SRI/USEPA-GHG-QAP-45
October 2006

Test and Quality Assurance Plan

American Clean Energy Systems ACES-II Diesel Additive

Prepared by:

Greenhouse Gas Technology Center
Southern Research Institute

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

EPA REVIEW NOTICE

SRI/USEPA-GHG-QAP-45
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Greenhouse Gas Technology Center

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

Test and Quality Assurance Plan
American Clean Energy Systems
ACES-II Diesel Additive

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

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Test Plan Final: (October 2006)

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List of Acronyms and Abbreviations

ACES	American Clean Energy Systems
ADQ	audit of data quality
APPCD	Air Pollution Prevention and Control Division
Bhp	brake horsepower
CAR	corrective action report
CFR	Code of Federal Regulations
CO	carbon monoxide
CO_2	carbon dioxide
DAS	data acquisition system
DOE	Department of Energy
DQO	data quality objective
EPA-ORD	Environmental Protection Agency Office of Research and Development
ETC	Environmental Technology Centre
ETV	Environmental Technology Verification
^{o}F	degrees Fahrenheit
FS	full scale
FTP	Federal Test Procedure
g/bhp-h	grams per brake horsepower-hour
gph	gallons per hour
GHG	greenhouse gas
kW	kilowatt
lb/bhp-h	pounds per brake horsepower-hour
MQO	measurement quality objective
MW	megawatt
NDIR	non-dispersive infrared
NIST	National Institute of Standards and Technology
NO_X	blend of NO, NO_2, and other oxides of nitrogen
PEA	performance evaluation audit
PM	total particulate matter
psia	pounds per square inch, absolute
QA	quality assurance
QA/QC	quality assurance / quality control
SO_2	sulfur dioxide
THC	total hydrocarbons (as carbon)

1.0 INTRODUCTION

1.1. BACKGROUND

The U.S. Environmental Protection Agency's Office of Research and Development (EPA-ORD) operates the Environmental Technology Verification (ETV) program to facilitate the deployment of innovative technologies. The program's goal is to further environmental protection by accelerating the acceptance and use of these technologies. Primary ETV activities are independent performance verification and information dissemination. Congress funds ETV in response to the belief that many viable environmental technologies exist 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 will be better equipped to make informed decisions regarding new technology purchases and use.

The Greenhouse Gas Technology Center (GHG Center) is one of several ETV organizations. EPA's ETV partner, Southern Research Institute (Southern), manages the GHG Center. The GHG Center conducts independent verification of promising GHG mitigation and monitoring technologies. It develops verification Test and Quality Assurance Plans (test plans), conducts field tests, collects and interprets field and other data, obtains independent peer-review input, reports findings, and publicizes verifications through numerous outreach efforts. The GHG Center conducts verifications according to the externally reviewed test plans and recognized quality assurance / quality control (QA/QC) protocols.

Volunteer stakeholder groups guide the GHG Center's ETV activities. These stakeholders advise on appropriate technologies for testing, help disseminate results, and review test plans and reports. National and international environmental policy, technology, and regulatory experts participate in the GHG Center's Executive Stakeholder Group. The group includes industry trade organizations, environmental technology finance groups, governmental organizations, and other interested parties. Industry-specific stakeholders provide testing strategy guidance within their expertise and peer-review key documents prepared by the GHG Center.

GHG Center stakeholders are particularly interested in transportation technologies with the potential to increase fuel economy and reduce GHG and criteria pollutant emissions. The U.S. Energy Information Administration estimates that the Petroleum industry released 304.8 Million metric tons of carbon dioxide equivalents in 2002 - 21.8 percent of the total greenhouse gas (GHG) emissions produced by the manufacturing sector in the United States. Petroleum industry sources also released substantial quantities of criteria air pollutants and have recently become a focus of state and federal efforts to reduce emissions and achieve compliance with National Ambient Air Quality Standards.

American Clean Energy Systems (ACES) manufactures and sells "ACES-II," a diesel fuel additive suitable for use on all diesel engines. The GHG Center received the ACES Application for Testing on February 24, 2006, for independent performance verification of the ACES-II additive applied to stationary diesel generators operating on oil and gas drilling rigs. The GHG Center has agreed to verify the ACES-II technology based on the potential significant impact this technology could have on environmental quality and ETV program stakeholder requests for verified data on the performance of technologies that reduce fuel consumption and emissions. This test plan specifies additive verification performance parameters and the rationale for their selection. It contains the verification approach, data quality objectives (DQOs), and the relevant QA/QC procedures. The test plan will guide test implementation, document creation, data analysis, interpretation, and reporting.

The technology developer, expert peer reviewers, and the EPA-ORD QA team have reviewed this test plan. Once approved, as evidenced by the signature sheet at the front of this document, it will have met the GHG Center's Quality Management Plan (QMP) requirements. The GHG Center will post the final test plan on their internet site at www.sri-rtp.com and the ETV program site at www.epa.gov/etv.

The GHG Center will prepare an Environmental Technology Verification Report and Verification Statement (report) upon field test completion. The same organizations listed above will review the report. When the reviews and responses are complete, the GHG Center Director and the EPA-ORD Laboratory Director will sign the Verification Statement, and the GHG Center will post the final documents as described above.

ACES understands that this verification will not result in data that may be used for submission to the U.S. EPA's Voluntary Diesel Retrofit Program (VDRP). No attempt is being made to ensure that the data will be useful for any purpose except evaluation of the impact of the ACES-II additive under specified conditions.

1.2. DIESEL FUEL ADDITIVE DESCRIPTION

ACES-II is a registered fuel additive under 40 CFR 79.23 (ACES II Diesel Multifunction Additive registration number 196520002). The formulation of the registered additive is identical to that proposed for verification here. According to ACES, the ACES-II additive has four main functions:

- Cetane enhancer – intended to improve combustion;
- Lubricity increase – reduces fuel component(s) and engine friction,
- Detergent – cleans fuel stream components and other surfaces where deposits might collect
- Biocide – prevents growth of algae, fungus and bacteria.

Primarily targeted for use in heavy duty diesel engines, ACES-II is added to conventional diesel fuels at a ratio of 1:1000 during a cleanout and run-in phase, and 1:2000 for normal operation afterwards. According to ACES, additive run-in time should typically be 60 days long under steady engine operating loads. ACES states that a variety of internal field and laboratory tests on ACES-II have indicated both fuel efficiency improvements and emissions reductions of NO_X and hydrocarbons.

1.3. TEST SITE AND ENGINE DESCRIPTION

Diesel generators used to power oil and gas drilling rigs and other applications represent a large potential market for ACES-II. A common engine generator set used on drilling rigs is the Caterpillar D-399 generator with rated capacity of approximately 800 kW. Encana, a large North American energy and resource development firm, has offered to participate in this verification and host the testing. Encana employs hundreds of Caterpillar D-399 generators in Canada and the US on oil and gas drilling rigs. This verification will be conducted at an Encana gas drilling facility in eastern Texas. The drilling rig is owned and operated by Nabors Industries, Ltd.

Three generators are typically installed to operate each drilling rig. Normally two engines will be in service and a third on backup standby. Nabors' drilling rig No. 313 (shown in Figure 1-1), employs three Cat 399s and has been selected to host this verification. Because of the multi-function nature of the additive claims it is considered beneficial to separately investigate the effects on two similar engines at different points in their service cycle. The first is an engine that has been recently re-built, with approximately 2,000 to 5,000 hours of operation and consequently having less build-up of deposits on injectors and other components.

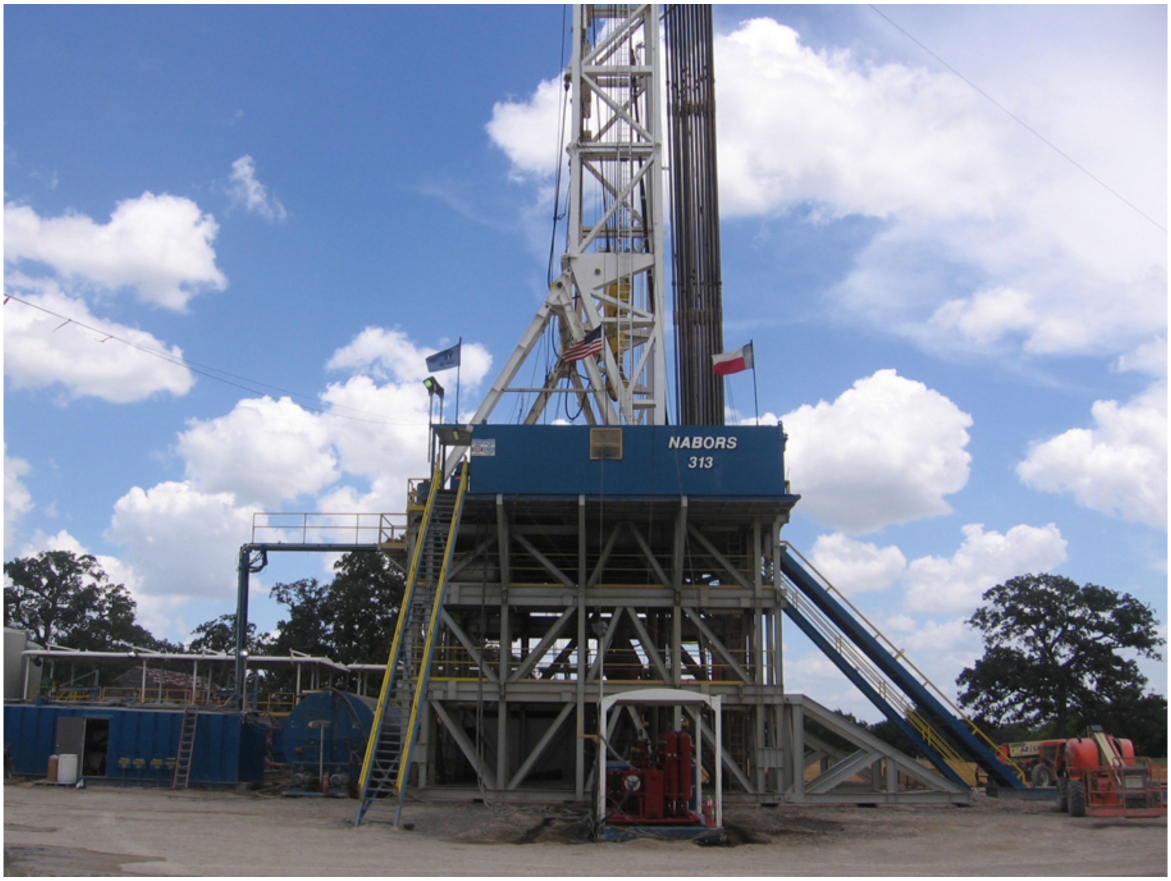

Figure 1-1. Nabors No. 313 Drilling Rig

The second is an engine with more operating hours logged (between 10,000 and 15,000 hours) and likely a greater build-up of deposits on injectors and components. Rebuilds are typically performed after 12,000 to 15,000 hours of operation. A third engine will be used as a control unit and will not be treated with ACES. Table 1-1 summarizes the three engines on Nabors 313 that will be used for testing. Figure 1-2 shows two of the engines generator sets. Detailed specifications for the Caterpillar Model 399 are presented in Appendix A-1.

