SRI/USEPA-GHG-QAP-14
July 2001

Test and Quality Assurance Plan

JCH Fuel Solutions, Inc.
JCH Enviro Automated Fuel Cleaning and Maintenance System

Prepared by:

Greenhouse Gas Technology Center
Southern Research Institute

Under a Cooperative Agreement With
U.S. Environmental Protection Agency

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Greenhouse Gas Technology Center

U.S. EPA Sponsored Environmental Technology Verification (ET✓) Organization

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Test and Quality Assurance Plan
JCH Fuel Solutions, Inc.
Enviro Filtration and Treatment Fuel Cleaning System
(AlgaeX Fuel Catalyst AFC-705 and Enviro Model 4)

This Test and Quality Assurance Plan has been reviewed and approved by the Greenhouse Gas Technology Center Verification Manager and Center Director, the U.S. EPA APPCD Project Officer, and the U.S. EPA APPCD Q/A Manager.

Original signed by:

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Original signed by:

David Kirchgessner APPCD Project Officer U.S. EPA	Date

Original signed by:

Robert Richards Verification Manager Greenhouse Gas Technology Center Southern Research Institute	Date

Original signed by:

Nancy Adams APPCD Q/A Manager U.S. EPA	Date

Test Plan Final: July 2001

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1.0 INTRODUCTION

1.1. BACKGROUND

The U.S. Environmental Protection Agency's Office of Research and Development (EPA-ORD) operates a program to facilitate the deployment of innovative technologies through performance verification and information dissemination. The goal of the Environmental Technology Verification (ETV) program is to further environmental protection by substantially accelerating the acceptance and use of improved and innovative environmental technologies. Congress funds the ETV program in response to the belief that there are many viable environmental technologies that are not being used for the lack of credible third-party performance data. With performance data developed under this program, technology buyers, financiers, and permitters in the United States and abroad will be better equipped to make informed decisions regarding environmental technology purchase and use.

The Greenhouse Gas Technology Center (GHG Center) is one of six verification organizations operating under the ETV program. Southern Research Institute (SRI), EPA's partner verification organization, manages the GHG Center and conducts verification testing of promising GHG mitigation and monitoring technologies. The GHG Center's verification process consists of developing verification protocols, conducting field tests, collecting and interpreting field and other data, obtaining independent peer-review input, and reporting findings. Performance evaluations are conducted according to externally reviewed verification Test Plans and established protocols for quality assurance.

Volunteer groups of stakeholders guide the GHG Center. These stakeholders offer advice on specific technologies most appropriate for testing, help disseminate results, and form Technical Panels for review of Test Plans and Verification Reports. The GHG Center's stakeholder groups consist of national and international experts in the areas of climate science, environmental policy, technology, and regulation. Memberships include industry trade organizations, environmental technology finance groups, governmental organizations, and other interested groups. In certain cases, technical panels are assembled for specific technology areas where the existing stakeholder organizations do not have the expertise. The stakeholder technical panel members provide guidance on the verification testing strategy related to their area of expertise and peer review key documents prepared by the GHG Center.

JCH Fuel Solutions (JCH), located in North Las Vegas, NV, has requested the GHG Center perform an independent third-party performance verification of their diesel fuel treatment and filtration system. JCH markets their services and technology to a wide variety of owners and operators of diesel-powered equipment. This Verification specifically addresses the JCH Enviro Model 4 Automated Fuel Cleaning and Maintenance system. The Enviro Model 4 system incorporates the JCH/Algae-X Model 46-LG-X1500 magnetic fuel conditioner and the JCH/Algae-X Fuel Catalyst AFC-705.

JCH states that use of their technology will allow continuous maintenance of diesel fuel quality at or above ASTM standards and that use of this cleaned fuel will reduce air emissions relative to contaminated fuel. The GHG Center will test diesel engine emissions from a generator set located at the Cummins Intermountain facility located in North Las Vegas, NV. The tests will compare engine emissions performance from a contaminated lot of fuel and engine emissions performance from the same lot of fuel after it is treated and filtered. The change in emissions performance between contaminated and cleaned fuel, expressed as a percentage, will verify whether cleaned fuel emits less pollution than contaminated fuel.

This document is the Test and Quality Assurance Plan (Test Plan) for verifying the emissions performance. It contains rationale for the selection of verification parameters, verification approach, data quality objectives, and Quality Assurance/Quality Control (QA/QC) procedures. The Test Plan will guide implementation of the test, creation of test documentation, data analysis, and interpretation.

This Test Plan has been reviewed by JCH, Algae-X, selected members of the GHG Center's Engine and Fuels Technical Panel (Technical Panel), and the US EPA QA team. Once approved, as evidenced by the signature sheet at the front of this document, it will meet the requirements of the GHG Center's Quality Management Plan (QMP) and thereby will satisfy the ETV QMP requirements.

Upon test completion, the GHG Center will prepare a Verification Report and Statement (Report), which will first be reviewed by JCH. Once all comments are addressed, the Report will be peer-reviewed by the Technical Panel and the U.S. EPA QA team. When this review is complete, the GHG Center Director and the U.S. EPA Laboratory Director will sign the Verification Statement, and the final Report will be posted on the Web sites maintained by the GHG Center and the ETV program.

The remaining discussion in this section describes JCH's fuel treatment and filtration technology. This is followed by a list of performance verification parameters that will be quantified through testing and a description of the Cummins Intermountain facility. The section concludes with a discussion of key organizations participating in the verification, their roles, and a schedule of activities. Section 2.0 describes the technical approach for verifying each parameter including sampling, analytical, and QA/QC procedures. Section 3.0 identifies the data quality objectives for critical measurements and states the accuracy, precision, and completeness goals for each measurement. Section 4.0 discusses data acquisition, validation, reporting, and auditing procedures.

1.2. JCH FUEL TREATMENT AND FILTRATION TECHNOLOGY DESCRIPTION

Many types of facilities operate stationary and mobile equipment whose prime movers are diesel-fueled internal combustion engines. These facilities often maintain their own diesel fuel storage tanks at central locations. Stationary engines draw their fuel supply through direct piping to the central storage tanks or they may operate from integral tanks ("day tanks") mounted on the engine chassis.

Diesel fuel is best used "fresh," or within a few months from when it was manufactured. A given inventory of fuel can, however, remain in a storage tank for long periods. For example, a hospital or hotel with a diesel-powered emergency electric generating plant may keep the same tank of fuel for a long time before using it up. Some facilities buy fuel months or even years in advance of projected needs to take advantage of favorable pricing.

The fuel can become contaminated during long storage periods even when it is stored in a clean tank. This contamination decreases fuel quality and may increase engine emissions when it is ultimately consumed.

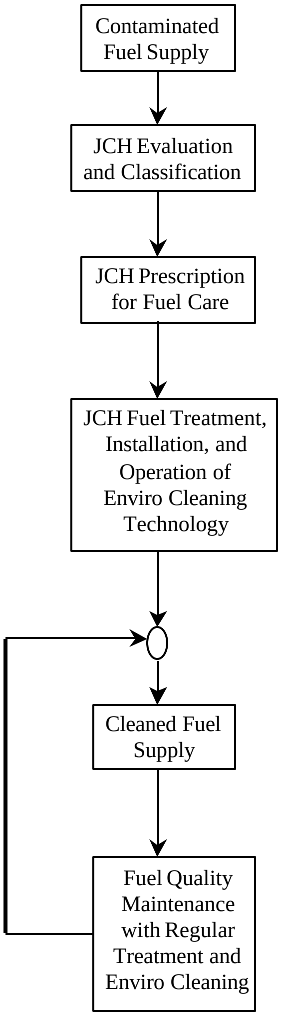
During storage, the fuel may:

- acquire water from atmospheric condensation and separation
- grow colonies of algae and fungi
- form clouds and gels
- oxidize into gums and resins
- accumulate other particles such as ambient dust, rust, and other fines.

Each of these contaminants alter diesel fuel properties. The contaminants can harm the precision mechanisms of a diesel engine, increase wear, clog filters, and reduce combustion quality. Consequently, contaminated fuel can increase fuel consumption and emissions.

JCH's technology treats and cleans contaminated fuel. It also maintains the cleaned fuel while in storage. Figure 1-1 depicts the process flow of JCH's technology.

Figure 1-1. JCH Fuel Treatment and Cleaning Process Flow



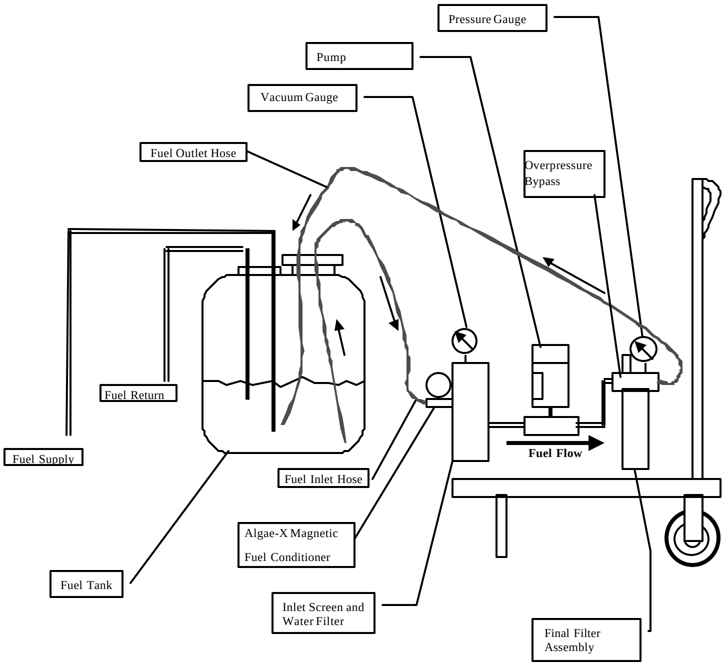
When a client requires a solution to a fuel contamination problem, JCH initially collects a fuel sample for field testing and laboratory classification of contaminants. The field test equipment yields a quick qualitative evaluation of the fuel for sediment and water, micro-organisms, appearance, clarity/brightness, and debris/contamination. The JCH representative rates the fuel for each of these factors on a qualitative scale from 1 to 10; 1 is no observable contamination, 10 is heavy contamination. The field tests roughly correspond to standard laboratory (ASTM) methods, and are sufficient for most customers' applications. JCH then develops a prescription of care for fuel treatment and filtration.

Treatment consists of the application of the proper amount of Algae-X AFC-705 fuel catalyst. The AFC-705 solution contains a preservative and dispersant to stabilize fuel in storage by retarding gum formation; a corrosion inhibitor; a demulsifier to drop out entrained water; detergents; and lubricity enhancers. The tank owner adds the fuel treatment directly to the stored fuel. One gallon treats 5,000 gallons of fuel.

JCH then installs the Enviro filtration equipment at or near the storage tank. JCH manufactures and markets approximately 12 Enviro models in various sizes and capacities. Figure 1-2 shows a schematic of a portable cart-mounted system which can be moved from tank to tank. Figure 1-3 depicts a larger capacity system intended to be permanently floor- or wall-mounted at a single storage tank.

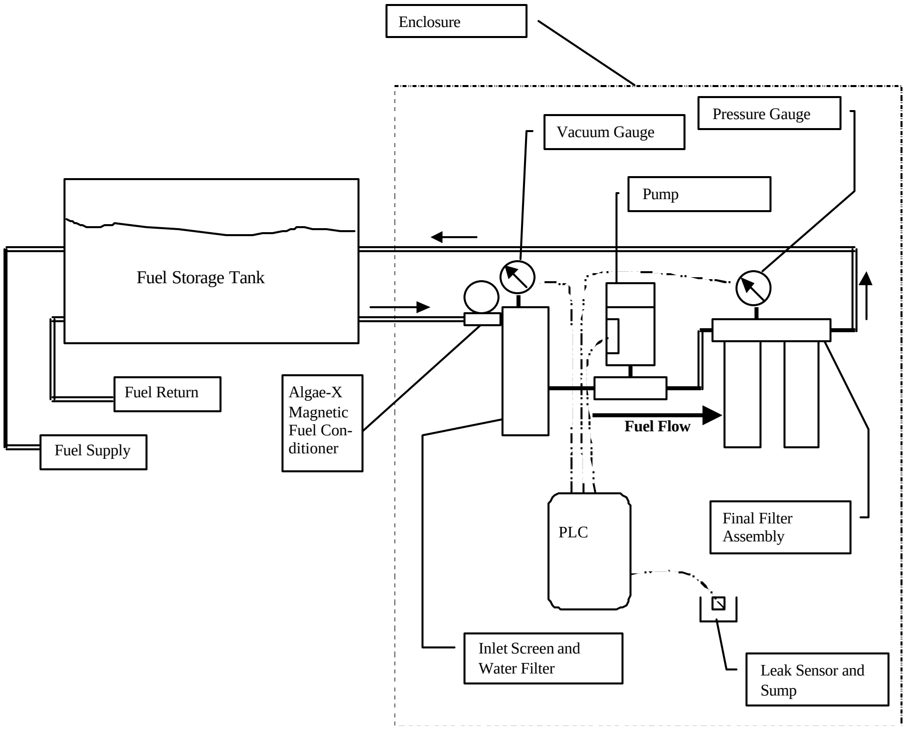
This Test Plan is designed to verify the overall effects on emissions and fuel quality performance of an Enviro system. Each system consists of several components. An electric pump moves fuel from the tank through an Algae-X magnetic fuel conditioner, a multi-stage filter train and then back to the tank. The Algae-X fuel conditioner is designed to eliminate and prevent problems related to fuel deterioration, re-polymerization, stratification, and organic debris and acid buildup. Most portable Enviro models (Figure 1-2) employ two-stage filtration. The first stage is a cartridge-type coarse particulate screen and bulk water separator. The second stage is a 2-micron particulate filter which also removes emulsified water. Depending on pumping capacity, a typical portable unit is 49" x 21" x 19" (h/w/d) and weighs about 175 pounds.

Figure 1-2. JCH Portable Cart-Mounted System



The larger floor-mounted units (Figure 1-3) are housed in an enclosure and use three-stage filtration. The first stage is a 150-micron particulate and bulk water separator cartridge. Stage 2 is a 10-micron particulate filter which removes 95 percent of entrained water. Stage 3 is a 2-micron particulate filter which removes emulsified water. The stage 2 and 3 filters are spin-on canister-type elements. Depending on the system's pumping capacity, the enclosure is designed to be permanently attached to a wall or to a floor stand near the tank. These systems are plumbed directly into the tanks which they serve. Inlet piping conveys the fuel from the lowest point of the tank to the inlet strainer and water filter. The electric pump circulates the fuel through the final filter train and back to the storage tank.

Figure 1-3. JCH Floor-Mounted System



The system size and pumping capacity varies depending on the size of the tank to be served. The Enviro 2 is intended for use on tanks up to 2,000 gallonsand has a 3 GPM pump. Its wall-mounted enclosure is 24" x 24" x 10" (h/w/d); the unit weighs 150 lb. The largest model, the Enviro 9, monitors and maintains tanks up to 80,000 gallons with a 40 GPM pump. It is in a 40" x 54" x 26" (h/w/d) floor-mounted enclosure and weighs 750 lb.

JCH qualitatively monitors the fuel quality with their field test equipment during treatment and cleaning, applying the 1 to 10 score to the fuel properties described above. Once a contaminated lot of fuel is satisfactorily treated and cleaned, its quality must be maintained by regular operation of the Enviro systems. JCH recommends that at least one tank volume per week be circulated through the Enviro system. Portable systems are operated manually: the operator moves the cart to the tank to be treated, installs the inlet and outlet hoses through the tank fill cap, and runs the system for the time required.

For wall-mounted systems, a programmable logic controller (PLC) provides unattended operation. The operator programs the PLC according to the pumping capacity of the Enviro system and the size of the tank. For example, if the system has a 5 GPM pump, JCH recommends the following:

Tank Fuel Volume (Gallons)	Enviro Operation Hours per Week
4000	12
2000	6
1000	3
500	2

For a 2000 gallon tank, the operator could program the PLC to run the system from 0800 to 1000 on Monday through Wednesday for a total of six hours per week.

The PLC also monitors vacuum and pressure gauge readings. A vacuum gauge alarm alerts the operator to the need to clean or replace the inlet screen and filter. A pressure gauge alarm indicates the need to change the final filter elements. The PLC shuts the system off during overpressure conditions such as if the final filter were to become clogged. It also monitors the leak sump and pump motor, shutting the system down or triggering alarms as appropriate.

System maintenance includes draining water and sludge from the inlet screen and filter into an adsorbent to stabilize it. The 10- and 2-micron filter canisters must be changed periodically. Users transfer the used canisters and spent adsorbent media to a Class I landfill for ultimate waste disposal.

1.3. TEST FACILITY DESCRIPTION

This Test Plan provides for testing and reporting the emissions performance and fuel cleaning performance of JCH's treatment and filtration technology. The GHG Center will quantify and compare diesel engine emissions and fuel properties between a contaminated fuel batch and the same batch of fuel after it has been treated and filtered. JCH has a contaminated lot of fuel in inventory for this test. It will be transferred to a 275-gallon test day tank at the test facility for the emissions and cleaning performance measurements.

Engine tests will occur at the Cummins Intermountain (CI) facility located in North Las Vegas, NV. CI is a full-service Cummins engine dealer which maintains a large inventory of diesel-driven generator (genset) rental equipment. The unit selected for testing is an Onan Model 200DGFC 200 KW trailer-mounted test genset is driven by a Cummins Model 6CTAA8.3-G1 6-cylinder, direct injected, turbocharged engine. During the mid-May, 2001 site visit the engine hourmeter showed that it had run 159.9 hours.

Table 1-1 shows factory performance and emissions data for the engine. The emissions data serve as starting estimates for the actual field determinations.

Table 1-1. Onan/Cummins Model 200DGFC
Engine/Generator Emissions Data; Prime Power Service

Description	Predicted Value
Brake Horsepower (BHP) @ 1800 RPM (60 Hz)	285 BHP
Prime Power Generating Capacity (480 VAC)	180 KW
Fuel Consumption	13.3 gal/hr
Total Nitrogen Oxide (NO_x) Emissions	4.34 lb/hr
Total Carbon Monoxide (CO) Emissions	5.34 lb/hr
*Total Sulfur Dioxide (SO_2) Emissions	*0.50 lb/hr
*Total Carbon Dioxide (CO_2) Emissions	*285.8 lb/hr
Total Unburned Hydrocarbons, as Methane	0.63 lb/hr

* Factory data unavailable; estimate based on AP-42 “Emission Factors of Uncontrolled Gasoline and Diesel Industrial Engines

The engine fuel system includes a two-stage fuel filter as standard equipment. The first (primary)stage is rated as 100 micron; the secondary is rated as 10 micron. This compares with the 10 micron and 2 micron filters in the Enviro equipment.

During emissions tests, the GHG Field Team Leader will log generator amperage, voltage, frequency, engine oil, water, and exhaust temperatures to ensure stable operations. The genset instrument panel will be the source of these data.

A custom fabricated test duct installed on the engine exhaust will be required for proper emissions measurements. The test duct will consist of a stainless steel tube about 6” diameter and 10’ long with an adaptor to fint the genset’s rain cap. It will feature flow straightening vanes if needed and the appropriate ports for gaseous and particulate emissions sampling. The top shroud of the genset will support the test duct about 9’ above ground level.

An adjustable load bank will provide a steady state, pure resistive load for the genset at 100 percent ± 5 percent of the prime power capacity (180 KW). In the load bank, fan-cooled resistor arrays convert electrical energy into heat. Various resistors can be switched into and out of the circuit to provide the appropriate load for each generator phase.

The GHG Center reviewed this engine’s size and generation capacity with representatives from Cummins, Inc., Caterpillar, Inc., International Truck and Engine Co., John Deere & Co., and several diesel fuel experts including the chairman of the ASTM D-975 fuels committee. The consensus is that this engine/generator combination is a good selection for the test campaign for several reasons.

First, engines of all sizes must achieve EPA Tier I emissions requirements for diesel engines. The more restrictive Tier II regulations are phasing in from 2001 through 2006. Most manufacturers are using similar technologies such as direct injection, turbocharging, computerized engine control, etc. to meet the requirements. The increasingly stringent emissions regulations are forcing a convergence in engine design and operation across all manufacturers, regardless of size. Emissions from engines of different manufacturers are reported to be very similar for a given horsepower range

Second, the 180 KW engine/generator combination is representative of a large number of installed gensets. In the fourth quarter of 2000 alone, the Electrical Generating Systems Association reported sales of 4461 gensets between 150 and 4000 KW capacity. Of these, 60 percent were between 150 and 750KW.

Third, a generator with a resistive load provides a consistent, predictable load for the engine. The constant 100 percent prime power load cycle proposed here represents normal operating conditions for genset engines. The only differences which arise when compared with other service classes are the load rating of the engine and the operating time allowed at that load. For example, this genset can supply 200 KW of emergency power for the duration of normal power interruption. Net emissions per hour at the higher rating will be greater because the engine is working harder and burning more fuel. The normalized emission rates at both power ratings ($lb_{pollutant}/lb_{fuel}$), however, will be virtually same.

Finally, this genset represents a good compromise between a large engine which requires a large amount of test fuel, and a small engine which presents emissions testing and fuel flow measuring difficulties.

1.4. PERFORMANCE VERIFICATION PARAMETERS

The verification factors to be addressed are:

- Mass emission rates (lb/hr) of criteria air pollutants and greenhouse gases from combustion of contaminated and cleaned fuel. The cleaned fuel will consist of the same lot of contaminated fuel which has been treated with the JCH fuel treatment and filtration technology.
- Fuel properties (consumption rate, lower heating value [LHV], and quality) for contaminated and cleaned fuel.
- Emissions performance: Percent change in emissions between contaminated and cleaned fuel. This will be reported as the percent difference in mass of pollutant emitted per mass of fuel consumed (lb/lb) and the percent difference in mass of pollutant emitted per million BTU of heat input (lb/mmBTU) between contaminated and cleaned fuel.
- Fuel cleaning performance: Percent change in fuel properties, cleaned as compared to contaminated fuel

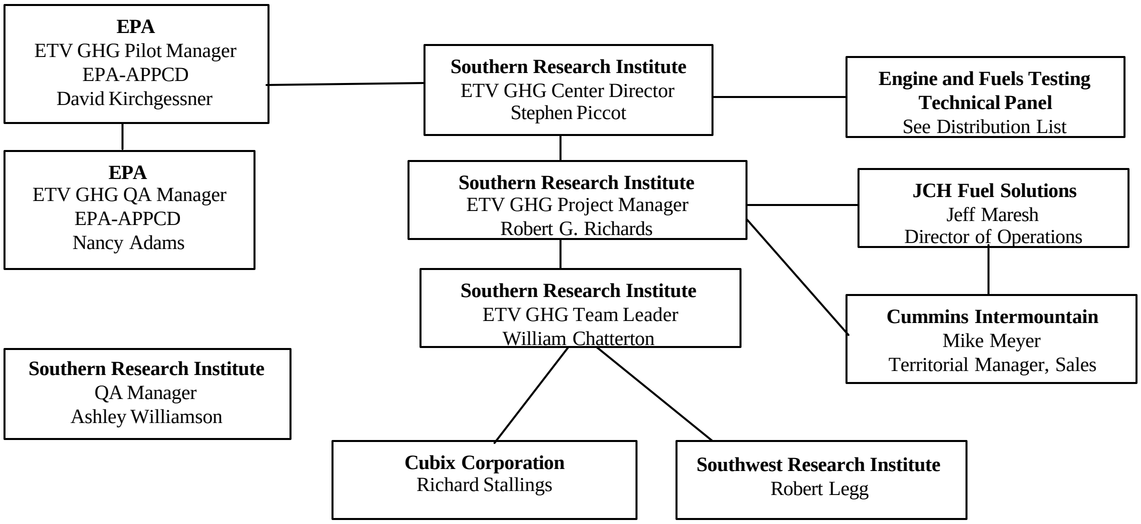
EPA reference methods will be employed to measure engine exhaust stack emission rates for contaminated and cleaned fuel. Fuel samples collected during the reference method test runs will be analyzed to quantify fuel properties for cleaned and contaminated fuel. The results of these measurements will allow emissions performance and cleaning performance comparisons between the two fuel conditions.

During both sets of tests on contaminated and cleaned fuel, operators will maintain the engine load as consistently and as close as possible to 100 percent of the genset's prime power capacity. The GHG Center will compare the contaminated and cleaned fuel reference method results to determine performance of the JCH technology. A total of 3 valid test runs, 1-hour duration each, will be conducted while the engine consumes the contaminated fuel and then the cleaned fuel. The entire test campaign is expected to last 2 to 4 days.

1.5. ORGANIZATION

Figure 1-4 presents the project organization chart. The following section discusses functions, responsibilities, and lines of communications for the verification test participants.

Figure 1-4. Project Organization



Southern Research Institute's Greenhouse Gas Technology Center has overall responsibility for planning and ensuring the successful implementation of this verification test. The GHG Center will ensure effective planning, development and fulfillment of schedules. The GHG Center will also manage emissions testing activities performed by a qualified contractor and fuel analyses performed by an ASTM-certified laboratory.

The GHG Center's Mr. Robert Richards will have the overall responsibility as the Project Manager, under supervision of Mr. Stephen Piccot, the GHG Center Director. He will be responsible for overseeing the GHG Center's Field Team Leader's field data collection activities, including determination of the data quality indicators (DQIs) for engine emissions prior to the completion of testing. Mr. Richards will follow the procedures outlined in Sections 2.0 and 3.0 to make this determination, and he will have the authority to repeat tests as determined necessary to ensure that data quality objectives (DQOs) are met. Should a situation arise during testing that could affect the health or safety of any personnel, Mr. Richards will have full authority to suspend testing. He will also have the authority to suspend testing if quality problems occur. In both cases, he may resume testing when problems are resolved. Mr. Richards will be responsible for maintaining communication with JCH and EPA.

Mr. Bill Chatterton will serve as Field Team Leader, and will support Mr. Richards' data quality determination activities. The Field Team Leader will provide field support activities related to all measurements and data collected. He will observe the emissions testing crew from Cubix Corporation (Cubix) and ensure that QA/QC procedures outlined in Section 2.0 are followed. He will submit all results to the Project Manager, such that it can be determined that the DQIs for engine emissions are met. The Field Team Leader will be responsible for ensuring that performance data, collected by continuously monitored instruments, are based on procedures described in Section 4.0 for data collection, storage, and retrieval practices.

The GHG Center's Quality Assurance Manager, Mr. Ashley Williamson, will review the results from the verification test. He will conduct an Audit of Data Quality, as is required in the GHG Center's QMP. Section 4.4.3 discusses this audit. Mr. Williamson will report the results of the internal audits and corrective actions to the GHG Center Director. The results will be used to prepare the final Verification Report.

