedure.

4.3 Field Data Reduction

Data gathered during this program falls into the following categories:

1. Manual methods sampling operations data and sample analysis data; and
2. Process data.

Manual methods operations data were input to computer spreadsheets each day following receipt from testing. Results of samples analysis were input to the computer system upon receipt from analytical labs. Process data consisted of logs and continuously monitored data. Data was reduced and analyzed using hand-held calculator programs, computer spreadsheets, and other computer programs. The actual equations and nomenclature are shown on the calculator program data sheets and on the spreadsheets. This feature enables operator and analyst familiarity with the programmed computations, gives facilities separate spot-checking of computed results by hand, and eliminates the need to show equations separately in the text.

TABLE 4-1. SUMMARY OF QA/QC CRITERIA FOR STACK GAS SAMPLES

STACK GAS PARAMETER	QUALITY PARAMETER	METHOD OF DETERMINATION	FREQUENCY	CRITERIA
Gas Flow	Pitot tube angle & dimensions	Measurements with vernier micrometer and angle indicator	Post-test	Specifications in EPA Method 2
	Barometer	Calibrated against lab Hg-in-glass barometer	Pre-test	Within 0.1 in. Hg
	Stack thermocouple	Calibrated against ASTM Hg-in-glass thermometer	Pre- and post-test	Within 1.5% as deg. R
Isokinetic sampling trains	Dry gas meter	Calibrated against a reference test meter	Pre- and post-test	Y within 0.05 of pre-test
	Metering orifice			
	Probe nozzle	Measurements with vernier micrometer to 0.001 in.	Post-test	Maximum difference in any two dimensions within 0.004 inches
	Dry gas meter thermocouples	Calibrated against ASTM Hg-in-glass thermometer	Post-test	Within 5°F
	Trip balance	Calibrated against 10 LM weights	Post-test	Within 0.5 g
Particulate matter	Electronic balance	Calibrated against Class S weights	Post-test	Within 1.0 mg
	Constant filter weight	Documentation	Each sample	Difference of no more than 0.5 mg or 1% of total weight, whichever is greater
	Accuracy	Documentation of train component and analytical calibrations	N/A	N/A
	Precision	Not possible to assess	N/A	N/A
	Blanks	One filter and reagent blank carried through sample prep & analysis	One per test	Reagent blank less than 0.00001 mg/g; filter weight change less than 5 mg or 2% of sample weight

4.3.1 *Manual Method 5i Data Reduction*

Standardized run data forms were used for each method. All run sheets were reviewed daily by the Field Manager for evaluation of progress, completeness, and problems. Standardized computer spreadsheets were used to reduce and analyze field data. At the end of each test day, test data was input to these spreadsheets. Lab analytical results were not available at the end of each test day. However, analytical results were input as they became available. A standard data set, which has been verified by hand, was used to demonstrate the accuracy of the spreadsheet calculations before and after the test program.

For each manual method, the field data were reduced manually at the end of each run. An isokinetic ratio was then estimated at the end of each run using an average, typical, or dry/wet bulb measured moisture value. The estimated moisture value, estimated isokinetic ratio, and all intermediate calculations were noted on the run sheet. Upon entry into the computer spreadsheet program, both the data and the program were checked by comparing the estimated isokinetic ratio against the spreadsheet determined value.

Spreadsheet calculations for the various runs observed the following guidelines:

1. Isokinetic calculations for each train were conducted using the input run data from that specific run rather than from the average or other values from previous runs. Stack gas moisture content was determined using the condensed water measured in that train; and

2. Stack temperature, moisture content, velocity, and flow rate values for each train were averaged.

The accepted range for the isokinetic rate is 90 to 110%. Data outside this range were discarded.

Upon daily completion of testing, the Field Manager was responsible for preparation of a data summary which will include each of the following for each run:

- Raw data sheets;
- Calculation of isokinetic ratio for each run;
- Traverse start and stop times for each run;
- Calculation of sample volume for each run;
- Calculation of stack gas flow rate; and
- Problems encountered during sampling and/or deviations from standard procedure.

The daily data summary was submitted to the QA Coordinator. The final project report includes a separate QA/QC section which summarizes any audit results from manual sampling procedures, as well as, QC data collected throughout the duration of the program. The EER QA/QC Officer reviewed the manual methods QC data and provided data quality input for the final report.

4.3.2 *Data Validation*

Data validation is a systematic procedure of reviewing data against a set of established criteria to provide a level of assurance of its validity prior to intended use. Data were validated internally by QC personnel. All measurement data were validated based upon process conditions during sampling or testing, acceptable sample collection/testing procedures as outlined in Section 3, consistency with expected and/or other results, adherence to prescribed QC procedures, and the specific acceptance criteria. The data were coded as valid or invalid based on its adherence to these criteria. Data validation was conducted at several critical stages of data reduction:

- Field checks of raw and reduced field data by the Field Manager and Crew Leaders;
- Analytical laboratory QC Checks by a lab QA Supervisor;
- Spot checks of reduced raw data by the Project QA Coordinator;

- Review of summary tables for consistency with reduced raw data by the Project QA

Coordinator;

- Draft final report review by the QA Manager, Program Manager, Principal Investigator and Project Manager;
- Final report review by the Program Manager, Principal Investigator, and Project Manager; and
- A comprehensive review of all input data, spreadsheets, calculations, analytical data, and general QC procedures by an independent QA consultant.

Data validation consists of verification of calculation methodology, consistency of raw, reduced and summarized data tables, comparison of expected results, and consistency of results among multiple measurements at the same location.

Field data were initially validated by the EER Field Manager and the internal QC Coordinator based on their judgement of the representativeness of the sample, maintenance and cleanliness of sampling equipment, and the adherence to the sample collection procedures defined in Section 3. They also validated the data daily based on :

- Process conditions during sampling;
- Adherence to acceptance criteria; and
- Acceptable external performance evaluation and technical system audit results conducted by an external auditor.

When the data set is complete, the EER field QA Officer performed an overall review of the data. This review considered:

- The previously listed criteria; and
- The reasonableness and consistency of the data based on a knowledge of the site characteristics and the specific location of the samples.

The review also contained an evaluation of the data in terms of meeting the quality assurance objectives of the program discussed in Section 4 of this plan. The QC criteria for data validation

contains consistency, duplicate sample calibration, tests for outliers, transmittal error, and uncertainty analysis.

Outliers were identified by comparison with other measurements in a set of observations using the standard student T-Test procedures for outliers. This test flagged specific data points as potential outliers; however, it did not automatically disqualify any data. Corrective action was initiated immediately to determine the outlier cause. If possible, the associated sample was reanalyzed. The acceptance rejection of the data was in a uniform and consistent manner based on the established validation criterion of paired train RSD values of > 30%. Data were rejected only on that basis.

Validation of spreadsheet calculations used for data reduction was conducted by entering a QA data set which has been verified by hand. This was done at the beginning and end of the test program.

Data flags were added to all tables to identify special handling procedures or unusual data results. These flags included:

- Quantities including analytical results which are at or below method minimum detection limits;
- Any results where contamination is suspected;
- Any average results which exclude any individual test run results; and
- Other special data handling procedures or qualifications.

4.4 CEMS Data Acquisition/Reduction

The CEMS data are transferred by modem from the site CEMS's data acquisition system to the EER office. The data are stored in a holding directory and later printed as an Excel file.

CEMS data taken during the field reference method test are averaged. The data average is an average of the time the manual method sampling was conducted, minus the period of time needed for port changes.