Table 1-1. Test Engine Specifications

Engine Verification ID	Make/Model	Serial Number	Operating Hours on Current Overhaul (as of August 1, 2006)
Test Engine 1	Caterpillar 399 Diesel	36Z1200	9,713
Test Engine 2		LG05998	743
Control Engine		36Z00820	3,957

Each engine drives a corresponding KATO 1,030 kW, 3-phase, 60 hertz generator. During testing, the engines will be taken out of service and connected to a load bank for testing. The load bank is a 1,000 kW resistive load bank manufactured by Simplex and supplied and operated by Caterpillar. The unit includes data logging capabilities and can monitor and record engine power output (kW), real power (kVA), volts, amps, hertz, and speed (rpm). Load bank example data printouts are presented as Appendix A-2.

Figure 1-2. Cat 399s on Nabors 313 Rig

Exhaust gases from each of the engine are discharged directly to atmosphere at approximately 15 feet above grade through identical 10-inch diameter steel exhaust pipes.

1.4. PERFORMANCE VERIFICATION PARAMETERS

A verification approach has been designed to provide credible data on fuel consumption and emissions improvements attributable to the ACES-II additive based on recognized and reliable field measurement and data analysis procedures. The GHG Center will verify the following parameters for stationary diesel generators as described above for baseline conditions and after treatment with the ACES-II additive:

- fuel consumption, gal/MW·hr, g/bhp·hr
- carbon monoxide (CO) emissions, g/MW·hr, g/bhp·hr
- carbon dioxide (CO_2) emissions, g/MW·hr, g/bhp·hr
- nitrogen oxides (NO_x) emissions, g/MW·hr, g/bhp·hr
- sulfur dioxide (SO_2) emissions, g/MW·hr, g/bhp·hr
- total hydrocarbon (THC) emissions, g/MW·hr, g/bhp·hr
- particulate matter (PM) emissions, g/MW·hr, g/bhp·hr

The verification will include two separate engines for evaluation of ACES-II performance and a third control engine for evaluation of baseline drift.

1.5. PROJECT ORGANIZATION

Figure 1-3 presents the project organization chart.

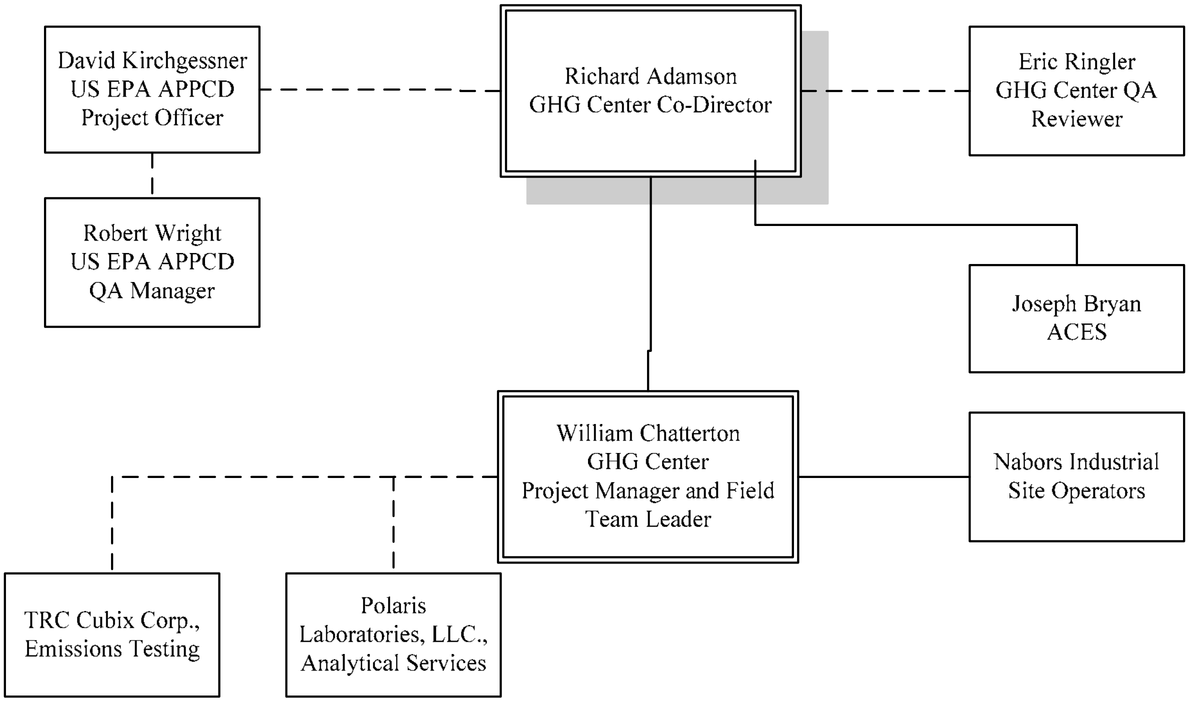

Figure 1-3. Project Organization

The GHG Center has overall verification planning and implementation responsibility. The GHG Center will consult with nationally recognized experts and regulatory authorities to support the planning, review, and the wide distribution of verification results. Organizations or individuals that pose a real or perceived conflict of interest may be excluded from participation in this verification at the discretion of the GHG Center and as advised by ACES and other independent stakeholders. The GHG Center will coordinate all participants' activities; develop, monitor, and manage schedules; and ensure the acquisition and reporting of data consistent with the strategies in this test plan. The Director will have authority to suspend testing for health and safety reasons and if the QA/QC goals presented in Section 3.0 are not being met. The GHG Center Co-Director, Mr. Richard Adamson, will:

- review the test plan and report for consistency with ETV operating principles
- allocate appropriate resources for the verification
- oversee GHG Center staff activities

Mr. Joseph Bryan of ACES is the technology developer's primary point of contact. He will:

- review the test plan and report especially with respect to accuracy in the technology description and its application

- secure the involvement of the drilling rig and engine's owner, engine operating and maintenance personnel, and facilities where testing will occur
- provide a sufficient supply of the additive to the engine owner for the run-in period and for the final test period

The GHG Center's Mr. William Chatterton will serve as project manager. Responsibilities include:

- drafting the test plan, report, and verification statement
- overseeing the field team leader's activities
- ensuring collection of high-quality data and that all DQOs are met
- maintaining communications with all test participants
- budgetary and scheduling review

Mr. Chatterton will also serve as the field team leader and will supervise all field operations and the testing contractor's activities. He will assess data quality and will have the authority to repeat tests as deemed necessary to ensure achievement of data quality goals. He will:

- coordinate the installation of the electrical, and fuel metering equipment on the engine with the owner
- operate the electrical and fuel metering equipment during the tests
- declare the beginning and end of each test run, with input from the testing contractor
- collect interim test data for use in consultations with the project manager
- supervise and coordinate subcontractor activities
- ensure that all site safety requirements are followed by GHG personnel and subcontractors
- perform other QA/QC procedures as described in Section 3.0

At the completion of each test run, the field team leader will communicate test results to the GHG Center director. The field team leader and director will collaborate on all major project decisions including the need for further test runs or corrective actions.

The GHG Center QA manager, Mr. Eric Ringler, is organizationally independent of the GHG Center staff involved in this verification. He has reviewed this TQAP and will also review the verification test results, report, will conduct the Audit of Data Quality (ADQ) including assessment of DQOs, and will review QC checks on measurement instrumentation. The QA manager will report all internal audit and corrective action results directly to the GHG Center Director who will provide copies to the project manager for inclusion in the report

EPA-ORD will provide oversight and QA support for this verification. The Air Pollution Prevention and Control Division (APPCD) project officer, Dr. David Kirchgessner, and QA manager, Mr. Robert Wright, will review and approve the test plan and report to ensure that they meet EPA QA goals and represent sound scientific principles. Dr. Kirchgessner will be responsible for obtaining final test plan and report approvals.

The verification will include the services of two subcontractors. Emissions testing will be conducted by TRC/Cubix Corporation of Austin, Texas, with Todd Harbour serving as project manager. Fuel and additive analyses will be conducted by Polaris Laboratories of Houston, Texas under the management of Elaine Walsh.

1.6. SCHEDULE

The tentative schedule of activities for the ACES-II additive verification test is:

Table 1-2. Verification Schedule

Verification Test Plan Milestones	**Dates**
GHG Center internal draft development	April 10 – August 11, 2006
ACES review	August 14 – 18, 2006
Industry peer review and plan revision	August 21 – 25, 2006
EPA review	August 28 – September 15, 2006
Final test plan posted	September 22, 2006
Verification Testing and Analysis Milestones	**Dates**
Initial tests on untreated fuel	October 23 - 27, 2006
Revenue service break-in period on additive-treated fuel	October 23 – December 13, 2006
Final tests on treated fuel	December 14 – 21, 2006
Verification Report Milestones	**Dates**
GHG Center internal draft development	January 2007
ACES, industry peer review and report revision	February 2007
EPA review	March, 2007
Final report posted	March 31, 2007

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2.0 VERIFICATION APPROACH

The testing approach and procedures are based in part on the *Distributed Generation and Combined Heat and Power Field Testing Protocol* [1], the ETV Verification Protocol *Determination of Emissions Reductions Obtained by Use of Alternative or Reformulated Liquid Fuels, Fuel Additives, Fuel Emulsions, and Lubricants for Highway and Nonroad use Diesel Engines and Light Duty Gasoline Engines and Vehicles Rev.3* [2], the ISO Standard 8178-4 *Reciprocating Internal Combustion Engines – Exhaust Emission Measurement* [3], and the SAE Protocol J1321 *Fuel Consumption Test Procedure – Type II* [4].

