QUALITY ASSURANCE PROJECT PLAN: VERIFICATION TESTING OF EMULSIFIED OIL

Date prepared: June 5, 1997

Prepared for:

Cooperative Research and Development Agreement

between:

National Risk Management Research Laboratory
U.S. Environmental Protection Agency
Air Pollution Prevention Control Division
Research Triangle Park, NC 27711

and

A-55 Limited Partnership
Reno, NV

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List of Terms

APCS	Air Pollution Control System
APPCD	Air Pollution Prevention and Control Division
APTB	Air Pollution Technology Branch
ASME	American Society of Mechanical Engineers
CARB	California Air Resources Board
CEM	Continuous Emission Monitors
CFR	Code of Federal Regulations
CRADA	Cooperative Research and Development Agreement
DAS	Data Acquisition System
DQA	Data Quality Audits
DQI	Data Quality Indicators
EMF	Exhaust Molar Flow
EPA	U.S. Environmental Protection Agency
ERC	Environmental Research Center
ETV	Environmental Technology Verification
FID	Flame Ionization Detector
GO	Generator Output
MW	Molecular Weight
NAPB	North American Package Boiler
NRMRL	National Risk Management Research Laboratory
PEA	Performance Evaluation Audit
PM	Particulate Matter
QA /QC	Quality Assurance/Quality Control
QAPP	Quality Assurance Project Plan
ROP	Recommended Operating Procedure
SMPS	Scanning Mobility Particle Sizer
THC	Total Hydrocarbons
TSA	Technical Systems Audit
WA	Work Assignment

Section 1.0
Project Description

1.1 BACKGROUND

The use of oil/water emulsions (emulsified fuels) reduces pollutant emissions such as nitrogen oxides (NO_x), carbon monoxide (CO), and particulate matter (PM) without a substantial loss of operating efficiency compared to the corresponding non-emulsified oil. The Environmental Protection Agency's (EPA) National Risk Management Research Laboratory (NRMRL) has conducted a series of in-house tests on the performance of emulsified oils. Through its Environmental Technology Verification (ETV) program, EPA made an objective comparison between the emulsified fuel and the non-emulsified fuel it is intended to replace.

This Quality Assurance Project Plan (QAPP) originates from a Cooperative Research and Development Agreement (CRADA) between EPA's NRMRL and an emulsified fuel producer A-55 Limited Partnership. EPA will conduct testing of the manufacturer's products through the ETV program to allow for direct comparisons between the performance of the A-55's emulsified fuels and corresponding non-emulsified fuels.

1.2 PROJECT DESCRIPTION

To demonstrate the performances of emulsified oils, tests will be conducted on the G-Wing-High Bay North American Package Boiler (NAPB) to replicate the combustion of these fuels in equipments found in many institutional and industrial applications. EPA will provide quantitative, repeatable data on the emissions from and performance of emulsified fuels burned in a consistent manner according to a standard test protocol that outlines the specific tests to be conducted, the measurements to be taken during these tests, and the basis for quantifying the fuel's performance.

The primary objective of the tests is to determine the performance of each emulsified fuel compared to its corresponding base fuel under a specified range of operating conditions. The main operational parameter that will vary for each test is the boiler load. Since the heating value of an emulsified fuel is lower than the heating value of the base fuel, the fuel flow rate will be adjusted to obtain the same specified heat load for each fuel.

The O_2 level required for optimum burning conditions and minimal pollutant emissions will be determined by the directions of the fuel manufacturer to ensure that the fuel is being used according to their specifications.

This QAPP defines the variables to be measured and the quantitative criteria that will be used to evaluate the precision and accuracy of those measurements. Since any measurement carries some degree of uncertainty, the QAPP provides the means of measuring those uncertainties as well as a method for determining acceptable and unacceptable test measurements.

Any special operating instructions or modifications to the boiler will be supplied by the manufacturer. Modifications to equipment will be made by or as directed by the manufacturer. Any problems associated with meeting the desired modifications will be documented for subsequent review.

This test program has two major objectives that focus on the impact of substituting conventional fuel with its emulsified version: the effect on pollutant emissions and the effect on boiler thermal efficiency. This part of the project will follow EPA QA Category II requirements.

Emissions Testing

The verification tests will include continuous monitoring and recording of the concentrations of carbon dioxide (CO_2), CO, nitrogen oxides (NO and NO_2), oxygen (O_2), sulfur dioxide (SO_2), and total hydrocarbons (THC). PM concentrations (both total and size fractioned) will also be sampled in the flue gas of the system being used.

Thermal Efficiency Testing

Measurements of the impact of using emulsified fuel instead of a base fuel on the thermal efficiency of a boiler will be assessed. Determination of the thermal efficiency for the boiler will follow procedures derived from the American Society of Mechanical Engineers (ASME) Power Test Code for stationary steam generating units. The thermal efficiency parameters will be stated clearly in sub-section 1.5.3 of this QAPP.

1.3 FACILITY DESCRIPTION

The NAPB Test Facility is located in the EPA/Environmental Research Center's (ERC) G-Wing High-Bay area. The NAPB, shown in Figure 1, is a 2.5 106 Btu/h, 3 pass, Scotch marine utility boiler capable of firing natural gas or a variety of fuel oils. The burner is a North American model 6121-2.5H6-A65 with a ring-type natural gas burner and an air atomizing center nozzle oil burner capable of firing No. 2 through No.6 oils. The boiler has 300 square feet of heating surface and generates up to 24,000 lb/hr of saturated steam at pressures up to 15 psig. The steam generated by the boiler is extracted by a condensing heat exchanger tied to the ERC industrial water chilling system to simulate actual boiler load. Fuel flows are measured with a liquid volume totalizer and stoichiometric ratios are verified through O_2 and CO_2 emission concentrations. Fuel oil temperature can be adjusted using an electric heater to maintain proper viscosity; the fuel and atomizing air flow rates are variable to ensure adequate oil atomization.

The NAPB is fully instrumented with continuous emission monitors (CEMs) for O_2, CO_2, CO, NO, NO_2, SO_2, and THCs such as methane. A computerized data acquisition system (DAS) is used to record

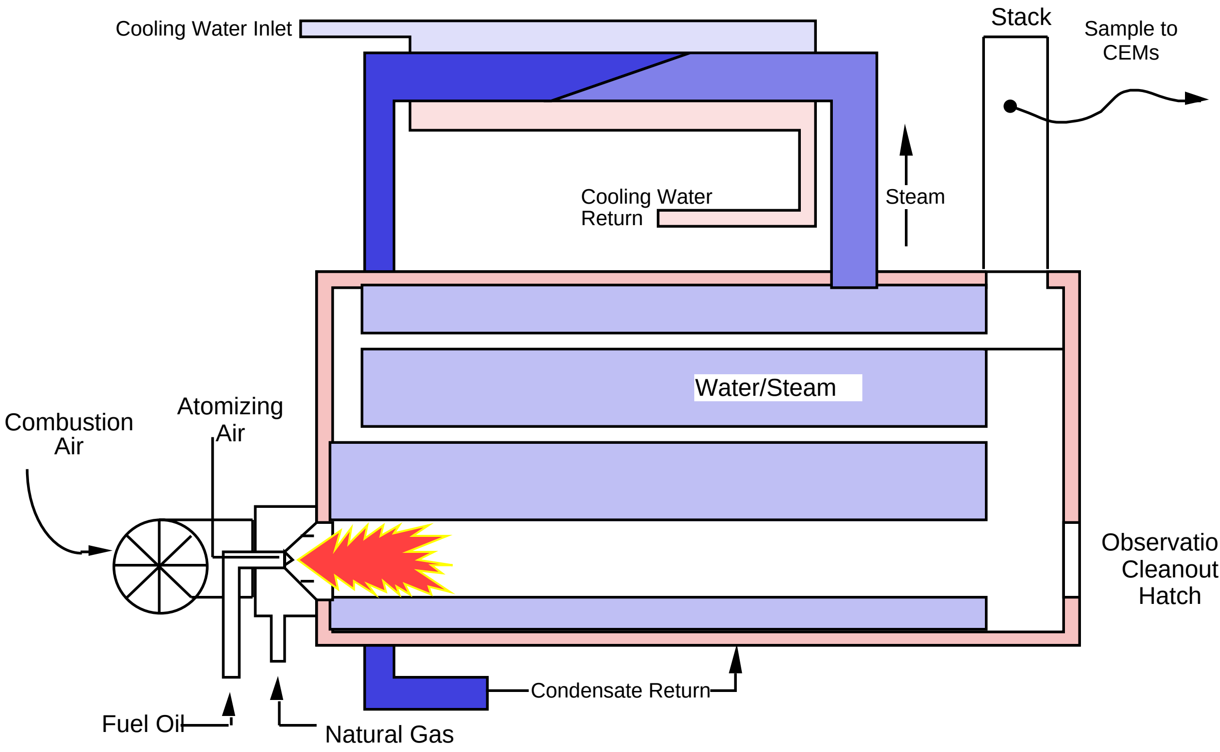


Figure 1. Schematic of the North American Package Boiler.

CEM measurements as well as steam and flue gas temperatures. The flue gas from the unit passes through a manifold to an air pollution control system (APCS) consisting of a natural-gas-fired secondary combustion chamber, an acid gas scrubber, and a fabric filter to ensure proper removal of pollutants emitted by any other combustion facility unit. All emission measurements are taken before the flue gas passes through the APCS.