EPA's Air Pollution Prevention and Control Division (APPCD) will provide oversight and QA support for this verification. The EPA APPCD Pilot Manager, David Kirchgessner, is responsible for obtaining final approval of the project Test Plan and Verification Report. The EPA QA Manager reviews and approves the Plan and Final Report to ensure that they meet the ETV Program's QMP requirements and represent sound scientific practices. At the discretion of the EPA QA Manager, an external audit of this verification may be conducted.

Jeff Maresh, Director of Operations, will serve as the primary contact person at JCH. Ron Sickles, Director of Engineering and Sales, is the inventor of the Enviro system and will provide technical assistance. Wout Lisseveld, Operations Manager (Algae-X International) holds the patents on the Algae-X technology and will provide technical assistance. Mike Meyer, Territorial Manager of Generator Sales of Cummins Intermountain, will coordinate installation and operation of the test generator and associated equipment.

Richard Stallings is the primary contact person for Cubix, Corporation (Cubix; Albuquerque, NM), the emissions testing contractor. The fuel analysis laboratory will be Southwest Research Institute (SwRI; San Antonio, TX); Robert Legg is the QA Director.

To support the planning, review, and wide distribution of the verification results, a special Engine and Fuels Testing (EFT) Technical Panel has been formed (see Distribution List). The Technical Panel members will advise on the selection of verification factors and provide guidance to ensure that the overall verification is based on recognized and reliable field measurement and data analysis procedures acceptable to stakeholders associated with this technology. The panel members represent engine manufacturers, research groups, and standards organizations which have a national and international focus on engine manufacturing, fuels, and fuel quality. Individuals selected to serve on this Technical Panel will be called upon to provide credible guidance and broad recognition of the verification, and will support the wide distribution of the final verification results.

1.6. SCHEDULE OF ACTIVITIES

The tentative schedule of activities for testing the JCH fuel treatment and filtration system is as follows:

Verification Plan Development

GHG Center Internal Draft Development	January, 2000 - May, 2001
GHG Center Site Visit	May 8, 2001
Vendor Review/Revision	May 29 - June 1, 2001
EPA and Technical Panel Review/Revision	June 4 - June 29, 2001
Final Draft Posted	Week of June 25, 2001

Verification Testing and Analysis

Field Testing	July 6 - July 13, 2001
Data Validation and Analysis	July 16 - July 27, 2001

Verification Report Development

GHG Center Internal Draft Development	July 30 - August 16, 2001
Vendor and Tech. Panel Review/Revision	August 17 - August 28, 2001
EPA Review/Revision	August 31 - September 19, 2001
Final Draft Posted	September 28, 2001

The GHG Center has scheduled testing to take place during July, 2001. GHG Center staff visited the site for an initial survey in May, 2001. Although not expected, delays may occur for various reasons, including mechanical failures at the site, weather, and operational issues. If significant delays are likely, the schedule will be updated and all participants will be notified.

2.0 VERIFICATION APPROACH

2.1. VERIFICATION STRATEGY OVERVIEW

Emissions from mobile and stationary diesel engines are coming under increased scrutiny by regulators, permittees, and engine manufacturers. Nitrogen oxides (NO_x) from diesel engines are a contributor to ground-level ozone formation. Small diameter particulate emissions from engines are becoming a concern as the new PM 10 and PM 2.5 regulations are implemented. Carbon dioxide (CO_2) from fuel combustion is a greenhouse gas and is of interest to stakeholders focused on mitigating global climate change.

More engines are being installed or brought on line each year. Enterprises in the communications, entertainment, hotel, and network server industries, for example, are installing significant emergency generation capacity. Deregulation of the electric power industry is encouraging the reallocation of some generators from emergency to peak shaving or even prime power service with the associated environmental impacts.

Each of these installations may represent an opportunity for reduced emissions if the fuel at that facility is kept as clean as is possible. Clean fuel is a fundamental requirement for good engine operation. JCH's treatment/filtration technology (which incorporates Algae-X's magnetic fuel conditioner and fuel catalyst) reportedly provides clean fuel to the engine. This verification will test the assertion that fuel cleaned with JCH's cleaning/filtration technology and treated with Algae-X's magnetic fuel conditioner and fuel catalyst reduces engine emissions.

The core verification strategy is to compare engine emissions from a contaminated lot of fuel to the emissions from the same lot of fuel after treatment and filtration with the JCH equipment. GHG Center personnel will document contaminated and cleaned fuel properties concurrently with emissions from a stationary engine coupled to a generator ("genset"). The emissions tests will conform to well-documented EPA reference methods; fuel measurements will be according to ASTM test specifications and other protocols as described in following sections. A resistive electrical array (load bank) will load the genset to 100 percent of its prime power capacity. While the actual engine loading is not a verification parameter, genset and load bank data will act as valuable diagnostics of test stability.

The verification factors to be addressed in the Test Plan are:

- Mass emission rates of criteria air pollutants and greenhouse gases from contaminated and cleaned fuel as follows:
    - Nitrogen Oxides as Nitrogen Dioxide (NO_x), lb/hr
    - Carbon Monoxide (CO), lb/hr
    - Carbon Dioxide (CO_2), lb/hr
    - Total Hydrocarbons (THC or VOC) as Methane, lb/hr
    - Methane (CH_4), lb/hr
    - Sulfur Dioxide (SO_2), lb/hr
    - Total Particulate Matter (TPM), lb/hr

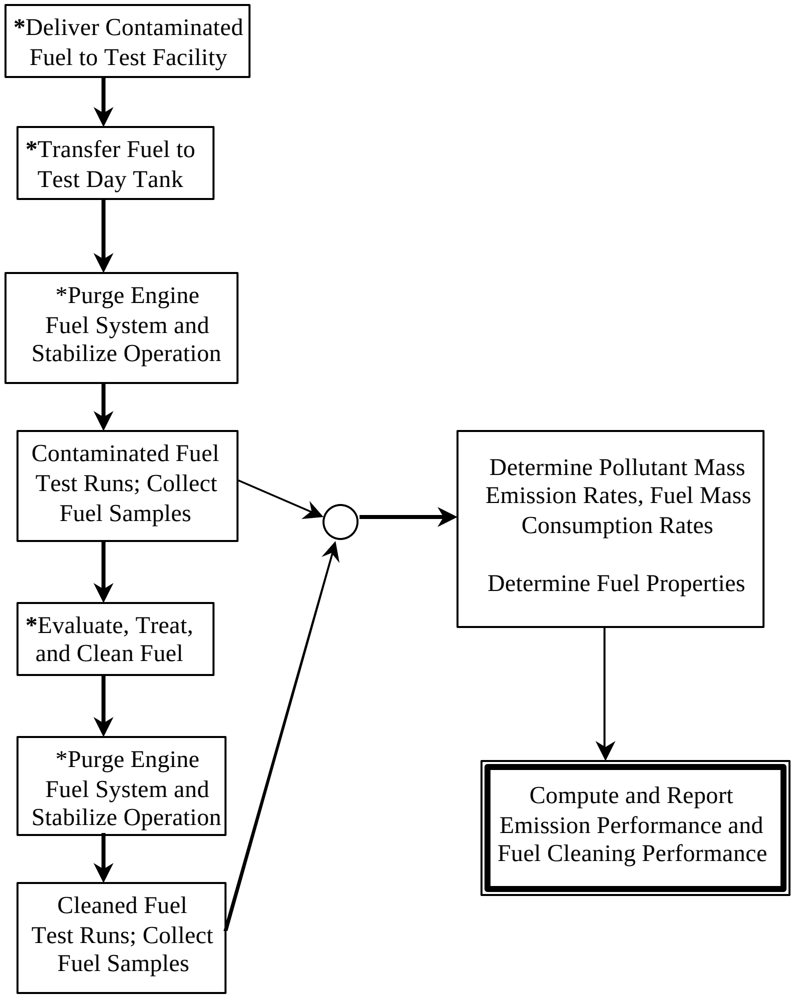
- Fuel properties for contaminated and cleaned fuel, consisting of:
  - Fuel consumption rate, lb/hr
  - Fuel lower heating value (LHV), BTU/lb
  - Fuel Quality properties as follows:
    - API Gravity
    - Flash Point, ^{o}C
    - Water and Sediment, vol %
    - Ash, vol %
    - Cetane Number
    - Particulate Matter, mg/l
    - Gums and Resins, mg/l
    - Lubricity
    - Microbial Contamination

- Emissions performance in terms of the percent change in mass emission rates between contaminated and cleaned fuel, percent. Emission rates will be normalized as pounds of pollutant per pound of fuel ($lb_{pollutant}/lb_{fuel}$) and as pounds of pollutant per million BTU of heat input ($lb_{pollutant}$/mmBTU).

- Fuel cleaning performance: Percent change in each cleaned fuel property as compared to the corresponding contaminated fuel property.

Figure 2-1 is a schematic overview of the verification approach.

Figure 2-1. Verification Approach Overview



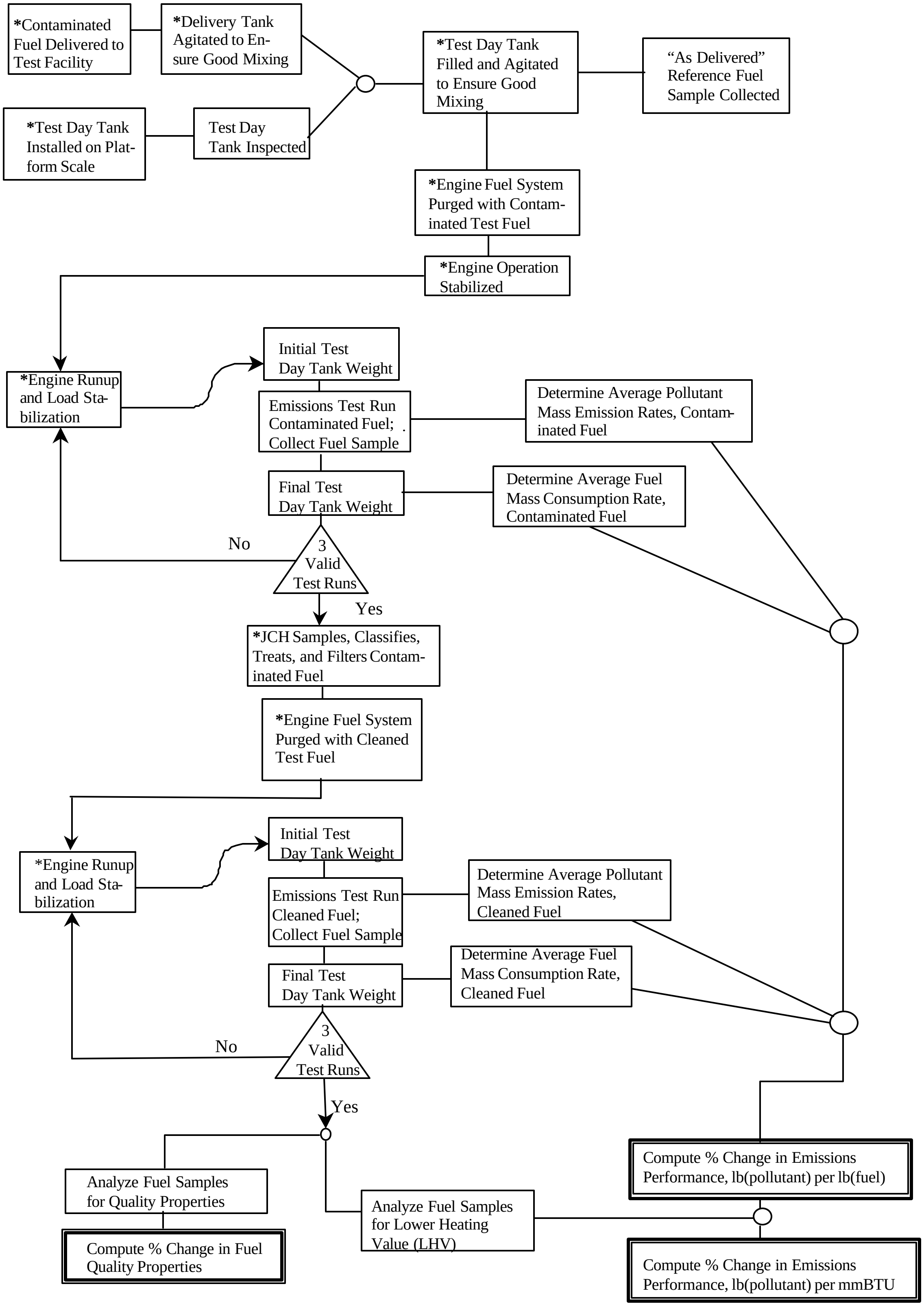
* Activities performed by JCH and/or CI technicians

2.2. VERIFICATION OPERATIONS

This section discusses verification operations including test mobilization, the planned sequence of events, and assigns responsibilities for Test Plan activities.

Figure 2-2 shows a detailed overview of verification operations. Most verification operations will occur at the Cummins Intermountain (CI) facility in North Las Vegas, NV. The GHG Center will perform data review, computations, and write the Verification Report in Research Triangle Park, NC.

Figure 2-2. Detailed Verification Overview



* Activities performed by JCH and/or CI technicians

The following table summarizes verification operations which will occur at CI. All engine loads are percentages of the 180 KW prime power rating

Table 2-1. Verification Operations Sequence at Cummins Intermountain

Step	Description/Operating Condition	Genset Load/ Test type	Duration	Responsibility
1	Inspect engine, day tank	--	~ 1 hr	GHG
2	Fill and agitate day tank	--	~ 1 hr	JCH
3	Start Engine/purge fuel	50 %-80 % load	~ 0.2 hr	CI
4	Evaluate engine op's with contaminated fuel. If engine stalls, change engine filters	50 %-80 % load	~ 1 hr	CI/JCH
5	Engine runup and load stabilization	100 % load	0.2 hr	CI
6	3 emissions test runs, contaminated fuel	Test Runs 1,2,3	1 hr each	GHG/Cubix
7	Contaminated fuel diagnosis/classification; Development of treatment/filtration schedule	--	~ 1 hr	JCH
8	Fuel treatment/filtration	--	~ 2 - 10 hr	JCH
9	Cleaned fuel diagnosis/classification	--	~ 1 hr	JCH
10	Start Engine/purge fuel	50 % - 80 % load	~ 0.2 hr	CI
11	Evaluate engine op's with cleaned fuel	50 % - 80 % load	~ 0.5 hr	CI/JCH
12	Engine runup and load stabilization	100 % load	2 hr	CI
13	3 emissions test runs, cleaned fuel	Test Runs 1,2,3	1 hr each	GHG/Cubix
14	Sample custody transfer, shipping, test demobilization	--	~ 3 hr	GHG/Cubix/ SwRI

During field operations, the GHG Field Team Leader will maintain a daily Test Log which summarizes all testing activities. The log keeper will sign each page of entries and the closing entry for each day.

JCH has a contaminated fuel batch in inventory. The fuel is representative of a typical genset application and measures from “5” to “8” on JCH’s qualitative scale for various contaminants (Section 1.2). They will transport the contaminated fuel batch to CI by truck. The fuel will be continuously agitated in the truck to prevent stratification and to ensure that only well-mixed fuel goes into a 275 gallon polyethelene test day tank. The test day tank will be mounted on a platform scale for fuel mass consumption measurements.

At CI, the GHG Field Team Leader will inspect the day tank to ensure that it is clean and empty and that the platform scale is operating properly. JCH personnel will then fill the day tank from the truck. A propeller-type stirrer will continuously agitate the day tank contents during the test campaign. This will prevent stratification of the fuel and ensure that the well-mixed fuel pumped to the engine is truly representative of the contaminated fuel. JCH will be responsible for the handling and agitation of the fuel. The Field Team Leader will log JCH activities in the Test Log.

A single filling of the 275 gallon test day tank should provide about 15 hours of engine operation with a 75-gallon reserve. Should refilling of the day tank become necessary, the contaminated fuel in the truck will again be agitated to ensure that only well-mixed fuel goes into the day tank.

CI personnel will connect the genset to the load bank, install the test duct on the engine exhaust, and operate the genset.

Cubix test operators will be responsible for all engine emissions testing and the associated setup activities. The GHG Center and Cubix will coordinate adequate and safe access to the test duct for the required equipment and personnel. Their activities will be supervised by the GHG Center Field Team Leader to ensure that data are collected as specified in this Test Plan.

When the test day tank is filled, CI will start the genset and operate the engine at 50 to 80 percent of prime power capacity while placing the engine's fuel return line in a waste container. This will purge the engine of fuel from previous activities. A 10 minute run will purge approximately 5 gallons of fuel through the engine, and should be sufficient because the engine's fuel system holds approximately 1 gallon of fuel.

CI will then reconnect the engine fuel return line to the test day tank, and operate the engine at 100 percent prime power load to verify whether or not it will stall while using the contaminated fuel. If the engine stalls, CI technicians will replace the engine's fuel filters. This sequence will continue until the engine runs reliably on all 6 cylinders without excessive smoking. CI will install a new set of engine fuel filters, and the contaminated fuel test runs will commence. The engine fuel filters will be left in place during the contaminated fuel test runs to stabilize contamination level changes as the fuel cycles through the engine. If the engine should stall during a test run, the run and any samples collected during that run will be voided. Technicians will change the engine fuel filters, and test runs will recommence beginning with the run that was voided.

After Cubix conducts the required instrument zero and span checks, the GHG Field Team Leader will review the results to ensure that data quality indicators are within the ranges specified in Section 3.0 and declare the start (and end) for each test run. The instrumental analyzer operator will supply master clock readings for each test run and provide start/stop signals to other test operators.

There will be 3 valid test runs for contaminated fuel. Each test run will last for one (1) hour and will include emissions tests for all pollutants and greenhouse gases listed in Section 2.1, collection of fuel samples, fuel mass consumption, genset operating data, ambient temperature and humidity data, and the associated quality assurance activities.

Test personnel will operate the genset and the load bank to provide 100 percent, ± 5 percent of the genset's 180 KW prime power load rating, as measured by the genset and load bank instruments, during all emissions testing periods for contaminated and cleaned fuel. Genset operations must be as steady and consistent as possible because transient loads can profoundly affect engine emissions. The GHG Field Team Leader will manually log the readings listed in Table 2-2 10 minutes before a test run starts, at the beginning, at 15 minute intervals during, and at the end of each emissions test period:

Table 2-2. 200 kW Genset and Load Bank Parameters and Permissable Variation During Test Periods

Description	Expected Value	Permissible Variation During Test Period
Generator Ammeter, Each Phase	215 Amps	± 5.4 Amps
Generator Voltmeter, Each Phase	483 VAC	± 12.1 VAC
Generator Frequency Meter, Hz	60	± 1.2 Hz
Engine Oil Temp., °F	260	± 10 F
Engine Water Temp., °F	210	± 10 F
Engine Exhaust Temp., °F	925	± 50 F

All engine, generator, and load bank parameters must stabilize within the permissible variations for at least 10 minutes before a test run may commence. If test personnel observe readings outside these ranges, the emissions test run will not be initiated. Test and facility personnel will remedy the cause(s) of any problems before test runs resume. Appendix A contains a sample field data form.

Engine performance and emissions characteristics can vary with changing ambient conditions. The Field Team Leader will acquire ambient temperature and relative humidity data during each test run with a Vaisala Model HMP 35C meter connected to a Campbell datalogger.

After 3 valid test runs, JCH will diagnose and classify the contaminated fuel to determine the treatment and filtration schedule. The GHG Field Team Leader will note the proposed treatment in the Test Log and JCH will commence treatment and filtration. JCH will determine when to conclude treatment and filtration based on their field tests. In JCH's experience, it is necessary to pass from three to ten tank volumes through the Enviro system to initially treat a batch of fuel. There is little benefit in running longer than this because there is a point at which the filters cannot further clean the fuel.

When treatment and filtration is complete, CI technicians will install new engine filter canisters to prevent possible recontamination of the cleaned fuel. CI will again start the engine and route the fuel return to a waste container to purge the engine of remaining contaminated fuel. After fuel purging, CI will operate the engine at 100 percent of prime power load for two (2) hours. During the contaminated fuel test runs, it is possible that carbon and other deposits can build up in the engine's cylinders, valve train, and exhaust system. These deposits could contaminate the exhaust gases during the cleaned fuel test runs. The two-hour period at 100 percent load will allow potential emissions-forming deposits to burn out. There will then be 3 valid test runs performed for cleaned fuel.

The following sections discuss each verification factor and the measurements which will contribute to computation of that factor.

2.3. EMISSION RATES (LB/HR) OF CRITERIA POLLUTANTS AND GREENHOUSE GASES FOR CONTAMINATED AND CLEANED FUEL

Measurement of pollutant and greenhouse gas emission rates is a multi-step process including:

- Measurement of the stack gas flow rate, molecular weight, and moisture concentration
- Measurement of the NO_x, CO, CO_2, THC, and SO_2 volume concentrations (parts per million [PPMV]) in the stack gas *via* instrumental methods
- Measurement of the CH_4 volume concentration (PPMV) in the stack gas *via* a Tedlar bag gas sample collection method and laboratory analysis by gas chromatography
- Measurement of the TPM gravimetric concentration (grains per dry standard cubic foot; gr/dscf) in the stack gas *via* isokinetic sampling and "back half" quantification of condensible particulate matter

The concentrations of the pollutants per unit of stack gas (PPMV for gases or gr/dscf for particulate) are multiplied by the stack gas flow rate (lb.mol/hr for gases or dscf/hr for particulate) to arrive at the emission rates in pounds per hour.

The Test Plan will employ the following Title 40 CFR 60 Appendix A (40CFR60) reference methods to quantify volumetric concentrations and mass emission rates of criteria pollutants, greenhouse gases and oxygen:

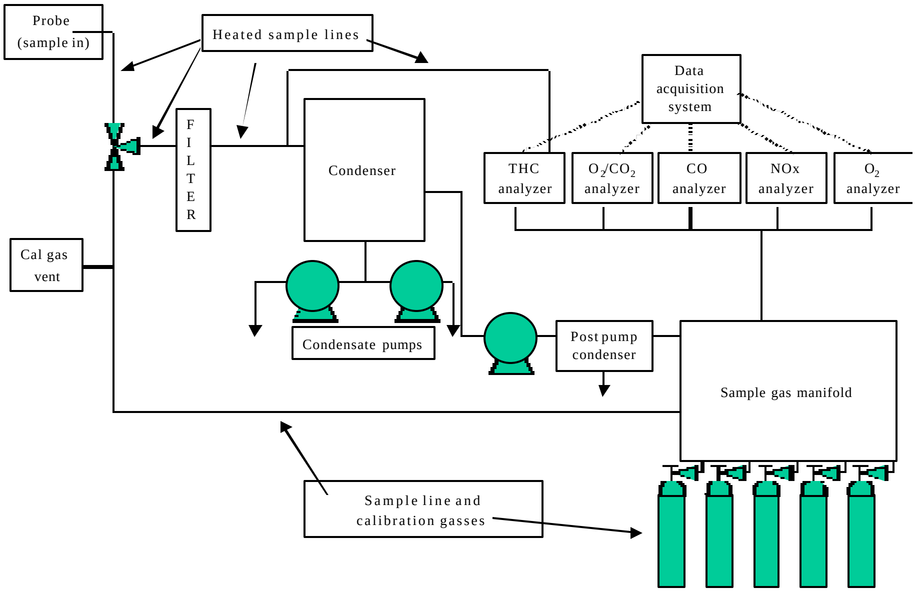
Table 2-3. Summary of Emission Testing Methods

Pollutant/ Parameter	**Reference Method**	**Principle of Detection**	**Proposed Analytical Range (Span)**
NO_x	7E	Chemilumenescence	0-1500 PPMV
CO	10	NDIR -- Gas Filter Correlation	0-2500 PPMV
CO_2	3A	NDIR	0-20 %
O_2	3A	Fuel Cell	0-25 %
THC	25A	Flame Ionization	0-500 PPMV
SO_2	6C	UV Pulsed Fluorescence	0-150 PPMV
CH_4	18	GC/FID	0-50 PPMV
TPM	5/202	Isokinetic Sampling	--

2.3.1. Gaseous Sample Collection, Conditioning and Handling

Figure 2-3 provides a schematic of the sampling system to be used for determination of concentrations of NO_x, CO, CO_2, O_2, and THC. In order for the CO_2, O_2, NO_x, and CO instruments to operate properly and reliably, the flue gas must be conditioned prior to introduction into the analyzer. The gas conditioning system removes water vapor and/or particulate from the sample. The THC analyzer requires wet unconditioned stack gas. Therefore, a second heated sample line delivers unconditioned exhaust gas directly to the analyzer.

Figure 2-3. Gaseous Pollutant Sampling Train Schematic



All interior surfaces of the gas handling system are made of stainless steel, Teflon™, or glass to avoid or minimize any reactions with the sample gas components. A sampling pump pulls stack gas from the engine exhaust duct through a heated stainless steel probe, filter, and heated umbilical. The heated umbilical splits at a sampling manifold. One sampling line leads directly to the THC analyzer. The other leads to a chiller/condenser.

The condenser removes moisture from the gas stream. The clean, dry sample is then transported to a flow distribution manifold where sample flow to each analyzer is controlled. Test operators route calibration gases through this manifold to the sample probe by way of a Teflon™ line. This allows calibration and bias checks to include all components of the sampling system. The distribution manifold also routes calibration gases directly to the analyzer when linearity checks are made on each of the analyzers.

2.3.2. Gaseous Emissions Sampling and Analysis Procedures

An API Model 200 AH chemilumenescence analyzer (or equivalent) will determine NO_x concentrations. This analyzer catalytically reduces nitrogen oxides in the sample gas to NO. The gas is then converted to excited NO_2 molecules by oxidation with O_3 (normally generated by ultraviolet light.) The resulting NO_2 emits light in the infrared region. The emitted light is measured by an infrared detector and reported as NO_x. The intensity of the emitted energy from the excited NO_2 is proportional to the concentration of NO_2 in the sample. Test operators verify the efficiency of the catalytic converter in making the changes in chemical state for the various nitrogen oxides as an element of instrument set up and checkout. This analyzer has the capability to quantify NO and NO_2 separately. During each test run, the NO and NO_2 fractions of the overall NO_x concentration will be checked. The NO_x analyzer and all other instrumental analyzers will be operated on an appropriate range where no exhaust gas readings are less than 30 percent of full scale or greater than full scale. Suggested instrument span is 0 - 1500 PPMV.

For CO determinations, an API Model 300 gas filter correlation analyzer (or equivalent) utilizing an optical filter arrangement will be used. This method provides high specificity for CO. Gas filter correlation utilizes a constantly rotating filter with two separate 180-degree sections (much like a pinwheel.) One section of the filter contains a known concentration of CO, and the other section contains an inert gas without CO. The sample gas is passed through the sample chamber containing a light beam in the region absorbed by CO. The sample is then measured for CO absorption with and without the CO filter in the light path. These two values are "correlated", based upon the known concentrations of CO in the filter, to determine the concentration of CO in the sample gas. Suggested instrument span is 0 - 2500 PPMV.