Following procedures detailed in these reference documents, the GHG Center will verify the following parameters on the three CAT D399 diesel generators described in Section 1.3 for baseline conditions and after treatment with the ACES-II additive:

- fuel consumption, gal/MW·hr, g/bhp·hr
- carbon monoxide (CO) emissions, g/MW·hr, g/bhp·hr
- carbon dioxide (CO_2) emissions, g/MW·hr, g/bhp·hr
- nitrogen oxides (NO_x) emissions, g/MW·hr, g/bhp·hr
- sulfur dioxide (SO_2) emissions, g/MW·hr, g/bhp·hr
- total hydrocarbon (THC) emissions, g/MW·hr, g/bhp·hr
- particulate matter (PM) emissions, g/MW·hr, g/bhp·hr

The absolute values of these parameters will be reported for the engines treated with the ACES-II additive as well as the percent change in these values compared to the baseline tests. The control engine will not be dosed with additive but used to evaluate baseline drift. The changes in each parameter will be corrected for baseline drift and calculated for each engine as follows:

$$\Delta \text{ parameter [units]} = \text{average parameter}_{\text{(Engine after treatment)}} - \text{average parameter}_{\text{(Baseline Engine)}}$$

Details regarding the baseline drift approach are presented in Section 2.4.7. Testing will be conducted on two identical engines that are in different engine rebuild cycles. Typically, this operator rebuilds engines after 12,000 to 15,000 hours of operation. For this program, the first (Test Engine 1) will be near the end of a rebuild cycle (currently is at approximately 10,000 hours of last rebuild), and the other (Test Engine 2) will be near the beginning of its cycle (currently has approximately 1,000 hours of operation logged since last rebuild). This may allow the verification to demonstrate the effectiveness of the ACES-II additive on engines that may have injector and surface deposits (detergent and biocide effectiveness) as well as engines that are relatively deposit free (cetane enhancer and lubricity effectiveness).

Characteristic of most cumulative effect fuel additives, baseline engine drift cannot be easily evaluated after the engines have been treated. However, a third engine, designated as the Control Engine, has been selected and tested to evaluate baseline drift. The Control Engine has less than 10,000 hours of operation since its last rebuild, will not be dosed with ACES-II, and will be operated for a period of time similar to the two test engines during the additive run-in period. The same suite of testing conducted on the two test engines will be conducted on the Control Engine to see if baseline drift occurs and needs consideration when evaluating changes in performance on the two test engines.

2.1. TESTING DESIGN

Each engine tested will be defined as a separate device under test (DUT). Figure 2-1 depicts a typical DUT for this verification.

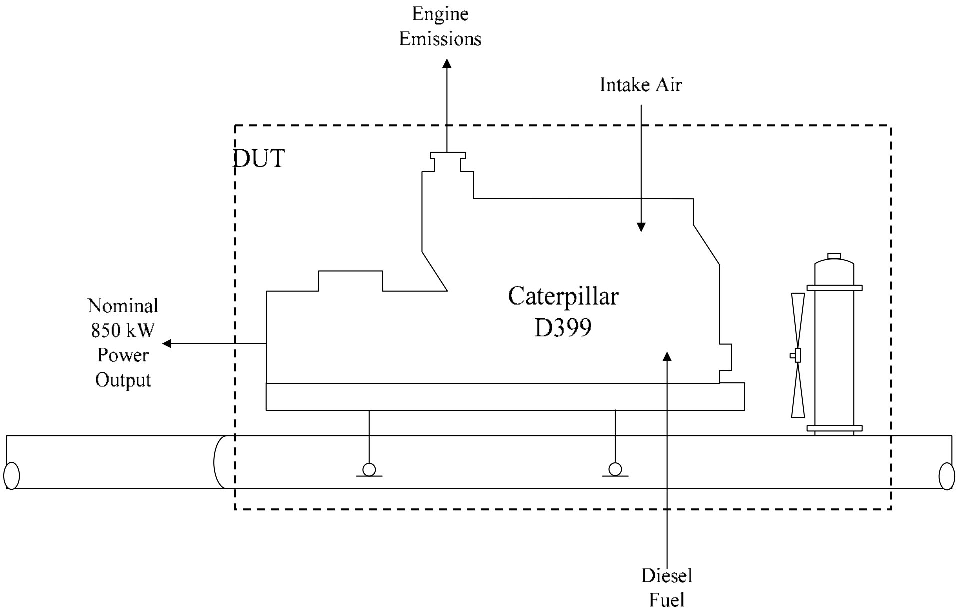

Figure 2-1. DUT for ACES-II Verification

On each engine, the testing program will consist of a sequential baseline test period, an additive run-in period, and a conditioned test period. The testing sequence is summarized in Table 2-1 and will be conducted on all three engines separately.

Table 2-1. Engine Test Sequence

Event	Description	Day
1	Engine preparation – oil & filter change – connect to load bank	1
2	Run-in new oil & filter (24 hours at 50% load followed by shut-down overnight)	2 - 3
3	Conduct two baseline test runs – shut down overnight	4
4	Conduct third baseline test run - then reconnect to rig load after third test run	5
5	Treat fuel & run-in (test engines only) – run under normal operating load for 60 days (all three engines) – shut down overnight on the last day	6 - 66
6	Engine preparation oil & filter change, connect to load bank	66
7	Run-in new oil & filter (24 hours at 50% load followed by shut-down overnight)	67
8	Conduct two conditioned test runs – shut down overnight	68
9	Conduct third conditioned test run - then connect to rig load after third test run	69

Because the rig normally has only two engines in service at any given time, the testing should not interfere with drilling operations. Only one engine will be out of service and connected to the load bank for testing at any given time.

With the 60 day additive run-in period, it is anticipated that 69 days are required to complete a test sequence on each engine. Test results from the Control Engine will be used to estimate baseline engine drift during this time period. During the baseline and conditioned test run series each engine will be connected to a load bank so that steady engine operations can be maintained and monitored at specified load levels. Each engine will be prepared for testing the day prior to each set of baseline and conditioned test runs. Engine preparation will include inspection, oil and oil filter change, and air filter change. Each of the engines will be returned to service on the drill rig during the 60 day run-in period. All engine maintenance, preparations, inspections, and in-service operating hours will be logged by site operators and provided to GHG Center personnel.

2.2. IN-SERVICE RUN-IN PERIOD AND FUEL TREATMENT

At the conclusion of the baseline test runs, the field team leader will release the engines for a 60 day additive run-in period in regular revenue service. During this time it is anticipated that each engine will consume up to 45,000 to 50,000 gallons of fuel. If site operational issues prevent use of this much fuel, the project manager may extend the run-in period. ACES will supply a calibrated dosing pump which will enable site personnel to administer the ACES-II additive to the sites fuel supply on a continuous basis. A Hammonds additive injector system, accurate to ± 2% reading will be used. Appendix B-2 provides a description and diagram of the injector. Fuel samples will be collected and analyzed for composition and heating value to demonstrate the consistency of fuel composition over the verification period.

The initial treated fuel dosing ratio during the run-in period will be 1000:1 for Test Engines 1 and 2. The dosing rate will be increased to the maintenance dosage rate of 2000:1 for a minimum of 30 days prior to the final test period. The dosing pump has a totalizing readout which, when correlated with the site's fueling records, will allow verification that the additive was properly mixed with the fuel. Additive totalizing records will be obtained and summarized in the verification report. The control engine will be fueled from a separate fuel holding tank that is not dosed with additive.

Because the drill rig is moved to a new drilling location at intervals of approximately 60 days, it is likely that the after treatment testing will occur at a different drilling site that the baseline testing. The same engines will be configured exactly the same at both sites, so the move is not expected to impact the verification. Furthermore, the initial 20 days of drilling at a new site are particularly rigorous and require the service of all three engines full time. As such, no verification testing will be conducted during the first 20 days at any given drilling location.

During the break-in period and final testing, the engines will not be scheduled for any maintenance activities (other than the oil and filter changes) to ensure that no modifications are made to the engines that may affect their performance prior to the final test period.

2.3. TESTING PROCEDURES

The test sequence includes a series of baseline and conditioned test runs on each engine. Three replicate test runs will be completed on each engine during each series. The mean results of these test runs are the basis for comparison of engines operating on treated and untreated fuel on the two test engines, and an evaluation of baseline drift on the control engine.

Each test run will include a range of operating conditions according to ISO 8178-4 Type D1 weighting for constant speed non-road diesel engines. The weighting factors specify engine operation at three different loads and sampling durations at each load, thus resulting in weighted average emissions and fuel consumption rates for each individual run. Table 2-2 summarizes the Type D1 weighting loads and duration of operation at each load during each test run. This approach results in average fuel economy and emission rates time weighted to be representative for these engine types.

Table 2-2. ISO 8178-4 Type D1 Weighting Factors for Constant Speed Engines

Step	Description of Operations	Duration (min.)	Fuel Economy and Emissions Data Recorded?
1	Warm up – 100% load	30	No
2	Full load test – 100% load	36	Yes
3	Transition – 75% load	15	No
4	75% test	60	Yes
5	Transition – 50% load	15	No
6	50% test	24	Yes

During each test run, fuel economy and emissions data will be collected during the full load, 75 % load, and 50 % load periods as shown in the table. Fuel economy and gaseous pollutant emissions data will be sampled at intervals of approximately 5 seconds and recorded as one-minute averages over the test periods. One integrated particulate matter sample will be collected during each test run that includes each of the three operating points. By varying the period of testing under each mode, the integrated PM samples will represent the correct proportions of sample corresponding with ISO 8178 Type D1 weighting.

During each test, test personnel will acquire the following measurements:

- fuel use, gallons per hour (gal/hr)
- generator power output, kilowatts (MW)
- ambient barometric pressure, pounds per square inch absolute (psia)
- ambient temperature, ^{o}F
- exhaust gas volumetric flow rate (dscfm)
- exhaust gas concentrations of NO_X, CO, SO_2, and THC (ppm)
- exhaust gas concentrations of O_2 and CO_2, and THC (%)
- exhaust gas concentrations of PM, (gr/dscf)
- additive dosing rate (gal/hr)

These data will allow the evaluation of each of the verification parameters. The following subsections detail the field measurements that will be used to determine engine fuel economy and emissions during the test sequences.

2.3.1. Fuel Consumption

Fuel consumption as gal/MW-hr will be calculated as the ratio of the average power delivered to the load bank divided by the total amount of fuel consumed during each test. Also reported is fuel consumption as gal/Bhp-hr using a simple conversion of MW delivered to Bhp. Detailed procedures for determination of fuel consumption and power output are provided in the *Distributed Generation and Combined Heat and Power Field Testing Protocol* [1]. The following site specific instrumentation is planned for use in this verification.

<u>Fuel Metering</u>
Fuel metering will be conducted using two coriolis meters to measure total fuel flow to engine (supply) and fuel spill (return) for the DUT. Fuel consumption will be the difference between the measured supply and return flow rates. The data from the two flow meters will be logged on a one-second interval and logged and stored as 1-minute averages using the GHG Centers' data acquisition system (DAS).

The meters will be Krohne MFS 7000 series coriolis flow meters with T15 titianium flow tubes and MFL050K signal converters. Engine fuel consumption rates are expected to range from approximately 30 gph at 50 % load to 62 to 70 gph at full load meaning that actual flow rates on the supply and return lines will be significantly higher that that. At these flow rates, rated accuracy of these meters is better than 1 percent of reading.