The NAPB Facility is equipped with several sampling ports located at the exit of the boiler. The vertical section of the duct (8-inch steel pipe) is sufficient in length and free of flow disturbances so that particulate matter can be sampled at an axial location that meets EPA Method 1A particulate matter sampling requirements.

Several sampling ports are located along the horizontal section of the duct approximately nine feet above the facility catwalk. The horizontal section of the duct (8-inch steel pipe) is sufficient in length and free of flow disturbances so that particulate matter can be sampled at an axial location that meets EPA Method 1A particulate matter sampling requirements.

1.4 SAMPLING METHODOLOGY

In order to fulfill the objectives of this program, data will be acquired using NAPB equipment, such as instrumentation and control, flame safety system, thermocouples, and flow meters, as well as shared equipment such as CEMs, the DAS, and particulate loading and sizing systems. Data measurements include stack gas chemical composition, stack PM concentrations, temperatures (fuel, stack, ambient air, etc.), and fuel feed rate.

1.4.1 Continuous Emission Monitoring System

Continuous emission monitoring of chemical species is performed with using shared CEMs for the NAPB Facility. The CEM bench for the NAPB includes six gas analyzers (high range CO, low range CO, O_2, CO_2, NO/NO_2, SO_2, and THC), each with multiple ranges.

1.4.2 Particulate Sampling

Several sampling devices will be operated during each test condition to provide PM data (particulate concentration and particulate size distribution) on both the base and emulsified fuels tests. Total particulate will be collected in accordance with 40 CFR Part 60 Method 5 "Determination of Particulate Emissions from Stationary Sources", an extractive method.

Two particle sizing devices will be operated to provide particle size information. To determine PM size distributions from 0.013 µm to 0.72 µm, a scanning mobility particle sizer (SMPS) will be used for each test condition. This instrument relies on differences in each particle's aerodynamic diameter; an electric field provides the driving force to separate the particle sizes instead of mechanical momentum, as in cascade impactors.

As a reference method to determine the concentrations of particulate from approximately 0.3 µm to 12 µm, a method modified from a standard California Air Resources Board Method 501 (CARB 501). The cascade impactor to be used for each test is the Andersen Mark III In-Stack Cascade Sampler. This instrument classifies particles aerodynamically and automatically separates particulate into multiple size ranges by relying on the interactions between the gas flow and the particle momentum to separate the particles onto different filters based on the aerodynamic diameter of the particles. The modifications to CARB 501 include the use of a button hook nozzle and extractive sampling instead of in situ.

1.5 EXPERIMENTAL DESIGN

The goal of the tests is to quantify performance and pollutant emissions of the A-55 Clean Fuel Technology fuels in comparison to baseline non-emulsified fuels in an independent testing facility.

For each series of tests, a baseline test of a base fuel will be followed by testing of the same fuel converted to the corresponding A-55 emulsified alternative fuel, as well as the naphtha/water emulsified fuel at the same heat input. The converted fuels are expected to have lower heating values, so their flow rates will be adjusted accordingly to obtain the same heat input or load as the base fuel. Other boiler operating parameters such as the degree of atomization, temperature of combustion air, and boiler pressure will be kept constant to the degree possible. If it turns out that such parameters cannot be maintained constant across the base fuel and emulsified fuel tuns, careful notes about necessary changes should be kept so that the performance of the various types of fuels can be discussed and justifiably compared.

The emulsified fuels will be burned according to the recommendations of the manufacturer. These recommendations include varying the excess air level of the emulsion test run to obtain maximum performance of the emulsified fuels at normal operating conditions. The excess air will be adjusted for the base fuel to confirm the boiler design value which results in the optimum boiler efficiency (~15 excess air).

For each test condition, measurements will be made to determine the concentrations of CO_2, CO, NO and NO_2, O_2, SO_2, and THC, as well as PM concentrations (both total and fractioned) in the flue gas. To ascertain experimental repeatability, each test will be repeated four times at each condition. Moreover, the fuel tested at the beginning of the project will be tested at the end of the project to show if the boiler operations and the data collection and measurement systems have not changed over the course of the experiments.

The Quality Assurance/Quality Control (QA/QC) approach for this project is to assess the critical and non-critical input/output parameters and document the accuracy, precision, and completeness of the measurements related to:

Gaseous species concentration
Particulate loading
Particulate sizing
Thermal efficiency

1.5.1 Stack Emissions Testing

One of the objectives of this project is to test emissions of the emulsified fuels compared to base fuels. The critical emission measurements identified in this project are : NO/NO_x , CO, THC, O_2, SO_2, and CO_2. These measurements will serve to evaluate pollutant emissions for two different fuels, emulsified fuels of the same bases with water emulsions, and a third fuel composed of naphtha and water. All of these flue gas pollutants will be prepared by the manufacturer and will be used to determine the thermal efficiency of the boiler and to characterize combustion conditions. Each flue gas pollutant will be corrected to a standard O_2 concentration, such as three percent, a typical O_2 concentration for boilers.

1.5.2 Particulate Sampling

The exhaust gas will be characterized for particulate loading and size distribution for all test conditions. For this particular project the critical measurement for particulate sampling will be particulate loading or concentration. Particulate size distribution measurements will be performed for each set of conditions but will not be considered as critical in meeting the objectives of this project.

Total particulate loading will be collected in accordance with 40CFR Part 60 Method 5 "Determination of Particulate Emissions from Stationary Sources", which is an extractive method. Particles emitted from the boiler stack are captured using a sampling train. The mass of particulate carried within a sample of gas and the volume of the flue gas are measured and the concentration determined using Method 5. Sampling will be done isokinetically, so that a portion of the gas stream sampled represents the same mass concentration of total particles and the same distribution of particle sizes as does the bulk of the flue gas in the stack.

1.5.3 Thermal Efficiency

The intent of this portion of the project is not the determination of the boiler thermal efficiency but how the latter is affected by a substitution of base oil by its emulsified version. It measures the ability of the boiler to transfer heat from the combustion process to the water or steam flowing through it. In this project, thermal efficiency determinations will characterize the performance of the respective fuels on the same boiler. The thermal efficiency of the boiler will be determined by the Heat Loss Method. Data and calculation procedures will follow the ASME Simplified Efficiency Test Method specified in PTC 4.1 Test Code For Steam Generating Units. The abbreviated efficiency test considers only major losses, and only the chemical heat in the fuel as input.

The Heat Loss Method consists of accounting for all the heat losses of the boiler. The actual measurement method consists of subtracting all the thermal losses of the boiler from the total heat input, dividing by the latter and multiplying the result by 100. This method is the one used generally to evaluate the effectiveness of a boiler since each thermal loss represents a relatively small percentage of the heat entering the system and small measurement errors are not going to significantly affect the final outcome. Radiation and convection losses represent the heat losses radiating from the boiler and are typical for each boiler design and essentially constant throughout the firing range of the boiler.

The key parameters to include in the computation of the thermal efficiency of the boiler using this method are:

Fuel specification
Fuel flow rate
Flue gas temperature at the stack
Flue gas composition

Fuel Specification

The fuel specification can have a significant effect on the thermal efficiency. Emulsified fuels contain considerably more water than their corresponding base fuels. This water uses energy as it changes phase from liquid to vapor in the combustion process, resulting in lower thermal efficiencies. The lower heating value of both the base and the emulsified fuel will be used in the computation of the heat input to take into account the heat losses due to the sensible and latent heat associated with the excess water in the emulsified oil. Samples of each oil used will be subjected to an analysis which will include measurements of specific gravity, viscosity, heat value, and ultimate analysis of the fuel (water, carbon, hydrogen, nitrogen, sulfur, ash, and oxygen) on a percent basis. This analysis will be performed by a suitable contracted laboratory.

Fuel Flow Rate

The fuel flow rate along with the fuel specification are the main input parameters concerning the total heat input needed for computation of the thermal efficiency of the boiler for each tested fuel. A three-fourths-inch Oval Mini Oil totalizer with a flow capacity of 5.3-200 gal/hr is used to measure fuel oil consumption. This totalizer will be calibrated prior to the start of the project. A stop-watch is used in conjunction with the totalizer to record flow rates at different time intervals.

Flue Gas Temperature

The flue gas or stack gas temperature primarily measures the heat loss by the dry gases and the moisture associated with the flue gas leaving the boiler and reflects how efficiently the boiler is transferring heat from the combusted fuel to the steam or hot water. The aim of this project is not the determination of the optimal boiler design thermal efficiency but how the thermal efficiency is affected by a change in the type of fuel for the same operating conditions. This key parameter will be continuously recorded during each test and its averaged value will be included in the computation of the thermal efficiency using "The Heat Loss Method". Thermocouples associated with this measurement will be calibrated prior to testing.

Flue Gas Composition and Flow Rate

Flue gas measurements are discussed extensively in Section 4.1 of the QAPP. The flue gas flow rate can be determined using balances on elements of the fuels which allow the computation of the theoretical air required to completely oxidize carbon, net hydrogen, etc., flue gas composition, and fuel flow rate input to the boiler. This flue gas flow rate can be compared to the measured flue gas flow rate determined by pitot used as part of particulate sampling.