A Servomex Model 1400 non-dispersive infrared (NDIR) analyzer (or equivalent) will determine CO_2 concentration. NDIR measures the amount infrared light that passes through the sample gas versus a reference cell. As CO_2 absorbs light in the infrared region, the light attenuation is proportional to the CO_2 concentration in the sample. The CO_2 analyzer range will be set at or near 0 to 20 percent.

The same Servomex Model 1400 analyzer uses a fuel cell to measure Oxygen concentrations. This analyzer uses electrolytic concentration cells that contain a solid electrolyte to enhance electron flow to the O_2 as it permeates through the cell. The fuel-cell technology used by this instrument determines levels of O_2 based on partial pressures. The electrode is porous zirconium oxide. It acts as an electrolyte and as a catalyst. The sample side of the reaction has a lower partial pressure than the partial pressure in the reference side. The current produced by the flow of electrons is directly proportional to the O_2 concentration in the sample. The O_2 analyzer range will be set at or near 0 to 25 percent.

Total hydrocarbon vapors in the exhaust gas will be measured using a JUM Model VE-7 flame ionization analyzer or equivalent. This method passes the sample through a hydrogen flame. The intensity of the resulting ionization is amplified and measured and then converted to a signal proportional to the concentration of hydrocarbons in the sample. Unlike the other methods, the sample stream going to the JUM analyzer does not pass through the condenser system and is kept heated until it is analyzed to prevent condensation. This is necessary to avoid loss of the less volatile hydrocarbons in the gas sample.

Because all combustible hydrocarbons are being analyzed and reported, the emission value must be calculated to some base (methane or propane). The calibration gas for THC will be methane in nitrogen. The THC analyzer range will be set at or near the 0 to 500 ppm range (as methane). Concentrations of THC measured on a wet basis will be converted to a dry basis using exhaust gas moisture data. The conversion formula is shown in Equation 1.

$$C_{THC,Corr} = C_{THC,Analyzer}\left(\frac{1}{1-B_{ws}}\right) \qquad \text{(Eqn. 1)}$$

Where:

$C_{THC,Corr}$ = Corrected hydrocarbon concentration, PPMV
$C_{THC,Analyzer}$ = Average analyzer concentration, PPMV
B_{ws} = Stack gas moisture concentration, as a fraction

A Western Research Model 721, or equivalent ultraviolet (UV) pulsed fluorescence analyzer will acquire SO_2 concentrations. This instrument measures fluorescence from SO_2 molecules excited by ultraviolet light. Suggested instrument span is 0 - 150 PPMV.

Concentrations of methane in the exhaust gas will be determined in accordance with EPA Method 18. Test personnel will collect a slipstream of the Method 25A unconditioned gas stream into precleaned Tedlar sample bags. They will ship the bags to a laboratory for analysis by gas chromatography (GC) equipped with a flame ionization detector. Each sample will be injected into the GC three times to determine methane PPMV concentrations. The GC/FID will be calibrated with appropriate certified calibration gases.

All instrumental analyzers produce a varying voltage or 4 - 20 MA output for recording by a chart recorder or data acquisition system (DAS). This system will consist of either a multichannel chart recorder or a digital DAS connected to a PC. The test operator will adjust the chart recorder or DAS so that a 100 percent reading corresponds to the analyzer span. For example, a 100 percent trace for NOx on the chart recorder equals 1500 PPM. Data reduction from chart recorder traces or DAS digital files will conform to the reference methods.

Measured pollutant concentrations will be converted to mass rates as lb/hr using Equation 2.

$$E_{poll,i} = C_{poll,i} K_{poll} Q_{stack,std,i} \qquad \text{(Eqn. 2)}$$

Where:

$E_{poll,i}$ = Emission rate for test run number i, lb/hr
$C_{poll,i}$ = Average analyzer concentration for test run number i (where i=1 to 3), PPMV
(Note: For THC use $C_{THC,corr}$ per Eqn. 1; for CH_4 use the average result from the three GC injections)
K_{poll} = PPMV to lb/dscf conversion factor listed below
$Q_{stack,std,i}$ = Stack dry volumetric flow rate, dscf/hr (dscfm*60), corrected to standard conditions (60^oF, 29.92" Hg) for test run i

In Equation 3, the appropriate K_{gas} listed below converts PPMV analyzer readings to lb/dscf concentrations. Section 2.3.4 describes stack dry volumetric flow measurements.

K_{CH4}: 1 PPMV = 4.15E-08 lb/dscf
K_{CO}: 1 PPMV = 7.264E-08 lb/dscf
K_{CO2}: 1 PPMV = 1.142E-07 lb/dscf
K_{NOx}: 1 PPMV = 1.194E-07 lb/dscf
K_{SO2}: 1 PPMV = 1.661E-07 lb/dscf
K_{THC}: 1 PPMV = 4.15E-08 lb/dscf (THC emissions are quantified as methane)

For all gaseous pollutants and greenhouse gases, the average emissions and sample standard deviation will be:

$$E_{poll} = \frac{\sum_{i=1}^{i=3} E_{poll,i}}{3} \qquad \text{(Eqn. 3)}$$

$$s_{poll} = \sqrt{\frac{\sum (E_{poll,i} - E_{poll})^2}{n-1}} \qquad \text{(Eqn. 4)}$$

Where:

E_{poll} = Average emissions for the given pollutant or greenhouse gas, lb/hr
$E_{poll,i}$ = Average emissions for the given pollutant or greenhouse gas for run number i, where i = 1 to 3
s_{poll} = Sample standard deviation, lb/hr
n = Number of available measurements (3)

2.3.3. Gaseous Emissions Calibrations and Quality Control Checks

Analyzer and sampling system calibrations and bias checks will conform to methods and criteria specified in the Reference Methods. These QC procedures will be used to determine if overall data quality objectives (DQOs) for emissions were met during the verification. The corresponding 40CFR60 Reference Methods provide details; they will not be repeated here in entirety. However, the following sections outlines specific procedures to be conducted during this test.

NO_x Analyzer Interference Test

In accordance with Method 20, test operators will conduct an interference test on the NO_x analyzer once before the first test run. This test is conducted by injecting the following calibration gases into the analyzer:

CO: 500 ± 100 ppm in balance nitrogen (N_2)
SO_2: 200 ± 20 ppm in N_2
CO_2: 10 ± 1 % in N_2
O_2: 20.9 ± 1 %

For acceptable analyzer performance, the sum of the interference responses to all of the interference test gases must be $\leq$ 2 percent of the analyzer span value. Analyzers failing this test must be repaired or replaced.

NO_2 Converter Efficiency Test

The NO_x analyzer converts any NO_2 present in the gas stream to NO prior to gas analysis. An efficiency test on the converter must be conducted prior to beginning the testing. This procedure is conducted by introducing to the analyzer a mixture of mid-level calibration gas and air. The analyzer response is recorded every minute for 30 minutes. If the NO_2 to NO conversion is 100 percent efficient, the response will be stable at the highest peak value observed. If the response decreases by more than 2 percent from the peak value observed during the 30-minute test period, the converter is faulty. A NO_x analyzer failing the efficiency test must be either repaired or replaced prior to testing.

NO_x Field Audit

At least once during the test campaign, the GHG Center Field Team Leader will initiate a field audit of the entire NO_x sampling and analysis system. He will supply the Cubix test operator with a cylinder of EPA Protocol gas containing a known concentration of NO_x in N_2. The test operator will introduce the gas to the sampling system and the GHG Field Team Leader will note the results in the Daily Test Log. Results must be equal to the concentration noted on the cylinder, ± 5 percent of the instrument span.

CO Analyzer Interference Check

Method 10 specifies a CO_2 scrubbing system for CO instrumental analyzers because of possible interference with NDIR - type instruments. Modern instruments, however, employ gas filter correlation techniques which should eliminate interference problems. To check this, test operators will introduce a calibration gas with known concentrations of CO and CO_2 to the analyzer after analyzer calibration. Gas concentrations will be as follows:

> CO: Select a concentration at 80 percent to 100 percent of instrument span (400 - 500 PPM for 500 PPMV span)
> CO_2: 10 percent ± 1 percent
> N_2: Balance

For acceptable analyzer performance, the analyzer must record the proper CO gas concentration ± 2 percent. Analyzers failing this test must be repaired.

Instrumental Analyzer Calibration Error, System Bias, and Calibration Drift Tests

These calibrations will be conducted to verify accuracy of NO_x, CO, CO_2, O_2 , and SO_2 measurements. Test operators will conduct calibration error tests at the beginning of each day of testing. The operator introduces a suite of calibration gases directly to the analyzer and records analyzer responses. The Test Plan requires that EPA Protocol 1 calibration gases for these calibrations. The three gases used for NO_x, CO_2, O_2 and SO_2 calibrations include zero, 40 to 60 percent of span, and 80 to 100 percent of span. Four gases are used for CO including zero and approximately 30, 60, and 90 percent of span. The maximum allowable error in response to any of the calibration gases is ± 2 percent of span.

Before and after each test conducted during the day, the operator introduces zero and mid-level calibration gases to the sampling systems at the probe and records the responses. The operator calculates system bias by comparing the system responses to the calibration error responses recorded earlier. System bias must be less than ± 5 percent of span for the sampling system to be acceptable.

Analysts will adjust instrumental analyzer concentrations after field operations are completed by using the system bias values in the following equation.

$$C_{gas,corr} = (C_{gas} - C_o) * [C_{ma} / (C_m - C_o)] \qquad \text{(Eqn. 5)}$$

Where:

$C_{gas,corr}$ = Corrected gas concentration, PPMV
C_{gas} = Average measured test run gas concentration, PPMV
C_o = Average system bias for zero gas
C_{ma} = Upscale calibration gas value
C_m = Average system bias for upscale calibration gas

The pre- and post-test system bias calibrations are also used to calculate sampling system drift for each pollutant. Drifts in excess of ± 3 percent are unacceptable and the test must be repeated. Appendix B provides a sample calibration records sheet.

THC Sampling System Calibration Error and Drift

Test operators will conduct THC sampling system calibration error tests prior to the start of the first test on each day. The calibration is conducted by sequentially introducing a suite of calibration gases to the sampling system at the sampling probe, and recording the system response. All calibration gases will conform to EPA Protocol No. 1 specifications. The four required calibration gases are: zero, 20 to 30 percent of span, 40 to -60 percent of span, and 80 to 90 percent of span (methane in N_2 or air). The maximum allowable error in response to any of the calibration gases is ± 5 percent of span for THC.

At the conclusion of each test conducted during the day, the zero and mid-level calibration gases are again introduced to the sampling systems at the probe and the response is recorded. System response is compared to the initial calibration error to determine sampling system drift. Drifts in excess of ± 3 percent for THC are unacceptable and the test must be repeated.

Instrumental Analyzer Data Completeness and Reasonableness

The GHG Field Team Leader will review the chart traces (or a line chart representation of the DAS digital file) for each instrumental analyzer at the completion of each test run. The data must be reasonable and complete for each analyzer. Some criteria are:

- The trace must fall entirely within the boundaries of the instrument span; no flattened peaks at high concentrations.
- The trace must move smoothly and continuously from concentration to concentration; no abrupt steps or extended flat lines (periods with no concentration changes).
- The data must be 100 percent complete defined as no gaps in the chart trace for each analyte.
- Average values should reasonably be within ± 35 percent of the concentrations listed in the following table.

Table 2-4. Expected Stack Gas Concentrations

Gas	Concentration, PPMV
NO_x	1188
CO	2405
CO_2	8.2 %
THC	495
SO_2	99

The GHG Field Team Leader will initial each day's chart. For digital DAS, he will obtain a disk copy of the data file and make the appropriate entry in the test log book.

2.3.4. Stack Gas Flow Determination

Test operators will measure stack gas flow at a test duct which CI shop personnel will install onto the engine's exhaust stack downstream from the engine muffler. The test duct will conform to the requirements of 40CFR60, Method 1A, "Sample and Velocity Traverses for Stationary Sources with Small Stacks or Ducts." Stack gas flow determination requires measurement of stack gas velocity, the molecular weight, moisture content, and the area of the stack.

Stack gas velocity, temperature, and moisture content determinations are included in the total particulate (TPM) isokinetic test method. The test operator moves a pitot and thermocouple across the test duct, recording the differential pressures with a manometer and temperatures at several points during the traverse. Moisture is determined gravimetrically by withdrawing a measured stack gas sample through a probe and passing it through a chilled impinger train to condense the water. Test operators then weigh the collected water.

Oxygen (O_2) and Carbon Dioxide (CO_2) data are required to calculate the stack gas molecular weight. Test operators will obtain these data *via* instrumental analyzers which conform to 40CFR60 Method 3a. Section 2.3.2 and Table 2-4 above outline the instruments' detection principles and proposed analytical ranges (span).

Analysts use the data from these tests and the physical measurement of the test duct area to determine the average dry volumetric flow rate at standard conditions (dry standard cubic feet per minute; dscfm) for each test run. These values will be correlated with measured pollutant concentrations to calculate pollutant emission rates.

2.3.5. Stack Gas Flow Data Quality Assurance and Completeness

The GHG Field Team Leader will review O_2 and CO_2 instrumental analyzer data at the end of each test day. Review criteria will be as described for instrumental analyzers. Stack volumetric flow and moisture field data will be reviewed according to Section 2.3.7.

Cubix test operators will certify that pitot tubes meet applicable Method 2 requirements for dimensional accuracy. They will also perform post-test thermocouple calibrations by subjecting the thermocouples used during testing to the average temperature found during testing. The thermocouple reading will be compared to a NIST-traceable reference thermometer. For acceptable results, the thermocouple reading must be within 1.5 percent of the reference thermometer. Refer to 40CFR60 Method 2, section 10.3.1 for details on thermocouple calibration.

Barometers used during testing must be calibrated against a NIST-traceable instrument. Field data sheets will indicate how test operators correct barometric pressures for the altitude of the sampling site.

2.3.6. Total Particulate (TPM) Emissions Sampling and Analysis procedures

The Method 5/202 sampling system collects stack gas through a nozzle on a probe inserted in the stack. The test operator adjusts the velocity of the stack gas which enters the probe to be the same as the stack gas velocity ("isokinetic sampling"). This procedure minimizes inertial effects on the stack gas particulate matter and allows representative sampling.

The stack gas and its particulate pass through the heated, glass-lined, probe and through a filter which is maintained at 250 ^{o}F, ± 25 ^{o}F. The filter collects particulate (usually inorganic matter) which condenses above that temperature; the rest of the stack gas and condensible particulate pass through the filter. The weights of particulate collected on the filter and deposited in the probe and nozzle are correlated with the total volume of stack gas collected and comprises the “front half” particulate concentration.

The stack gas then passes into a chilled impinger train charged with distilled water. Stack gas moisture and condensible particulate (usually organic matter) drop out in the impinger train for recovery at the end of the test run. Test operators forward the recovered samples to the laboratory for extraction with methylene chloride and gravimetric analysis. The collected stack gas moisture is correlated with the gas volume for stack gas moisture computation. The condensed impinger particulate is correlated with the total volume of stack gas collected and comprises the “back half” particulate concentration.

Total particulate matter (TPM) will be reported as the sum of the front half and back half concentrations by Equation 6.

$$C_{TPM} = \frac{((m_{filter} + m_{condens} - m_{blank}) / 64.799)}{VM_{std}} \qquad \text{(Eqn. 6)}$$

Where:

C_{TPM} = Particulate mass concentration, gr/dscf
m_{blank} = Total mass of filter, probe rinse, “back half,” and extraction reagent blanks, mg
$m_{condens}$ = Mass of particulate collected in impingers, mg
m_{filter} = Mass of particulate collected on the filter, mg
VM_{std} = Volume of collected stack gas, corrected to dry standard conditions (68 ^{o}F, 29.92” Hg), dscf
64.799 = milligrams per grain, mg/gr

Total particulate emission rate will be reported as:

$$E_{TPM,i} = C_{TPM,i} Q_{stack,std,i} \qquad \text{(Eqn. 7)}$$

Where:

$E_{TPM,i}$ = Particulate emission rate, lb/hr
$C_{TPM,i}$ = Mass concentration of particulate matter for run number i (where i = 1 to 3), gr/dscf
$Q_{stack,std,i}$ = Stack dry volumetric flow rate, dscf/hr (dscm*60) corrected to standard Conditions (60 ^{o}F, 29.92” Hg)

The average particulate emissions and sample standard deviation will be:

$$E_{TPM} = \frac{\sum_{i=1}^{i=3} E_{TPM,i}}{3} \qquad \text{(Eqn. 8)}$$

$$s_{TPM} = \sqrt{\frac{\sum (E_{TPM,i} - E_{TPM})^2}{n-1}} \qquad \text{(Eqn. 9)}$$

Where:

E_{TPM} = Average particulate emissions, lb/hr
$E_{TPM,i}$ = Average particulate emissions for run number i, where i = 1 to 3
s_{TPM} = Sample standard deviation, lb/hr
n = number of measurements available (3)

Methods 5 and 202 include the required equations for the contributing calculations; they will not be repeated here. It is possible that the balance between condensible (organic) and noncondensible (inorganic) particulate could change between the contaminated and cleaned fuel batches. This approach will allow the results for the condensible and non-condensible particulate emissions to be separated.

2.3.7. Particulate Emissions Data Completeness and Quality Assurance

For a valid sample, the minimum sample volume will be 31.8 dry standard cubic feet (dscf). The GHG Field Team Leader will review field data sheets for each test run to ensure that the proper sample volume was collected.

Particulate matter must be sampled isokinetically; in general, this means that the velocity of the stack gas entering the sampling nozzle must be the same as the surrounding stack gas. Method 5 provides equations for computing the isokinetic sampling rate, I. The results are expressed as a percentage of the ideal rate. For these tests, the allowable variation is 90 percent $\leq$ I $\leq$ 110 percent of the ideal isokinetic sampling rate. Cubix test operators will compute I at the conclusion of each test run, and the GHG Field Team Leader will review the calculation before proceeding with the next test run.

To minimize the possibility of sample contamination, sampling probes must have glass liners. Glass nozzles are preferred, but not required. All nozzles must be dimensionally calibrated; GHG Center personnel will review the calibration data while at the test site.

To minimize variability in the back half analysis, Cubix test operators will collect sampling filters, reagents and rinses in a clean environment and as expeditiously as possible. The Field Team Leader will observe these efforts for each test run. He will note the starting and ending times for particulate sample recovery and any problems in the Daily Test Log.

Note that Methods 5 and 202 include procedures for collecting and analyzing filter and reagent blanks. This Test Plan specifically requires filter and reagent blanks as follows:

Filter Blank
Test operators will install an unused filter into the isokinetic sampling chain and conduct a normal leak check as specified in the Methods. This could be done in conjunction with the sample blank described below. They will recover the filter and analyze it along with the test run filters.

Reagent Blanks

Before the first test run, test operators will collect a 200 ml aliquot of each sampling and recovery reagent from the storage containers to be used during testing. They will label these as “Trip Blanks” and analyze them along with other samples.

Before the first test run, test operators will charge the impinger train with the required sampling reagents. They will conduct a normal leak check as specified in the Methods. This could be done in conjunction with the Filter Blank described above. The sampling train will then be washed and sample recovered as if a normal test run had occurred. The recovered reagents will be labeled as “Sample Blank” (including separate labeled bottles for “Probe/nozzle”; “Impinger Water”; “Impinger Acetone”; and “Impinger Methylene Chloride”) and analyzed along with the other samples.

Particulate Data Completeness and Reasonableness

The GHG Field Team Leader will review and initial each field data sheet for each particulate sampling test run for completeness and reasonableness. The individual reference methods detail the data to be collected and the review criteria to be employed, but some points are emphasized here for specific methods.

All data sheets must:

- Be signed and dated, with times of day for each test run noted
- Have all appropriate information blanks completed

Method 2 (stack initial velocity traverse and cyclonic flow check) forms must clearly depict the stack traverse points and cyclonic flow readings at those points. Probes and thermocouples must be uniquely identified and calibration information must be traceable to the probe ID.

Method 4 (moisture content) impinger weight forms must include tare and final impinger weights and the total weight of moisture collected. Appendix B contains sample field data forms.

Method 5 (particulate sampling) forms must include entries for ambient temperature, stack static pressure, nozzle, probe, dry gas meter, and other sample train ID numbers. Barometric pressure must be noted for local conditions, uncorrected to sea level, and must include statements about the elevation difference between the instrument’s location and the stack sampling location. Calibration information must be traceable to the probe, nozzle, sampling train, and other ID’s. Leak check data must include vacuum (“Hg), start reading and end reading of the dry gas meter, and a notation that the sample train conforms to leak check requirements. Appendix B contains sample field and laboratory data forms.

All sample containers must be sealed and marked with unique identification numbers which can be traced to each test run. Test operators will mark the outside of all liquid sample containers with a line at the liquid level contained in the bottle. Laboratory personnel will inspect the marks and note whether any fluid has been lost in transport and handling.

At the conclusion of the first emissions test run, test operators will calculate stack moisture content, molecular weight, velocity, volumetric flow, and percent isokinetic sampling rate. The GHG Center representatives will review the calculations before they authorize the following test runs. Comparison of the field data from the first run with following runs will show if the collected data are reasonable and consistent.

2.4. FUEL PROPERTIES (CONSUMPTION RATE, HEATING VALUE, AND QUALITY) FOR CONTAMINATED AND CLEANED FUEL

The Test Plan requires acquisition of fuel consumption rates, heating values, and quality data for contaminated and cleaned fuel as burned in the engine. The Verification Report will present comparisons and correlate the data with the engine emissions for the two fuel conditions.

2.4.1. Fuel Consumption Rate for Contaminated and Cleaned Fuel

Diesel engines use their fuel for cooling and lubrication of fuel system components. Engine-operated pumps constantly circulate fuel from the storage tank, through the engine galleries and past the injectors, and back to the storage tank. The Cummins test engine circulates approximately 55 gal/hr under normal conditions. The injectors actually use only a portion of the total flow depending on the engine load and revolutions per minute (RPM). For this engine, fuel consumption will be about 13.3 gal/hr at 100 percent of prime power load (180 KW). The 42 gal/hr return flow to the storage tank is usually hot and foamy, and must be tempered by the mass of unused fuel in the tank.

Under these conditions, gravimetric methods are the optimum way to monitor the fuel consumed. The Test Plan provides for use of a 275-gallon polyethelene day tank which will rest on a 2500-lb capacity platform scale. This should allow about 15 hours of engine operation at 100 percent prime power load, leaving a 75 gallon reserve. The engine will pull its fuel from the day tank and return the circulating excess to the same tank. The GHG Field Team Leader will record fuel starting and ending weights on the field data form provided in Appendix A.

The engine will be connected to the test day tank with flexible hoses, routed through the tank's cap and supported so that they do not contact the tank walls or floor. This will minimize any effect on the weighing process.

At the beginning of each test run, test operators will record the time, the weight of the tank and fuel, and initial fuel temperature upon a signal from the instrumental analyzer operator. At least 3 scale readings will be collected at 15 minute intervals during each test run. This will contribute to the evaluation of the stability of genset operations. The final scale reading and fuel temperature must be recorded at the end of each test run upon a signal from the instrumental analyzer operator. The total fuel used during the run is as follows:

$$FuelRate = (Wt_1 - Wt_2)\left(\frac{60}{T_{elapse}}\right) \qquad \text{(Eqn. 10)}$$

Where:

FuelRate = Mass fuel consumption rate, lb/hr
T_{elapse} = Run elapsed time, as recorded by the instrumental analyzer operator, min.
Wt_1 = Initial tank/fuel weight at the beginning of the test run, lb
Wt_2 = Final tank/fuel weight at the end of the test run, lb

To prevent engine fuel system wear and scoring, Cummins recommends that fuel temperature should not rise above 110 ^{o}F. Test operators will log fuel temperature from a mercury-in-glass thermometer or thermocouple suspended in the fuel in the center of the test day tank.

2.4.2. Fuel Consumption Rate Quality Assurance and Completeness

Scale Specifications and Calibrations

Fuel mass consumption data will be taken from a rented Fairbanks Aegis™ 2500-lb capacity platform scale. Accuracy is ± 0.01 percent of the scale reading. Resolution of the display is 0.2 lb.

The empty test day tank weighs approximately 200 lb. Filled with 250 gallons of fuel, the combined weight will be approximately 1900 lb. Each test run will consume approximately 94 lb of fuel. Fairbanks will provide a NIST-traceable calibration certification for the scale. Before testing commences, Fairbanks will challenge the scale with 1900, 1800, 1700, 1600, 1500, 1400, and 1300-lb NIST-traceable weights after the scale is installed at the test site to ensure that the calibration has not changed during transport. They then will repeat the challenge with the same weights at the test campaign's conclusion. This will simulate the weight change during each test run, and may permit refining the accuracy of the fuel consumption data.

Test operators will record these field verifications on the field data form provided in Appendix A. Fairbanks will provide a copy of the weight's NIST-traceable calibration certificate for inclusion in the Verification Report.

Fuel Consumption Data Completeness and Reasonableness

The GHG Field Team Leader will review the fuel mass consumption data sheets at the end of each test day. Initial and final tank/fuel weights and times must be entered for each test run to be deemed valid. A minimum of one mid-run reading may be omitted if, in the GHG Field Team Leader's professional judgement, the genset operations are predictable and consistent. The GHG reviewer will compare the measured fuel consumption rate with the published factory fuel consumption rate (13.3 gal/hr @ 100 percent of prime power load) for reasonableness.

If fuel temperature rises to 110 ^{o}F, test operators may interrupt the test campaign at the end of the current test run. Testing will resume when fuel temperature falls below 110 ^{o}F. If a run was interrupted, it will be repeated.

2.4.3. Heating Value and Quality of Contaminated and Cleaned Fuel

To determine fuel cleaning performance, the Test Plan requires fuel sample collection, laboratory analysis of fuel quality properties, and comparison of the results. The selection of fuel quality properties discussed here is based on input from engine manufacturing representatives (Association of Engine Manufacturers, Cummins, Caterpillar, International Truck and Engine, John Deere), fuel biological contamination experts, the chairman of the ASTM D-975 fuels committee, and several testing laboratories.

JCH's treatment and filtration technology is most likely to affect properties such as water, sediment, particulate, API Gravity, and microbial contamination. It is possible that the technology may affect other properties like LHV, flash point, gums and resins, cetane number, or lubricity.

ASTM D-975, "Standard Specification for Diesel Fuel Oils" (D-975) specifies some of these properties and lists the associated test methods. Other properties of interest here can be analyzed *via* additional ASTM test methods not specified in D-975. The following table outlines the consensus selection of fuel properties which may be affected by JCH's technology, the D-975 specifications and test methods where applicable, and the methods which the Test Plan will employ.