The return fuel flow from the engine may be aerated. Excessive aeration significantly degrades the performance and accuracy of any volumetric flow meter, and the changes cannot be quantified. Mass flow meters, such as the coriolis meters to be used in this test, can quantify aeration effects, but severe aeration may trigger an error signal from the meter. Southern will evaluate the degree of aeration prior to the verification on a similar engine and will plan to install de-aeration equipment and a surge tank on the engines if needed.

<u>Power Metering</u>
An external resistance load bank will dissipate the power produced by each generator. Maintenance personnel will connect the load bank to the proper test point in each engine's electrical distribution bus according to the engine's standard load test procedure. Maintenance personnel will install the current sensor around the two positive output cables at the terminal block and they will connect the voltage sensor leads to the positive and negative output terminals or buses.

A digital power meter, manufactured by Power Measurements Ltd. (Model 7500 or 7600 ION) will be used to measure the electric power output from the generators. Current transformers (CTs) will be used to wire the power meter to the load bank. The meter scans power output once per second and sends the 4 - 20 milliamp (mA) signal to the DAS. The DAS then computes and records 1-minute averages. The 1-minute average power output readings will be furthered reduced to provide an average power output for each test run.

The CTs and the power meter will be accompanied by current NIST-traceable calibration certificates. Pre-mobilization cross checks will be performed on these instruments to confirm that no substantial change in performance has occurred since calibration. Details regarding this and additional QA/QC checks (instrument setup, calibration, and sensor function checks) on these instruments are provided in Section 3.1.

2.3.2. Emissions Measurements: General

Emissions measurements will be conducted by the GHG Center personnel with the assistance of TRC/Cubix Corporation under subcontract to Southern Research Institute. Being stationary sources, engine emissions will be determined following the guidelines in following §5.0 and Appendix D4.0 of the *Distributed Generation and Combined Heat and Power Field Testing Protocol*. The Protocol refers to

EPA Reference Methods specified in 40 CFR 60 to measure emissions of SO_2, NO_x, CO, THC, CO_2, O_2, and PM. Pollutant concentrations will be measured directly during each test run and will be used along with measured exhaust gas flow rates to report emission rates in units of lb/hr. Measured power output will be used to normalize emissions to lb/MW-hr and lb/Bhp-hr.

Figure 2-2 shows the three identical exhaust pipes. Sample ports will be cut in each exhaust pipe the duct that will allow testers to perform the exhaust gas flow rate pollutant concentration measurements in accordance with the appropriate reference methods. Test ports will be approximately 5 diameters downstream of the muffler and 1 diameter upstream of the exhaust point.

Figure 2-2. Engine Exhaust Pipes

2.3.3. Gaseous Emissions:

A fully equipped mobile emissions testing laboratory will be transported to the facility to conduct the EPA Reference Methods emission testing. The field team leader will confirm that the subcontractor satisfies the required QA elements of the methods. Proposed analytical ranges for the gas analyzers are listed in Table 2-3. Results for each pollutant will be reported in units of ppm, ppm corrected to 15% O_2, lb/hr, lb/MW-hr, and lb/BHp-hr.

Table 2-3. Gaseous Pollutant Measurement Instrumentation

Pollutant / Reference Method	Expected Range of Measurement	Principle of Detection	Instrument Range	Instrument Accuracy
NO_X / Method 7E	600 – 1100 ppmv	Chemiluminescence	0 – 2500 ppmv	± 2% FS
CO / Method 10	200 – 400 ppmv	(NDIR)-gas filter correlation	0 – 1000 ppmv	± 2% FS
SO_2 / Method 6C	50 – 150 ppmv	Pulse fluorescense	0 – 500 ppmv	± 2% FS
THC / Method 25A	100 – 500 ppmv	Flame ionization detector (FID)	0 – 1000 ppmv	± 2% FS
CO_2 / Method 3C	5 – 10 %	NDIR	0 – 20 %	± 2% FS
O_2 / Method 3C	8 – 15 %	Electrochemical cell	0 – 25 %	± 2% FS

Sample exhaust gas will be extracted from a point near the center of each engine exhaust stack and directed to the analyzers in the mobile laboratory. Concentration data will be logged at 1-second intervals and stored and reported as 1-minute averages for each parameter throughout each test run. All of the QA/QC and calibration requirements specified in the Reference Methods will be followed during the verification.

2.3.4. Particulate Emissions:

Particulate Emissions are measured using EPA Methods 5 and 202. The system will be configured to draw an isokinetic sample during each test period and to collect solid particulate matter in the sampling train “front half” and condensable particulates in the “back half”. One sampling train will be used to accumulate sample through all indicated steps of each Test Sequence. Sample will not be drawn through the filters during transitions and warm-up. At the conclusion of each test, the front half and back half particulate samples will be recovered, labeled, stored, and returned to the laboratory for analysis.

All of the QA/QC and calibration procedures specified in Methods 5 and 202 will be followed during the verification. Sampling system leak checks will conducted on site immediately before and after each test run. Test runs with failing post-test leak checks will be repeated. The particulate emissions testing methods include determination of exhaust gas flow rate (dscfm) which will also be used to convert measured gaseous pollutant concentrations to mass emission rates.

2.3.5. Additive and Fuel Testing:

Prior to finalizing the field work, three samples of additive will be acquired from different lots of additive, numbered and sent to an independent laboratory (Polaris Laboratories, LLC of Houston, Texas) for elemental analysis. Should metals or phosphorus be detected in significant quantities, suitable additional emissions testing (Method 29 or a variant) will be incorporated into the testing matrix. (Metals are not expected, in accordance with the manufacturer specifications.)

Three samples of fuel will be taken during each 2-day testing period. These samples will be numbered and sent to an independent analytical lab to provide analysis of:

- Heating value in GJ/kg
- Sulfur content
- Lubricity
- Density
- Viscosity
- Flow point

Sample collection, transfer, and documentation will be conducted using the procedures and forms in §6.0 and Appendix B6.0 and B7.0 of the *Distributed Generation and Combined Heat and Power Field Testing Protocol*. An example fuel analysis report is provided in Appendix B-1.

2.3.6. Oil Analyses:

The host site conducts engine crankcase oil analyses on the 1st and 15th of every month. These analyses conducted before, during, and after the verification test periods will be procured from the site for each engine. The analyses will not be independently verified during this program, but will be included in the verification report so that potential ACES users can compare changes in oil quality for the test and control engines. The analyses will include the following parameters:

- Viscosity
- Oxidation
- Nitration
- Total acid number

An example oil analysis for the Nabors facility is presented in Appendix C-1.

2.4. DATA ANALYSIS

The reference documents include all the methods' required calculations, so they are not reproduced here. This subsection discusses the generalized emissions and fuel consumption calculations and introduces the statistical methods the field team leader will use to determine if changes in engine performance are statistically significant.

The verification budget allows for three replicate test runs only. Therefore, no additional test runs will be performed to reduce data variability. The statistical tests will be used to:

- evaluate the statistical significance of any changes
- establish that the test results have similar variability between the baseline and treated fuel
- calculate the confidence interval on the changes

The subsections below discuss these tests.

2.4.1. Fuel Consumption

Fuel Consumption is:

$$FC_{gal} = \frac{Q_{fuel} * hr}{MW_{gen} * hr} \qquad \text{Eqn. 2-1}$$

Where:

FC_{eng} = average engine fuel consumption for a test run, gal/MW-hr
Q_{fuel} = weighted average fuel consumption for a test sequence, gal/hr

MW_{gen} = mean power delivered to load bank, MW
hr = total duration steady operations during test sequence, hr

This analysis will not include data collected during warm up or load transition periods. Only the 1-minute fuel flow and power output averages collected during steady operations will be used.

A conversion factor of 0.746 horsepower per kilowatt will be used to convert the fuel consumption into units of gal/Bhp-hr.

2.4.2. Engine Emissions

The following equations use the FTP nomenclature where possible. The normalized emission rates and fuel consumption for each test mode are:

$$E_i = \frac{M_i}{MW_{gen}} \qquad \text{Eqn. 2-2}$$

Where:

E_i = power-specific mass emission rate of pollutant i, lb/MW-hr
M_i = weighted average mass emission rate for pollutant i during test, lb/hr
MW_{gen} = mean power output for test, MW

2.4.3. Changes in Engine Performance

The verification parameters for this test are defined in terms of changes, delta (Δ), in these quantities after introduction of the ACES-II fuel additive. Thus, the brake-specific fuel consumption rate changes for each test will be:

$$\Delta FC = FC_{\text{eng-baseline}} - FC_{\text{eng-additive}} \qquad \text{Eqn. 2-3}$$

Where:

ΔFC = fuel consumption rate change, gal/MW-hr
$FC_{\text{eng-,baseline}}$ and $FC_{\text{eng-,additive}}$ are computed using Equation 2-1.

The change in power weighted emissions will be calculated similarly:

$$\Delta E_i = E_{\text{i-baseline}} - E_{\text{i-additive}} \qquad \text{Eqn. 2-4}$$

Where:

ΔE_i = emission rate change for pollutant i, lb/MW-hr
$E_{\text{i-baseline}}$ and $E_{\text{i-additive}}$ are computed using Equation 2-2.

2.4.4. Baseline Versus Treated Fuel Statistical Significance

The GHG Center will evaluate the statistical significance of the emissions and fuel consumption changes between the baseline and treated fuel conditions. If fuel consumption changes are statistically significant, the GHG Center will calculate the difference's confidence interval.

After the 3rd test run, and analysts will calculate a test statistic, t_{test}, and compare it with the Student's T distribution value with ($n_1 + n_2 - 2$) degrees of freedom as follows [5]:

$$t_{test} = \frac{(\overline{X}_1 - \overline{X}_2) - (\mu_1 - \mu_2)}{\sqrt{s_p^{\,2}\left(\frac{1}{n_1} + \frac{1}{n_2}\right)}} \qquad \text{Eqn. 2-5}$$

$$s_p^2 = \frac{(n_1 - 1)s_1^{\,2} + (n_2 - 1)s_2^{\,2}}{n_1 + n_2 - 2} \qquad \text{Eqn. 2-5}$$

Where:

X_1 = mean fuel economy with baseline fuel
X_2 = mean fuel economy with treated fuel
μ_1 - μ_2 = zero (H_o hypothesizes that there is no difference between the population means)
n_1 = number of repeated test runs with baseline fuel
n_2 = number of repeated test runs with treated fuel
s_1^2 = sample standard deviation with baseline fuel, squared
s_2^2 = sample standard deviation with treated fuel, squared
s_p^2 = pooled standard deviation, squared

Selected T-distribution values at a 95-percent confidence coefficient ($t_{0.025,\ DF}$) for data sets of 3 runs is 2.776 [5].