1.6 TEST MATRIX

Tests will be conducted by APTB to determine the performance of each fuel under a range of operating conditions. The primary parameter to be varied is the boiler load: three loads will be set for all fuels (low, mid, and high). These loads will be determined during testing because of the high level of water contained in the emulsified fuels which may exceed the capacity of the ancillary equipments (fuel pump, metering valve, pipe size, etc.) associated with the boiler. The excess air for the base fuel tests will be adjusted to confirm the boiler design value which results in the optimum boiler efficiency (roughly 3.0% O_2 in the stack). The excess air for the emulsified fuel test runs will be adjusted separately according to the recommendations of the manufacturer.

Test conditions will be repeated four times for each load and for each fuel. Table 1 shows the tests to be conducted for the boiler portion of the emulsified fuels verification program. The fuels that are planned for testing on the NAPB are No.6 fuel oil, emulsified No.6 fuel oil, No.2 fuel oil, emulsified No.2 fuel oil, and emulsified naphtha. Since naphtha is not widely used in conventional boilers, it will not be used as a base for comparison to the emulsified naphtha. The latter will be compared to a more conventional No.2 fuel oil. Each test condition will last about four hours (three hours required by the DEMPS and one hour contingency) and two tests are planned to be performed each day. The time interval between two tests is estimated to be around one hour to change the type of fuel and burn the remaining fuel in the lines from a previous test.

1.7 SCHEDULE OF PLANNED TEST ACTIVITIES AND MILESTONES

Testing is expected to occur over the course of six to eight weeks, depending on other planned activities in the G-Wing High Bay area.

Testing is expected to begin the second week of June following approval and signing this QAPP.

1.8 FINAL REPORT AND DISTRIBUTION

Dr. Andy Miller is responsible for writing the Final Report and disseminating the results. A copy of the Final Report will be kept in the laboratory as a reference for further work on the unit.

Table 1. Test Matrix for Verification Tests

Test Condition	1	2	3	4	5	6
Load	High	High	Mid	Mid	Low	Low
Oil	Emulsified(7)	Base	Emulsified(7)	Base	Emulsified(7)	Base
Number of Runs[1]	4	4	4	4	4	4
CO(2)	Each test	Each test	Each test	Each test	Each test	Each test
CO_2(2)	Each test	Each test	Each test	Each test	Each test	Each test
NO (NO_x)(2,3)	Each test	Each test	Each test	Each test	Each test	Each test
O_2(2)	Each test	Each test	Each test	Each test	Each test	Each test
THC(2)	Each test	Each test	Each test	Each test	Each test	Each test
Total PM(4)	Each test	Each test	Each test	Each test	Each test	Each test
Cascade Impactors(4)	3	3	3	3	3	3
SMPS(6)	3	3	3	3	3	3
Thermal Efficiency	Each test	Each test	Each test	Each test	Each test	Each test

Notes:
1. Sixty tests are planned for this part of the project.
2. Measurements made by the CEMs, which will operate during the entirety of each test.
3. The NO_x CEM analyzer can be operated either on NO mode or NO_x mode. Typically, 95% of NO_x from combustion sources is NO and therefore many measurements reported either as NO_x or NO but seldom as NO and NO_2 because simultaneous measurements of the two are difficult to make. The test will measure NO_x for all the test but one test that will be used to quantify the difference between NO and NO_x.
4. One method 5 sample will be taken during each test run
5. One Modified CARB Method 501 sample will be taken during each of three test runs.
6. One SMPS measurement will be taken during each of three test runs.
7. The emulsified oils will consist of the base oil, surfactant and water for both the No.6 and the No.2 fuel oil. 1 test sequence will also be conducted using emulsified naphtha which will be compared to conventional No.2 oil.

Section 2.0
Project Organization and Responsibilities

The project organization for this test program is shown in Figure 2. As shown in the organization chart, Dr. Andy Miller will be the EPA WA Manager for this effort. Dr. Miller will be responsible for all communications with the manufacturer, A-55, whose primary contact is Mr. Rick Polak. Dr. Miller will oversee contractor activities, review and approve any test plan revisions prior to implementation, as well as be responsible for maintaining project budgets. Dr. Miller will also be responsible for final data validation and interpretation and, reporting final results to the manufacturer.

Acurex Environmental is responsible for the operation of the test facilities. Dr. A. Dahman Touati is the Acurex Environmental WA Leader for this effort. Dr. Touati will be responsible for supervising all technical aspects of this project including final data validation and reporting to EPA. He will also make sure that the combustion parameters and boiler controls are adjusted to the desired conditions during operation and sampling. In addition to supervision, Dr. Touati will also be responsible for instrument calibration.

Mr. Charly King will assist Dr. Touati in all aspects of the project. He will coordinate all sampling activities and will be responsible for the actual sampling work, which includes direct supervision of Mr. Richard Perry for the boiler operation and fuel handling system operations. Christian Elmore, with the assistance of Mr. Daniel Janek, will be responsible for all SMPS work and particle size data reduction. Mr. Tony Lombardo, as the G-High Bay facility manger, will assist Dr. Touati with test scheduling and personnel deployment.

This project has been assigned a QA Category II, which requires a high level of support from EPA and contractor QA staff. The EPA QA Representative for this effort is Richard Shores. He is responsible for final approval of the QA Project Plan and for organizing and coordinating any external audit activity associated with this project. Acurex Environmental's QA Officer, Libby Beach, will provide support to the preparation of the QAPP and be responsible for ensuring that this QAPP is implemented by Acurex Environmental personnel. She will perform an internal systems audit at an early stage in the project and determine that methods are being followed and any deviations from standard methods or this QAPP are adequately documented. Ms. Beach will also work closely with EPA QA staff to coordinate audit activity and accommodate auditors requests.

Mr. Jerry Revis is Acurex Environmental's Safety Officer and will be responsible for ensuring that this project is carried out in accordance to all permit and EPA safety requirements. He will also ensure that anyone working on the project has fulfilled all of the safety training requirements.

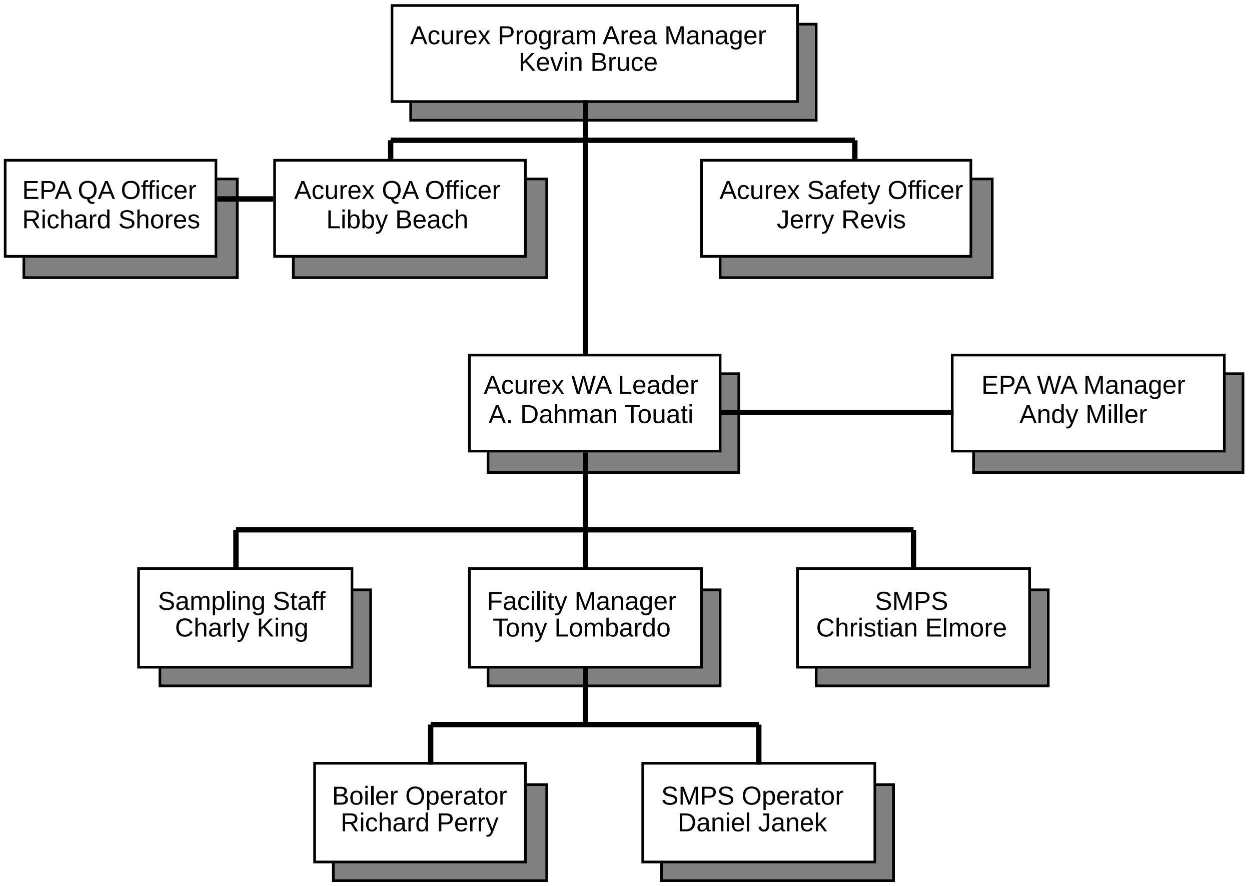


Figure 2. Project Organization Chart.