Table 2-5. Diesel Fuel Properties Test Methods

Description	Expected Values (Clean Fuel)	D-975 Method	Test Plan Method	Method Accuracy
Lower Heating Value (LHV)	18,400 BTU/lb	--	D-4809	± 97.1 BTU/lb
API Gravity	30 - 42 °API	--	D-4052	± 0.22 % of reading
Flash Point	52 °C	D-93	D-93	± 5 % of reading
*Water and Sediment	< 0.05 % (vol)	D-2709	D-2709	varies; ± 9.4 % at 3 % vol. conc.
*Ash	< 0.02 % (wt)	D-482	D-482	± 21 % of reading
Cetane Number	40 - 45	D-613	D-613	± 5.2 % of reading
*Particulate Matter	10mg/100ml	--	D-6217	varies; ± 25.3 % at 10 mg/l
*Gums and Resins	10mg/100ml	--	D-381	± 6 mg/100 ml
Lubricity	**WSD < 0.45 mm	--	D-6079	± 21.3 % of reading
Bacterial Microbial Contamination	$< 10^3$ colony forming units (CFU)	--	LiquiCult	± 1 $\log_{10}$ of reading
Fungal Microbial Contamination	$< 10^3$ CFU	--	LiquiCult	± 1 $\log_{10}$ of reading

NOTES: At least one sample will be collected and analyzed during each emissions test run. A reference sample will be collected and analyzed from the test day tank prior to the start of testing.
* Duplicate sample to be collected during Run 2 for contaminated and cleaned fuel
** Wear Scar Diameter < 0.45 mm at 60 °C as measured with high-frequency reciprocating rig

Test operators will acquire samples of contaminated and cleaned fuel during each test run. They will forward the samples to Southwest Research Institute's Petroleum Products Research Department (SwRI) for analysis. Table 2.5 shows the expected values and accuracy of the analysis. The following section describes the fuel sampling protocol.

SwRI is an accredited, full-service non-profit laboratory and research organization located in San Antonio, TX. They are equipped to perform a wide variety of ASTM, SAE, EPA, and proprietary (e.g., GM, Ford) methods on fuels, lubricants, greases, and other petroleum products. Appendix B provides sample laboratory results, certifications, and ASTM method control charts.

2.4.3.1. Fuel Sampling Protocol

The fuel tests in Table 2-5 require approximately 5 liters total sample size for all the analyses; approximately 2.5 liters for the duplicate sample analyses. The GHG Center Field Team Leader will collect one complete fuel sample during each test run for contaminated and cleaned fuel, filling two 2.5 liter aluminum sample bottles supplied by SwRI. The samples will be collected from a petcock and hose installed in the fuel return line fitting on the engine's fuel pump. Test operators will regulate the petcock such that approximately 10 minutes are required to fill each 2.5 liter sample container approximately 85 percent full. This will provide a reasonably well integrated fuel sample for each 1-hour test run. The 15 percent headspace is required for expansion during transportation and sample agitation at the laboratory. Test operators will then seal the sample containers and forward them to the laboratory for analysis.

Immediately after the first 2.5 liter fuel sample is collected, the GHG Center Field Team Leader will collect a separate fuel sample during each test run for LiquiCult analysis. He will fill the syringe from the petcock and immediately inject the sample into the agar solution. The second 2.5 liter aluminum sample bottle will then be filled approximately 85 percent full.

During Run 2 for each fuel condition (contaminated and cleaned), the Field Team Leader will collect a 2.5 liter duplicate sample for water and sediment, ash, particulate, and gums/resin analysis. He will fill a third 2.5 liter aluminum sample bottle approximately 85 percent full immediately after the second 2.5 liter bottle is filled.

For reference, the GHG Center Team Leader will collect an "as received" fuel sample from the test day tank after it has been filled prior to commencement of testing. The test operator will utilize a hand-operated fuel sampling pump supplied by JCH to transfer fuel from the agitated test day tank to the two 2.5 liter sample containers.

2.4.3.2. Fuel Properties Analysis Methods and Data Quality Assurance

GHG Center personnel will enter fuel sample information onto the Fuel Sample Collection Log (see Appendix A) at the time the samples are collected. They will mark all samples with a unique identification number, seal them, prepare them for shipping, and note the required information on the custody transfer form. All shipping containers will bear the proper labels and conform to DOT requirements for flammable liquids transportation.

SwRI will receive the samples, note any discrepencies, and analyze them according to the information on the Fuel Sample Collection Log and Chain of Custody forms. SwRI will combine all samples collected during the individual test runs to prepare a mixture that represents the fuel for each 1-hour test run. For example, the three 2.5 liter samples from Run 2 contaminated fuel will be combined and mixed. Fuel analyses will be performed on this mixture according to the methods summarized in Table 2-5.

The fuel analysis methods listed in Table 2-5 employ a wide variety of procedures. Some ASTM methods include a direct comparison against a reference material or standard; bias and accuracy can be derived from this comparison. The LHV method (D-4809), for example, utilizes a bomb calorimeter whose performance has been verified with a NIST-traceable standard reference material (SRM) of known calorific content.

For other methods, no reference material exists. Bias becomes nearly impossible to compute and "accuracy " (derived from repeatability and reproduceability) depends upon the proper application of the method. In general, SwRI ensures correct performance of test methods through an annual verification of test technicians' performances. During this verification, the technicians must demonstrate their proficiency with the method; only certified technicians conduct final testing.

SwRI also participates in "round robin" comparison testing where test results are compared to other laboratories performing the same tests on a given lot of fuel. If the results, repeatability, and interlaboratory reproducibility fall outside the group data spread, then SwRI launches an investigation into the cause of the outlier.

For the specific test methods of interest here, SwRI has in place the following:

D-4809; Lower Heating Value

Fuel mass consumption rate (Section 2.4.1) and lower heating value (LHV) are required for computation of emissions performance in terms of pounds of emissions per million BTU of heat input.

The analyst places a fuel sample in a sealed bomb calorimeter with an excess of oxygen and ignites it. A recording thermometer system logs heat transferred to the surrounding cooling medium as a rise in temperature. The LHV calculation requires data for fuel sulfur (S), hydrogen (H), and carbon (C). The analyst will perform Method D-2622 for S and D-5291 for H and C as part of this method.

The Bomb calorimeters are standardized per the method after any maintenance or system changes. Benzoic acid is analyzed at the start of each run period. This standard is control charted and the acceptance criteria are based upon a statistical sampling of the data. Currently the Limits are 11308.79 ± 16.63 BTU's. Control Limits are based upon three times the sample standard deviation. In addition the thermometers and balances used in the test process are calibrated at six month intervals. Each sample result is also run in duplicate and must agree within 50 BTU.

System performance is verified at least once per shift by analysis of a benzoic acid SRM.

To verify SwRI quality assurance procedures, GHG Center will require inclusion of the duplicate test fuel sample results, benzoic acid SRM analysis results, and control charts with each fuel sample's LHV data. Copies of the most recent thermometer calibrations, balance calibrations, and NIST-traceable SRM analysis must accompany the report. The laboratory will include fuel S, H, and C data in their report for information. The supporting QC documentation must be associated with each shift during which the samples are analyzed. SwRI will challenge the balance with an NIST-traceable Class A test weight to verify that the calibration has not changed. Results of the challenge must be included with analysis results. GHG Center's review of the QC documents with respect to the SRM analysis, control limits, and duplicate sample results will be included in the Verification Report.

D-4052; ^{o}API (API Gravity)

The analyst measures the fuel density directly with a densitometer. Each Densitometer is calibrated weekly using the physical standards of water and dry air. Each day that the instrument is used its performance is verified using distilled water and heptane SRMs. The acceptance limits on the water is 0.9999 ± 0.0004 and for heptane it is 0.6885 ± 0.0002. These values were developed using statistical analysis of the QC data. This translates into an API acceptance of about ± 0.06 °API.

To verify SwRI quality assurance procedures, GHG Center will require inclusion of the distilled water and heptane SRM analyses and method control charts with each fuel sample's ^{o}API data. The supporting QC documentation must be associated with each shift during which the samples are analyzed. Copies of the NIST-traceable SRM analyses must accompany the report. GHG Center's review of the QC documents with respect to the SRM analysis and control charts will be included in the Verification Report.

D-93; Flash Point

A fuel sample is placed in a Pensky-Martens closed cup apparatus and heated while an ignition source is applied. The analyst records the temperature at which an ignition flash occurs.

Each shift, the flash point of Anisole is determined as a secondary reference standard. This flash point must be 117 ± 2 °F. In addition every six months pure n-Decane is analyzed as a certified reference standard. It has a known flash point of 127 ± 4 °F. The temperature probe and the speed of the impeller are calibrated every six months as well, in conjunction with the certified reference material determination.

To verify SwRI quality assurance procedures, GHG Center will require inclusion of the Anisole analysis, the most recent n-Decane analysis, temperature probe calibration, impeller speed calibration, and method control charts with each fuel sample's flash point data. The supporting QC documentation must be associated with each shift during which the samples are analyzed. GHG Center's review of the QC documents with respect to the Anisole and SRM analyses, equipment calibrations, and control charts will be included in the Verification Report.

D-2709; Water and Sediment

The analyst places a 100 ml sample into two 50 ml centrifuge tubes with marked graduations. The centrifuge spins the assembly at a rate which yields a known centrifugal force based on the dimensions of the tubes and their separation. The denser water and sediment fractions migrate to the bottom of the tubes, and the analyst reads the volumetric concentration according to graduations on the tube.

Reference materials are not available for this method. The only control SwRI currently has is the calibration of the centrifuge speed to ensure the proper relative centripetal force. SwRI purchases the glassware in accordance with the method specification; however, no additional QC is done on the glassware.

Some control can be inferred from the use of two centrifuge tubes because if the two results are not equal, there might be methodological or glassware problems. This is a standard part of the test method.

To verify SwRI quality assurance procedures, GHG Center will require inclusion of each of the two tube's readings and their proportion of the total result for each sample as part of the report. Duplicate analyses will be performed on the Run 2 fuel samples for each fuel condition. Copies of the most recent centrifuge calibration and method control charts must also be attached. GHG Center's review of the QC documents with respect to the two tube readings, equipment calibrations, and control charts will be included in the Verification Report.

D-482; Ash

A fuel sample is placed in a tared crucible and heated to ignition. When all flames have died down, the crucible is placed in a muffle furnace for baking at 775 ± 25^{o}C. After baking, the crucible is weighed to determine the remaining mass of ash. Reference materials are not available for this method.

SwRI runs an internal reference oil each time samples are analyzed. This standard is control charted and the acceptance criteria are based upon an statistical sampling of the data. Currently the Limits are 1.675 percent (mass) ± 0.148 percent. Control Limits are based upon three times the sample standard deviation. In addition, The muffle furnace temperature probe and the balance used to weigh the crucibles are calibrated every six months.

To verify SwRI quality assurance procedures, the GHG Center will require inclusion of the internal reference oil analysis in the report. The reference oil analysis must occur during the same shift that the fuel samples are analyzed. Copies of the most recent muffle furnace temperature probe and balance calibrations and method control charts must also be attached. In addition, GHG Center will require that muffle furnace temperatures and baking times be included in the report. SwRI will challenge the balance with an NIST-traceable Class A test weight to verify that the calibration has not changed. Results of the challenge must be included with analysis results. Duplicate analyses will be performed on the Run 2 samples for each fuel condition. The GHG Center's review of the QC documents with respect to the reference oil analysis, equipment calibrations, and control charts will be included in the Verification Report.

D-613; Cetane Number

Analysts operate a cetane engine with the fuel. Engine injection and valve timing is varied until a knock is heard. Reference materials are not available for this method.

SwRI will analyze a consensus standard, ASTM Cetane Check Fuel, each shift to check the engine performance. The current acceptance criteria on this standard is 41.6 ± 0.9 Cetane numbers. The cetane engines are subject to an extensive maintenance schedule, including overhaul of the cylinder head, cleaning of the injector, checks of bump pressure and spray pattern. The thermometers for the head temperature, water jacket temperature and intake air temperature are calibrated every six months as is the timer used to verify the flow rate.

To verify SwRI quality assurance procedures, GHG Center will require inclusion of the consensus standard analysis results in the report. The consensus standard analysis must occur during the same shift that the fuel samples are analyzed. Copies of the thermometer and timer calibrations, method control charts, and engine maintenance activities within the last six months must also be attached. Copies of the interlaboratory results for the Cetane Check Fuel must accompany the report. GHG Center's review of the QC documents with respect to the consensus standard analysis, equipment calibrations, maintenance activities, and control charts will be included in the Verification Report.

D-6217; Particulate

A fuel sample is passed through a tared filter. Filter weight gain is a measure of particulate matter in the fuel. Reference materials are not available for this method; SwRI analyzes a blank tared filter in conjunction with each test. In addition, SwRI maintains calibrations on the balances used to weigh filters and the thermometers used for drying oven control.

To verify SwRI quality assurance procedures, GHG Center will require inclusion of the blank filter analysis with the report. Copies of the most recent balance and thermometer calibrations and method control charts must be attached.. In addition, GHG Center will require that SwRI challenge the balance with an NIST-traceable Class A test weight to verify that the calibration has not changed. Results of the challenge must be included with analysis results. Duplicate analyses will be performed on the Run 2 samples for each fuel condition. GHG Center's review of the QC documents with respect to the blank filter analysis, equipment calibrations, and control charts will be included in the Verification Report.

D-381; Gums and Resins

A steam jet apparatus evaporates the volatile fractions of the fuel under controlled conditions, leaving gums and resins in a tared cup. Reference materials are not available for this method. The steam flow rate is calibrated annually. Technicians also check the block temperature with a calibrated thermometer and the weights are determined on a calibrated balance. Both the Thermometers and balance are calibrated at 6 month intervals.

To verify SwRI quality assurance procedures, GHG Center will require inclusion of the most recent steam flow, thermometer, weight, and balance calibrations and method control charts with the report. In addition, GHG Center will require that SwRI challenge the balance with an NIST-traceable Class A test weight to verify that the calibration has not changed. Results of the challenge must be included with analysis results. Duplicate analyses will be performed on the Run 2 samples for each fuel condition. GHG Center's review of the QC documents with respect to the equipment calibrations and control charts will be included in the Verification Report.

D-6079; Lubricity

The analyst places a fuel sample on a steel plate which is held at 60 °C. Then, a reciprocating scuffing pad rubs across the plate at high frequency for a given number of cycles. The size of the resulting scuff mark is a measure of the fuel's lubricity. The test is repeated with a 25 °C plate temperature.

Every 20 samples, SwRI checks the instrument with the two reference fluids described in the method: "Cat-1H" and "isopar." Cat-1h is a consensus diesel fuel standard; isopar is a solvent. These checks are run in duplicate and the duplicates must agree to within 0.08 mm wear scar diameter (WSD). In addition the average of the two values must meet the following criteria:

Cat -1H	0.29 ± 0.08 mm WSD at 25 °C; 0.41 ± 0.08 mm WSD at 60 °C
Isopar	0.58 ± 0.08 mm WSD at 25 °C; 0.62 ± 0.08 mm WSD at 60 °C.

The entire unit is also calibrated to ensure the temperature, time and reciprocation frequency are correct.

To verify SwRI quality assurance procedures, GHG Center will require inclusion of the Cat-1H and Isopar analyses with the report. These analyses must occur within 20 samples of the test fuel analyses. Copies of the most recent temperature, time, and frequency calibrations and method control charts must be attached. GHG Center's review of the QC documents with respect to the Cat-1H and Isopar analyses, equipment calibrations, and control charts will be included in the Verification Report.

2.4.3.3. Liquicult Microbial Analysis and Data Quality Assurance

The LiquiCult test is a proprietary method supplied by Metalworking Chemicals and Equipment Company, Inc.; (MCE) Lake Placid, NY. A wide variety of industries use LiquiCult cultures to track biological contamination of solvents, fuels, oils, and other process fluids. It consists of a sealed bottle of agar solution and colorimetric charts. The user injects a sample of the fuel into the solution through a septum with a syringe and incubates the sample. After incubation, a comparison with the colorimetric charts yields estimates of bacterial and fungal growth.

LiquiCult specifies incubation "at room temperature" for 30 hours. The GHG Field Team Leader will place the samples in an air conditioned office space at the test facility for incubation. At 30 ± 3 hours, the GHG Center representative will read and record colorimetric information for bacterial contamination. Each fuel sample will then be incubated for another 42 hours. At that time, 72 hours ± 3 hours since the sample was collected, the Field Team Leader will read and record colorimetric information for fungal contamination. Data is in the form of an exponential count of colony forming units (CFU); i.e. 10^2 CFU, 10^4 CFU, etc. Appendix A provides a data collection form.

According to MCE, the manufacturer prepares bacterial suspensions with known concentrations of colony forming units (CFU) corresponding to the color chart values. The suspensions are injected into the agar bottles, incubated, and compared to the chart to verify each batch's performance prior to release.

2.4.3.4. Fuel Properties Data Reduction and Reporting

The Test Plan requires one analysis for each test run for each of the fuel properties listed in Table 2-6 for cleaned and contaminated fuel. The Verification Report will include the results for each analysis. The average value and sample standard deviation for each property as follows:

$$X_{avg} = \frac{\sum_{i=1}^{i=3} X_i}{3} \quad \text{(Eqn. 11)}$$

$$s_X = \sqrt{\frac{\sum (X_i - X_{avg})^2}{n-1}} \quad \text{(Eqn. 12)}$$

Where:

X_{avg} = Average laboratory value of fuel property X (LHV, API Gravity, etc.) for each fuel condition
X_i = Reported laboratory value of fuel property X for run number i for each fuel condition
s_X = sample standard deviation
n = number of available results for each fuel condition (3)

The Verification Report will also include the results of the "as received" reference sample drawn from the test day tank prior to the start of testing.

2.5. EMISSIONS PERFORMANCE OF CONTAMINATED AND CLEANED FUEL

This verification will report emissions performance as the percent change in emission rates for each pollutant between contaminated and cleaned fuel, after pollutant mass emissions are normalized using average diesel fuel mass consumption rates and LHVs. Results will be in two forms:

- Percent change of mass of pollutant emitted per mass of fuel consumed (percent change, $lb_{pollutant}/lb_{fuel}$)
- Percent change of mass of pollutant emitted per million BTU heat input (percent change, $lb_{pollutant}$/mmBTU)

2.5.1. Emissions Performance as Pounds of Pollutant per Pound of Fuel Consumed

The calculation of emissions in terms of pounds of a pollutant per pound of fuel consumed requires the emission rate for each pollutant (Section 2.3) and the fuel consumption rate (Section 2.4). The Verification Report will use the following equation:

$$E_{norm,i} = \frac{E_i}{FuelRate_i} \qquad \text{(Eqn. 13)}$$

Where:

E_i = Emission rate of the given pollutant or greenhouse gas, for run number i (where i = 1 to 3), lb/hr
$E_{norm,i}$ = Normalized emission rate of the given pollutant or greenhouse for run number i, lb/lb of fuel
$FuelRate_i$ = Fuel consumption rate for run number i, lb/hr

For all pollutants and greenhouse gases, average normalized emissions and sample standard deviation from contaminated and cleaned fuel will be:

$$E_{norm} = \frac{\sum_{i=1}^{i=3} E_{norm,i}}{3} \qquad \text{(Eqn. 14)}$$

$$s_{norm} = \sqrt{\frac{\sum (E_{norm,i} - E_{norm})^2}{n-1}} \qquad \text{(Eqn. 15)}$$

Where:

E_{norm} = Average normalized emissions for the given pollutant or greenhouse gas, lb/lb of fuel
$E_{norm,i}$ = Average normalized emissions for the given pollutant or greenhouse gas for run number i, where i = 1 to 3
s_{norm}= Sample standard deviation, lb/lb of fuel
n = number of available results (3)

There must be a statistically significant difference in average emissions performance to allow a meaningful computation of the percent change. Analysts will test the hypothesis that average emissions performance between the two fuel conditions are different by computing the following test statistic:

$$t = \frac{(E_{norm,cleaned} - E_{norm,contam})}{\sqrt{s_p{}^2\left(\frac{1}{n_{cleaned}} + \frac{1}{n_{contam}}\right)}} \qquad \text{(Eqn.16)}$$

$$s_p{}^2 = \frac{(n_{cleaned} - 1)s^2{}_{norm,cleaned} + (n_{contam} - 1)s^2{}_{norm,contam}}{n_{cleaned} + n_{contam} - 2} \qquad \text{(Eqn. 17)}$$

Where:

t = Test statistic
s_p = Pooled sample standard deviation
s = Sample standard deviation for cleaned and contaminated fuel conditions

If the test statistic (t) is > 2.776 (assuming a 95 percent confidence level and 4 degrees of freedom), we can accept the hypothesis that the average emissions performances are different and proceed with calculation of the percent change.

The percent change (emission performance) between contaminated and cleaned fuels will be:

$$\%Change = \left(\frac{E_{norm,contam} - E_{norm,cleaned}}{E_{norm,contam}}\right) * 100 \qquad \text{(Eqn. 18)}$$

Where:

% Change = Emissions performance for a given pollutant
$E_{norm,contam}$ = Average normalized emissions from contaminated fuel for the given pollutant or greenhouse gas, lb/lb of fuel
$E_{norm,cleaned}$ = Average normalized emissions from cleaned fuel for the given pollutant or greenhouse gas, lb/lb of fuel

2.5.2. Emissions Performance as Pounds of Pollutant per Million BTU Heat Input

The calculation of emissions in terms of pounds of a pollutant per million BTU of fuel heat input requires the emission rate for each pollutant (Section 2.3), the fuel consumption rate (Section 2.4), and the LHV (Section 2.4) of the fuel. The Verification Report will use the following equation:

$$E_{normheat,i} = \frac{E_i}{(FuelRate_i * LHV_i / 1000000)} \qquad \text{(Eqn. 19)}$$

Where:

E_i = Emission rate of the given pollutant or greenhouse gas, for run number i (where i = 1 to 3), lb/hr
$E_{normheat,i}$ = Normalized emission rate of the given pollutant or greenhouse for run number i, lb/mmBTU
$FuelRate_i$ = Fuel consumption rate for run number i, lb/hr
LHV_i = Fuel net heating value for run i, BTU/lb
1000000 = BTU/mmBTU

For all pollutants and greenhouse gases, average normalized emissions and sample standard deviation from contaminated and cleaned fuel will be:

$$E_{normheat} = \frac{\sum_{i=1}^{i=3} E_{normheat,i}}{3} \tag{Eqn. 20}$$

$$s_{\ normheat} = \sqrt{\frac{\sum (E_{normheat,i} - E_{normheat})^2}{n-1}} \tag{Eqn. 21}$$

Where:

E$_{normheat}$ = Average normalized emissions for the given pollutant or greenhouse gas, lb/mmBTU of heat input
E$_{normheat,i}$ = Average normalized emissions for the given pollutant or greenhouse gas for run number i, where i = 1 to 3
s$_{normheat}$= Sample standard deviation, lb/mmBTU of fuel
n = number of available results (3)

There must be a statistically significant difference in average heat-based emissions performance to allow a meaningful computation of the percent change. Analysts will test the hypothesis that average emissions performance between the two fuel conditions are different by computing the following test statistic:

$$t = \frac{(E_{normheat,cleaned} - E_{normheat,contam})}{\sqrt{s_p{}^2\left(\frac{1}{n_{cleaned}} + \frac{1}{n_{contam}}\right)}} \tag{Eqn. 22}$$

$$s_p{}^2 = \frac{(n_{cleaned} - 1)s^2{}_{normheat,cleaned} + (n_{contam} - 1)s^2{}_{normheat,contam}}{n_{cleaned} + n_{contam} - 2} \tag{Eqn. 23}$$

Where:

t = Test statistic
s$_p$ = Pooled sample standard deviation
s = Sample standard deviation for cleaned and contaminated fuel conditions

If the test statistic (t) is > 2.776 (assuming a 95 percent confidence level and 4 degrees of freedom), we can accept the hypothesis that the average emissions performances are different and proceed with calculation of the percent change.

The percent change (emission performance) between contaminated and cleaned fuels will be:

$$\%Change = \left(\frac{E_{normheat,contam} - E_{normheat,cleaned}}{E_{normheat,contam}}\right)*100 \tag{Eqn. 24}$$

Where:

% Change = Emissions performance for a given pollutant
$E_{normheat,contam}$ = Average normalized emissions from contaminated fuel for the given pollutant or greenhouse gas, lb/mmBTU
$E_{normheat,cleaned}$ = Average normalized emissions from cleaned fuel for the given pollutant or greenhouse gas, lb/mmBTU

2.6. FUEL CLEANING PERFORMANCE

The Verification Report will include fuel cleaning performance as the percent change in fuel parameters between contaminated fuel and the same fuel when it has been treated and cleaned with the JCH technology.

The laboratory results for contaminated and cleaned fuel properties (Section 2.4) are necessary to calculate fuel cleaning performance.

There must be a statistically significant difference in fuel properties to allow a meaningful computation of the percent change between cleaned and contaminated fuel. Section 2.4 discusses the calculations for average values of fuel properties and their sample standard deviations. Analysts will test the hypothesis that average fuel properties for the two fuel conditions are different by computing the following test statistic:

$$t = \frac{(X_{cleaned} - X_{contam})}{\sqrt{s_p^{\,2}\left(\frac{1}{n_{cleaned}} + \frac{1}{n_{contam}}\right)}} \qquad \text{(Eqn. 25)}$$

$$s^2{}_p = \frac{(n_{cleaned} - 1)s^2{}_{X,cleaned} + (n_{contam} - 1)s^2{}_{X,contam}}{n_{cleaned} + n_{contam} - 2} \qquad \text{(Eqn. 26)}$$

Where:

t = Test statistic
X = Average laboratory value for the fuel property (LHV, °API, etc.; see Section 2.4)
s_p = Pooled sample standard deviation
s = Sample standard deviation for cleaned and contaminated fuel conditions
n = number of available results (3)

If the test statistic (t) is > 2.776 (assuming a 95 percent confidence level and 4 degrees of freedom), we can accept the hypothesis that the average emissions performances are different and proceed with calculation of the percent change.

The percent change in each fuel property is as follows:

$$\%Change_X = \left(\frac{X_{cleaned} - X_{contam}}{X_{contam}} \right) * 100 \qquad \text{(Eqn. 27)}$$

Where:

% $Change_x$ = Percent change of fuel property X
$X_{cleaned}$ = Average laboratory value of property X (LHV, API Gravity, etc.) for cleaned fuel
X_{contam} = Average laboratory value of property X for contaminated fuel

3.0 DATA QUALITY

3.1. BACKGROUND

Verifications conducted by the GHG Center and EPA's Office of Research and Development employ methodologies and instruments which are selected to ensure that the desired level of data quality occurs in the final results. This Test Plan states data quality objectives (DQOs) for key verification parameters before testing commences.