If $t_{test} > t_{0.025,DF,}$ conclude that the data shows a statistically significant difference between the baseline and treated fuel parameters. Otherwise, it will be concluded that a significant parameter difference does not exist. If significant, the difference and its confidence interval will be reported. The field team leader and project manager may decide to conduct additional test runs if it appears that such runs may improve the ability to demonstrate parameter changes of significance.

2.4.5. Sample Variance Similarity

Use of equations 2-5 and 2-6 requires the assumption that the baseline and treated fuel test run results have similar variance. The ratio of the sample variances (sample standard deviation squared) between the two fuel test series is a measure of this similarity [6]. Analysts will calculate an F_{test} statistic according to Eqn. 2-7 and compare the results to the appropriate values in Table 2-4 to determine the degree of similarity between the sample variances (in this case, 19.00).

$$F_{test} = \frac{s^2_{\max}}{s^2_{\min}} \qquad \text{Eqn. 2-7}$$

Where:

F_{test} = F-test statistic
s^2_{max} = larger of the sample standard deviations, squared
s^2_{min} = smaller of the sample standard deviations, squared

Table 2-4 presents selected $F_{0.05}$ distribution values for the expected number of test runs and the acceptable uncertainty (α; 0.05).

Table 2-4. Selected F0.05 Distribution Values

	s^2_{max} number of runs	**3**	**4**	**5**	**6**
s^2_{min} number of runs	**Degrees of Freedom**	**2**	**3**	**4**	**5**
3	**2**	**19.00**	19.16	19.25	19.30
4	**3**	9.55	9.28	9.12	9.01
5	**4**	6.94	6.59	6.39	6.26
6	**5**	5.79	5.41	5.19	5.05

If the F-test statistic is less than the corresponding value in Table 2-4 (19.00), then analysts will conclude that the sample variances are substantially the same and the statistical significance evaluation and confidence interval calculations are valid approaches. If the F-test statistic is equal to or greater than the Table 2-4 value, analysts will conclude that the sample variances are not the same and will consequently modify the confidence interval calculation according to Satterthwaite's approximation [6]. The report will discuss Satterthwaite's approximation if the actual test data indicate that it must be applied.

2.4.6. Baseline Versus Treated Fuel Confidence Interval

If a statistically significant difference in parameters is observed, the 95-percent confidence interval will be calculated. The half width (e) of the 95 percent confidence interval is [5]:

$$e = t_{.025,DF}\sqrt{s_p^{\,2}\left(\frac{1}{n_1}+\frac{1}{n_2}\right)} \qquad \text{Eqn. 2-8}$$

Analysts will calculate and report ΔE_i, and ΔFC_{gen}, for the steady-state test sequences conducted here. All reported results will include the 95 percent confidence interval, if the results are statistically significant.

2.4.7. Evaluation of Baseline Drift

This verification focuses on the cumulative affect of the ACES-II additive on engine performance. Because the vendor specified run-in period is at least 60 days of normal operation, it is possible that baseline engine performance may drift over that period. The ETV Verification Protocol *Determination of Emissions Reductions Obtained by Use of Alternative or Reformulated Liquid Fuels, Fuel Additives, Fuel Emulsions, and Lubricants for Highway and Nonroad use Diesel Engines and Light Duty Gasoline Engines and Vehicles Rev.3* [2] includes two methods to evaluate baseline drift for evaluation of cumulative effects, neither of which are applicable to this verification. Specifically, post test baseline drift cannot be evaluated on the test engines because of fuel additive long-term residual effects on the engine. In addition, pre-test baseline drift on the test engines is not feasible because the protocol specifies that the pre-test testing be conducted at a point in time five times before the run-in period (requiring five months of maintenance free service in this case).

For these reasons a control engine will be used to examine baseline drift following the procedures outlined in SAE Protocol J1321 [4]. With all three engines being operated similarly over the run-in period it is presumed that the baseline drift will be similar for each. If significant changes in fuel consumption and emissions performance are evident for the control engine, drift for test engines will be assumed to be proportional (statistical significance will be determined following procedures discussed in §2.4.4). Therefore, for any parameters that change significantly on the control engine, baseline normalization factors will be applied to those parameters on the test engines.

J1321 is designed for determination of fuel consumption changes, but this approach will be applied to all parameters for this verification. Baseline test runs will establish initial fuel consumption and emissions performance ratios between the test and control engines. This test campaign will compare the performance of the two test engines and the control engine. After run-in of the ACES-II additive, the candidate test runs then establish the final test engine to control engine fuel consumption and emissions performance ratios. The change in the ratio after the greening period, as compared to the baseline ratio, is the change in verification parameter.

Table 2-5 provides a sample J1321 fuel consumption calculation for a single test engine and control engine pair. This example, which implies that fuel consumption decreased by 7.7 percent, is for illustration only.

Table 2-5. Sample J1321 Calculation

Test location	Baseline fuel consumption, gph	Baseline ratio	Candidate fuel consumption, gph	Candidate ratio	Ratio change	Percent change from baseline
Test Engine	95.30	0.9565	84.90	0.8828	- 0.0737	- 7.7 %
Control Engine	99.63		96.17			

3.0 DATA QUALITY

Under the ETV program, the GHG Center specifies data quality objectives (DQOs) for each verification parameter before testing commences as a statement of data quality. The DQOs for this verification were developed based on past verifications conducted by the GHG Center, input from EPA's ETV QA reviewers, and input from both the GHG Centers' executive stakeholders groups and industry advisory committees. As such, test results meeting the DQOs will provide an acceptable level of data quality for technology users and decision makers. The DQOs for determination of fuel consumption are quantitative, as determined using a series of measurement quality objectives (MQOs) for each of the measurements that contribute to the parameter determination:

Verification Parameter	DQO (relative uncertainty)
Fuel Consumption	±2.0 %
Δ Fuel Consumption	±4.0 %

Each test measurement that contributes to the determination of a verification parameter has stated MQOs, which, if met, ensure achievement of that parameter's DQO. This verification is based on the *Distributed Generation and Combined Heat and Power Field Testing Protocol* which contains MQOs including instrument calibrations, QA/QC specifications, and QC checks for each measurement used to support the verification parameters being evaluated. Details regarding the measurement MQOs are provided in the following sections of the protocol:

§ 7.1	Power production
§ 7.2	Liquid fuels consumption

The DQO for emissions is qualitative in that the verification will produce emission rate data that satisfies the QC requirements contained in the EPA Reference Methods specified for each pollutant. The verification report will provide sufficient documentation of the QA/QC checks to evaluate whether the qualitative DQO was met. Details regarding the measurement MQOs for emissions are provided in the following section of the protocol:

§ 7.4	Emissions Data Validation

Completeness goals for this verification is to obtain valid data for 90 percent of the test periods (controlled test period and extended monitoring).

3.1. INSTRUMENT TESTING, INSPECTION, AND MAINTENANCE

GHG Center personnel or TRC/Cubix will subject all test equipment to the required QC checks. Before tests commence, operators will assemble and test all equipment as anticipated to be used in the field. They will, for example, operate and calibrate all controllers, flow meters, computers, instruments, and other measurement system sub-components per the specified test methods and/or this test plan. Test personnel will repair or replace any faulty sub-components before starting the verification tests. Test personnel will maintain a small amount of consumables and frequently needed spare parts at the test site. The field team leader will handle major sub-component failures on a case-by-case basis such as by renting replacement equipment or buying replacement parts.

3.2. INSPECTION AND ACCEPTANCE OF SUPPLIES AND CONSUMABLES

Emission analyzer calibrations will employ NIST-traceable or EPA Protocol 1 gases supplied either by a gas-divider dilution system or directly from cylinders. Per EPA protocol gas specifications, the actual concentration must be within ± 2 percent of the certified tag value. Gases certified to ± 1.0 percent will be used for multipoint gas analyzer calibrations in accordance with 40 CFR 92 specifications. Copies of all EPA protocol gas certifications will be available on-site.

The field team leader will provide technical oversight of the TRC/Cubix field activities. The GHG Center QA manager will review calibration data and QA/QC check results to verify that emissions measurements conform to reference method requirements.

4.0 DATA ACQUISITION, VALIDATION, AND REPORTING

4.1. DATA ACQUISITION AND DOCUMENTATION

Test personnel (responsible parties are noted below in parentheses) will acquire the following types of data and generate the following documentation during the verification:

- fuel consumption and power data (GHG Center)
- emissions data (GHG Center and TRC/Cubix)
- manually acquired parameters and printed output data from the sampling systems such as sampling and dilution air flow rates, exhaust gas analyzer concentration, ambient pressure, exhaust gas pressure, temperature, and ambient conditions (TRC/Cubix)
- QA/QC documentation as described in Section 3.0 (TRC/Cubix, GHG Center)
- field test documentation (GHG Center)
- corrective action and assessment reports (GHG Center)

TRC/Cubix will submit copies of all test-run printed outputs, calibration forms, analyses, certificates, etc. to the Field Team Leader as each test run is completed. These submittals must be complete prior to the Field Team Leader's departure after the final test run.

TRC/Cubix will prepare and submit a report in printed and electronic format to the GHG Center Field Team Leader within three weeks of the field activities' completion. The report will describe the test conditions, document all QA/QC procedures, include copies of calibrations, calibration gas, and the verification test results. The report will include a signed certification which attests to TRC/Cubix's conformance with all QA/QC procedures and the accuracy of the results. TRC/Cubix will attach all relevant test data as appendices.

The following subsections discuss each of these items and their role in the test campaign. The GHG Center will archive all electronic data, paper files, analyses, and reports at their Research Triangle Park, NC office in accordance with the QMP.

4.1.1. Fuel Consumption and Power Data

The GHG Center Field Team Leader will obtain fuel consumption and power data during the tests. In addition to documenting the data for use in the report, he will supply these data to TRC/Cubix staff for their use in the following sections.

4.1.2. Emissions Data

TRC/Cubix will be responsible for all emissions data, associated QA/QC log forms, paper, and electronic files until they are accepted by the Field Team Leader.

TRC/Cubix will report emission measurements for each test mode to the Field Team Leader as:

- ppmv (percent for CO_2) of emissions
- g/bhp-h of pollutants
- calculated exhaust flow rate based on Method 2 traverses.

4.1.3. Engine Documentation

The Field Team Leader will document the applicable engine specifications. Documentation will generally conform to 40 CFR §92.133 and will include information such as:

- engine family identification
- alternator generator efficiency specifications
- hourmeter readings prior to the baseline and treated fuel test series
- general duty description
- a description of the service during the break-in period

4.1.4. QA/QC Documentation

Upon completion of the field test activities, TRC/Cubix will provide copies of calibrations, pre-test checks, system response time, NO_2 converter efficiency, and other QA/QC documents to the Field Team Leader. 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 names of participating staff. These records will provide source material for the Verification Report's Data Quality section, and will be available to the QA Manager during audits.