Section 3.0
Data Quality Indicator Goals for Critical Measurements

3.1 BIAS, PRECISION, COMPLETENESS

The data quality indicators (DQIs) are specific criteria used to quantify how well the collected data meet the appropriate data quality objectives. The DQI goals for bias, precision, and completeness for the critical measurements, including gaseous emissions, total particulate loading, and boiler operating parameters associated with this project are presented in Table 2, Table 3, and Table 4.

The methods selected enable comparisons to other combustion systems and exhaust streams where emissions were similarly collected. The test conditions also provide a means for comparison between the different fuels used. The methods used to calculate bias, precision, and completeness are presented in Section 10.

3.2 REPRESENTATIVENESS

Representativeness evaluates how well the measured quantity reflects the property of the system or substance in general. The representativeness of each sample collected is assured through the sampling approach. Particulate-containing samples are collected isokinetically at varied radial locations within the duct. The tests will be performed in a sequence that will ensure at least three valid tests for each test condition. CEM data representativeness is related to the location of the sampling probe and degree of the flue gas mixing. For this project, the probe is located in the stack which leads to minimal stratification of the flue gas. The test material, the test fuels supplied by the manufacturer will be characterized by a third party.

3.3 COMPARABILITY

Comparability evaluates the degree to which the collected data can be compared to measurements of similar parameters at other locations or from other systems. All test data which satisfy the data validation criteria will be compared consistently with the reference methods used or with the

Table 2. Data Quality Indicator goals for continuous emission monitors.

Measurement Parameter	Method	Experimental Conditions	Precision (RSD) (%)	Bias[1] (%)	Completeness (%)
O_2	CEM	Boiler Exit Gas Concentrations	<7	<10	>90
C O_2	CEM	Boiler Exit Gas Concentrations	<5	<15	>90
NO_x	CEM	Boiler Exit Gas Concentrations	<5	<10	>90
CO	CEM	Boiler Exit Gas Concentrations	<7	<15	>90
SO_2	CEM	Boiler Exit Gas Concentrations	<5	<10	>90
THC	CEM	Boiler Exit Gas Concentrations	<5	<10	>90

Notes.

1 Analyzer bias is based daily, it measures the degree of agreement between an averaged measurement and an accepted reference value, expressed as a percentage of the reference value.

Table 3. Data Quality Indicator goals for particulate loading.

Measurements	Method	Reference	Bias	Precision	Completeness %
Particulate weights	Gravimetric	40 CFR Part 60 Method 5	+/- 0.1 mg based on weight	+/-0.5 mg agreement successive weighing	>70
Volume Sampled	Dry Gas Meter	As Defined	5%	2%	>70

Table 4. Data Quality Indicators for other measured parameters.

Measurement Parameter	Method	Experimental Conditions	Precision (RSD) (%)	Bias (%)	Completeness (%)
Fuel Flow	Volume Totalizer	As Defined	15	10	>90
Exhaust Gas Flow Rate	Pitot Tube	As Defined	10	10	>90
Temperature	Thermocouple	As Defined	2	10	>90
Pressure	Manometer	As Defined	10	10	>90
Fuel Lower Heating Value	ASTM D240	Not Available	±0.5KJ/kg	Not Available	>90

procedures derived and agreed upon the finalization of this QAPP and using standard units. Thus, the test data generated in the test program will be comparable to both other NRMRL data sets and other organization data developed using comparable EPA-approved methods or other derived methods used by the scientific community.

Section 4.0
Operation and Sampling Procedures

4.1 CONTINUOUS EMISSION MONITORING SYSTEM

Continuous emission monitoring of chemical species will be performed with a CEM system for the NAPB facility. The CEM bench for the NAPB includes seven gas analyzers (high range CO, low range CO, O_2, SO_2, CO_2, NO/NO_x, and THC), each with multiple ranges. The effluents from the stack are transported to the cabinet via heated insulated Teflon tubing. The sample is then split between two analyzer subsystems. The total hydrocarbon analyzer contains an additional heated line to carry the sample to the analyzer. The temperature of this line is controlled by the analyzer itself. The second subsystem conditions the sample for use by the remaining analyzers. Once conditioned the sample is distributed to the appropriate analyzer via a rate control valve/indicator and selector valve. After passing through the analyzer, the sample is then removed from the cabinet through an exhaust manifold and vent. Instructions for the CEM bench are provided by the manufacturer. The CEM data are logged continuously during testing using the computer-based data acquisition system. A small description of each analyzer is presented in the following sub-sections:

4.1.1 NO/NO_x Analyzer

The NO/NO_x analyzer is a Rosemount Analytical Inc. Model 951A analyzer that operates via chemiluminescence. A small portion of the sample flow to the instrument is metered into a vacuum (reaction chamber) where it is allowed contact with an excess of ozone from an integral ozonator. As nitric oxide (NO) and ozone (O_3) mix in the reaction chamber the chemiluminescence reaction produces a light emission that is directly proportional to the concentration of NO. This light is detected by a photomultiplier tube, and the output is amplified and scaled to read directly in parts per million by volume. In the NO measurement mode, NO is quantitatively converted into NO_2 by gas-phase oxidation with molecular ozone produced within the analyzer from air supplied from an external cylinder. The NO_x mode of the analyzer operates in the similar fashion except that a small portion of the sample flow to the instrument is diverted to a converter where the NO_2 is dissociated to form NO. The NO measurement mode can be used at relatively low temperatures because the great majority of NO_x is in the form of NO. The measurement ranges of this instrument are: 0-3, 10, 30, 100, 1,000, 3,000, 10,000, and 30,000 ppm NO or NO_x.

4.1.2 Oxygen Analyzer

The O_2 analyzer is a Rosemount Analytical Model 755R oxygen analyzer, that operates by utilizing the paramagnetic property of oxygen. Other gases present in significant concentration in the stack effluent do not exhibit this property. The instrument is calibrated with an oxygen free standard gas (typically high purity N_2) and a suitable span gas at or near the upper range limit. If the upper limit is around 21 percent, room air can be used for the upper limit of the range. Its measurement ranges are 0-5, 10, and 25 percent.

4.1.3 CO and CO_2 Analyzers

The CO_2 and CO monitors are Rosemount Analytical Model 880A Non-Dispersive Infrared Analyzers. They operate by directing identical infrared beams through an optical sample cell and a sealed optical reference cell. A detector located at the opposite end of the cell continuously measures the difference in the amount of infrared energy absorbed within each cell. This difference is a measure of the concentration of the component of interest in the sample. Calibration is accomplished with a high purity N_2 gas and a known concentration sample of the span gas. The ranges of the CO_2 analyzer are

0-5, 15, and 25 percent. The ranges of the low CO monitor are 0-500, 1000, and 2000 ppm, and the ranges of the high CO level are 0-1, 3, and 5 percent.

4.1.4 THC Analyzer

A Rosemount Analytical Model 402 hydrocarbon analyzer is used to measure the THC content of a sample. The analyzer uses a flame ionization detector (FID), a heated temperature-controlled sample line, and an electronic unit containing an electrometer amplifier and associated circuitry, readout meter, and recorder output provisions. The hydrocarbon sensor uses a burner where a regulated flow of sample gas passes through a flame sustained by regulated flows of fuel and air. Within the flame, the hydrocarbon components of the sample stream undergo a complex ionization that produces electrons and positive ions. Polarized electrodes collect these ions, causing current to flow through the measuring circuitry of the electronic unit. The ionization current is proportional to the concentration of hydrocarbons in the original sample. The sample is maintained at a selectable temperature during its passage through the sample line and the interior of the analyzer. Methane of known concentration is usually used as the span gas to calibrate the THC analyzer. The THC analyzer reports hydrocarbon levels in terms of methane concentration based on C-H bond breaking. The instrument ranges are 0-3, 10, 30, 100, 300, 1,000, 3,000, 10,000, and 30,000 ppm.

4.1.5 SO_2 Analyzer

A Dupont Photometric Model 400 analyzer is used to measure the SO_2 concentration in the stack. The basic principle of operation of this type of analyzer involves the quantification of the decay or absorption of light at a specific wavelength by the sample material. SO_2, colorless in visible light, is strongly absorbent in the region of ultraviolet light (300 nm wavelength). Radiation from a light source in the analyzer passes through the sample (flue gas in this situation) where some of is absorbed. Light transmitted through the sample is divided by a transparent mirror into two beams. Each beam then passes through its own filter which permits only a particular wavelength to reach its associated phototube. The optical filter in one beam permits only radiation at the measuring wavelength, which is chosen so light intensity reaching the measuring photo detector varies significantly with a change in concentration to pass through. The optical filter in the other beam permits only light at the reference wavelength to pass through so light intensity reaching the reference phototube varies relatively little with a change in concentration. Electronic signal processing transfers the light energy impinging on the detectors into a voltage which is in direct proportion to the SO_2 concentration in the sample stream being analyzed.

4.2 PARTICULATE SAMPLING

The NAPB facility is equipped with several sampling ports located at the exit of the combustor for emissions sampling. All sampling locations in the duct (8-in stainless steel pipe nominal inside diameter 8.25-in) are sufficient in length and free of flow disturbances that particulate matter can be sampled according to EPA Method 1A sampling requirements. At each sampling location separate velocity measurement ports are not available for simultaneous velocity measurements. As a result, radial sampling locations will be determined by a separate velocity traverse performed before and after sampling at each axial sampling location. Table 5 shows the total number of PM measurements to be made during the test program. Table 6 lists the purpose of each method associated with PM measurements. Each of the measurements are described in the following subsections.

4.2.1 Particulate Loading (Method 5)

A total of sixty Method 5 trains will be operated for this test program. Sampling will adhere to standard EPA Method 5. One blank Method 5 train will be prepared and set up at the sampling location for one test run. It will remain at the sampling location for the duration of Method 5 testing. This blank train will be recovered and analyzed along with the actual trains. This information will identify any possible source of contamination. Impingers for the blank train will be set up and processed in the same manner as for actual samples.

4.2.2 Particle Size Measurements

The data obtained from these measurements are classified as secondary or non-critical and will not impact the acceptability of the PM concentration results.

Cascade Impactor

Cascade impactors are typically large (2.75-in diameter) in situ devices designed to sample large power plant stacks. These stacks are often 20 or more feet in diameter, and contain 600 ˚F flue gases that may be highly acidic and moist (>10%). A California Air Regulatory Board (CARB) Method to which many cascade impactor tests are referenced, states that the following items should be adhered to:

CARB Method 501 Criteria

- It is recommended that seven sets (multiple runs synthesizing a complete traverse) be performed. The minimum set used to characterize a condition is three.
- An initial Impactor run (often called a trash run) should be performed to gather data that can be used to adjust sampling times and other strategies before subsequent tests. Blank runs are often performed at the same time. Initial Impactor runs are seldom useful as data.
- After the first initial (trash) run is completed a second (trash) run can be performed and if acceptable results are obtained then it can be counted as acceptable data.
- Only a straight nozzle can be used. 40 CFR Part 60 Appendix A, Method 5 goose neck (button hook) may not be used.
- Collect no more than 50 mg of particulate. No individual stage may collect more than 15 mg without risking breakthrough.

G-Wing High Bay modification to CARB Method 501 criteria:

- Although CARB 501 recommends several "trash runs" (trash runs are conducted to allow loss of data due to poor initial conditions, unfamiliarity of equipment, etc.) plus seven actual runs to get the best available data, the non-critical nature of these measurements for this project does not require the same level of validation as required during testing for regulatory or compliance purposes. Operation of 3 Method 501 cascade impactors per condition is expected to provide adequate information.
- A straight nozzle can be used only if the precutter is in situ. The ducts in G-Wing High-Bay are too small to perform in situ cascade sampling, thus all cascade Impactor test have been extractive using a button hook nozzle.
- These tests will attempt to follow the 50 mg limit for Impactor, and 15 mg limit per stage. However, due to the non-critical nature of these measurements, the validity of all data will be assessed even if excessive material is collected.

Scanning Mobility Particle Sizer (SMPS)

The TSI SMPS measures particle size distributions in the range of .07 to 1.00 µm. Particles enter an Electrostatic Classifier and pass a Kr-85 radioactive source, which results in an equilibrium state where known percentages of particles have no charge, a single and multiple charges. Singularly charged particles have electrical mobilities which are dependent on their size. Because of this relationship, particles of the desired sizes are separated from the polydisperse aerosol by applying the appropriate voltage to an electrode. Particles with the correct electrical mobility will traverse the electric field and exit as a monodisperse aerosol. The multiple charged particles of various sizes with the same mobility

will also exit, but are accounted for by the SMPS software.
The concentration of the monodisperse aerosol is determined by a Condensation Particle Counter. The aerosol enters an area supersaturated with butanol and passes through a condenser. The supersaturated vapor condenses onto the particles, forming droplets. An optical detector is then able to determine particle concentrations between 2 and 108 particles/cm3. The SMPS sample will be pulled isokinetically from the NAPB stack and diluted with nitrogen at the probe nozzle, at a dilution ratio of approximately 5:1. The dilution flow will be controlled by a mass flow controller and the total sample flow will be measured with a laminar flow element. Both devices have been calibrated using a Gilabrator bubble flow meter.

These measurements are not critical in terms of this QAPP, and failure to meet the DQI goals for these measurements will not result in the invalidation of a test run.

4.2.3 Particulate Sampling Equipment

The dry gas meters for the CARB Method 501 trains will be calibrated pre- and post-test per Federal Register Method utilizing a wet test meter. The nozzles will also undergo a pre-test and post-test calibration. Pitot tubes and thermocouples will be calibrated pre-test only. The SMPS is a qualitative optical technique and will not be calibrated.

Table 5. Total trains operated for test series.

Methods	Number operated for series
EPA Method 5	60 (4 per condition)
CARB Method 501	45 (3 per condition)
SMPS	45 (3 per condition)

Table 6. Sampline measurement equipment

Methods/Measurements	Purpose
Method 5	Particulate loading
Stack Impactor/CARB Method 501	Particulate matter size distribution in stack (0.3-12 µm)
SMPS	"Real time" measurements of fine particulate matter (<1 µm)

Section 5.0
Sample Custody Procedures

5.1 FUEL COMPOSITION

Samples sent for fuel composition analysis will be the only types of samples to leave the custody of the sampler and be transported off-site for analysis. A formal chain-of-custody form like the one shown in Figure 3 will be completed by the sampler and accompany the samples at all times.

Each individual fuel sample will be labeled in ink with the following information:

Sample ID
Fuel type
Date sampled
Sampled by
Sample volume

The sampler will also record pertinent information regarding each sample in the project notebook. This information may include how each sample was acquired, the location or barrel identification from which the fuel sample was taken, or any unusual aspects regarding the appearance of the sample.

5.2 PARTICULATE SAMPLES

Sample custody, handling, and preservation procedures will follow APPCD Recommended Operating Procedure (ROP) No. 54, "Recommended Operating Procedure for Handling and Custody of Combustion Research Branch Generated Samples." Those issues not addressed in this ROP are addressed in the respective sampling and analytical methodologies.

After completion of each Method 5 test, the sampling train will be taken to the on-site sample recovery laboratory and recovered in accordance with the method. During sample recovery, individual samples will be labeled using the coding described below, and entered into a sample log by the recovery personnel.

Samples will be identified with the following codes:

BL2	Baseline No.2
BL6	Baseline No.6
EM2	Emulsified No.2
EM6	Emulsified No.6
ENA	Emulsified Naphtha

In general, the following identifiers will be used to label all other samples generated from this project and submitted to the analytical laboratory:

Form of sample identifier - YMMDDHHMM1234

Original Generation

Y = Year, last digit 1=91, 2=92
M = Month: Jan - 01, Feb - 02, March - 03, Apr - 04, May - 05, June - 06,
Jul - 07, Aug - 08, Sep - 09, Oct - 10, Nov - 11, Dec - 12.
DD = Day, Numeric

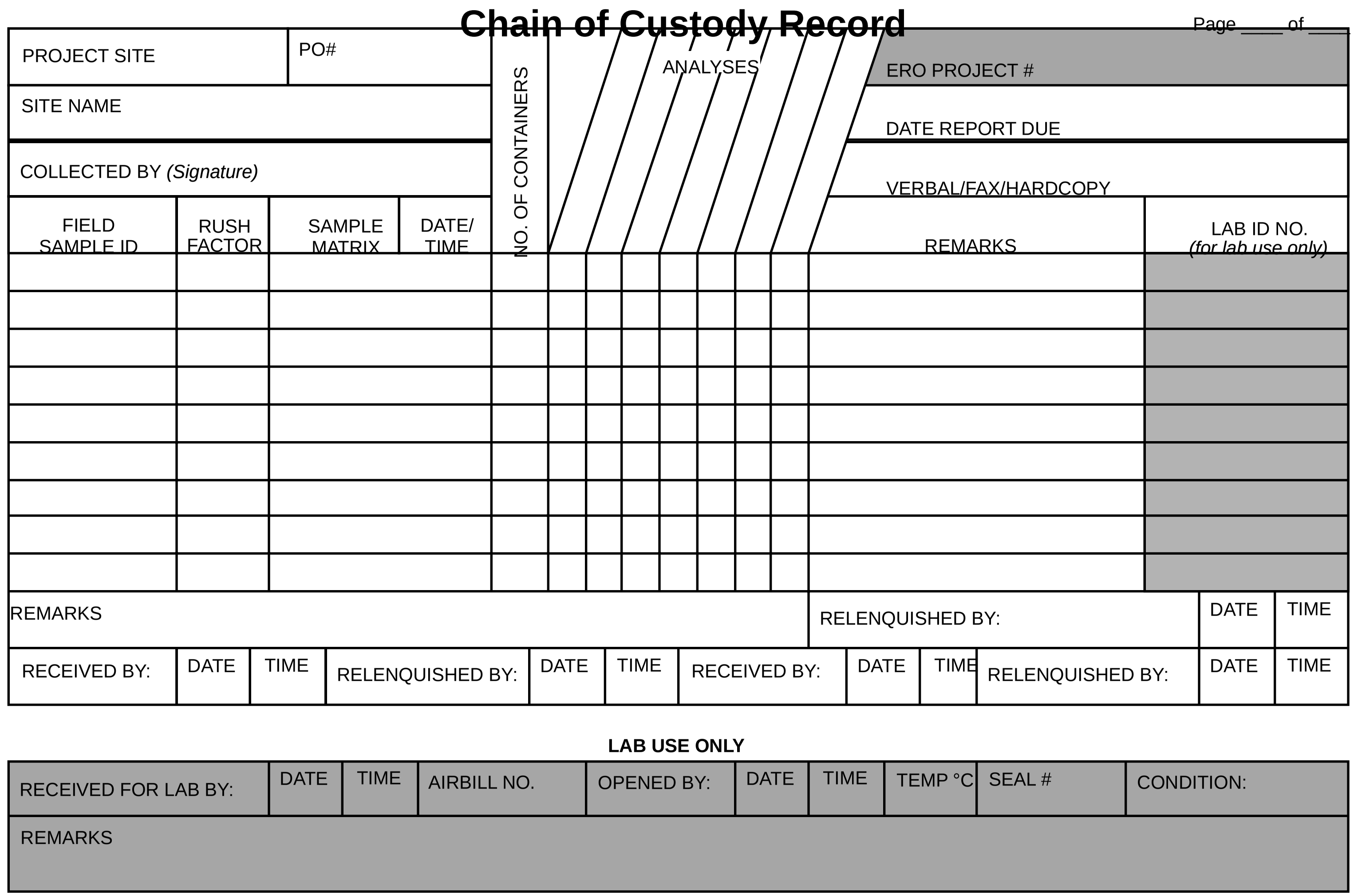
HH = Hour, numeric 24 hour convention
MM = Minute, numeric