Each test measurement that contributes to the determination of a verification parameter has certain data quality indicators (DQIs) which, if met, ensure achievement of that parameter's DQO. This section presents the DQOs for critical verification parameters, followed by a discussion of the data quality indicators.

The process of establishing data quality objectives begins with determining the desired level of confidence in the verification parameters. The next step is to identify all measured values which affect the verification parameters, and determine the levels of error which can be tolerated. Two JCH verification parameters are based on comparisons of emissions performance between contaminated and cleaned fuel: Emissions Performance and Fuel Cleaning Performance. DQOs are established for these two critical verification parameters, and consists of maximum error that will be allowed for these parameters. The following sections state the DQOs, define the DQI which will be used to determine if the stated DQOs were satisfied, and presents the mathematical approach for reconciling the DQOs using measurements data.

3.1.1. Emissions Performance DQOs

Emissions performance is the percent change in emissions between the two fuel conditions. The values reported for this verification parameter are the results of multiple inputs from different types of measurements. Each contributing measurement has its own errors which must be accounted for to determine the cumulative effects on the verification parameter. For example, emissions performance as the percent change between contaminated and cleaned fuel in pounds of NO_x emitted per pounds of fuel burned ($lb_{pollutant}$/mmBtu) is a primary verification parameter. It requires measurement of (1) energy consumed during the test run, (2) stack gas flow rate, and (3) volumetric concentration of NOx in the stack gas. In developing the DQOs for emissions performance verification parameter, stack gas concentrations were assumed to be at least 10 percent less for cleaned fuel as compared to contaminated fuel. Table 3-2 summarizes the DQOs for pollutant specific emissions performance, and an example calculation for NOx DQO is provided below to illustrate the methodology used.

Table 3-1. Data Quality Objective: Maximum Emissions Performance Measurement Error for 10 % Stack Gas Concentration Reduction

Pollutant	**Mass-Based ($lb_{pollutant}/lb_{fuel}$)**	**Heat Input-Based ($lb_{pollutant}$/mmBTU)**
NO_x	± 5.4 %	± 6.1 %
CO	± 7.5 %	± 8.2 %
CO_2	± 7.5 %	± 8.1 %
THC	± 7.4 %	± 8.2 %
SO_2	± 7.6 %	± 8.2 %
CH_4	± 7.3 %	± 8.2 %
TPM	± 4.5 %	± 4.7 %

Space permits discussion of the chain of calculations and their associated random errors for the NO_x heat input-based ($lb_{pollutant}$/mmBTU) emissions performance DQO. Derivation of the other emissions performance DQOs is similar. Most of the calculations below assume that all random measurement errors are additive and are at their maxima. For example, if the NO_x measurement has a maximum positive error of 2 percent and the stack gas flow measurement has a maximum error of +2 percent, the total error assumed here would be +4 percent. This is a conservative approach because in reality, each member of a chain of measurements are rarely taken at their maximum error and the sign of the errors are rarely the same. The chances of all of the contributing measurements for stack gas flow rate being at their maximum positive error, for example, is approximately 1 in 10^{14} (*Shigehara, Todd, Smith*).

It is important to note that all calculations were performed with numbers to 14 decimal places (Excel spreadsheets). Truncation and rounding using the values below will lead to slightly different results in manual calculations. The percent variation conclusions below are based on manual calculations; the values in parentheses are quoted from the spreadsheet calculations. Data from the Cummins Engine Co. for the test engine horsepower, fuel consumption (gal/hr), stack temperature (^oF), stack gas actual flow rate (ACFM), and NO_x emissions (g/hp-hr); laboratory records for fuel specific gravity (^{o}API) and LHV (BTU/lb); and combustion calculations are the basis for the initial "nominal" estimates of stack gas composition (lb/lb.mol), flow rates (lb.mol/hr), and NO_x volumetric (PPMV) concentrations.

1. We can expect field determination of lb/hr NO_x emissions to vary as follows:

Measurement/Computation	Est. Nominal Value	Max	Min
Stack gas flow rate	79.3 lb.mol/hr	80.9	77.7
NO_x concentration	1188 PPMV	1212	1164
NO_x emission rate	4.33 lb/hr	4.51	4.16

If all errors are additive, the maximum variation from the expected NO_x emission rate is 4.2 percent (4.1 percent).

2. The measured engine fuel consumption (lb/hr) is needed to determine normalized emissions in terms of $lb_{pollutant}/lb_{fuel}$. Nominal fuel consumption is 94.1 lb/hr, based on Cummins specifications of 13.3 gallons/hr and fuel density of 7.076 lb/gallon (35^o API). Test personnel will measure fuel consumption as the difference in weight of the test day tank at the end of a test run compared to beginning of the test run. Scale specifications are ± 0.1 percent for each weighing. Error in the weight determination is:

Measurement/Computation	Nominal Value	Max	Min
Initial test day tank weight	1844 lb	1845.8	1842.2
Final test day tank weight	1750 lb	1753.5	1746.3
Engine fuel consumption	94.4 lb/hr	97.7	90.5

The maximum variation from the expected fuel consumption rate is 4.1 percent (4.1 percent).

3. Based on the above estimates, normalized NO_x emissions would be 4.33 lb/hr divided by 94.1 lb/hr or an expected value of 0.046 lb_{NOx} / lb_{fuel}. The maximum could be 0.050; the minimum could be 0.043 for a maximum 8.7 percent (8.8 percent) variation about the expected value.

4. Determination of normalized heat input based emissions ($lb_{pollutant}$/mmBTU) requires the weight of the fuel consumed and the laboratory values for LHV to determine mmBTU/hr heat input. These data contribute to the computation of normalized emissions.

Measurement/Computation	Nominal Value	Max	Min
Engine fuel consumption	94.1 lb/hr	97.7	90.5
Fuel LHV	18400 BTU/lb	18592	18208
Heat input	1.74 mmBTU/hr	1.82	1.65
NO_x emission rate	4.33 lb/hr	4.51	4.16
NO_x Normalized emissions	2.50 lb/mmBTU	2.74	2.29

Maximum variation about the expected value is 9.6 percent (9.4 percent).

5. To determine emission performance as the percent change in heat input-based NO_x emissions (lb/mmBTU) between contaminated and cleaned fuel, a statistically significant difference in normalized emissions must exist between the two fuel conditions. For each condition, we can conservatively assume three possibilities: 1) emissions at the expected value; 2) all positive errors are additive (maximum value); 3) all negative errors are additive (minimum). If we assume a 10 percent reduction in stack gas NO_x concentration (from 1188 to 1069 PPMV), expected normalized emissions will be 2.25 lb/mmBTU; maximum of 2.46 and minimum of 2.06. This leads to nine (9) possible comparisons between contaminated and cleaned fuel:

Contaminated Fuel lb/mmBTU	Cleaned Fuel lb/mmBTU	Emissions Performance as a Percent Change
2.29	2.06	-10.0
2.29	2.25	-1.7
2.29	2.46	7.6
2.50	2.06	-17.6
2.50	2.25	-10.0
2.50	2.46	-1.53
2.74	2.06	-24.7
2.74	2.25	-17.7
2.74	2.46	-10.0

Average heat input-based emissions performance (the percent change in normalized emissions between contaminated and cleaned fuel) is -9.5 percent; sample standard deviation is 9.9 percent. Based on a 90 percent level of confidence and a T-distribution with 8 degrees of freedom, the resulting confidence interval about the -9.5 percent emissions performance is ± 6.1 percent. The data quality objective (DQO) for NO_x heat input based emissions performance quoted in Table 3-1 is therefore ± 6.1 percent.

3.1.1.1. Determination of Emission Measurement DQIs

As shown in the example above, each of the contributing measurements have errors which, in turn, have a mathematical relationship to its corresponding DQO. To determine if these DQOs were met, DQI goals are established for critical measurements (see Table 3-2). The DQI goals consists of achieving a specified level of accuracy in each measurement, and meeting the completeness goals for the test run. The onsite calibrations and QC checks listed in Table 3-3 will serve as a direct means of monitoring and quantifying sampling and analysis errors, and determining if the stated DQI goals were met. For example, if the NO_x analyzer fulfills all of the calibration and QC checks listed, this implies that NO_x PPMV measurements are within the error specified as the DQI goal. If each contributing measurement meets its DQI goals, then achievement of the DQO is assured.

The EPA Reference Methods clearly specify the sampling methods, calibration methods, and data quality checks that must be followed to achieve a data set that meets the required objectives. These Methods ensure that run-specific quantification of instrument and sampling system drift and accuracy occurs, and that runs are repeated if specific performance goals are not met. Furthermore, the Methods require adjustments of instruments and sampling systems in response to calibration checks. These data are used to adjust measured values to ensure the highest possible quality exists in the final results. Given this, the GHG Center will consider emissions determinations to be of acceptable quality if all Reference Method calibrations, performance checks, and concentration corrections specified in the Reference Methods have been successfully conducted (described in detail in Section 2.3).

Fuel mass consumption is an important component of emissions performance. The Test Plan specifies a 275-gallon test day tank which should contain enough fuel for the entire test sequence, including a 75-gallon reserve. Total tank and fuel weight will be approximately 1900 lb. Given this capacity, scale accuracy of ± 0.1 percent of reading, and two readings per test run (beginning and end), a worst case error propagation (see Section 3.1.1) yields approximately ± 4 percent error in fuel mass consumption per test run. This will be sufficient to meet the DQOs listed in Table 3-1. Quality assurance/quality control (QA/QC) checks which will be performed for fuel consumption measurements consists of performing a NIST-traceable calibration prior to and after testing, and conducing field verification with NIST traceable standard weights. The differences between the measured values and reference values must of within 0.1 percent of reading to satisfy the DQO. Details on these procedures were discussed in Section 2.4.2.

The GHG Center Field Team Leader will be responsible for on-site quality assurance of all field tests. If DQI goals are not met, the Field Team Leader will have the authority to halt testing until the measurement system(s) is corrected and proved to meet the DQI goals.

Table 3-2. Measurement Instrument Specifications and Data Quality Indicator Goals

		Instrument Specifications			Data Quality Indicators		
Measurement Variable		Instrument Type / Manufacturer or Method	Instrument Accuracy	Frequency of Measurements	Accuracy	Complete -ness	How Verified / Determined
Engine Emissions	NO_x Levels	Chemilumenescense / API 200 AH or equivalent	± 1 % FS (FS = 1500 PPM)	1-minute averages (DAS polls analyzer outputs at 5-second intervals)	± 2 % FS (includes sampling system bias corrections)	100 %	Follow EPA Method calibration and system performance check criteria. Review Manufacturer calibration certificates where applicable
	CO Levels	NDIR / API 300 or equivalent	± 1 % FS (FS = 2500 PPM)		± 2 % FS (includes sampling system bias corrections)		
	THC Levels	FID / JUM Mode 3-100 or equivalent	± 1 % FS (FS = 1000 PPM)		± 5 % FS		
	CO_2 / O_2 Levels; Stack Gas Molecular Weight	Servomex 1400 NDIR/fuel cell or equivalent	± 0.5 FS (FS = 20 % / 25 %)		± 2 % FS (includes sampling system bias corrections)		
	CH_4 Levels	GC / FID HP Model 5890 or equivalent	± 0.1 % FS (FS = 1000 PPM)		± 2 % FS		
	SO_2 Levels	UV Pulsed Fluorescence / Western Research 721 or equivalent	± 1 % FS (FS = 150 PPM)		± 2 % FS (includes sampling system bias corrections)		
	H_2O content	Gravimetric / NA	± 0.2 % FS (FS = 100 %)	Once per test run	± 5 % FS		
	Stack Gas Flow	Pitot and Thermocouple	n/a	Once per test run	± 5 % FS		
	TPM Levels	Gravimetric with Method 202 condens. extraction / NA	± 5 % reading for µ 139 mg particulate catch	Once per test run	± 5 % reading		
	Fuel Mass consumption	Gravimetric; Fairbanks Platform Scale	± 0.1 % reading	Once per test run	± 5 % after accumulated weighings		
	Amb. Temp.	RTD/ Vaisala HMP 35A	± 0.2 °F	once/min	± 0.2 °F		
	Relative Humidity	Vaisala HMP 35A	± 2 % (0 to 90 % RH)	once/min	± 2 %		

Table 3-3. Summary of Calibrations and QC Checks

Measurement Variable		Calibration/QC Check	When Performed/Frequency	Expected or Allowable Result	Response to Check Failure or Out of Control Condition
Emission Rates	NO_x	Analyzer interference check NO_2 converter efficiency	Once before testing begins	± 2 % of analyzer span 98 % efficiency	Repair or replace analyzer
		System field audit check	Once before testing begins	± 5 % of analyzer span	Repair analyzer, sampling system
		Analyzer calibration error test	Daily before testing	± 2 % of analyzer span	Repair or replace analyzer
		System bias checks	Before each test run	± 5 % of analyzer span	Correct or repair sampling system
		Calibration drift test	After each test run	± 3 % of analyzer span	Repeat test
	CO, CO_2, O_2	Analyzer calibration error test	Daily before testing	± 2 % of analyzer span	Repair or replace analyzer
		System bias checks	Before each test run	± 5 % of analyzer span	Correct or repair sampling system
		Calibration drift test	After each test run	± 3 % of analyzer span	Repeat test
		CO Analyzer Interference Check	Once before testing begins	< 2 % of analyzer span	Correct or install CO_2 scrubbbing system
	THC	System calibration error test	Daily before testing	± 5 % of analyzer span	Correct or repair sampling system
		System calibration drift test	After each test run	± 3 % of analyzer span	Repeat test
	SO_2	Analyzer calibration error test	Daily before testing	± 2 % of analyzer span	Repair or replace analyzer
		System bias checks	Before each test run	± 5 % of analyzer span	Correct or repair sampling system
		Analyzer interference check (modified Method 6)	During first test run	< 7 % of avg. conc. during first test run	Repair or replace analyzer
	CH_4	Calibration drift test	after each test run	± 3 % of analyzer span	Repeat test
		Calibration with gas standards by certified laboratory	Prior to analysis of each lot of samples submitted	± 2 % for CH_4 concentration	Repeat analysis
	TPM	Minimum Sample Volume	after each test run	Corrected Vol. $\geq$ 31.8 dscf	Repeat test run
		Percent Isokinetic Rate	after each test run	80 % $\leq I \leq$ 120 %	Repeat test run
		Analytical Balance Calibration	Once before analysis	± 0.0001 g	Repair/replace balance
		Filter and Reagent Blanks	Once during testing after first test run	< 1 % of particulate catch for first test run	Recalculate emissions based on high blank values, all runs; recalculate DQO
		Dry Gas Meter Calibration	Once before and once after testing	± 5 %	Recalculate emissions based on whichever meter coeficcient yields smallest sample volume; recalculate DQO
		Sampling Nozzle Calibration	Once for each nozzle before testing	± 0.004”	Select different nozzle

(continued)

Table 3-3. Summary of Calibrations and QC Checks (continued)

Measurement Variable		Calibration/QC Check	When Performed/Frequency	Expected or Allowable Result	Response to Check Failure or Out of Control Condition
Ambient Temperature and RH		Mfg. Calibration	Within 6 months	Temp: ± 0.2 °F RH: ± 2 %	Repair or replace meter and/or sensors
		Reasonableness checks	Once per day during test	Comparable with Las Vegas Airport data	Repair or replace meter and/or sensors
Emission Rates (con't.)	Stack Gas Flow	Pitot Tube Dimensional Calibration / Inspection	Once before and once after testing	See 40CFR60 Method 2, Section 10.0	Select different pitot tube
		Thermocouple Calibration	Once after testing	± 1.5 % of average stack temperature recorded during final test run	Adjust average stack temperatures for all test runs; recalculate stack flow rates
		Barometer Calibration	Once before and once after testing	± 0.1” Hg	Acquire average station pressure from local airport; adjust for elevation at sample site

3.1.2. Fuel Cleaning Performance DQOs

Fuel Cleaning Performance is based on the percent change in fuel properties between contaminated and cleaned fuels. The Test Plan specifies a set of ASTM fuel test methods to measure the fuel properties of interest. The results of each method for each fuel property has an associated error estimate. The DQO for the percent change in each fuel property is therefore based on the associated measurement error for that property. Table 3-4 lists the DQOs for fuel cleaning performance verification parameter. The percent difference between contaminated and cleaned fuel properties must be larger than the values in Table 3-2 to draw valid conclusions. For example, LHV for cleaned fuel must be at least 1.05 percent different from LHV for contaminated fuel to conclude that JCH’s technology has an effect. The following discussion justifies the development of the DQOs, and methods to be followed to assess whether the DQOs are met.

Table 3-4. Fuel Cleaning Performance Data Quality Requirements
(Minimum Percent Change in Properties Between Contaminated and Cleaned Fuel)

	ASTM Method	DQO for Fuel Cleaning Performance	DQI Goal For Fuel Property Measurement
LHV	D-4809	± 1.05 %	± 0.53 %
° API	D-4052	± 0.44 %	± 0.22 %
Flash Point	D-93	± 10 %	± 5 %
Cetane Number	D-613	± 15.9 %	± 7.5 %
Lubricity	D-6079	± 43 %	± 21.3 %
Water and Sediment	D-2709	± 23.3 %	± 9.4 %
Ash	D-482	± 42 %	± 21 %
Particulate	D-6217	± 57.2 %	± 25.3 %
Gums and Resins	D-381	± 60 %	± 30 %

For all fuel quality analyses, the GHG Center is using industry-standard methods developed by ASTM, and believes the QA guidelines required by those standards provide a sound, defensible, and industry-accepted way of ensuring good quality data is collected. Further, these methods provide an industry-accepted means by which data quality can be determined and reported, and thus, are used to judge how close SRI came to achieving its original DQOs for fuel quality.

Each ASTM method specifies a different combination of QC checks, calibrations, reference material analyses, duplicate sample analyses, and others. ASTM states that if each of these QC checks are performed according to the method, the corresponding sample analysis has a specific numerical reproducibility. ASTM further states that method accuracy may be derived from these reproducibility results, and has justified this through extensive interlaboratory "round robin" testing for each method. The ASTM method accuracy statements are widely accepted throughout the industrial community, and are selected as the DQI goals for fuel property measurements (see Table 3-4). The approach adopted for the JCH verification is that the DQI goals must be met, and results of specific pre-defined QC checks (e.g., duplicate sample analysis, comparisons with standard reference methods) will be used to determine if the DQIs goals were achieved. If they do not meet the specifications, the analyst must remedy the cause and re-perform the QC check before analyzing the fuel sample. GHG Center will require that SwRI submit the results of the QC checks in their report.

Using the ASTM specified accuracy statements, which are also the DQI goals for the verification, the Center computed errors in fuel cleaning performance verification parameter, and have assigned these as the DQOs. Recall, fuel cleaning performance is defined as the percent change in fuel properties between contaminated and cleaned fuel. The DQOs were developed by propagating errors in the contaminated fuel and clean fuel measurements. In the worst case, the value of a fuel property for cleaned fuel must be different from contaminated fuel by at least twice the ASTM method's accuracy to enable the conclusion that JCH's technology has had an effect. Fuel cleaning performance DQOs, then, are generally twice the ASTM method's accuracy. The DQOs will be determined to be met, provided the accuracy goals for each fuel property measurements are met.

3.1.2.1. Determination of Fuel Property Measurement DQIs

In general, achievement of fuel properties DQIs consist of proper performance of the analysis, comparison to SRMs, in-house, or consensus standards, and tracking of method/technician performance on control charts as described in Section 2.4. Appendix B contains copies of SwRI's relevant accreditations, control charts for example methods, and sample laboratory reports. Test and laboratory personnel must employ the proper equipment, methods, and procedures listed in Table 3-5. If this is done correctly, each test method should provide repeatable results which conform to the stated accuracy of that method.

Table 3-5. Summary of Fuel Properties Calibrations and QC Checks

Measurement Variable	Calibration / QC Check	When Performed / Frequency	Expected or Allowable Result	Response to Check Failure or Out of Control Condition
Mass Consumption	Platform scale NIST calibration	Once before testing begins	± 0.1 % of reading	Repair or replace scale
	*Scale field verification	Once before testing begins	± 0.1 % of reading	Repair or replace scale
		Once after testing ends	± 0.1 % of reading	Consider repeat of test campaign
D-4809 LHV	*Benzoic acid SRM analysis	Once per shift	11308.79 ± 16.63 BTU/lb	Troubleshoot and re-analyze
	Duplicate sample analysis	Once per shift	± 50 BTU	Troubleshoot and re-analyze
	Balance Verification	Once per sample	± 0.1 mg of Class A mass standard	Repair/replace
	Equipment calibrations	Within 6 months	Varies; see Section 2.4	Repair/replace; Re-analyze affected samples
D-4052 °API	*Water SRM analysis	Once per shift	0.9999 ± .0004	Troubleshoot and re-analyze
	*Heptane SRM analysis	Once per shift	0.6885 ± .0002	Troubleshoot and re-analyze
D-93 Flash Point	*Anisole analysis	Once per shift	117 ± 2 °F	Troubleshoot and re-analyze
	n-Decane analysis	Within 6 months	127 ± 4 °F	Troubleshoot and re-analyze
	Equipment calibrations	Within 6 months	Varies; see Section 2.4	Repair/replace; Re-analyze affected samples
D-2709 Water and Sediment	Comparison of the two centrifuge tube readings	Once per sample	± 1 scale division	Troubleshoot; evaluate methodology; re-analyze sample
	Equipment calibrations	Within 6 months	Varies; see Section 2.4	Repair/replace; Re-analyze affected samples
	*Duplicate Sample Analysis	Once for each Run 2, contaminated and cleaned fuel	at 3% water concen, duplicates must be within ± 0.4%	Repeat analysis if additional fuel sample is available
D-482 Ash	Reference oil analysis	Once per shift	1.675 % (mass) ± 0.148 %	Troubleshoot and re-analyze
	Oven temperature record	Once per sample	775 ± 25°C	Troubleshoot and re-analyze
	Equipment calibrations	Within 6 months	Varies; see Section 2.4	Repair/replace; Re-analyze affected samples
	Balance Verification	Once per sample	± 0.1 mg of Class A mass standard	Repair/replace
	*Duplicate Sample Analysis	Once for each Run 2, contaminated and cleaned fuel	Duplicates must be within 0.18 ± 0.024 mass %	Repeat analysis if additional fuel sample is available

(continued)

Table 3-5. Summary of Fuel Properties Calibrations and QC Checks (continued)

Measurement Variable	Calibration / QC Check	When Performed / Frequency	Expected or Allowable Result	Response to Check Failure or Out of Control Condition
D-6217 Particulate	Tare filter analysis	Once per sample	[0.5 mg weight gain	Troubleshoot and re-analyze
	Balance Verification	Once per sample	± 0.1 mg of Class A mass standard	Repair/replace
	Equipment calibrations	Within 6 months	Varies; see Section 2.4	Repair/replace; Re-analyze affected samples
	*Duplicate Sample Analysis	Once for each Run 2, contaminated and cleaned fuel	Duplicates must be within 10 ± 3.6 mg/l	Repeat analysis if additional fuel sample is available
D-613 Cetane Number	*Consensus Standard analysis	Once per shift	41.6 ± 0.9 Cetane Numbers	Troubleshoot and re-analyze
	Equipment calibrations	Within 6 months	Varies; see Section 2.4	Repair/replace; Re-analyze affected samples
D-381 Gums and Resins	Equipment calibrations	Within 6 months	Varies; see Section 2.4	Repair/replace; Re-analyze affected samples
	Balance Verification	Once per sample	± 0.1 mg of Class A mass standard	Repair/replace
	*Duplicate Sample Analysis	Once for each Run 2, contaminated and cleaned fuel	Duplicates must be within 20 ± 8.5 mg/l	Repeat analysis if additional fuel sample is available
D-6079 Lubricity	*Cat 1-H oil analysis	Every 20 samples	0.29 ± 0.08 mm WSD @ 25 °C; 0.41 ± 0.08 mm WSD @ 60 °C	Troubleshoot and re-analyze
	*Isopar solvent/oil analysis	Every 20 samples	0.58 ± 0.08 mm WSD @ 25 °C; 0.62 ± 0.08 mm WSD @ 60 °C	Troubleshoot and re-analyze
	Cat 1-H and Isopar duplicate analyses	Every 20 samples	Duplicate results ± 0.08 mm WSD @ 25 °C and 60 °C	Troubleshoot and re-analyze
	Equipment calibrations	Within 6 months	Varies; see Section 2.4	Repair/replace; Re-analyze affected samples

* Results from this QC check will be used to determine if the DQI goals were met, provided that all other QC checks are performed and their results are within the ASTM specifications.

SwRI will perform calibrations, QC checks, duplicate analyses, etc. to ensure that each method is properly performed. If the QC checks are satisfactory, then achievement of the method's stated reproduceability, derived accuracy, and the corresponding DQO are assured. Use of reference materials, where available, (as with LHV, Cetane Number, Lubricity, etc.) are analogous to challenging a balance with a NIST-traceable mass. If the reference material results are within the expected range, the reviewer can quantitatively judge that the laboratory's methodology was satisfactory.

There are no reference materials, in-house standards, or consensus standards available for water and sediment (D-2709), Ash (D-482), particulate (D-6217), and gums and resins (D-381). Test personnel will collect duplicate samples during each Run 2 for contaminated and cleaned fuel as described in Section 2.0. The laboratory will analyze the duplicate samples as outlined in Table 3-5. Results of these analyses will allow evaluation of the laboratory methodology and whether or not they have achieved the accuracy goals for these fuel properties.

The following paragraphs describe the approach for determining whether the DQI goals for fuel property measurements and DQOs for fuel cleaning performance are met.

LHV (D-4809)

The DQI goal for LHV measurement is to achieve an accuracy of ± 0.53 %. To achieve this accuracy, ASTM method D-4809 requires comparisons with NIST traceable benzoic acid reference standard. The maximum error allowed for 11,308.79 Btu benzoic acid is ± 16.63 Btus. This QC check will be performed by SwRI, and its results will be reviewed to determine if they are within the specified limits. If they are not, SwRI will be required to troubleshoot and repeat the analysis until the specifications are met. It will then be concluded that the DQI goal is met, and by substitution, DQO for fuel cleaning performance is also met.

The Test Plan identifies additional QC checks that must be performed by SwRI to achieve high quality data. This includes: duplicate analysis of the same sample (LHV must be within ± 50 BTU/lb of the original sample result), calibrating the thermometer, and challenging the balance with a NIST-traceable Class A test weight.

^{o}API

The accuracy goal for ^{o}API is ± 0.22 %. To achieve this, two separate QC checks will be performed: water standard reference method analysis and heptane standard reference method analysis. The measured specific gravity for water must be 0.9999 ± .0004, and the specific gravity for heptane must be 0.6885 ± .0002 when verified with NIST traceable standards. In the event SwRI is unable meet these specifications, they will be required to troubleshoot and perform reanalysis until the specifications are met. It will then be concluded that both the DQI and DQOs are met.