4.1.5. Field Test Documentation

The Field Team Leader will obtain copies of all manually and digitally logged data. He will take site photographs and maintain a Daily Test Log which will include the dates and times for setup, testing, teardown, and other activities.

The Field Team Leader will record test run information and observations in the Daily Test Log and on a Daily Testing Checklist form such as the example in Appendix D-1. The Field Team Leader will submit digital and paper data files and the Daily Test Log to the Project Manager.

4.1.6. Corrective Action and Assessment Reports

A corrective action will occur when audits or QA/QC checks produce unsatisfactory results or upon major deviations from this Test Plan. Immediate corrective action will enable quick response to improper procedures, malfunctioning equipment, or suspicious data. The corrective action process involves the field team leader, project manager, and QA Manager. The GHG Center QMP requires that test personnel submit a written corrective action request to document each corrective action.

The field team leader will most frequently identify the need for corrective actions. In such cases, he or she will immediately notify the project manager. The field team leader, project manager, QA Manager and other project personnel, will collaborate to take and document the appropriate actions.

Note that the project manager is responsible for project activities. He is authorized to halt work upon determining 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 a problem's recurrence.

4.2. DATA REVIEW, VALIDATION, AND VERIFICATION

The project manager will initiate the data review, validation, and analysis process. At this stage, analysts will classify all collected data as valid, suspect, or invalid. The GHG Center will employ the QA/QC criteria specified in Section 3.0 and the associated tables. Source material for data classification include factory and on-site calibrations, maximum calibration and other errors, audit gas analyses results, and lab repeatability results.

In general, measurements which:

- meet the specified QA/QC checks,
- were collected when an instrument was verified as being properly calibrated,
- are consistent with reasonable expectations (e.g., manufacturers' specifications, professional judgment)

will form the basis for valid data.

The report will incorporate all valid data. Analysts may or may not consider suspect data, or it may receive special treatment as will be specifically indicated. If the DQO cannot be met, the project manager will decide to continue the test, collect additional data, or terminate the test and report the data obtained.

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

- on site -- by the field team leader
- before writing the draft report -- by the project manager
- during draft report QA review and audits -- by the GHG Center QA Manager

The field team leader's primary on-site functions will be to monitor TRC/Cubix activities and acquire fuel consumption and power generation data. He will review, verify, and validate certain data during testing. He will plan to be on-site during all test activities.

The QA Manager will use this test plan and documented test methods as references with which to review and validate the data and the draft report. He will review and audit the data in accordance with the GHG Center's QMP. For example, the QA Manager will randomly select raw data and independently calculate the verification parameters. The comparison of these calculations with the results presented in the draft report will yield an assessment of the GHG Center's QA/QC procedures.

4.3. DATA QUALITY OBJECTIVES RECONCILIATION

A fundamental component of all verifications is the reconciliation of the collected data with its DQO. In this case, the qualitative DQO assessment consists of evaluation of whether the stated methods were followed and satisfactory results obtained for the QC checks specified in Section 3.0. As discussed in Section 4.2, the field team leader and project manager will initially review the collected data to ensure that they are valid and are consistent with expectations. They will assess the data's accuracy and completeness as they relate to the stated QA/QC goals. If this review of the test data show that QA/QC goals were not met, then immediate corrective action is feasible, and will be considered by the project manager. DQOs will be reconciled after completion of corrective actions. As part of the internal Audit of Data Quality (ADQ), the GHG Center QA Manager will include an assessment of DQO attainment.

4.4. ASSESSMENTS AND RESPONSE ACTIONS

The field team leader, project manager, QA Manager, GHG Center Director, and technical peer-reviewers will assess the project and the data's quality as the test campaign proceeds. The project manager and QA Manager will independently oversee the project and assess its quality through project reviews, inspections if needed, a scheduled PEA, and an ADQ.

4.4.1. Project Reviews

The project manager will be responsible for conducting the first complete project review and assessment. Although all project personnel are involved with ongoing data review, the project manager must ensure that project activities meet measurement and DQO requirements.

The GHG Center Director will perform the second project review. The director is responsible for ensuring that the project's activities adhere to the ETV program requirements and stakeholder expectations. The GHG Center Director will also ensure that the field team leader has the equipment, personnel, and resources to complete the project and to deliver data of known and defensible quality.

The QA Manager will perform the third review. He is responsible for ensuring that the project's management systems function as required by the QMP. The QA Manager is the GHG Center's final reviewer, and he is responsible for assuring the achievement of all QA requirements.

ACES, Encana, and selected GHG Center stakeholders and/or peer reviewers will then review the report. Technically competent persons who are familiar with the project's technical aspects, but not involved with project activities, will function as peer reviewers. The peer reviewers will provide written comments to the project manager.

The GHG Center will submit the draft report to EPA QA personnel, and the Project Manager will address their comments as needed. Following this review, the report will undergo EPA management reviews, including the GHG Center Director, EPA ORD Laboratory Director, and EPA Technical Editor.

4.4.2. Performance Evaluation Audit

The GHG Center will conduct a performance evaluation audit (PEA) of the emission sampling system and analyzers. The PEA will be performed by introducing a sample of audit gas of known concentration to the system. The performance evaluation audit (PEA) gas will consist of a mixture of NO_X in N_2, but whose exact concentration is blind to the system operator. The field team leader will supply the audit gas to the sample probe from the cylinder through one leg of a sample line with a tee fitting. The remaining leg will be open to atmosphere through a rotameter. The cylinder regulator will supply gas at the system's normal sampling rate (approximately 40 lpm) with enough surplus such that the rotameter shows flow to the atmosphere. The field team leader will submit the data to the QA Manager, who will incorporate them into a PEA report to the GHG center.

4.4.3. Test/QA Plan Implementation Assessment

The GHG Center has previously conducted numerous internal technical systems audits (TSAs) of the methods and procedures proposed for this verification and will therefore not repeat a TSA for this test. However, the GHG Center QA Manager or designee will conduct a readiness review and observe and document a pre-test assessment and bench test of the measurements system including the following systems:

- fuel meters, transmitter, and datalogger
- temperature and pressure sensors and datalogger
- power consumption meters

During the assessment, the QA Manager will verify that the equipment, procedures, and calibrations are as specified in this test plan. Should the QA Manager note any deficiencies in the implementation of the test plan, corrective actions will be immediately implemented by the project manager. The QA Manager will document this assessment in a separate report to the GHG Center Director.

4.4.4. Audit of Data Quality

The ADQ is an evaluation of the measurement, processing, and data analysis steps to determine if systematic errors are present. During the ADQ, the QA Manager, or designee, will randomly select approximately 10 percent of the data. He will follow the selected data through analysis and data processing. The ADQ's scope is to verify that the data-handling system functions correctly and to assess the quality of the analysis. The QA Manager will also include an assessment of DQO attainment.

The QA Manager will route the ADQ results to the project manager for review, comments, and possible corrective actions. Project records will document the results. The project manager will take any necessary corrective action needed and will respond by addressing the QA Manager's comments in the report.

4.5. VERIFICATION REPORT AND STATEMENT

The project manager will coordinate report preparation. The report will summarize each verification parameter's results as discussed in Section 2.0 but will not include the raw data or QA/QC checks that support the findings. All raw and processed measurements data as well as calibration data and QA/QC checks will be made available to EPA as a separate CD, and can be provided to other parties interested in assessing data trends, completeness, and quality by request. The report will clearly characterize the verification parameters, their results, and supporting measurements as determined during the test campaign. The report will also contain a Verification Statement, which is a 3 to 5 page document summarizing the technology, the test strategy used, and the verification results obtained.

The Project Manager will submit the draft Report and Statement to the QA Manager and Center Director for review. A preliminary outline of the report is as follows:

Preliminary Outline
ACES Diesel Fuel Additive Verification Report

Verification Statement

Section 1.0:	*Verification Test Design and Description* *Description of the ETV program* *Additive and Test Engine Description* *Overview of the Verification Parameters and Evaluation Strategies*
Section 2.0:	*Results*

Fuel Consumption Change
Emissions Performance

Section 3.0: *Data Quality*

Section 4.0: *Additional Technical and Performance Data (optional) supplied by ACES*

References:
Appendices: *Raw Verification and Other Data*

4.6. TRAINING AND QUALIFICATIONS

This test does not require specific training or certification beyond that required internally by the test participants for their own activities. The GHG Center's field team leader is an engineer with approximately 20 years experience in field testing of air emissions from many types of sources. He is also familiar with engine and vehicle testing, operations, maintenance, and repair. He is familiar with the test methods and standard requirements that will be used in the verification test.

The project manager has performed numerous field verifications under the ETV program, and is familiar with EPA and GHG Center QMP requirements. The QA Manager is an independently appointed individual whose responsibility is to ensure the GHG Center's conformance with the EPA approved QMP.

4.7. HEALTH AND SAFETY REQUIREMENTS

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

Encana and Nabors enforce strict adherence to a comprehensive health and safety program at all of their field drilling sites. The GHG Center staff will obtain a copy of the plan and will receive site safety orientation from the Nabors site safety supervisor upon arrival to the site. GHG Center staff and their subcontractors will comply with all aspects of the site safety plan. This includes use of personal protective gear (e.g., safety glasses, hard hats, hearing protection, safety toe shoes) as required by the host, completion of site safety orientation (i.e., site hazard awareness, alarms and signals), and personnel tie-offs when working at heights above six feet.

5.0 REFERENCES

1. *Distributed Generation and Combined Heat and Power Field Testing Protocol, DG/CHP Version*, Southern Research Institute, EPA Cooperative Agreement No. R-82947801, September 2005.

2. *Generic Verification Protocol for Determination of Emissions Reductions Obtained by Use of Alternative or Reformulated Liquid Fuels, Fuel Additives, Fuel Emulsions, and Lubricants for Highway and Nonroad Use Diesel Engines and Light Duty Gasoline Engines and Vehicle*s, Research Triangle Institute, EPA Cooperative Agreement No. CR826152-01-3, September 2003.

3. *Reciprocating Internal Combustion Engines – Exhaust Emission Measurement - Part 1,* ISO Standard 8178-4, Geneva, Switzerland, 1996.

4. *SAE J1321, Surface Vehicle Recommended Practice, Joint TMC/SAE Fuel Consumption Test Procedure* -- *Type II*, SAE International, Warrendale, PA 1986.