1 = Sample type
  - F - Feed (fuel)
  - S - Stack gas

2 = Sampling procedure
  - A - Method 501
  - D - SMPS
  - P - Method 5

3 = Sample Fraction
  - 0 - Total sample
  - 1 - Individual impinger or impactor Stage 1
  - 2 - Individual impinger or impactor Stage 2
  - 3 - Individual impinger or impactor Stage 3
  - 4 - Individual impinger or impactor Stage 4
  - 5 - Individual impinger or impactor Stage 5
  - 6 - Individual impinger or impactor Stage 6
  - 7 - Individual impinger or impactor Stage 7
  - 8 - Individual impinger or impactor Stage 8
  - F - Filter
  - I - Combined impinges
  - A - Acetone probe wash
  - N - Nitric acid probe wash
  - C - Cyclone catch

4 = QA Descriptions
  - 0 - Not applicable
  - D - Split duplicate sample
  - S - Spiked sample
  - P - Spiked sample duplicate
  - L - Lab blank
  - M - Method blank
  - F - Field Blank
  - T - Trip Blank
  - Z - Other



Chain of Custody Record

Page ____ of ____

PROJECT SITE			PO#	NO. OF CONTAINERS	ANALYSES							ERO PROJECT #	
SITE NAME												DATE REPORT DUE	
COLLECTED BY *(Signature)*												VERBAL/FAX/HARDCOPY	
FIELD SAMPLE ID	RUSH FACTOR	SAMPLE MATRIX	DATE/ TIME									REMARKS	LAB ID NO. *(for lab use only)*

REMARKS									RELENQUISHED BY:	DATE	TIME
RECEIVED BY:	DATE	TIME	RELENQUISHED BY:	DATE	TIME	RECEIVED BY:	DATE	TIME	RELENQUISHED BY:	DATE	TIME

LAB USE ONLY

RECEIVED FOR LAB BY:	DATE	TIME	AIRBILL NO.	OPENED BY:	DATE	TIME	TEMP °C	SEAL #	CONDITION:
REMARKS									

Figure 3. Chain-of-Custody Form.

Section 6.0
Calibration Procedures and Frequency

6.1 CEM PROCEDURES

6.1.1 Pre-start-up procedures for all analyzers:

1. Verify that all power switches on the front panel and analyzer fronts are in the "OFF" position.

2. Empty water traps for the main system and for the THC analyzer
3. Install sample probe and main heated sample line.
4. Connect the high purity nitrogen tank to port labeled "ZERO" and set regulator to 20 psig.
5. Connect the calibration span gas for the desired analyzer (s) to the appropriate span gas port(s) on the cabinet side and set the regulator to 10 psig.
6. Energize.

6.1.2 O_2 and CO/CO_2 analyzer start-up

1. Place the analyzer (s) OFF/ON switch to the "ON" position.
2. Place the analyzer flow control valve to the "SAMPLE" position.
3. Leak check the CEM sampling system by turning off power to the sample probe solenoid valve at the furnace stack and ensuring O_2, CO_2, and CO analyzer rotameter reflect zero flows.
4. If there are no leaks, turn solenoid valve back on to re-establish flow.
5. Assure flow to each analyzer is established (NOTE: Each gas analyzer is equipped with a rotameter sized so that proper flow yields a mid-scale reading).
6. After a warm-up period, calibrate the unit following the calibration procedure for each analyzer.

6.1.3 NO/NO_x analyzer start-up

1. Set the panel PPM range switch to the desired range
2. Set the front panel mode switch at NO or NOx. Place power switch at ON.
3. Adjust ozone pressure regulator to 20 psig (for max of 1000 ppm range).
4. Adjust sample back pressure regulator to 4 psig.
5. Adjust bypass needle valve for reading of two liters per minute on bypass flowmeter. This set point should be maintained during sampling.

6.1.4 THC analyzer start-up

1. The analyzer should be operated outside the panel.
2. Connect the appropriate fuel (40% hydrogen and 60% nitrogen), air (cylinder air), and calibration gases to the labeled ports directly on the analyzer.
3. Place the analyzer unit ON-OFF switches in the "ON" position.
4. Set the oven temperature to about 250 oF
5. Start the burner following the following ignition start-up sequence:
   a. Turn on the sample pump when the oven temperature has been reached
   b. Adjust the sample pressure regulator for reading of 3 psig on sample pressure gauge. Note reading on sample bypass flowmeter.
   c. Adjust the burner air pressure regulator for reading of 5 psig on air pressure gauge. The THC analyzer is then ready for calibration.

d. Place fuel shutoff override switch in override position
e. Adjust fuel pressure regulator for reading of 25 psig on fuel pressure gauge. Wait 30 second for fuel gas to purge flow system
f. Give the ignite switch a brief clockwise twist and then immediately release it. When the flameout indicator goes out, proceed with the following steps:
g Set burner air pressure regulator for 15 psig and fuel gas pressure regulator for 30 psig.
h. Place fuel shutoff override switch at normal

6.1.5 SO_2 Analyzer Start-up

At the beginning of the test program, the following checks and adjustments are performed:

The sample cell analyzer is clear of absorbing matter
The bias between light and dark readings are less than 10 divisions minimum
Amplifier balance test
Zero and span adjustment
Stability test
Allow the analyzer to run several hours and check the drift

6.2 CEM CALIBRATION

6.2.1 O_2, NO/NO_x , and CO/CO_2 Analyzers Calibrations

1. Check the zero for each analyzer by opening the zero gas toggle valves and setting the rotameter for the appropriate flows.
2. If necessary, adjust the zero for the analyzers as follows: Zero the O_2 and NO/NO_x analyzers by turning their respective zero knob until a zero value is read from the data acquisition system (DAS). Zero the CO and CO_2 analyzers by pressing the calibration button marked zero.
3. Span the CEMs at 80 percent of full scale by closing the zero toggle valve and opening the span valve. Flows should remain constant.
4. Correct the span values in the same manner used to adjust the zero values, but using the span control knob/button.
5. Conduct a mid-point span to confirm linear behavior for the analyzers by switching to 50 percent full scale span gas and recording the response. If the analyzer is slightly non-linear, the data may be corrected mathematically at a later time.
6. Sampling may be begin by opening the sample toggle valve, activating the pump, and setting rotameter flows to the same settings as for calibration.

6.2.2 THC Calibration

1. Adjust the zero control while nitrogen enters the flow system through the ZERO inlet port.
2. Turn the RANGE MULTIPLIER switch to setting appropriate to the span gas
3. Place SAMPLE/CALIBRATE gas selector valve in CALIBRATE
4. Adjust the zero for analyzer position and adjust flow control valve to the desired flow noted first in the THC analyzer start-up, and Zero the THC by turning the zero knob until a zero value is read from the data acquisition system (DAS).
5. Span the CEMs at 80 percent of full scale by closing the zero toggle valve and opening the span valve. Flows should remain constant.
6. Correct the span values by using the span control knob/button.
7. Conduct a mid-point span to confirm linear behavior for the analyzers by switching to 50 percent full scale span gas and recording the response. If the analyzer is slightly non-linear, the data may be corrected mathematically at a later time.
8. Adjust SPAN control so the DAS indicates the hydrocarbon content of the SPAN gas.
9. Close SPAN control valve.
10. Sampling may be begin by opening the sample toggle valve, and activating the sampling pump.

6.2.3 SO_2 Calibration

1. Turn the METER FUNCTION switch to RANGE A or B as specified on the calibration sheet.
2. Open the SAMPLE toggle valve and record the sample line vacuum. This vacuum should remain constant during the entire calibration procedure.
3. Span the CEMs at 80 percent of full scale by closing the SAMPLE toggle valve and opening the span valve.
4. Adjust the SPAN control to the setting on the calibration sheet
5. Zero the CEMs the SPAN toggle valve and opening the ZERO toggle valve. Flows should remain constant.
6. Adjust COARSE and FINE ZERO controls for 0 on the recorder

6.3 CEM CALIBRATION FREQUENCY

A three point calibration will be made daily, at the beginning of the test, with zero, midpoint, and span gases for all the respective analyzers. A three point calibration drift check will be made daily, at the end of the day, using the same zero, mid, and span gases.

6.4 SAMPLING EQUIPMENT CALIBRATION

Flow measurement equipments, Pitot tubes, thermocouples will be calibrated prior to testing only. The dry gas meters of the CARB 501 trains will be calibrated prior and post-test per Federal Register Method utilizing a wet test meter. The SMPS, being a qualitative technique will not be calibrated.

Section 7.0
Data Reduction, Validation, and Reporting

The data generated by this project are based on the sampling and CEM readings as well as the NAPB boiler operating parameter measurements. The results of each are combined to be included in calculation of the thermal efficiency, pollutants, and particulate emission rates.

7.1 DATA REDUCTION

Combustion gas CEM data and critical temperature measurements will be recorded using a computerized data acquisition system. The DAS consists of a Macintosh computer, two on-board Strawberry Tree data acquisition cards, four fanout boards with 16 analogue input channels and 16 thermocouple input channels. The DAS, along with the Strawberry Tree Analog Workbench Software, is used to measure analog inputs from sensors or instruments, log the acquired data, and perform simple calculations to aid in data recording and analysis. The DAS allows logging of pertinent data during its data acquisition phase. Data can be displayed graphically, with color analog displays that can easily be resized and moved anywhere on the screen. Data can be logged to disk in a text format that is compatible with spreadsheets, databases, and other analysis programs. Multiple channels may be logged into one file, as well as optional time and date stamping. Multiple log files may accept data from one or more channels simultaneously. ON/OFF signals are used to turn logging on and off separately to each file. Logging is only activated when actual testing occurs and is shut off when testing is completed, or suspended. The data will be taken continuously every 10 minutes. The data will be reviewed for accuracy.

NAPB operating parameter data (e.g. fuel flow rate, cooling water flow rate, fuel pressure, and vapor pressure) will be recorded manually on data sheets by the Test Engineer at preset intervals.

Sampling data recorded will initially be reduced by the sampling crew member performing the measurements. Field data will be entered directly into spreadsheet programs to determine parameters such as velocities, sampled volumes at standard conditions, and isokineticity. Because data entry is performed by the sampling crew member directly, data entry is not checked by a second party. However, recorded data will be reviewed during testing, data reduction, and analysis to ensure accuracy of entries. All reduced field measurements data will be transferred by the individual sampling member to the WA Leader.

7.1.1 CEM Data

CEM measurements for CO, NO_x, SO_2, O_2, and THC are in the form of concentration. The concentration of each of these flue gases except for O_2 will be corrected to a standard 3% O_2 concentration.

7.1.2 Particulate Sampling

Sampling data recorded for particulate loading will be reduced by the sampling crew member performing the measurements. Sampling will adhere to the EPA Method 5 procedures contained in the Code of Federal Regulations Volume 40, Part 60 for data reduction. Particulate sizing (non-critical measurements) will follow procedures and recommendations from the respective manufacturers of the cascade impactors and the SMPS.

7.1.3 Thermal Efficiency

Data and calculation procedures will follow the ASME Simplified Efficiency Test Method specified in

PTC 4.1 Test Code for Steam Generating Units. The thermal efficiency is defined in this code as:

$$\eta_t = 100\% - \frac{L}{H_f + B} \times 100\%$$

where L designates the heat losses due to sensible heat in the gases leaving the unit, latent-heat losses associated with the evaporation of fuel moisture and formation of water vapor resulting from burning of hydrogen in the fuel, unburned-combustible loss, and radiation and convection losses. The latter are considered constant throughout the firing range of a particular boiler; H_f designates the chemical heat input from fuel burning; B designates the heat credits supplied by entering air, sensible heat in fuel, heat supplied by atomizing steam, and heat supplied by the moisture entering air.

Since the intent of these measurements is to determine the relative impact of the different fuels on the thermal efficiency of the test, an abbreviated version of the thermal efficiency, as specified in the ASME Test Report for Simplified Efficiency Test, will be conducted. This abbreviated efficiency test considers only major losses, and only the chemical heat in the fuel as input.

7.2 DATA VALIDATION

The WA Leader will monitor the test and will abort testing if unacceptable data are recorded due a sudden change in the boiler operating conditions or CEM analyzer malfunctions. The aborted test will be documented and test will resume as soon as the problem is resolved and the proper corrective action is taken. The criteria for test failure that will be used by the WA leader to abort a test are:

1. The CEM measurements are well below the DQI for test precision set in Section 3.0
2. Sudden drop in the temperature differential of the cooling water
3. Steep increase in the stack temperature

The third and fourth criteria are inter-related and may be caused by particulate build-up and can occur during the test. The WA Leader will consult with the EPA WA Manager to assess if the test is to be continued or stopped.

The DQIs for each measurement parameter will also be used to validate that measurement. Measurement outlier will be identified as those where DQIs do not meet DQI goals. Because of the nature of this study, it is unlikely that any data will be totally invalidated.

Any outlier will be characterized to the fullest extent possible and documented as such, including data limitations.

When each test is completed, the WA Leader will review the data for completeness, and perform selected calculation audits to ensure that the data is valid. He will compare reported findings with expectations and verify selected calculations using independent algorithms, where possible.

7.3 DATA REPORTING

The Acurex Environmental WA Leader will integrate all test-related reports (operation, sampling, and analysis), perform data reduction, and report the data to the EPA WA Manager. Each test report will contain the following information:

A tabular summary of the process operating data, including test identification, date and operating time
Tabular summaries of all measured total particulate loading
Tabular summaries of all measured gaseous constituent concentrations by CEMs
Tabular summaries of all calculated thermal efficiencies

The Final Report will be prepared by the EPA WAM in the form of an EPA reviewed and published document. It will include a detailed description of the Test Facility, the testing methodology, sampling procedures, calculation methodology for determining the important parameters used for evaluation of the tested fuels, QA/QC activities, and summarized results. Conclusions will be based on the degree of emission reduction and overall efficiency improvement.

Section 8.0
Internal QC Checks

8.1 CEM QC

The overall objective is to provide the necessary methods, procedures, and independent checks to verify that the data generated from the CEMs are of known and documented quality. To achieve this the CEM QC plan must :

- Specify precise, accurate, and reliable CEM methods, and processing and reporting procedures
- Specify QC guidelines to insure that CEM data reported are valid and defensible. In order to fulfill these objectives, the following intermediate objectives must be realized:
- The CEMs are properly operated and maintained
- Calibration and operation procedures are established and utilized
- Documentation procedures are established and utilized

A three point calibration drift check will be made daily, at the end of each testing day, using the same zero, mid, and span gases. Each analyzer bias will be assessed at the end of each day using the midpoint span gas. A weekly sample system bias check will be performed as specified in EPA Method 6C by introducing calibration gases at the outlet of the sampling probe. The instruments and sampling system will be leak checked and calibrated according to EPA Method 7E.

The O_2 analyzer instrument and sampling system will be leak checked and calibrated according to EPA Method 3A. The CO/CO_2 analyzer and sampling system will be leak checked and calibrated according to EPA Method 10 for CO and EPA Method 3A for CO_2. The THC analyzer and sampling system will be leak checked and calibrated according to EPA Method 25. The SO_2 analyzer and sampling system will be leak checked and calibrated according to EPA Method 6C.

QC is the responsibility of all personnel operating the CEMs. The WA Leader has ultimate responsibility for insuring that CEM personnel are adequately trained and have demonstrated proficiency to perform their job function in a reliable fashion. The CEM operators are responsible for assuring that: all data reported have been acquired according to the procedures, all data reported have been evaluated prior to reporting, all data have been documented according to established procedures, and all documentation contains the required information established by written procedures.

8.2 PARTICULATE SAMPLING

For particulate measurements one set of filters and substrates will undergo all normal procedures except actual stack sampling. These filters and substrates will determine if any weight gains or losses are attributable to weighing, setup and recovery procedures.

In addition, data quality for particulate sampling can be verified by examining a number of data points. These data points can be separated into leak determination, volume/concentration measurement, weight/concentration measurement and isokineticity.

Leak Determination

If a train pulls ambient air into its collection system instead of flue gas, particulate concentrations will not be reliable. Leaks can be detected by leak checks comparing moisture concentrations. The method suggests that a pretest leak check be conducted. To conduct this check the nozzle is plugged and a 15 inch vacuum is created by running the sampling pump. If the dry gas meter indicates a flow rate less than 0.02 cubic feet per minute then the train is considered leak free. This information is recorded on the data sheet and testing can progress.

During testing one can assure leaks have not developed by visually inspecting the glassware at the beginning of each data point. Additionally the connector between the filter and first impinger shouldbe to hot to the touch and the second connector usually is coated with condensate.

After testing a mandatory leak check must be performed. The procedure is identical to the pretest leak check except the vacuum should be the maximum achieved during the run. If the leak rate is greater than 0.02 cfm during the run, the particulate data is unacceptable.

Although unlikely, a sampling train could conceivably pass pretest leak check and post test leak checks yet leaked unnoticed during a run. The trains are moved from sampling point to sampling point and from port to port which could cause connectors to leak and later reseal themselves for the final leak check. The way to detect such a problem is to look at the reduced flue gas moisture levels. The Method 5 train is equipped with preweighed condensers and desiccants. If the exit temperature from the train is less than 68 °F the drying system is considered functional and a post test weight can be taken to determine moisture levels. Trains with significantly lower flue gas moisture levels (1.5%) than normal are to be considered suspect leakers and possibly void.

Volume/ Concentration
The volume sampled is a very important parameter in determining PM concentration. The heart of the volume determination is the Method 5 dry gas meter. The meter must be calibrated by passing a known volume of air through it at a known temperature. The thermocouples used in this calibration must be calibrated and determined accurate within 2.5 F. Once the thermocouples are calibrated, the pretest dry gas meter calibration can commence. The dry gas meter is hooked up in series with a wet test meter. Air is pulled through both meters at 4 different flow rates (a range of flow rates expected to be encountered in actual use) at a minimum vacuum, and readings from the 4 flow rates are compared. If all readings agree within 2% of the average the meter is considered reliable and can be used without service. After testing a post test calibration at the average sample flow rate and maximum vacuum encountered is performed three times. If the post test average is 5% different than the pretest average the volume is suspect and results may be voided.

Weight/Concentration
The weight gain of the filters and probe washes are also very important parameters in determining PM concentration. Filters are weighed before testing and after testing to measure the particulate captured on its surface. Probe wash beakers are weighed before the wash is added and after the acetone carrier is evaporated to determine the weight of PM captured in the probe. Before each weight the balance is calibrated with certified S class weights. All filters and probe washes undergo a 24 hour desiccation before their first weighing and 6 hour before their second weighing. If the 24 and 6 hour weights agree within 0.5 mg the filter weight may be used. The 6 hour desiccation/weighing cycle is repeated up to 20 times until two weights agree to 0.5 mg. All desiccators are operated per normal laboratory procedures. Each desiccator contains a tray of color indicating silica gel. A blue color of the silica gel shows that it is relatively dry with a relative humidity of less than 40 percent, and is capable of drying up the filter. The silica gel is replaced as soon as its blue color changes indicating a relatively high moisture content.

The acetone used for the probe wash must be residue free or the residue will show up as PM weight gain. To remedy this situation a beaker of acetone alone will undergo the same steps as the other probe washes to provide an acetone blank. The initial and final acetone blank should be within 0.5 mg or the acetone likely contains residue and should not be used.

Velocity/Flow
The flue gas velocity/flow is an important parameter to compare to stoichiometric calculations and for determining an emission rate. All velocity measurements will adhere to EPA Methods 1 and 2. The pitot tube will be assigned a coefficient based on its geometry. Manometers, instead of differential pressure

magnehelics, are used because they have few working parts and they are not prone to errors. Manometers are made up of tubing, tubing connections, a linear scale and a working fluid. The only way a manometer will malfunction is due to leaks or plugs which are easy to identify. by simple tests. All flow measurements will be based on first principals; thus plugged pitot openings or leaking tubing are the only sources of errors in these measurements. The pitots will be purged with air occasionally to clear possible plugging and the pitot tube, and the tubing assembly will be pressure checked to identify possible leaks.

Isokineticity

Isokineticity is an important parameter in determining PM emissions. Isokineticity simply means the flue gas velocity through the sampling nozzle is the same as that in the duct work. If the flow is different unwanted particle size classification can occur due to flow stream lines. Isokineticity is determined during routine Method 5 data reduction and should be within 10%. Other parameters to be maintained are impinger exit temperatures, which should never exceed 68 F and filters should be kept at 248 °F +25 °F during testing.

Section 9.0
Audits

Audits are an integral part of any quality assurance program. Through systematic checking, audits confirm that appropriate quality assurance procedures are being followed and that project performance meets specified standards. Audits performed by the Acurex Environmental QA Officer on Acurex Environmental projects are considered internal audits. Audits performed by a second party, such as EPA, are considered external. During the course of a project, there are generally three types of audits that may be performed. There are technical systems audits (TSAs), performance evaluation audits (PEAs), and data quality audits (DQAs).

TSAs are generally conducted prior to or in the early stages of a project. The TSA is a qualitative, on-site evaluation that determines whether or not a project or analysis is being performed as described in existing test plans, QAPPs, or standard methods.

Quantitative evaluations are made using PEAs. A PEA involves the evaluation of a measurement system using a reference material with a known value or composition. EPA often provides PEA samples for their contractors to demonstrate their ability to adequately perform a specific analysis.

DQAs evaluate methods used to collect, interpret, and report project results. Selected samples are tracked through laboratory analysis, data processing, and statistical analysis procedures to determine whether all data modifications and the reasons for those modifications were adequately documented.

9.1 INTERNAL AUDITS

The Acurex Environmental QA Officer will conduct periodic internal audits during the course of this project. An internal TSA will be conducted in the early stages to ensure that the data collection and analysis systems meet established data quality indicator goals. Performance of the TSA will also ensure that methods are being followed and that any deviations from the methods are documented. Prior to the audit, a checklist will be prepared using this QAPP and any standard methods or operating procedures to assist the auditor in evaluating whether or not these documents are being implemented as written or if changes have been made. At the completion of the TSA, a formal report detailing any findings will be submitted to the Acurex Environmental Work Assignment Leader.

The Acurex Environmental QA Officer will also perform an internal DQA prior to submission of final data reported to EPA. This will entail a thorough review of at least 10 percent of the data presented in the report. Raw data will be used to verify calculations and validated tabulated results.

9.2 EXTERNAL AUDITS

Any QA Category II project requires external audits. For this project, a PEA is likely to consist of one or more externally provided samples of gas for evaluating the performance of the CEMs analyzers. Table 7 is provided to aid auditors in determining analytes of interest and PEA sample concentration. For instance, the external PEA may consist of a sample of CO in N_2 at a concentration known only to the external auditor. This sample is then measured for CO concentration using the CEM system, and the CEM measurement compared to the PEA sample will illustrate the CEMs performance. Other PEA samples may also be provided to check measurements taken during the test program.

External audits of data quality and technical systems performance may also be conducted at the request of the external auditor.

Table 7. Analytes and calibration ranges.

Analyte Measured	Calibration Range
CO (ppm)	0-100
CO_2 (%)	0-20
SO_2 (ppm)	0-2000
NO (ppm)	0-1000
O_2 (%)	0-10
THC (CH_4) (ppm)	0-100

As this is a Category II project, external audit activity is required. The Acurex Environmental project staff will cooperate fully with EPA or any other auditing agency to accommodate further audit plans for this project.

Section 10.0
Calculation of Data Quality Indicators

10.1 PERCENT BIAS

Bias can be determined using the following formula:

$$\text{Percent Bias} = \frac{\text{measured concentration} - \text{known concentration}}{\text{known concentration}} \times 100\%$$

A certified cylinder with a known concentration of one of the analytes (mid-point span gas) will be used to determine the percent bias or accuracy of the analyzer. The system must be operated in a routine manner during this test, and no adjustments, repair, or modification to the analyzer must be carried out.

10.2 PRECISION

Precision, expressed as percent relative standard deviation (RSD), can be determined using the formula:

$$\text{RSD} = \frac{\text{standard deviation of replicate measurements}}{\text{average of replicate measurements}} \times 100\%$$

This precision will be calculated using measurements collected over the test time span with each analyzer.

10.3 COMPLETENESS

Completeness, expressed as the percent of acceptable data collected, can be determined using the formula:

$$\text{Completeness} = \frac{\text{amount of valid collected}}{\text{intended collected data}} \times 100\%$$

Section 11.0
Corrective Action

Corrective actions are initiated whenever measurement precision, accuracy, or completeness limits deviate unacceptably from the objectives established in Section 3.0. In addition, corrective actions are initiated whenever problems are identified through the internal or external auditing procedures described in Section 9.0.

Corrective actions begin with identification of the source of the problem. Potential problem sources include failure to adhere to prescribed measurement procedures, equipment malfunction, or systematic contamination. The respective corrective actions appropriate for these problems are more intensive staff training, equipment repair followed by a more intensive preventive maintenance program, and removal of the source of contamination (e.g., disposal of contaminated reagents). Once corrective actions have been completed, if data affected by the problem can also be corrected, attempts will be made to do so. If data cannot be corrected, it may be necessary to repeat some testing.

The WA Leader approves all corrective actions and has the primary responsibility for directing the initiation and completion of corrective actions required for this project. Problems may be identified by sampling personnel, operation personnel, QA staff, or test engineers. If further staff training is required, the WA Leader if responsible for ensuring it takes place.

The Acurex Environmental QA Officer is responsible for monitoring the progress of major corrective actions and ensuring that they proceed in a timely manner.