Flash Point

The accuracy goal for flash point is defined to be ± 5 %. This goal will be determined to be met provided the flash point of Anisole is determined to be within ± 2 ^{o}F for a 117 ^{o}F reference standard. If the requirement is not met, the SwRI technician must troubleshoot, replace equipment (if needed), and conduct re-analysis. The DQI and DQO for flash point will be met if the Anisole specifications are met. Additional QC checks that will be performed include: flash point analysis of certified n-Decane reference standard and equipment calibration (temperature probe and impeller speed). These checks are intended to provide additional assurances in the procedures followed by the contractor.

Cetane Number

The DQI goal for Cetane measurement is to achieve an accuracy of ± 7.5 %. To achieve this accuracy, ASTM method D-613 requires comparisons with a consensus standard which is an ASTM Cetane Check Fuel. The current acceptance criteria on this standard is 41.6 ± 0.9 Cetane numbers. To verify this standard was met, SwRI will submit the consensus standard analysis results to the Center. Copies of thermometer and timer calibrations, method control charts, and engine maintenance activities within the last six month will also be submitted. The 7.5 % accuracy goal will be determined to be met, provided the Cetane numbers are within the acceptance criteria. If the Cetane number for a fuel is measured to be 44, the 15.9 percent DQO will be met.

Lubricity

In determining lubricity, an analyst places a fuel sample on a steel plate which is held at 60 C. Then a reciprocating scuffing pad rubs across the plate at high frequency for a given number of cycles. The size of the resulting scuff mark is a measure of the fuel's lubricity. The test is repeated with a 25 C plate temperature. The DQI goal for lubricity measurement is to achieve an accuracy of ± 21.3 %. To determine if this accuracy goal was met, SwRI will be required to check the instrument with two reference fluids described in the ASTM Method D-6079: Cat-1H (a consensus diesel fuel standard) and iospar (a solvent). These checks must be run in duplicate, and duplicates must agree to within 0.08 mm WSD. In addition the average of the two values must meet the following criteria:

Cat-1h: 0.29 mm WSD at 25 C
0.41 mm WSD at 60 C
Isopar: 0.58 mm WSD at 25 C
0.62 mm WSD at 60 C

If these specifications are not met, SwRI must troubleshoot the problem by all equipment are calibrated and functioning properly and then perform re-analysis of the samples. After these efforts are made, the DQO of 43 percent for a WSD of 0.45 mm @ 60 ^{o}C will be met.

Water and Sediment, Ash, Particulate, and Gums and Resins

Reference materials are not available for the above listed fuel properties. The ASTM methods have specific QC checks which can be used to determine reproducibility and measurement accuracy. To do this, the Test Plan now specifies collection of duplicate fuel samples from Run 2 for contaminated and cleaned fuel tests. The duplicate sample results must be within the method's reproducibility. The following lists the reproducibility levels required for each fuel property:

Water and Sediment: ± 0.4 percent, assuming a 3 percent water and sediment concentration
Ash: ± 13.3 percent, assuming 0.18 mass percent in original sample
Particulate: ± 35.7 percent, assuming 10 mg/l in original sample
Gums and Resins: ± 8.5 mg/l of the original sample results, assuming 20 mg/l in original sample

ASTM standard practice for determining measurement accuracy uses reproducibility results, and the technique for computing accuracy is described in the Manual on Determining Precision Data from ASTM Methods. The first step requires deriving an approximate value for standard deviation by dividing the reproducibility values by 2.77. This value times 1.96 (the Z value for a 95 probability of an event occurring under the standard normal distribution) yields an estimate of the method's accuracy. This approach was adopted to specify the DQI goals for the above listed fuel property measurements. The DQI goals will be determined to be met, provided the reproducibility results for the duplicate samples in Run 2 are within the above listed specified levels.

3.2. INSTRUMENT TESTING, INSPECTION, AND MAINTENANCE

All instruments used to collect verification data will be subject to the pre- and post-test QC checks discussed earlier. Before the equipment leaves the GHG Center, Cubix laboratories, or Fairbanks, operators will assemble it exactly as anticipated to be used in the field and fully test it for functionality. For example, heated umbilicals, condenser/dryers, sample pumps, manifolds, and analyzers will be operated and leak-checked before departure. Operators will repair or replace any faulty sub-components prior to arrival at the test site. Cubix will maintain a small amount of consumables and frequently needed spare parts in the testing trailer. Cubix will handle major subcomponent failure on a case-by-case basis in coordination with GHG Center (e.g. by renting replacement equipment or buying replacement parts).

3.3. INSPECTION AND ACCEPTANCE OF SUPPLIES AND CONSUMABLES

The GHG Field Team Leader will inspect supplies and consumables before commencement of testing. They will obtain copies of all documentation mentioned below.

Cubix will use EPA Protocol gases for all instrumental analyzer calibrations. Calibration gas compositions specified in Section 2.3.3 will be either certified mixes directly from gas cylinders or generated onsite from high-concentration gases with a dilution system. Per EPA Protocol gas specifications, the actual concentration must be within ± 2 percent of the certified tag value. Cubix will supply copies of the EPA protocol gas certifications while onsite.

Probes used for particulate sampling must be glass-lined; glass nozzles are preferred but not required.

Filters used for particulate sampling must meet specific standards for efficiency and composition. Cubix will supply documentation showing that the filters conform to the specifications in Section 7.1.1 of Method 5.

Impinger solutions used for particulate sampling and recovery must meet the Methods' requirements, with specific requirements highlighted as follows:

Water must conform to ASTM D-1193-74, Type II standards.

Methylene Chloride must have had blanks run prior to testing, with documented blank values < 0.001 percent.

Acetone must be at least reagent grade and have had blanks run prior to testing. Documented blank values must be < 0.001 percent.

4.0 DATA ACQUISITION, VALIDATION, AND REPORTING

4.1. DATA ACQUISITION AND STORAGE

Test personnel will acquire five types of data while in the field:

- Instrumental analyzer data, to be collected by the test contractor
- Particulate emissions and stack flow data, to be collected by the test contractor
- Fuel consumption data, to be collected by the Field Team Leader
- Liquicult (fuel microbial) data, to be collected by the Field Team Leader
- Ambient temperature and humidity data, logged by Campbell datalogger, operated by the Field Team Leader

The fuel laboratory (SwRI) will analyze the fuel samples after field operations have concluded. The Field Team Leader will collect samples for fuel quality properties analysis during each test run. He will forward them under a signed chain of custody form to SwRI for analysis.

The test contractor and the fuel laboratory will submit formal reports based on the field operations and fuel samples to the Project Manager. The Field Team Leader will submit original fuel consumption data sheets, Liquicult data sheets, ambient temperature and humidity data files, and the Daily Test Log to the Project Manager. GHG Center personnel will archive and store all data in accordance with the GHG Center QMP. These submittals will form the basis of the Verification Report; the appropriate data reductions and calculations will employ the field and laboratory data in accordance with the equations in Section 2.0. The Project Manager will initiate the data review, validation, and calculation process. Results of calculations will be presented in the Verification Report in table, chart, or text format as is suited to the data type. The Verification Report's conclusions will be based on the data and the resulting calculations.

4.1.1. Instrumental Analyzer Data

All instrumental analyzers provide analog and/or digital outputs for recording by chart recorders or digital data acquisition systems (DAS). Appendix B has sample copies of DAS outputs. Cubix will extract all analyzer data from the chart traces or DAS as described in the applicable Methods. Generally, a DAS queries each analyser at one-second intervals and compiles a series of one-minute averages. Data output will be in the form of minute-by-minute averages and an integrated average value for each test run. Data will be reported for each test run as:

- Minute-by-minute concentration values, percent of span (%) and PPMV
- Integrated average concentration for the run, percent of span (%) and PPMV
- Emission rate, lb/hr

Upon completion of the field test activities, the emissions contractor will provide the Field Team Leader with copies of calibration records, pre- and post-test checks (calibration error, system bias, system response time, etc.), and test run data prior to departure from the site. Cubix will submit a formal report to the Field Team Leader within three (3) weeks of the completion of testing. The report will describe the test conditions, documentation of all QA/QC procedures, including copies of calibrations, calibration gas certificates, and test results. The report will include field data as an appendix.

4.1.2. Particulate Emissions and Stack Flow Data

All particulate emissions and stack flow field data will be recorded on field data forms similar to the sample forms in Appendix B. Test operators will sign each form upon completion of each test run and provide a copy to the GHG Center Field Team Leader. The Field Team Leader will enter intermediate calculations, quality notes, and other information in the Daily Test Log. The test contractor will report data for each test run as:

- Average stack gas velocity and standard deviation, ft/sec
- Average stack gas dry molecular weight, lb/lb.mol
- Average stack gas moisture content, % (vol)
- Average stack gas volume, dscf/min, dscf/hr
- Front half particulate catch, mg
- Back half particulate catch, mg
- Stack gas total particulate concentration, gr/dscf
- Stack gas back half particulate concentration as a proportion of total particulate
- Stack gas total particulate emissions, lb/hr
- Stack gas back half particulate emissions as a proportion of total particulate
- Gas sample dry standard volume, dscf
- Average Isokinetic sampling rate, %

As with the instrumental analyzer data, Cubix will submit a formal report to the Field Team Leader within three (3) weeks of the conclusion of testing. The report will describe the test conditions, documentation of all QA/QC procedures, including copies of equipment calibrations, reagent blank analyses, and test results. The report will include field data as an appendix.

4.1.3. Fuel Consumption, Liquicult, Ambient Temperature and Humidity Data

The Field Team Leader will forward copies of the Fuel Mass Consumption data forms to the Project Manager for daily review. He will also provide copies of Fairbanks' pre- and post-test calibrations and the completed Platform Scale Field Verification form. Fuel consumption will be reported as:

- Total fuel consumption for each test run, lb/run
- Hourly fuel consumption for each test run, lb/hr

Upon completion of the Liquicult analyses, the Field Team Leader will forward the field data forms to the Project Manager for review. Microbial contamination data will be reported for each test run as:

- Bacterial colony forming units (CFU) in scientific notation (10^2, 10^4, etc.)
- Fungal CFU in scientific notation (10^2, 10^4, etc.)

The Field Team Leader will forward the Campbell datalogger files to the Project Manager for review. Average ambient temperature and relative humidity will be reported for each test run.

4.1.4. Fuel Properties Data

The fuel analysis laboratory, Southwest Research Institute (SwRI; San Antonio, Texas) will supply fuel properties analyses results for the ASTM methods. The GHG Field Team Leader will assign unique identifiers to each fuel sample when they are collected. He will forward a signed chain of custody form to SwRI with the fuel samples which identifies each sample. All fuel analyses and reports must retain and specifically refer to the sample identifiers assigned by the GHG Field Team Leader (although SwRI may assign their own control numbers if needed).

After the field test, the laboratory will submit formal results for each sample, calibration records, duplicate analyses, referenc materials analyses, etc. to the Field Team Leader within three (3) weeks of the completion of testing.

4.2. DATA REVIEW, VALIDATION, AND VERIFICATION

Data review and validation will primarily occur at the following stages:

- On-site following each test run – by the Field Team Leader
- Before writing the draft Verification Report – by the Project Manager
- During QA review of the draft Verification Report and audit of the data – by Center QA Manager

Some data, such as pollutant gas concentrations, instrumental analyzer calibrations, stack gas composition, fuel mass consumption, reasonableness checks, etc. will be reasonably easy to review, validate, and verify during the test campaign. The Field Team Leader will perform these tasks as outlined in Sections 2.0 and 3.0.

Other data, such as the filter and reagent particulate data, particulate emissions results in pounds per hour, fuel properties, laboratory and post-test calibrations must be reviewed, verified, and validated after testing has ended. The Project Manager holds overall responsibility for these tasks.

Upon review, all data collected will be classed as valid, suspect, or invalid. The criteria used to review and validate the data will be QA/QC criteria discussed in Sections 2.0 and 3.0; specified in Tables 3-3, 3-4, 3-5; and the determination of DQI goals discussed in Section 3.2. Review criteria are in the form of reference material analyses, balance calibrations, minimum sample volumes, maximum calibration errors, maximum analyzer drift and bias, thermocouple and probe calibration specifications, tare filter analyses, reagent blank analyses, etc.

In general, valid results are based on measurements meeting the specified data quality indicators and QC checks, that were collected when an instrument was verified as being properly calibrated, and that are consistent with reasonable expectations (manufacturers' specifications, professional judgement, etc.).

The data review process often identifies anomalous data. Test personnel will investigate all outlying or unusual values in the field as is possible. Anomalous data may be considered suspect if no specific operational cause to invalidate the data are found.

All data, valid, invalid, and suspect will be included in the final report. However, report conclusions will be based on valid data only and the report will justify the reasons for excluding any data. Suspect data may be included in the analyses, but may be given special treatment as specifically indicated. If the DQI goals cannot be met due to excessive data variability, the data will be presented to the Project Manager. Based on this, he will decide to either continue the test, collect additional data, or terminate the test and report the data obtained.

Figure 1-4 indicates the individuals who are responsible for data validation and verification. The QA Manager reviews and validates the data and the draft report using the Test Plan and test methods. The data review and data audit will be conducted in accordance with the GHG Center's QMP. For example, the QA manager will randomly select 10 percent of the raw data and independently calculate the Performance Verification Parameters dependent on that data.

4.3. RECONCILIATION WITH DATA QUALITY OBJECTIVES

The DQI process includes reconciliation of the test results with DQOs. When the primary data are collected, the GHG Center will review it to ensure that they are valid and are consistent with what was expected. In addition, the data will be reviewed to identify patterns, relationships, and potential anomalies.

The GHG Center will assess data quality in terms of accuracy and statistical significance as they relate to the stated DQI goals. If test data show that DQI goals were met, then we can conclude that DQOs were achieved. It is reasonably easy to show achievement of certain DQIs during field testing, such as percent isokinetic sampling rate or minimum sample volume for particulate testing. If such DQIs are not met, the Field Team Leader has the authority to conduct additional test runs.

DQIs and DQOs for the fuel properties analyses will be determined after the test campaign has ended. The laboratory will perform certain fuel property analyses (LHV, lubricity, etc.) in conjunction with reference material analyses. In these cases, the Project Manager will deem DQOs as achieved if the reference material analysis and other QC checks meet the Table 3-5 specifications and if the fuel cleaning performance exceeds the DQO for that property. Failing this, the Project Manager will order duplicate sample analyses if sufficient surplus fuel sample is available.

Some fuel properties analyses (particulate, ash, etc.) have no reference materials available. For these properties, comparisons of the Run 2 sample results to its corresponding duplicate sample will allow DQO reconciliation. If the duplicate sample result is within the method's reproduceability specification, this implies that sample collection and analyses were performed properly. If this is true for both contaminated and cleaned fuel, if the other QC specifications in Table 3-5 have been met, and if the fuel cleaning performance exceeds the DQO for that property, the Project Manager can conclude that the DQO is achieved. This is because the method accuracies (Table 2-5) and the minimum percent change DQOs (Table 3-2) are both derived from the method's reproduceability.

If the duplicate sample for cleaned fuel (for example) does not meet the reproduceability specification, the Project Manager will order a duplicate analysis of the cleaned fuel duplicate sample. If both results to not meet the reproduceability specification, when compared with the Run 2 sample, this is an indication that the results for Run 2 (and possibly for Runs 1 and 3) are uncertain. The Project Manager may conclude that the DQO was not achieved because of sampling or analysis problems associated with the cleaned fuel test runs.

If a DQI is not met, and if re-analysis, retesting, or reconciliation is not possible or convincing, then the Project Manager will report the best available data as gathered with the notation that the applicable DQO was not achieved.

4.4. ASSESSMENTS AND RESPONSE ACTIONS

The quality of the project and associated data are assessed within the project by the Field Team Leader, Project Manager, QA Manager, Center Director, and technical peer reviewers. Assessment and oversight of the quality for the project activities are performed through the review of data, memos, audits, and reports by the Project Manager and independently by the QA Manager.

The effectiveness of implementing the Test Plan are assessed through project reviews, in-phase inspections, audits, and data quality assessment.

4.4.1. Project reviews

The review of project data and the writing of project reports are the responsibility of the Project Manager, who also is responsible for conducting the first complete assessment of the project. Although the project's data are reviewed by the project personnel and assessed to determine that the data meet the measurement quality objectives, it is the Project Manager who must assure that overall the project activities meet the measurement and data quality objectives.

The second review of the project is performed by the GHG Center Director, who is responsible for ensuring that the project's activities adhere to the requirements of the program. The GHG Center Director's review of the project will also include an assessment of the overall project operations to ensure that the Field Team Leader has the equipment, personnel, and resources to complete the project as required and to deliver data of known and defensible quality.

The third review is that of the QA Manager, who is responsible for assuring that the program management systems are established and functioning as required by the QA Manual and corporate policy. The QA Manager is the final reviewer within the SRI organization, and is responsible for assuring that contractual requirements have been met.

JCH then reviews the draft document followed by an independent review by a selected stakeholder Technical Panel (minimum of two industry experts). Technically competent persons who are familiar with the technical aspects of the project, but not involved with the conduct of project activities, perform the peer reviews. The peer reviewers present to the Project Manager an accurate and independent appraisal of the technical aspects of the project. Further details on project review requirements can be found in the GHG Center's QMP.

The draft report will then be submitted to EPA QA personnel, and all comments will be addressed by the project Manager. Following this review, the Verification Report and Statement will undergo various EPA management reviews, including EPA Pilot Manager, EPA ORD Laboratory Director, and EPA Technical Editor.

4.4.2. Inspections

Inspections may be conducted by the Field Team Leader, Project Manager, or QA Manager. Inspections assess activities that are considered important or critical to key activities of the project. These critical activities may include, but are not limited to, pre- and post-test calibrations, the data collection equipment, sample equipment preparation, sample analysis, or data reduction. Inspections are assessed with respect to the Test Plan or other established methods, and are documented in the field records. The results of the inspection are reported to the Project Manager and QA Manager. Any deficiencies or problems found during the inspections must be investigated and the results and responses or corrective actions reported in a Corrective Action Report (CAR).

4.4.3. Audit of Data Quality

The audit of data quality (ADQ), an important component of a total system audit, is an evaluation of the measurement, processing, and evaluation steps to determine if systematic errors have been introduced. During the ADQ, the QA Manager, or designee, will randomly select approximately 10 percent of the data to be followed through the analysis and data processing. The scope of the ADQ is to verify that the data-handling system is correct and to assess the quality of the data generated.

The ADQ, as part of the system audit, is not an evaluation of the reliability of the data presentation. The review of the data presentation is the responsibility of the Project Manager and the technical peer reviewer.

4.5. DOCUMENTATION AND REPORTS

During the different activities on this project, documentation and reporting of information to management and project personnel is critical. To insure the complete transfer of information to all parties involved in this project, the following field test documentation, QC documentation, corrective action/assessment report, and verification report/statements will be prepared.

4.5.1. Field Test Documentation

The Field Team Leader will record all field activities. The Field Team Leader reviews all data sheets and maintains them in an organized file. The required test information was described earlier in Sections 2.0 and 3.0. The Field Team Leader will also maintain a field notebook that documents the activities of the field team each day and any deviations from the schedule, Test Plan, or any other significant event. Any problems found during testing requiring corrective action will be reported immediately by the field test personnel to the Field Team Leader through a Corrective Action Report. The Field Team Leader will document this in the project files and report it to the Project Manager and QA Manager.

Following each test run, the Project Manager will check the test results with the assistance of the Field Team Leader to determine whether the run met the method QA criteria. Following this review and confirmation that the appropriate data were collected and DQOs were satisfied, the GHG Center Director will be notified.

At the end of each test day, the Field Team Leader will collect all of the data from the field team members, which will include data sheets, data printouts, back-up copies of electronic files stored on computer, and field notebook. A copy of the field test documentation will be submitted to the Project Manager. These copies, original data, reports, notes, and other documents will be stored in the project records, as required by the QMP.

4.5.2. QC Documentation

After the completion of verification tests, test data, sampling logs, calibration records, certificates of calibration, and other relevant information will be stored in the project file in the GHG Center's RTP office. Calibration records will include information about the instrument being calibrated, raw calibration data, calibration equations, analyzer identifications, calibration dates, calibration standards used and their traceabilities, calibration equipment, and staff conducting the calibration. These records will be used to prepare the Data Quality section in the Verification Report, and made available to the QA Manager during audits.

4.5.3. Corrective Action and Assessment Reports

A corrective action is the process that occurs when the result of an audit or quality control measurement is shown to be unsatisfactory, as defined by the data quality objectives or by the measurement objectives for each task. The corrective action process involves the Field Team Leader, Project Manager, and QA Manager. In cases involving the analytical process, the correction action will also involve the analyst. A written Corrective Action Report is required on all corrective actions.

Since the tasks of this study involve a validations process to ensure data quality for the technology being verified, predetermined limits for the data acceptability have been established in the measurement and data quality objectives. Therefore, data determined to deviate from these objectives require evaluation through immediate corrective action process.

Immediate corrective action responds quickly to improper procedures, indications of malfunctioning equipment, or suspicious data. The analyst, as a result of calibration checks and internal quality control sample analyses, will most frequently identify the need for such an action. The Field Team Leader will be notified of the problem immediately. The Field Team Leader will then notify the Project Manager, who will take and document appropriate action. The Project Manager is responsible for and is authorized to halt the work if it is determined that a serious problem exists.

The Field Team Leader is responsible for implementing corrective actions identified by the Project manager, and is authorized to implement any procedures to prevent the recurrence of problems.

After technical assessments, the QA manager will submit the Assessment Report to the Project Manager and Center Director. The Project Manager will submit the Assessment Report to the EPA Pilot Manager and QA Manager for information purposes.

The results of TSA, inspections, and ADQ conducted by the QA Manager will be routed to the Project Manager for review, comments, and corrective action. The results will be documented in the project records. The Project Manager will take any necessary corrective action needed and will respond via the Corrective Action Report to the QA Manager. Inspections conducted by the QA Manager will be reported to the Project Manager in the same manner as other audits. The results of all assessments, audits, inspections, and corrective actions for the task will be summarized and used in the Data Quality section in the final report.

4.5.4. Verification Report and Verification Statement

A draft Verification Report and Statement will be prepared within 6 weeks of completing the field test by the Project Manager. The Verification Report will specifically address the fuel treatment used in the verification and the model number and capacity of the JCH filtration equipment. They are the AlgaeX Fuel Catalyst AFC-705 and Enviro Model 4, respectively.

The Project Manager will submit the draft verification report and statement to the QA Manager and Center Director for review. The final Verification Report will contain a Verification Statement, which is a 3 to 4 page summary of JCH's technology, the test strategy used, and the verification results obtained. The Verification Report will summarize the results for each verification parameter discussed in Section 2.0 and will contain sufficient raw data to support findings and allow others to assess data trends, completeness, and quality. Clear statements will be provided which characterize the performance of the verification parameters identified in Sections 1.0 and 2.0. A preliminary outline of the report is shown below.

Preliminary Outline
JCH Fuels Solutions Diesel Fuel Treatment and Cleaning Verification Report

Verification Statement

Section 1.	ETV Overview
	Verification Factors
	Technology Description
Section 2.	Verification Test Design and Approach
Section 3.	Verification Results and Evaluation
Section 4.	Data Quality Assessment
Section 5.	Additional Information Provided by JCH
References	

4.6. TRAINING AND QUALIFICATIONS

The GHG Center's Field Team Leader and CUBIX personnel have extensive experience (+ 15 years) in field testing of air emissions from many types of sources. They are familiar with the requirements of all of the test methods and standards that will be used in the verification test.

The Project Manager has approximately 7 years experience in environmental engineering management, and 4 years experience in manufacturing engineering. He has performed numerous field studies, stack tests, and network installations; he is familiar with requirements mandated by the EPA and Center QMPs. The QA Manager is an independently appointed individual whose responsibility is to ensure the GHG Center's activities are performed according to the EPA approved QMP.

The participants working on behalf of the GHG Center in support of this verification are selected by the GHG Center and evaluated by EPA. Evaluation criteria include relevant education, work experience, and experience in quality management. These qualifications are documented in project personnel resumes and files, as required by the GHG Center's QMP. Each field crew member will be thoroughly familiar with this Test Plan, the measurement equipment, procedures, and method for their assigned jobs. All field test personnel will receive a safety briefing by the GHG Center Field Team Leader.

4.7. HEALTH AND SAFETY REQUIREMENTS

This section applies to GHG Center personnel only. Other organizations involved in the project have their own health and safety plans - specific to their roles in the project.

GHG Center staff will comply with all known host, state/local and Federal regulations relating to safety at the test facility. This includes use of personal protective gear (e.g., safety glasses, hearing protection, safety toe shoes) as required by the host and completion of site safety orientation (i.e., site hazard awareness, alarms and signals).

5.0 REFERENCES

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APPENDIX A
Field Data Forms

JCH01 Engine, Generator, and Load Bank Data

Cummins/Onan Model 200 DGFC Genset
S/N: ______________________________

DATE: ____________________________

Load Bank Make: ______________________

Model: ______________________________

S/N: ________________________________

TEST RUN # AND DESCRIPTION: ____

	GEN, Amps	GEN, Volts	GEN, Hz	Engine Oil Temp, °F	Engine Water Temp, °F	Engine Exhaust Temp, °F
Permissable Values	220 to 210	495 to 470	61.2 to 58.8	265 to 255	215 to 205	950 to 900
Time (use 24-hr.)						
10 min. before						
test run start						
15 min. incr.						
15 min. incr.						
15 min. incr.						
test run end						
Average						

NOTES: ____
____
____

SIGNATURE: ____

JCH02 Platform Scale Field Verification

Platform Scale: Make: ____________________ Capacity: ____________________
Model: ____________________ S/N: ____________________
Scale Divisions (lb): __________

NOTE: Use nominal test weights of 1900, 1800, 1700, 1600, 1500, 1400, and 1300 lb.

Pretest Verifications						**Post Test Verifications**					
Date	**Time**	**Test Weight Data**		**Scale Display**		**Date**	**Time**	**Test Weight Data**		**Scale Display**	
		ID #	**lb**	**lb**	**% Diff**			**ID #**	**lb**	**lb**	**% Diff**

$$\%Diff = \left[\frac{(lb_{ScaleDisplay} - lb_{TestWeight}}{lb_{TestWeight}} \right] 100$$

NOTES: ____

____

____

____

SIGNATURE: ____

JCH03 Fuel Mass Consumption Data

DATE: ________________________

TEST RUN # AND DESCRIPTION: ____
____

Time (use 24-hr.)	**Description** (start, mid-run, end, etc.)	**Display Weight**	**Fuel Temp.**

NOTE: If fuel temperature rises above 110°F, see instructions on other side.

NOTES: ____
____
____
____

SIGNATURE: ____

SPECIAL INSTRUCTIONS FOR HIGH AMBIENT AIR AND FUEL TEMPERATURES (>110^{O}F)

- Select and install a long (approx. 75') fuel return line hose to the engine.
- Coil approximately 50' of the return line in a large container (picnic cooler or garbage can) and route the remainder to the test day tank. Support the return hose at the test day tank so that it does not contact the tank and in a place where temperature readings can be taken directly from the return flow.
- Pack the container with cubed ice.
- Operate the genset and monitor the temperature of the return flow with the immersion-type mercury therometer used for normal fuel temperature readings.
- When the test day tank contents and the engine return flow fall below 110^{o}F, resume testing.

JCH04 Fuel Sample Collection Log

IMPORTANT: FILL ALL SAMPLE BOTTLES APPROX. 85% FULL; LEAVE 15% HEADSPACE FOR TRANSPORTATION AND LABORATORY AGITATION

DATE: ______________________________

Sample Description	Sample Type	Sample ID#	Collected by: (initials)	Date	Time (use 24-hr)	Notes
Test Day Tank Fill	2.5 l					
Test Day Tank Fill	Liqui-Cult					
Test Day Tank Fill	2.5 l					
Contaminated Fuel						
Run 1	2.5 l					
	Liqui-Cult					
	2.5 l					
Run 2	2.5 l					
	Liqui-Cult					
	2.5 l					
	2.5 l duplicate					
Run 3	2.5 l					
	Liqui-Cult					
	2.5 l					
Cleaned Fuel						
Run 1	2.5 l					
	Liqui-Cult					
	2.5 l					
Run 2	2.5 l					
	Liqui-Cult					
	2.5 l					
	2.5 l duplicate					
Run 3	2.5 l					
	Liqui-Cult					
	2.5 l					

NOTES: ____

____

____

SIGNATURE: ____

JCH05 Daily Test Log Page: 1

DATE: ________________________

Time (use 24-hr.)	Notes

SIGNATURE: ____

JCH06 QA/QC Checklist

DATE: ________________________

TEST RUN # AND DESCRIPTION: ____
____

☐ Scale field verifications

☐ Test day tank agitator operating

☐ Engine, generator, and load bank data sheet for run

☐ Fuel mass consumption data sheet for run

☐ Fuel samples collected for run

☐ Analyzer checks performed
__ NO_x interference check
__ NO_x convertor efficiency
__ SO_2 interference check
__ Calibration Error
__ System Bias
__ Drift

☐ Analyzer data reasonable and complete

☐ Field data sheets complete and signed
__ Particulate field data forms
__ Particulate sample volume $\geq$ 40 dscf
__ Moisture Calculation
__ Isokinetics; $80\ \% \leq I \leq 120\ \%$
__ Platform Scale Field Verification
__ Pitot/Thermocouple Calibrations
__ Barometer Calibration
__ Protocol Gas Certs
__ Filter Cert
__ Impinger Reagent Blank Certs (Water, Methylene Chloride, Acetone)

☐ Sample containers marked and identified

NOTES: ____
____
____
____

SIGNATURE: ____

JCH07 Liquicult Analysis for Bacteria

30-hr Analysis - Bacteria

	COLLECTED		ANALYZED		RESULTS		
Sample ID	Date	Time (use 24-hr)	Date	Time (use 24-hr)	Count (10^x)	Slight/ Moderate/ Heavy	Notes

NOTES: ____

____

____

____

ANALYST SIGNATURE: ____

JCH08   Liquicult Analysis for Fungal Microbes

72-hr Analysis - Fungal

	COLLECTED		ANALYZED		RESULTS		
Sample ID	Date	Time (use 24-hr)	Date	Time (use 24-hr)	Count (10^x)	Slight/ Moderate/ Heavy	Notes

NOTES: ____

ANALYST SIGNATURE: ____________________________________

JCHO9 Corrective Action Report

VERIFICATION TITLE:____

VERIFICATION DESCRIPTION:____

DESCRIPTION OF PROBLEM:

____

____

____

____

ORIGINATOR:___________________________ DATE:___________

INVESTIGATION AND RESULTS:

____

____

____

____

____

____

INVESTIGATOR:_________________________ DATE:__________

CORRECTIVE ACTION:

____

____

____

____

____

ORIGINATOR:____________________________ DATE: __________

APPROVER:______________________________ DATE: __________

Copies to: *Project Manager, Center Director, Center QA Manager, EPA Pilot Manager*

JCH10 Chain of Custody Record

PHILIP SERVICES

PHILIP ANALYTICAL SERVICES CORPORATION

Anjou: (514) 493-4733 Burlington: (800) 668-0639 Burnaby: (800) 440-4808 Calgary: (403) 250-3225
Edmonton: (877) 463-8089 Halifax: (800) 565-7227 London: (800) 268-7396
Mississauga: (800) 263-9040 Reading: (800) 345-4036 St. John's: (800) 492-7227

LABORATORY USE ONLY
Work Order: ______
Comments: ______

CHAIN OF CUSTODY RECORD

Client: ______
Contact: ______
Phone: ______ Fax: ______

PASC Quote #: ______
Client P.O. #: ______
Client Project #: ______
Sampled By: ______
Please Specify Guideline (if applicable) ______

Page ______ of ______

Invoice to (if other than above): ______

TAT (Turnaround Time)

PLEASE PROVIDE ADVANCE NOTICE FOR RUSH PROJECTS

* some exceptions apply, please contact lab

STANDARD ☐

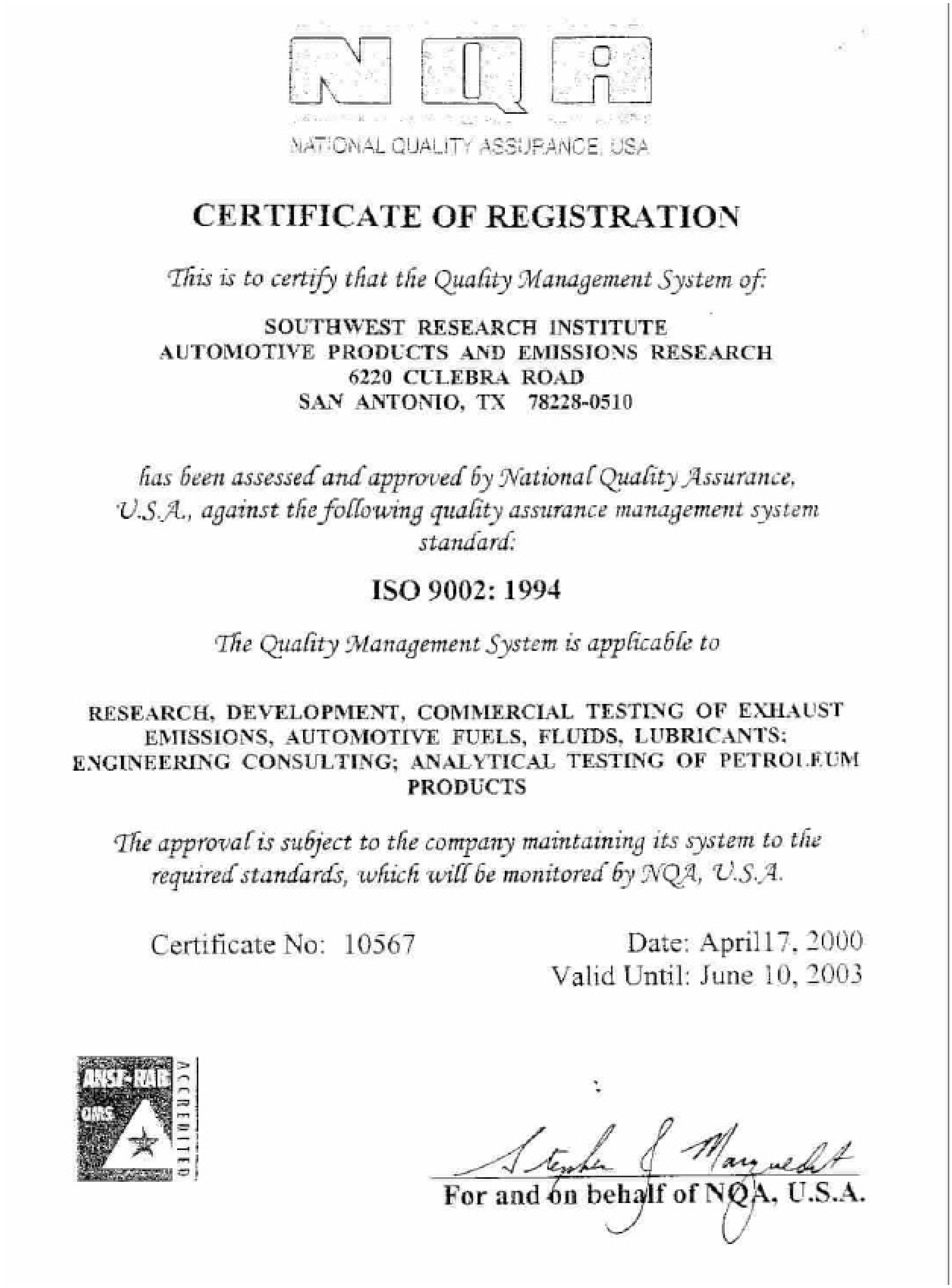
RUSH Specify Date ______
Time ______

Sample #	Client Sample I.D.	Date Sampled	Analysis Required:														Sample Matrix	No. of Containers	Comments/Contamination/ Site History
1																			
2																			
3																			
4																			
5																			
6																			
7																			
8																			
9																			
10																			
11																			
12																			

Samples Relinquished to PASC by: (Client Signature)	Date:	Time:	Method of Shipment:
Samples Received in lab by:	Date:	Time:	Condition of samples upon receipt at lab:

APPENDIX B
Laboratory Accreditations and Sample Data

Southwest Research Institute
Accreditations, Sample Report and Control Charts



NQA
NATIONAL QUALITY ASSURANCE, USA

CERTIFICATE OF REGISTRATION

This is to certify that the Quality Management System of:

**SOUTHWEST RESEARCH INSTITUTE
AUTOMOTIVE PRODUCTS AND EMISSIONS RESEARCH
6220 CULEBRA ROAD
SAN ANTONIO, TX 78228-0510**

has been assessed and approved by National Quality Assurance, U.S.A., against the following quality assurance management system standard:

ISO 9002: 1994

The Quality Management System is applicable to

RESEARCH, DEVELOPMENT, COMMERCIAL TESTING OF EXHAUST EMISSIONS, AUTOMOTIVE FUELS, FLUIDS, LUBRICANTS; ENGINEERING CONSULTING; ANALYTICAL TESTING OF PETROLEUM PRODUCTS

The approval is subject to the company maintaining its system to the required standards, which will be monitored by NQA, U.S.A.

Certificate No: 10567

Date: April17, 2000
Valid Until: June 10, 2003

ANSI-RAB
QMS
ACCREDITED

For and on behalf of NQA, U.S.A.

THE AMERICAN
ASSOCIATION
FOR LABORATORY
ACCREDITATION

ACCREDITED LABORATORY

A2LA has accredited

SOUTHWEST RESEARCH INSTITUTE
AUTOMOTIVE PRODUCTS AND EMISSIONS RESEARCH
DIVISION PETROLEUM PRODUCTS RESEARCH DEPARTMENT

San Antonio, TX

for technical competence in the field of

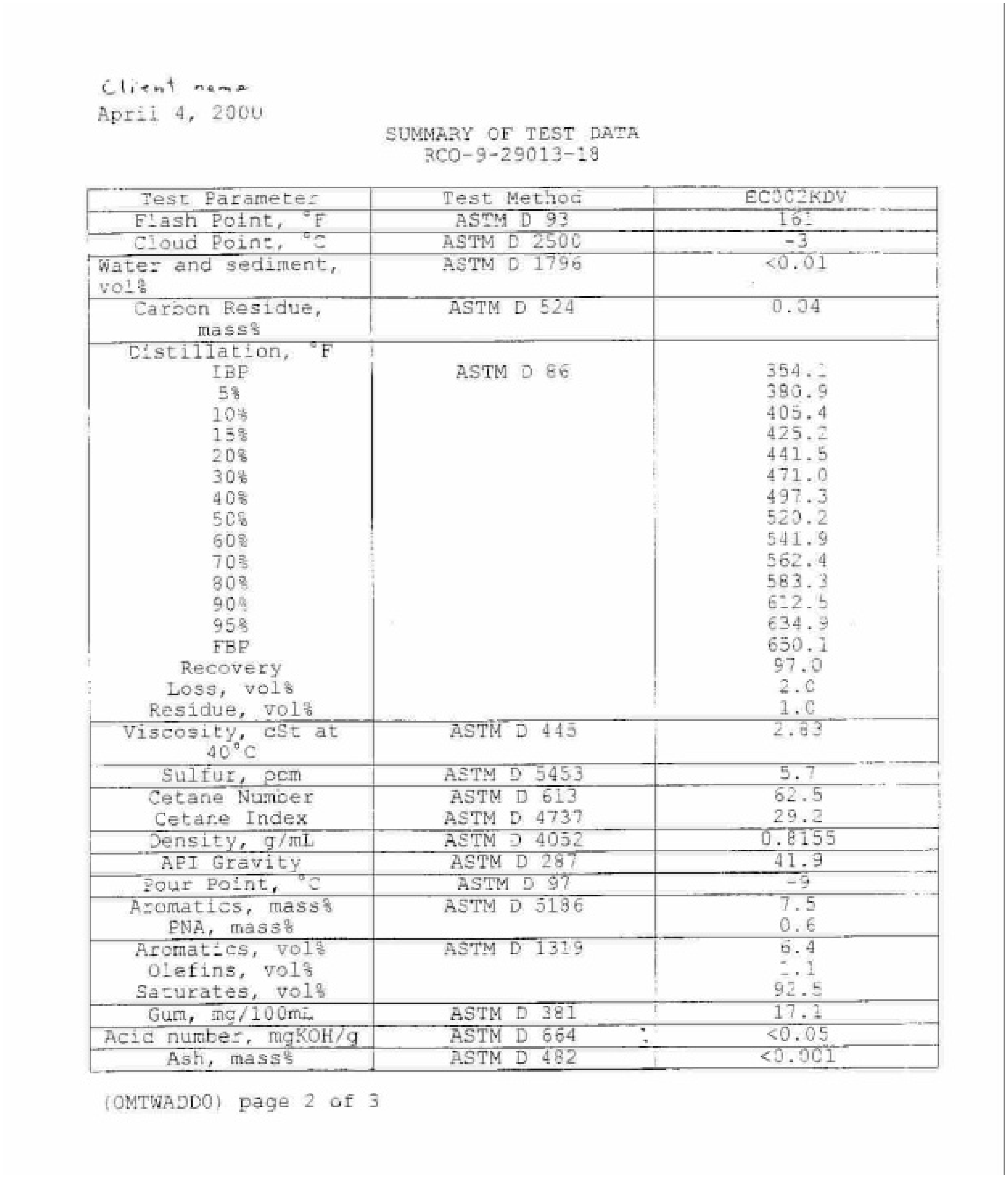
Chemical Testing

The accreditation covers the specific tests and types of tests listed on the agreed scope of accreditation. This laboratory meets the requirements of ISO/IEC Guide 25-1990 "General Requirements for the Competence of Calibration and Testing Laboratories" (equivalent to relevant requirements of the ISO 9000 series of standards) and any additional program requirements in the identified field of testing.

Presented this 16th day of October, 2000.

Peter Unger
President
For the Accreditation Council
Certificate Number 702.04
Valid to 05/31/2002

For tests or types of tests to which this accreditation applies, please refer to the laboratory's Chemical Scope of Accreditation.

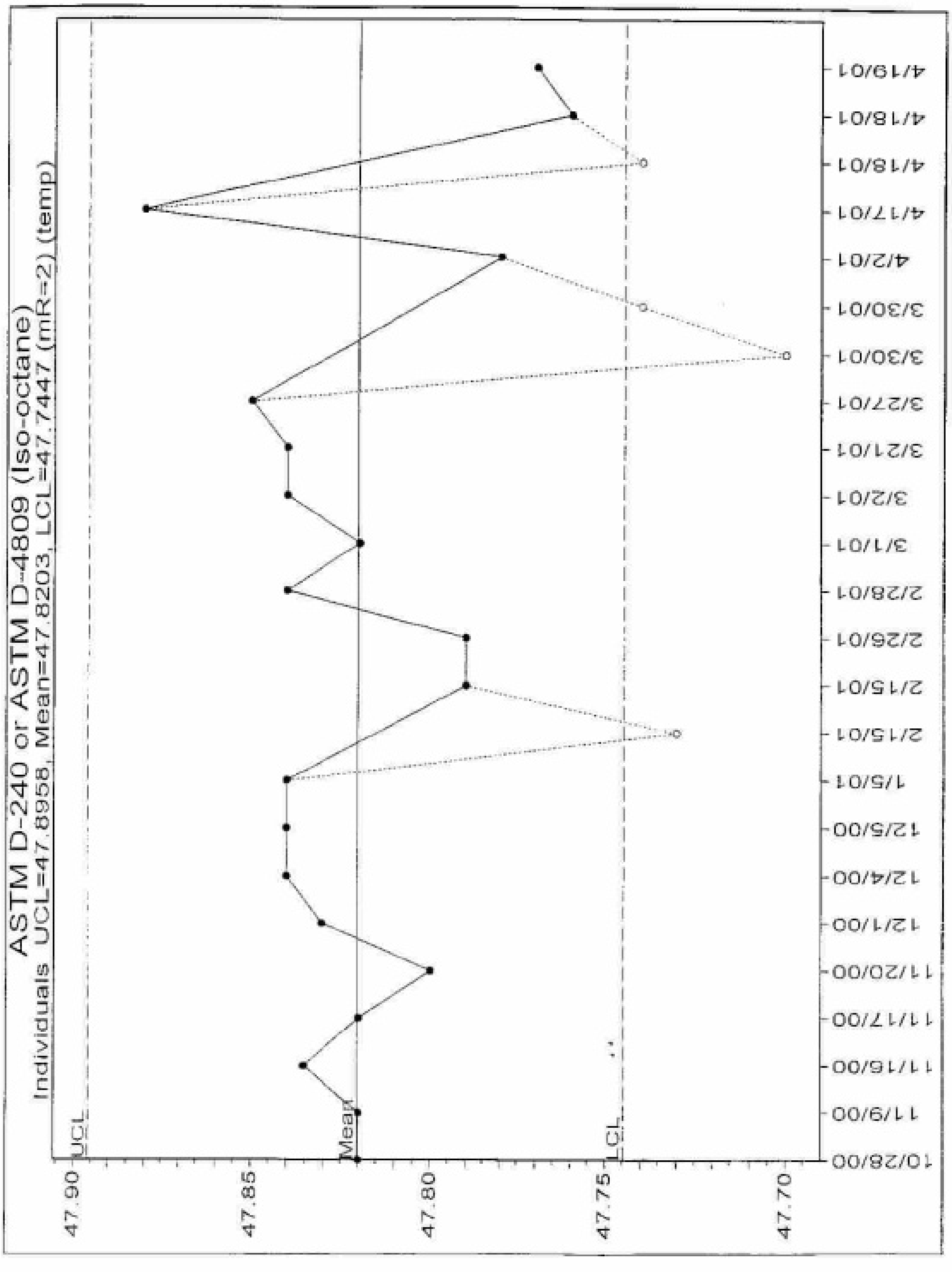


Client name
April 4, 2000

SUMMARY OF TEST DATA
RCO-9-29013-18

Test Parameter	Test Method	EC002KDV
Flash Point, °F	ASTM D 93	161
Cloud Point, °C	ASTM D 2500	-3
Water and sediment, vol%	ASTM D 1796	<0.01
Carbon Residue, mass%	ASTM D 524	0.04
Distillation, °F		
IBP	ASTM D 86	354.1
5%		380.9
10%		405.4
15%		425.2
20%		441.5
30%		471.0
40%		497.3
50%		520.2
60%		541.9
70%		562.4
80%		583.3
90%		612.5
95%		634.9
FBP		650.1
Recovery		97.0
Loss, vol%		2.0
Residue, vol%		1.0
Viscosity, cSt at 40°C	ASTM D 445	2.83
Sulfur, ppm	ASTM D 5453	5.7
Cetane Number	ASTM D 613	62.5
Cetane Index	ASTM D 4737	29.2
Density, g/mL	ASTM D 4052	0.8155
API Gravity	ASTM D 287	41.9
Pour Point, °C	ASTM D 97	-9
Aromatics, mass%	ASTM D 5186	7.5
PNA, mass%		0.6
Aromatics, vol%	ASTM D 1319	6.4
Olefins, vol%		1.1
Saturates, vol%		92.5
Gum, mg/100mL	ASTM D 381	17.1
Acid number, mgKOH/g	ASTM D 664	<0.05
Ash, mass%	ASTM D 482	<0.001

(OMTWADDO) page 2 of 3


ASTM D-240 or ASTM D-4809 (Iso-octane)
Individuals UCL=47.8958, Mean=47.8203, LCL=47.7447 (mR=2) (temp)
UCL
Mean
LCL
47.90
47.85
47.80
47.75
47.70
10/28/00
11/9/00
11/16/00
11/17/00
11/20/00
12/1/00
12/4/00
12/5/00
1/5/01
2/15/01
2/15/01
2/26/01
2/28/01
3/1/01
3/2/01
3/21/01
3/27/01
3/30/01
3/30/01
4/2/01
4/17/01
4/18/01
4/18/01
4/19/01

D613 - CETANE B.

DEPARTMENT OF PETROLEUM PRODUCTS RESEARCH

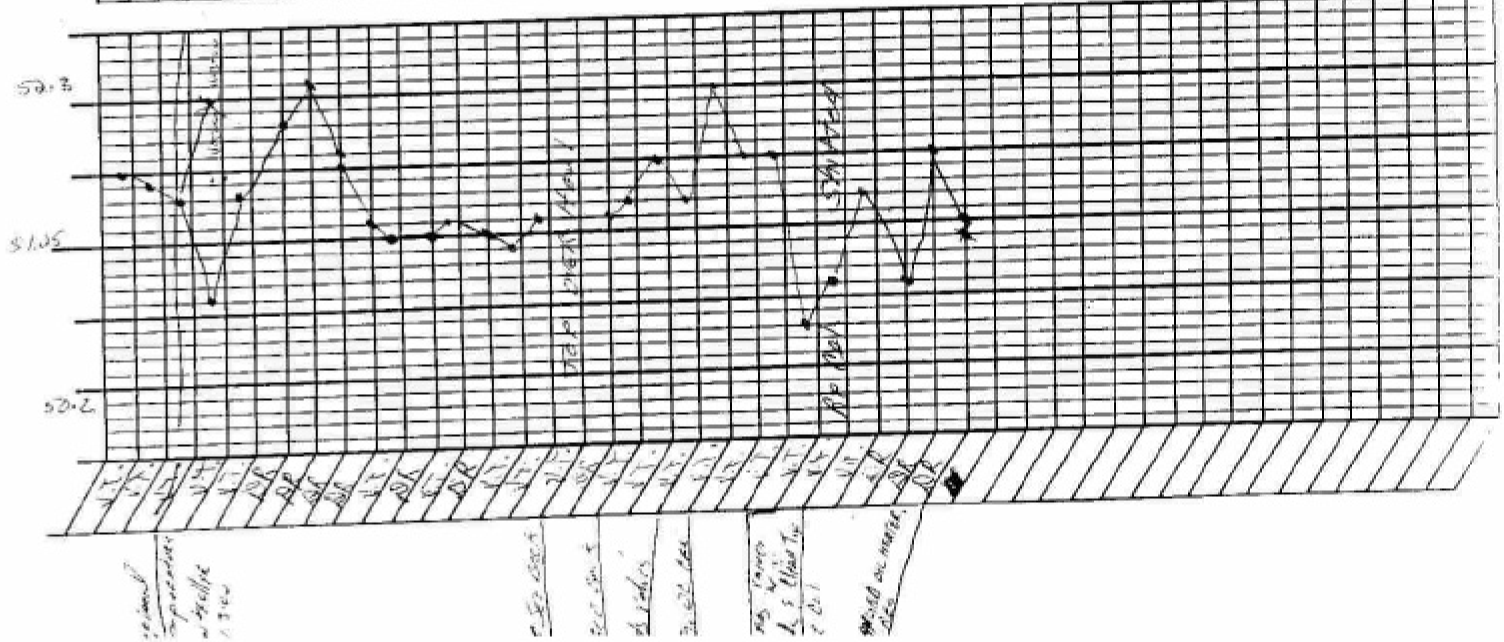
INDIVIDUALS CONTROL CHART

$\bar{X}$ - AVERAGE X - 51.05 UCL - ______ LCL - ______ FUEL CODE: High Cetane

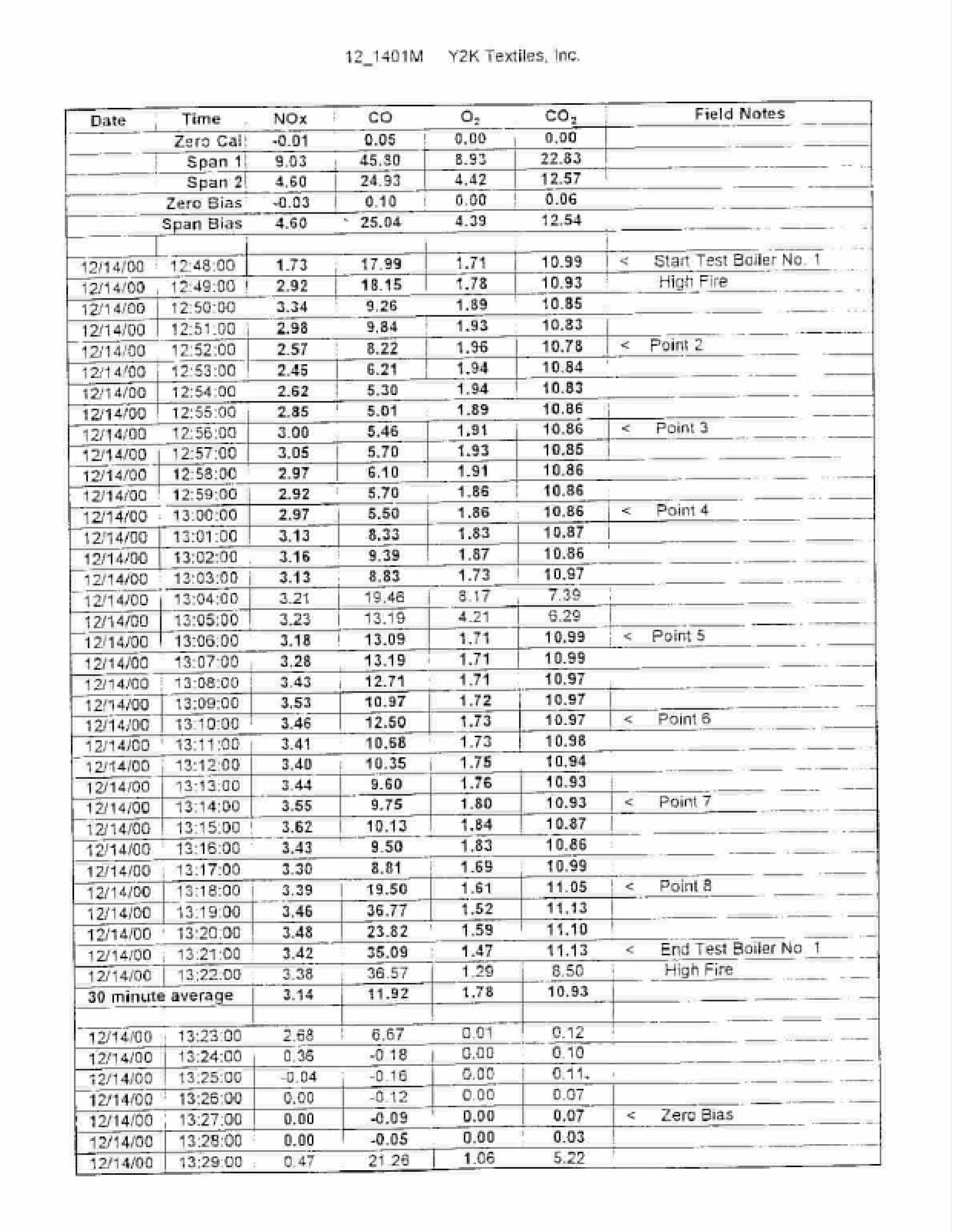
MONTH: Oct	TEST: Diesel Fuel	GRADE: Cetane Number	ENG.: #4

TIME	8:15	8:00	~~8:00~~	11:30	2:00	11:00	10:40	10:00	11:00	11:30	11:00	9:50	1:00	5:35	7:05
DATE	10-30-00	11-1-00	~~11-1-00~~	11-3-00	11-3-00	11-6-00	11-8-00	11-9-00	11-11-00	11-13-00	11-16-00	11-17-00	11/30/00	11/30/00	12-1-00
RESULT	51.7	51.6	~~51.5~~	50.9	51.5	52.0	52.3	51.9	51.3	51.2	51.2	51.5	51.2	51.1	51.3

TIME	10:50	10:00	11:15	8:30	9:30	9:30	10:45	8:40	11:30	6:51	9:00	10:00	2:00	3:30
DATE	12-15-00	12/19/00	1-18-01	2-26-01	3/1/01	3/5/01	3/6/01	3/7/01	3/12/01	3/13/01	3/20/01	3/21/01	3/22/01	3/27/01
RESULT	51.7	51.3	51.4	51.7	51.4	52.2	51.7	51.7	50.6	50.9	51.4	50.9	51.7	51.2

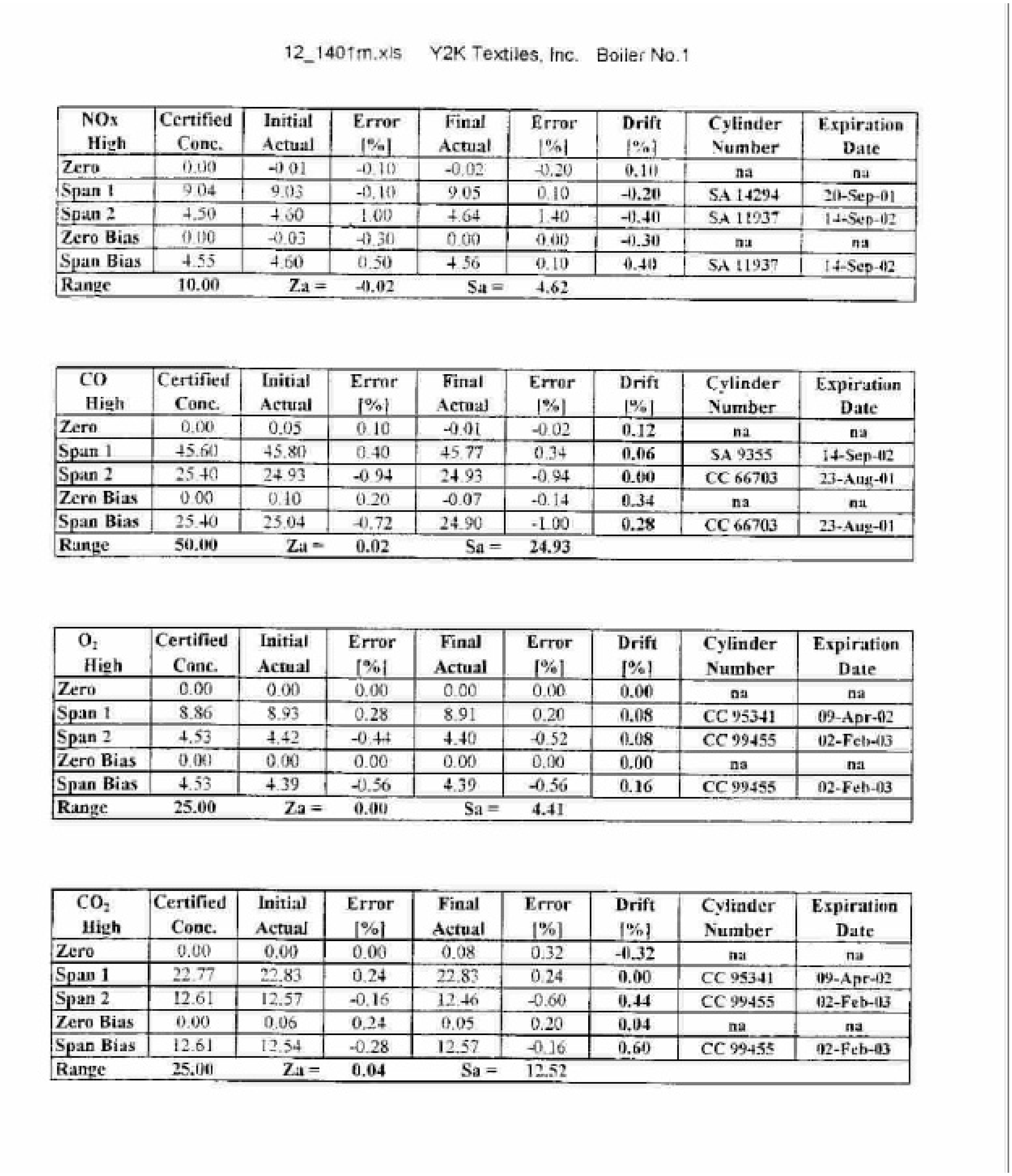


Sample Test Run, analyzer, and Calibration Data



12_1401M Y2K Textiles, Inc.

Date	Time	NOx	CO	O_2	CO_2	Field Notes
	Zero Cal	-0.01	0.05	0.00	0.00	
	Span 1	9.03	45.30	8.93	22.83	
	Span 2	4.60	24.93	4.42	12.57	
	Zero Bias	-0.03	0.10	0.00	0.06	
	Span Bias	4.60	25.04	4.39	12.54	
12/14/00	12:48:00	1.73	17.99	1.71	10.99	< Start Test Boiler No. 1
12/14/00	12:49:00	2.92	18.15	1.78	10.93	High Fire
12/14/00	12:50:00	3.34	9.26	1.89	10.85	
12/14/00	12:51:00	2.98	9.84	1.93	10.83	
12/14/00	12:52:00	2.57	8.22	1.96	10.78	< Point 2
12/14/00	12:53:00	2.45	6.21	1.94	10.84	
12/14/00	12:54:00	2.62	5.30	1.94	10.83	
12/14/00	12:55:00	2.85	5.01	1.89	10.86	
12/14/00	12:56:00	3.00	5.46	1.91	10.86	< Point 3
12/14/00	12:57:00	3.05	5.70	1.93	10.85	
12/14/00	12:58:00	2.97	6.10	1.91	10.86	
12/14/00	12:59:00	2.92	5.70	1.86	10.86	
12/14/00	13:00:00	2.97	5.50	1.86	10.86	< Point 4
12/14/00	13:01:00	3.13	8.33	1.83	10.87	
12/14/00	13:02:00	3.16	9.39	1.87	10.86	
12/14/00	13:03:00	3.13	8.83	1.73	10.97	
12/14/00	13:04:00	3.21	19.46	8.17	7.39	
12/14/00	13:05:00	3.23	13.19	4.21	6.29	
12/14/00	13:06:00	3.18	13.09	1.71	10.99	< Point 5
12/14/00	13:07:00	3.28	13.19	1.71	10.99	
12/14/00	13:08:00	3.43	12.71	1.71	10.97	
12/14/00	13:09:00	3.53	10.97	1.72	10.97	
12/14/00	13:10:00	3.46	12.50	1.73	10.97	< Point 6
12/14/00	13:11:00	3.41	10.68	1.73	10.98	
12/14/00	13:12:00	3.40	10.35	1.75	10.94	
12/14/00	13:13:00	3.44	9.60	1.76	10.93	
12/14/00	13:14:00	3.55	9.75	1.80	10.93	< Point 7
12/14/00	13:15:00	3.62	10.13	1.84	10.87	
12/14/00	13:16:00	3.43	9.50	1.83	10.86	
12/14/00	13:17:00	3.30	8.81	1.69	10.99	
12/14/00	13:18:00	3.39	19.50	1.61	11.05	< Point 8
12/14/00	13:19:00	3.46	36.77	1.52	11.13	
12/14/00	13:20:00	3.48	23.82	1.59	11.10	
12/14/00	13:21:00	3.42	35.09	1.47	11.13	< End Test Boiler No. 1
12/14/00	13:22:00	3.38	36.57	1.29	8.50	High Fire
30 minute average		3.14	11.92	1.78	10.93	
12/14/00	13:23:00	2.68	6.67	0.01	0.12	
12/14/00	13:24:00	0.36	-0.18	0.00	0.10	
12/14/00	13:25:00	-0.04	-0.16	0.00	0.11	
12/14/00	13:26:00	0.00	-0.12	0.00	0.07	
12/14/00	13:27:00	0.00	-0.09	0.00	0.07	< Zero Bias
12/14/00	13:28:00	0.00	-0.05	0.00	0.03	
12/14/00	13:29:00	0.47	21.26	1.06	5.22	



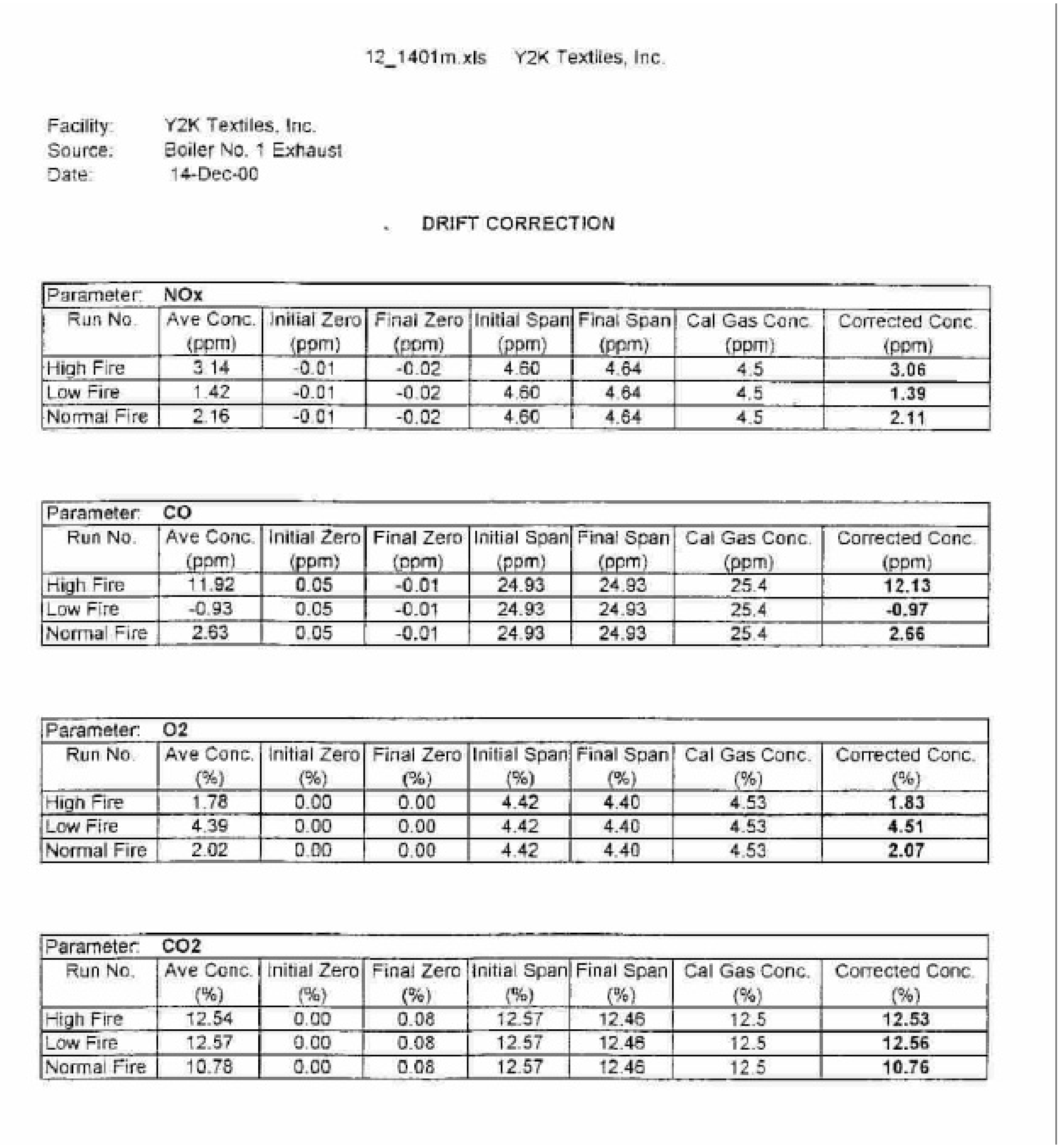
12_1401m.xls Y2K Textiles, Inc. Boiler No.1

NOx High	Certified Conc.	Initial Actual	Error [%]	Final Actual	Error [%]	Drift [%]	Cylinder Number	Expiration Date
Zero	0.00	-0.01	-0.10	-0.02	-0.20	0.10	na	na
Span 1	9.04	9.03	-0.10	9.05	0.10	-0.20	SA 14294	20-Sep-01
Span 2	4.50	4.60	1.00	4.64	1.40	-0.40	SA 11937	14-Sep-02
Zero Bias	0.00	-0.03	-0.30	0.00	0.00	-0.30	na	na
Span Bias	4.55	4.60	0.50	4.56	0.10	0.40	SA 11937	14-Sep-02
Range	10.00	Za =	-0.02	Sa =	4.62			

CO High	Certified Conc.	Initial Actual	Error [%]	Final Actual	Error [%]	Drift [%]	Cylinder Number	Expiration Date
Zero	0.00	0.05	0.10	-0.01	-0.02	0.12	na	na
Span 1	45.60	45.80	0.40	45.77	0.34	0.06	SA 9355	14-Sep-02
Span 2	25.40	24.93	-0.94	24.93	-0.94	0.00	CC 66703	23-Aug-01
Zero Bias	0.00	0.10	0.20	-0.07	-0.14	0.34	na	na
Span Bias	25.40	25.04	-0.72	24.90	-1.00	0.28	CC 66703	23-Aug-01
Range	50.00	Za =	0.02	Sa =	24.93			

O_2 High	Certified Conc.	Initial Actual	Error [%]	Final Actual	Error [%]	Drift [%]	Cylinder Number	Expiration Date
Zero	0.00	0.00	0.00	0.00	0.00	0.00	na	na
Span 1	8.86	8.93	0.28	8.91	0.20	0.08	CC 95341	09-Apr-02
Span 2	4.53	4.42	-0.44	4.40	-0.52	0.08	CC 99455	02-Feb-03
Zero Bias	0.00	0.00	0.00	0.00	0.00	0.00	na	na
Span Bias	4.53	4.39	-0.56	4.39	-0.56	0.16	CC 99455	02-Feb-03
Range	25.00	Za =	0.00	Sa =	4.41			

CO_2 High	Certified Conc.	Initial Actual	Error [%]	Final Actual	Error [%]	Drift [%]	Cylinder Number	Expiration Date
Zero	0.00	0.00	0.00	0.08	0.32	-0.32	na	na
Span 1	22.77	22.83	0.24	22.83	0.24	0.00	CC 95341	09-Apr-02
Span 2	12.61	12.57	-0.16	12.46	-0.60	0.44	CC 99455	02-Feb-03
Zero Bias	0.00	0.06	0.24	0.05	0.20	0.04	na	na
Span Bias	12.61	12.54	-0.28	12.57	-0.16	0.60	CC 99455	02-Feb-03
Range	25.00	Za =	0.04	Sa =	12.52			



12_1401m.xls Y2K Textiles, Inc.

Facility: Y2K Textiles, Inc.
Source: Boiler No. 1 Exhaust
Date: 14-Dec-00

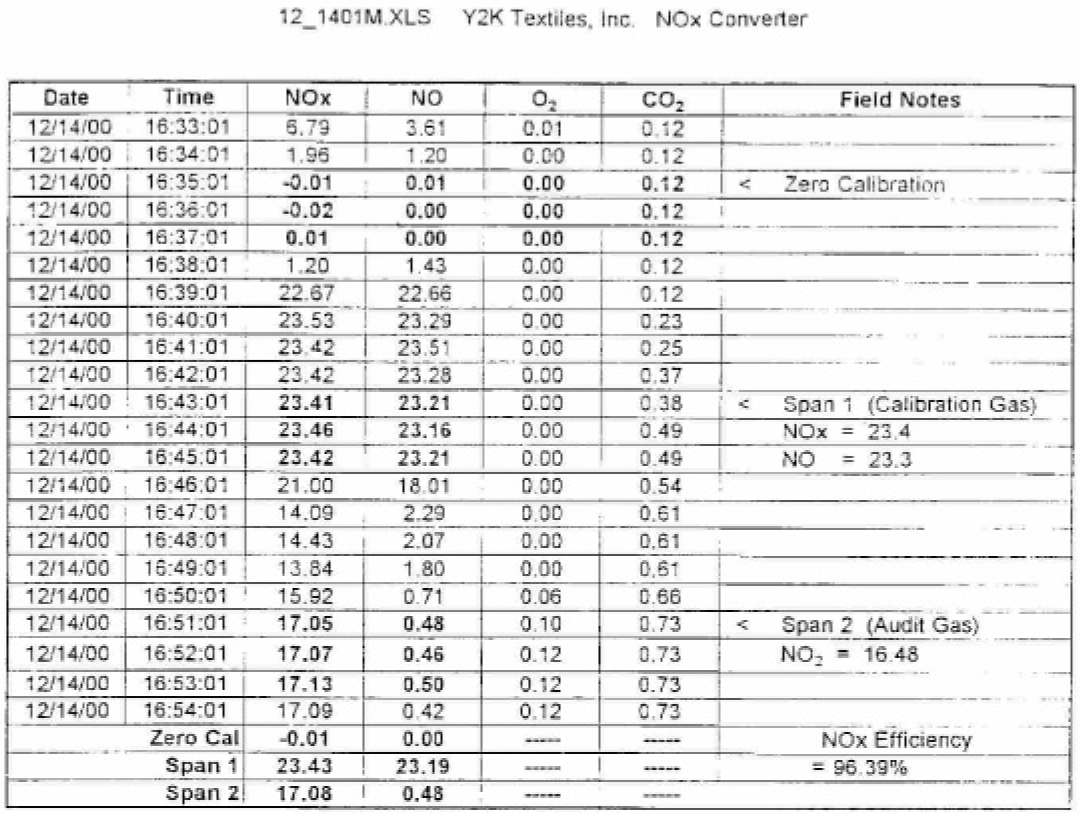
DRIFT CORRECTION

Parameter: **NOx**							
Run No.	Ave Conc. (ppm)	Initial Zero (ppm)	Final Zero (ppm)	Initial Span (ppm)	Final Span (ppm)	Cal Gas Conc. (ppm)	Corrected Conc. (ppm)
High Fire	3.14	-0.01	-0.02	4.60	4.64	4.5	**3.06**
Low Fire	1.42	-0.01	-0.02	4.60	4.64	4.5	**1.39**
Normal Fire	2.16	-0.01	-0.02	4.60	4.64	4.5	**2.11**

Parameter: **CO**							
Run No.	Ave Conc. (ppm)	Initial Zero (ppm)	Final Zero (ppm)	Initial Span (ppm)	Final Span (ppm)	Cal Gas Conc. (ppm)	Corrected Conc. (ppm)
High Fire	11.92	0.05	-0.01	24.93	24.93	25.4	**12.13**
Low Fire	-0.93	0.05	-0.01	24.93	24.93	25.4	**-0.97**
Normal Fire	2.63	0.05	-0.01	24.93	24.93	25.4	**2.66**

Parameter: **O2**							
Run No.	Ave Conc. (%)	Initial Zero (%)	Final Zero (%)	Initial Span (%)	Final Span (%)	Cal Gas Conc. (%)	Corrected Conc. (%)
High Fire	1.78	0.00	0.00	4.42	4.40	4.53	**1.83**
Low Fire	4.39	0.00	0.00	4.42	4.40	4.53	**4.51**
Normal Fire	2.02	0.00	0.00	4.42	4.40	4.53	**2.07**

Parameter: **CO2**							
Run No.	Ave Conc. (%)	Initial Zero (%)	Final Zero (%)	Initial Span (%)	Final Span (%)	Cal Gas Conc. (%)	Corrected Conc. (%)
High Fire	12.54	0.00	0.08	12.57	12.46	12.5	**12.53**
Low Fire	12.57	0.00	0.08	12.57	12.46	12.5	**12.56**
Normal Fire	10.78	0.00	0.08	12.57	12.46	12.5	**10.76**



12_1401M.XLS Y2K Textiles, Inc. NOx Converter

Date	Time	NOx	NO	O_2	CO_2	Field Notes
12/14/00	16:33:01	6.79	3.61	0.01	0.12	
12/14/00	16:34:01	1.96	1.20	0.00	0.12	
12/14/00	16:35:01	**-0.01**	**0.01**	**0.00**	**0.12**	< Zero Calibration
12/14/00	16:36:01	**-0.02**	**0.00**	**0.00**	**0.12**	
12/14/00	16:37:01	**0.01**	**0.00**	**0.00**	**0.12**	
12/14/00	16:38:01	1.20	1.43	0.00	0.12	
12/14/00	16:39:01	22.67	22.66	0.00	0.12	
12/14/00	16:40:01	23.53	23.29	0.00	0.23	
12/14/00	16:41:01	23.42	23.51	0.00	0.25	
12/14/00	16:42:01	23.42	23.28	0.00	0.37	
12/14/00	16:43:01	**23.41**	**23.21**	0.00	0.38	< Span 1 (Calibration Gas)
12/14/00	16:44:01	**23.46**	**23.16**	0.00	0.49	NOx = 23.4
12/14/00	16:45:01	**23.42**	**23.21**	0.00	0.49	NO = 23.3
12/14/00	16:46:01	21.00	18.01	0.00	0.54	
12/14/00	16:47:01	14.09	2.29	0.00	0.61	
12/14/00	16:48:01	14.43	2.07	0.00	0.61	
12/14/00	16:49:01	13.84	1.80	0.00	0.61	
12/14/00	16:50:01	15.92	0.71	0.06	0.66	
12/14/00	16:51:01	**17.05**	**0.48**	0.10	0.73	< Span 2 (Audit Gas)
12/14/00	16:52:01	**17.07**	**0.46**	0.12	0.73	NO_2 = 16.48
12/14/00	16:53:01	**17.13**	**0.50**	0.12	0.73	
12/14/00	16:54:01	17.09	0.42	0.12	0.73	
	Zero Cal	**-0.01**	**0.00**	-----	-----	NOx Efficiency
	Span 1	**23.43**	**23.19**	-----	-----	= 96.39%
	Span 2	**17.08**	**0.48**	-----	-----	

ISOKINETIC SAMPLING FIELD DATA

SPECIFIC SAMPLE TYPE(s) ___________

PLANT NAME	RUN NUMBER	K FACTOR SETUP DA	
		Stack Temp.	
PLANT LOCATION - CITY / STATE	TEST DATE	Avg. Del. P	
		Meter Temp.	
SAMPLING LOCATION	RUN START / STOP TIME	% H2O	
		Mole Wt. Dry	
		Sample Rate	
		K FACTOR =	

OPERATORS	BAROM. PRESSURE (in. Hg)	STATIC PRESSURE (in. H2O)	PITOT TUBE Cp	NOZZLE NUMBER	NOZZLE INSIDE DIA.	METER BOX NUMBER	METER BOX DELTA H@	METER BOX CAL. FAC. GAMMA (Y)	Intermediate Leak Checks

FILTER(s) NUMBER	FILTER(s) TARE	PITOT NUMBER	FLUE GAS THERM. NUMBER	IMPINGER THERM. NUMBER	PITOT LEAK CHECK	SAMPLE TRAIN LEAK CHECK INITIAL in. Hg	INITIAL cfm	FINAL in. Hg	FINAL cfm	
					I F					

	POINT NUMBER	ELAPSED TEST TIME (min.)	DRY GAS METER READING (cubic feet)	PITOT READING (in. H2O)	DELTA H ORIFICE (in. H2O)	FLUE GAS TEMP. (deg. F)	DRY GAS METER TEMP. (deg. F)	PROBE TEMP. (deg. F)	FILTER OVEN TEMP. (deg. F)	IMP. EXIT TEMP. (deg. F)	SAMPLE TRAIN VACUUM (in. Hg)
1											
2											
3											
4											
5											
6											
7											
8											
9											
10											
11											
12											
13											
14											
15											
16											
17											
18											
19											
20											
21											
22											
23											
24											
25											

Total Run Time	Total Volume Metered	Avg. SQRT Delta P	Avg. Delta H	Avg. Flue Gas Temp.	Avg. Dry Gas Meter Temp.

MOISTURE ANALYSIS DATA SHEET

Plant Name:	Project No.:
City and State:	Type of Sample Train:
Sampling Location:	

Run Number			
Test Date			
Recovery Date			
Recovered By			
Impinger 1			
Final Weight			
Initial Weight			
Net Weight			
Impinger 2			
Final Weight			
Initial Weight			
Net Weight			
Impinger 3			
Final Weight			
Initial Weight			
Net Weight			
Impinger 4			
Final Weight			
Initial Weight			
Net Weight			
Impinger 5			
Final Weight			
Initial Weight			
Net Weight			
Impinger 6			
Final Weight			
Initial Weight			
Net Weight			
Impinger 7			
Final Weight			
Initial Weight			
Net Weight			
Total Catch			