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Appendix A-1
Caterpillar Model 399 Specifications

ECI Conversion Specifications Tables

ECI CONVERSION SPECIFICATIONS -CAT 399 TURBOCHARGED DUAL FUEL ENGINE						
ENGINE TYPE	**379DF**		**398DF**		**399DF**	
NUMBER OF CYLINDERS	**8**		**12**		**16**	
RPM	1200		1200		1200	
BHP	645		970		1260	
KW prime	400		600		800	
KW standby w/o fan	450		675		905	
EFFICIENCY BTU/ hp-hr	**Diesel / Gas&Diesel**					
100% load	7670	6825**	7670	6825**	7670	6825*
75% load	7450	7920*	7350	7561*	7300	7950
50% load	9850	9920*	9950	10000*	9950	10750
AIR & EXHAUST SYSTEMS						
Intake air temp (77F) CFM	3800	5000*	5400	7500*	7380	10000
Exhaust temp in (F)	-	715*	-	740*	-	720
Exh. volume @ exh. temp CFM	7980	10500*	11340	15700*	15500	20350
EMISSIONS						
NHMC in g/hp-hr						
CO in g/hp-hr	CURRENTLY TESTING					
NOx in g/hp-hr						
AFTERCOOLING SYSTEM						
Water flow rate gal/min	40*		60*		60	
Heat Rejection rate BTU/hr	236K**		354K**		472K*	
Raw water	85 F					
Water Pump hp	2		3		3	
DIESEL FUELING RATES, gal/hr	**Diesel / Gas&Diesel**					
Gas Flow @ 100% load	36	11.5*	54	17.5*	72	23
Gas Flow @ 75% load	26	4.2*	39	6.3*	53	8.4
Gas Flow @ 50% load	17	2.5*	25	3.8*	35	4.7*
Injector timing set to 5 degrees after TDC						
GAS FUEL FUELING RATES, SCFM						
100% load	49*		73*		98	
75% load	41*		62*		82	
50% load	36*		54*		72	
* values extrapolated from 16 cylinder test data						
* Baseline figures. System details affect actual values.						

Appendix A-2
Example Load Bank Data

ENGINE GENERATOR PERFORMANCE TEST REPORT

DATE: **5/16/2005**

JOB NO:

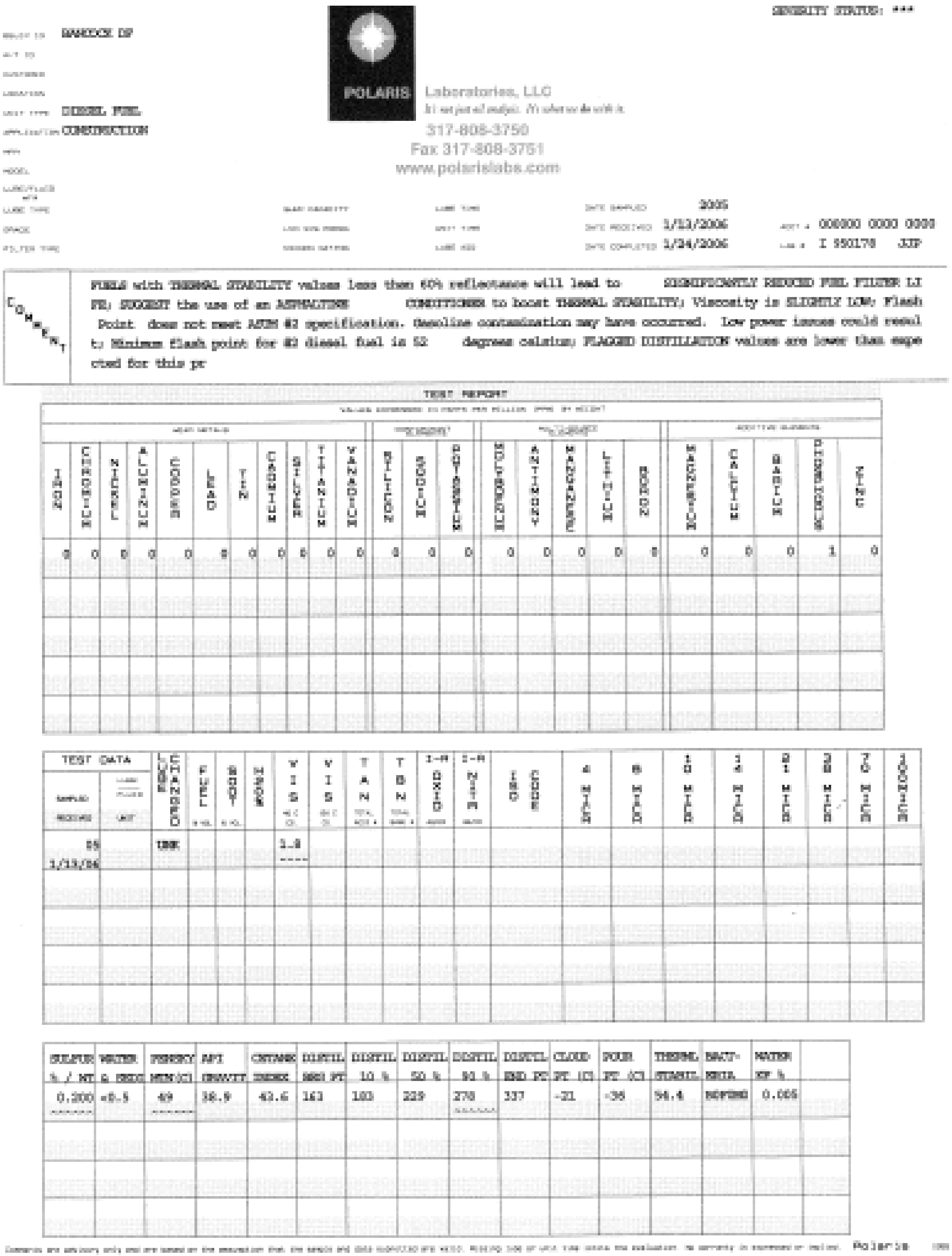
SERIAL NO:

EQUIP. NO:

KW : 800

TIME	PERCENT LOAD	VOLTS	AMPS	HERTZ	RPM	OIL PRESSURE	FUEL PSI	KVA	KW
11:00	99.740988	599	770	60	1200	65	35	797.928	797.928
:15	100.07401	601	770	60	1200	65	35	800.592	800.592
:30	100.07401	601	770	60	1200	65	35	800.592	800.592
:45	100.07401	601	770	60	1200	65	35	800.592	800.592
12:00	100.07401	601	770	60	1200	65	35	800.592	800.592
:15	100.07401	601	770	60	1200	65	35	800.592	800.592
:30	100.07401	601	770	60	1200	65	35	800.592	800.592
:45	100.07401	601	770	60	1200	65	35	800.592	800.592
1:00	100.07401	601	770	60	1200	65	35	800.592	800.592

Appendix B-1 - Example Fuel Analysis



SEVERITY STATUS: ***

BANCOCK DF

DIESEL FUEL

CONSTRUCTION

POLARIS Laboratories, LLC

317-808-3750

Fax 317-808-3751

www.polarislabs.com

2005

1/13/2006

1/24/2006

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COMMENT

FUELS with THERMAL STABILITY values less than 60% reflectance will lead to SIGNIFICANTLY REDUCED FUEL FILTER LIFE; SUGGEST the use of an ASPHALTINE CONDITIONER to boost THERMAL STABILITY; Viscosity is SLIGHTLY LOW; Flash Point does not meet ASTM #2 specification. Gasoline contamination may have occurred. Low power issues could result; Minimum flash point for #2 diesel fuel is 52 degrees celsius; FLAGGED DISTILLATION values are lower than expected for this pr

TEST REPORT

IRON	CHROMIUM	NICKEL	ALUMINUM	COPPER	LEAD	TIN	CADMIUM	SILVER	TITANIUM	VANADIUM	SILICON	SODIUM	POTASSIUM	MOLYBDENUM	ANTIMONY	MANGANESE	LITHIUM	BORON	MAGNESIUM	CALCIUM	BARIUM	PHOSPHORUS	ZINC
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0

TEST DATA		FUEL CHANGED	FUEL	SOOT	H2O	VIS	VIS	TAN	TBN	I-R OXID	I-R NITR	ISO CODE	4 MICR	6 MICR	10 MICR	14 MICR	21 MICR	38 MICR	70 MICR	100MICR
05 1/13/06		UNK				1.8														

SULFUR % / WT	WATER & SEDI	PENSKY MRTN (C)	API GRAVITY	CETANE INDEX	DISTIL INI PT	DISTIL 10 %	DISTIL 50 %	DISTIL 90 %	DISTIL END PT	CLOUD PT (C)	POUR PT (C)	THERML STABIL	BACT-ERIA	WATER KF %
0.200	<0.5	49	38.9	43.6	163	183	229	278	337	-21	-36	54.4	NOFUND	0.005

Appendix B-2. Hammonds Additive Injector

Hammonds

HAMMONDS TECHNICAL SERVICES, INC.

The Hammonds additive injectors are designed with two basic components.

1. The fluid motor
2. The pump

The motors and pumps can be manufactured together in a variety of ways to accommodate the product flow rate and the additive dosage which the application requires.

The fluid motor is a unique positive displacement drive which responds precisely to changes in product volume even at very low flow rates. All Hammond's additive injection systems dispense precise quantities of additive at a continuous rate. The additive is injected just ahead of the fluid motor which provides complete, consistent additive blending.

The additive pump is a positive displacement diaphragm or plunger design. The pump is connected to the fluid motor's shaft which travels in an eccentric motion. As the shaft turns the diaphragm or plunger is actuated which delivers the additive proportionate to product flow.

The additive is controlled via a stroke adjustment knob located directly on the additive pump. This knob can either increase or decrease the stroke length of the diaphragm or plunger. By doing so the additive dosage rate is either increased or decreased. The stroke adjustment knob is locked securely to maintain proper dosage rates.

The additive dosage rate is held to repeatable accuracy of +/- 2%

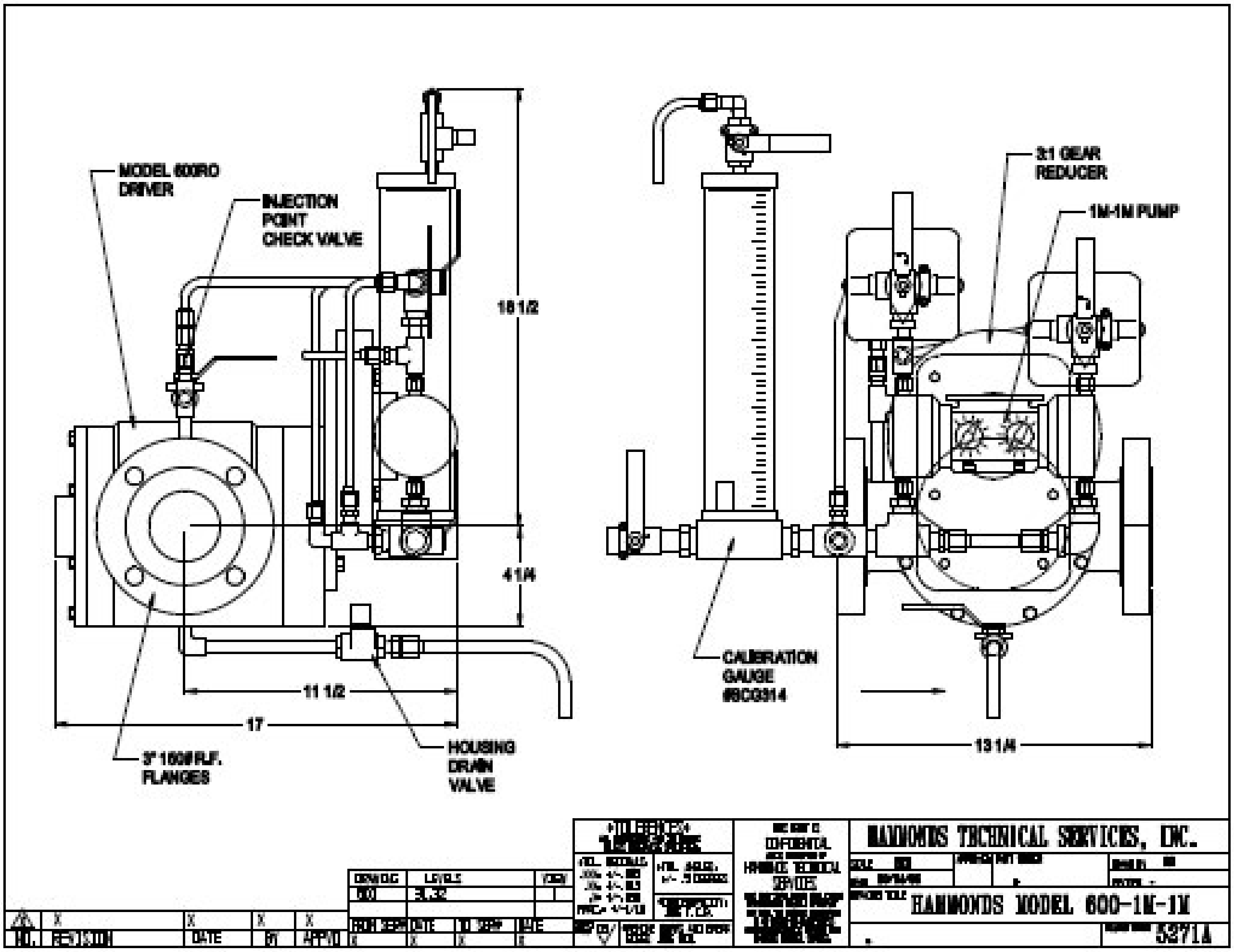
The injection rate can be verified by two methods;

1. Suction calibration gauge
2. Additive meter

The suction calibration gauge enables the operator to verify system operation at a glance, and calibrate the injector accurately without handling the additive. It consists of a graduated reservoir on the suction side of the injector. During calibration, the main additive tank is isolated and additive is drawn from the graduated column. This additive is measured and compared with the amount of product which has passed through the fluid motor (usually by the product meter located on the fueling vehicle or fuel storage facility). With the use of simple calculations the exact additive injection rate can be recorded. The Suction Calibration Gauge provides very accurate calibration at a fraction of the time and complexity normally associated with collecting samples in open containers.

The additive meter is another way of verifying accuracy. A digital meter can be installed on the discharge of the additive pump. These meters are factory calibrated to meet the additive requirements. The digital readout will display how many ounces of additive have passed through the meter and into the product line. This amount can then be verified against the amount of fuel which has been offloaded into the product storage tank.

910 RANKIN ROAD • HOUSTON, TEXAS 77073-4604 • (281) 999-2900 • (800) 582-4224 • FAX: (281) 847-1857



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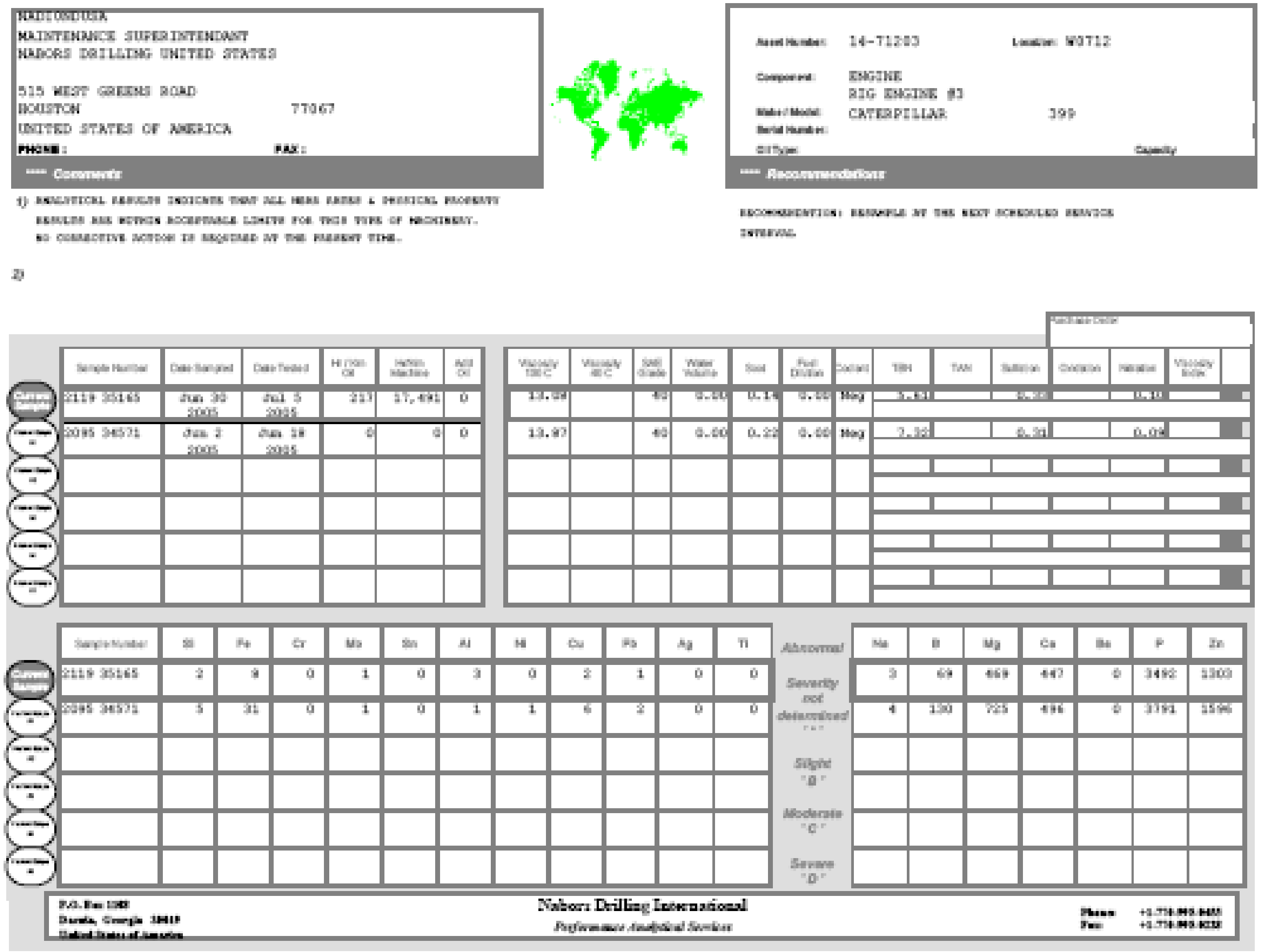
Appendix C-1
Example Crankcase Oil Analysis



NADIONDUSA
MAINTENANCE SUPERINTENDANT
NABORS DRILLING UNITED STATES

515 WEST GREENS ROAD
HOUSTON 77067
UNITED STATES OF AMERICA
PHONE: **FAX:**

Asset Number: 14-71203 Location: W0712
Component: ENGINE
RIG ENGINE #3
Make / Model: CATERPILLAR 399
Serial Number:
Oil Type: Capacity:

****** Comments**

1) ANALYTICAL RESULTS INDICATE THAT ALL WEAR RATES & PHYSICAL PROPERTY RESULTS ARE WITHIN ACCEPTABLE LIMITS FOR THIS TYPE OF MACHINERY. NO CORRECTIVE ACTION IS REQUIRED AT THE PRESENT TIME.

2)

****** Recommendations**

RECOMMENDATION: RESAMPLE AT THE NEXT SCHEDULED SERVICE INTERVAL.

Purchase Order

Sample Number	Date Sampled	Date Tested	Hr (on) Oil	Hr/Km Machine	Add Oil
2119 35165	Jun 30 2005	Jul 5 2005	217	17,491	0
2095 34571	Jun 2 2005	Jun 18 2005	0	0	0

Viscosity 100 C	Viscosity 40 C	SAE Grade	Water Volume	Soot	Fuel Dilution	Coolant	TBN	TAN	Sulfation	Oxidation	Nitration	Viscosity Index
13.08		40	0.00	0.14	0.00	Neg	[illegible]		[illegible]		[illegible]	
13.87		40	0.00	0.22	0.00	Neg	7.32		0.31		0.09	

Sample Number	Si	Fe	Cr	Mo	Sn	Al	Ni	Cu	Pb	Ag	Ti
2119 35165	2	9	0	1	0	3	0	2	1	0	0
2095 34571	5	31	0	1	0	1	1	6	2	0	0

Abnormal
Severity not determined "*"
Slight "B"
Moderate "C"
Severe "D"

Na	B	Mg	Ca	Ba	P	Zn
3	69	469	447	0	3492	1303
4	130	723	496	0	3791	1596

[illegible]
[illegible]
United States of America

Nabors Drilling International
Performance Analytical Services

Phone [illegible]
Fax [illegible]

Appendix D-1

DAILY TESTING CHECKLIST

Date:

Fuel:

Emission Control:

Location:

Vehicle Manufacturer:

Vehicle Identification #:

Engine Manufacturer:

Engine Displacement:

Sampling System Air Inlet Isolated From Exhaust Sources:

Sampling Bench checked for leaks:

LFE connections verified: N/A

Fuel meters operational:

Speed sensor operational: **or Signals available for speed calcs:**

Exhaust lines checked:

Sample probe alignment verified:

1 hour system warm-up
Analyzer bench:
Black Box main power on:

Note: The warmup is to allow the instruments and MFC's to reach operating temperature

Solenoid valves operational: Bench Boxes

Flow controllers operational:

SAMPLING SYSTEM READY

IS THE VEHICLE READY?

Installation verified/approved by: