SRI/USEPA-GHG-QAP-11
February 2001

Testing and Quality Assurance Plan

MIRATECH Corporation
GECO^{TM} 3001 Air/Fuel Ratio Controller

Prepared by:

Southern Research Institute
Greenhouse Gas Technology Verification Center

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

ETV ETV ETV

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Greenhouse Gas Technology Verification Center

A USEPA Sponsored Environmental Technology Verification Organization

Testing and Quality Assurance Plan
MIRATECH Corporation
GECO™ 3001 Air/Fuel Ratio Controller

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☒ indicates comments are integrated into Plan

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This plan is reviewed and approved by the Greenhouse Gas Technology Verification Center Director, the SRI Q/A Manager, the USEPA Pilot Manager, and the USEPA Pilot Quality Manager.

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ACRONYMS / ABREVIATIONS

A/cm	Angstrom per centimeter
BHp	Brake horsepower
^{o}BTDC	Before top dead center
cfh	Cubic Feet Per Hour
CFR	Code of Federal Regulations
CH_4	Methane
CO	Carbon monoxide
CO_2	Carbon dioxide
cSt	Centistokes
DQI	Data Quality Indicator
DQO	Data Quality Objective
DP	Differential pressure
EPA	United States Environmental Protection Agency
ETV	Environmental Technology Verification
ft^3	Feet Cubed
Ft-lbs	Foot-Pounds
g	Gram
g/BHp-hr	Grams per brake horsepower-hour
H_2O	Water
Hp	Horsepower
hr	Hour
lb	Pounds
lb/hr	Pounds per hour
MMbtu	Million British Thermal Units
Msec	Millisecond
NO_x	Nitrogen oxides
O_2	Oxygen
ppm	Parts per million
ppmvd	Parts per million volume drybase
PSIG	Pounds per square inch gauge
QA	Quality Assurance
rpm	Revolutions per minute
SCF	Standard cubic foot
SRI	Southern Research Institute
THC	Total hydrocarbons
GHG Center	Greenhouse Gas Technology Verification Center
WC	Water column
^{o} F	Degrees Fahrenheit

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1.0 INTRODUCTION

1.1 BACKGROUND

The U.S. Environmental Protection Agency's Office of Research and Development (EPA-ORD) has created a program to facilitate the deployment of innovative technologies through independent 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 more cost-effective technologies. The ETV program is funded by Congress in response to the belief that there are many viable environmental technologies that are not being used because of the lack of credible third-party performance testing. With performance data developed under this program, technology buyers and permitters in the United States and abroad will be better equipped to make informed decisions regarding environmental technology purchases.

The Greenhouse Gas Technology Verification Center (GHG Center) is one of 12 independent verification organizations operating under the ETV program. The GHG Center is managed by EPA's partner verification organization, Southern Research Institute (SRI). The GHG Center provides a verification testing capability to GHG technology vendors, buyers, exporters, and others that have a need for independent performance data. This process consists of developing verification protocols, conducting field tests, collecting and interpreting field and other data, and reporting findings. Performance evaluations are conducted according to externally reviewed test plans and established protocols for quality assurance.

The GHG Center is guided by volunteer groups of Stakeholders. These Stakeholders offer guidance on specific technologies most appropriate for testing, help disseminate results, and review test plans and verification reports. The GHG Center's stakeholder groups and/or external reviewers consist of national and international experts in the technology areas selected for verification. They also include industry trade organizations, environmental technology finance groups, and various government and international organizations. Based on stakeholder input, oil and gas industry technology areas have been targeted for verification by the GHG Center.

To pursue verification testing in oil and gas technology areas, the GHG Center established an Oil and Gas Industry Stakeholder Group. The group consists of representatives from the production, transmission, and storage sectors, technology manufacturers, industry consultants and service providers, and environmental regulatory groups. Individuals who are members of the Oil and Gas Industry Stakeholder Group have voiced support for the GHG Center's mission, identified a need for independent third-party verification, prioritized specific technologies for testing, and identified technology performance parameters of most interest to their industry.

In the natural gas industry, transmission pipeline operators use internal combustion (IC) gas-fired engines to provide the mechanical energy needed to drive pipeline gas compressors. As such, owners and operators of compressor stations are interested in the performance of these engines with regard to engine fuel consumption, reliability, availability, and emissions. MIRATECH Corporation has developed a technology that has the potential to improve these engine performance characteristics. MIRATECH's GECO 3001 Air/Fuel Ratio Controller (the Controller) is designed to balance lean-burn engine fuel mixtures and improve fuel economy, maintenance requirements, and emissions performance. MIRATECH has committed to participate in a verification of this technology. The test will be carried out at a gas processing station operated by Conoco Incorporated (Conoco) of Houston, Texas. This Test

Plan describes the technology to be tested, and outlines the GHG Center's plans to conduct the verification in a field setting.

1.2 VERIFICATION PARAMETERS

Field testing of the GECO Controller will be conducted at Conoco's Conger Station gas processing facility near Sterling City, Texas. The test is scheduled to begin in January 2001, and will continue for a period of approximately 3 months. After completion of the test, a Verification Statement and Report will be issued that documents the performance of the technology at test conditions. The specific verification parameters to be evaluated are listed below. Determination of each parameter is discussed in Section 2.2.

- Changes in fuel consumption rates for primary engine operating conditions,
- Changes in emissions of criteria pollutants and greenhouse gases,
- GECO Controller installation and shakedown requirements, and
- Lubrication oil degradation.

Evaluation of these verification parameters will be achieved through observation, collection and analysis several critical measurements including direct fuel gas measurements, direct measurements of engine emissions, direct measurement of engine power output, use of station monitoring data, and engine oil analyses. These parameters will be used to determine if installation and use of the Controller results in changes in engine performance.

1.3 GECO 3001 CONTROLLER DESCRIPTION

As engine operations and conditions change over time, engine performance and emissions can be impacted by these changes. Variables such as engine speed and load, fuel gas quality, and ambient air conditions can have significant effects on engine operation and the air/fuel ratio in the cylinders. The GECO Controller is an air/fuel ratio controller designed to improve performance of natural gas-fired, four-cycle, lean-burn reciprocating engines by optimizing and stabilizing the air/fuel ratio over a range of engine operations and conditions.

This device was first introduced in 1997 and currently there are about 25 units in operation in the gas transmission industry. The technology uses a closed-loop feedback system to automatically and continuously optimize the air/fuel mixture introduced to the engine. This function provides the potential to improve engine fuel consumption and reduce engine emissions, particularly when changes in engine load, fuel quality, or ambient conditions occur. Optimized and stabilized air/fuel ratios can improve engine performance, reduce lubrication oil degradation, and help minimize wear to major engine components and therefore, the Controller also has the potential to reduce engine maintenance. The Controller can be configured to operate based on engine exhaust oxygen (O_2) feedback, or generator output (kW) feedback for engines used to drive electrical generators. Using either approach, the controller monitors the O_2 or kW sensor inputs and controls the air-to-fuel ratio generated by the carburetor. This verification will address only the exhaust oxygen feedback system because the test engine will not be driving a generator.

The Controller uses relationships between excess air in the combustion chamber, measured exhaust gas O_2 concentrations, and engine emissions to calculate optimum air/fuel ratios at various engine loads. Typical relationships between excess air and emissions in lean-burn gas-fired engines are illustrated in Figure 1-1. Using exhaust gas O_2, intake air manifold pressure (MAP), intake air manifold temperature (MAT), and engine speed (MAG-pickup) as primary indicators of engine operation, the Controller continuously adjusts air/fuel ratios in the engine by adjusting and controlling fuel flow to the carburetor.

Fuel flow is adjusted using a full authority fuel valve that is supplied by the vendor and installed directly into the engine fuel line, upstream of the carburetor/mixer. Figure 1-2 presents a schematic of the GECO Controller. Table 1-1 summarizes the components that are included in a typical Controller installation and their function.

Figure 1-1. Relationship of Excess Air and Exhaust Gas Characteristics

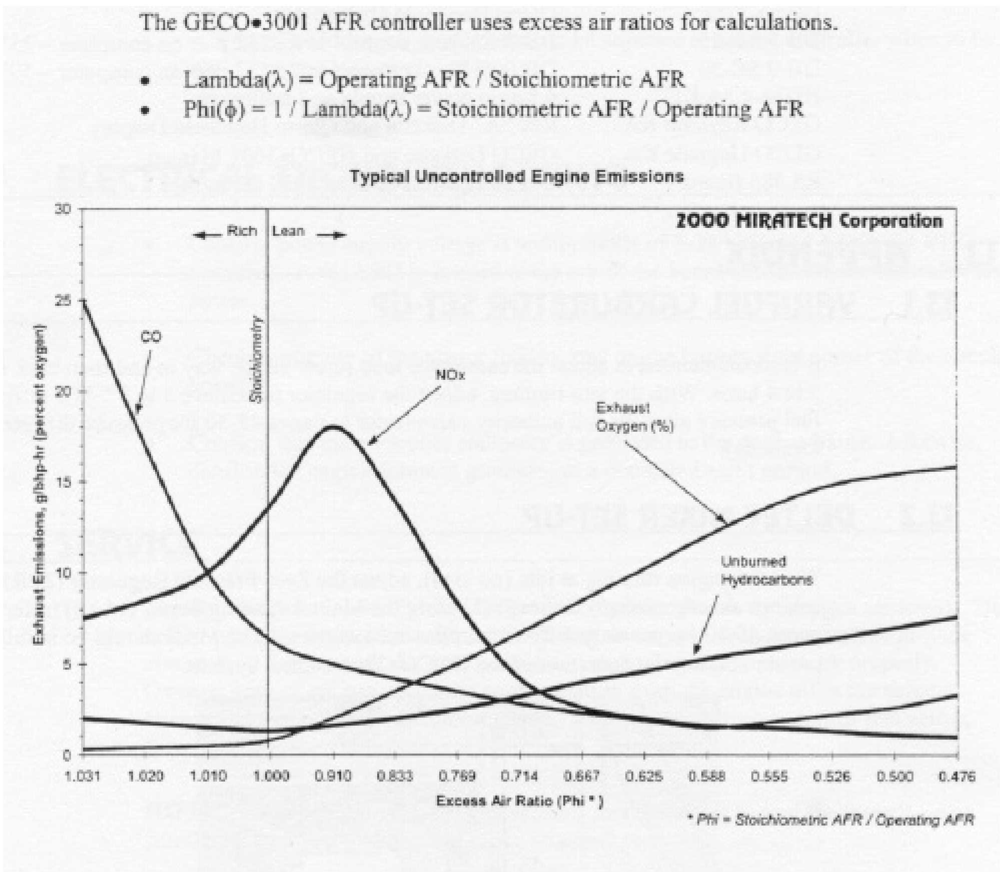


Figure 1-2. Schematic of the GECO 3001 Controller

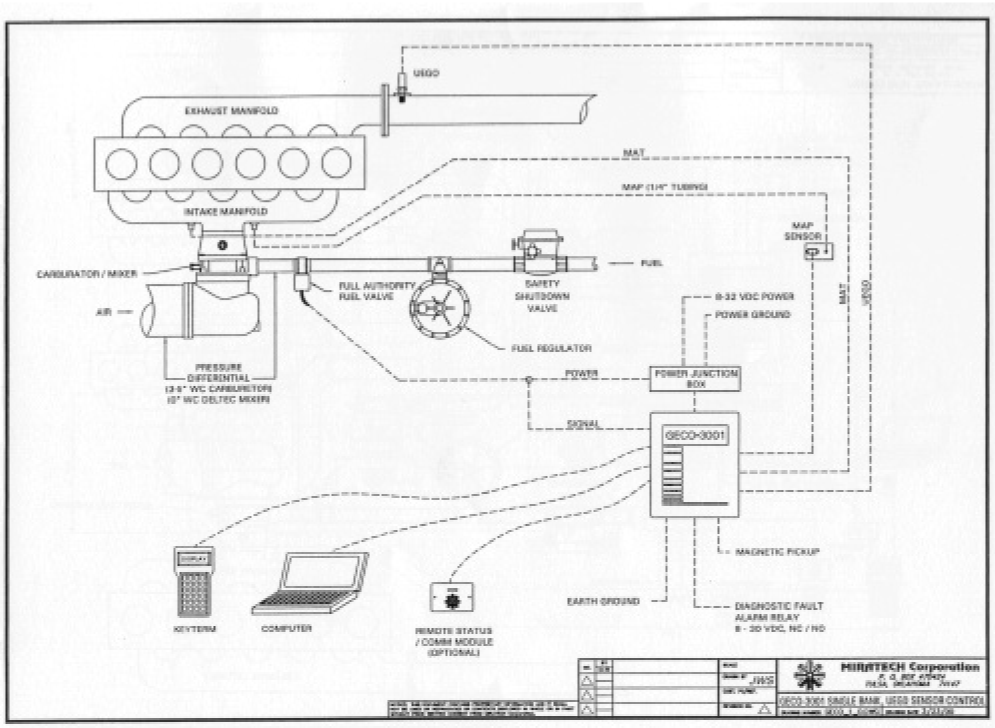


Table 1-1. GECO Air/Fuel Controller System Components	
Component	**Function**
ECU Control Board	Includes the microprocessor controller and all electronics associated with power regulation, signal inputs and filtering, controlled outputs, and communications. Also includes the closed-loop enable switch.
Keyterm	A communication terminal useful for communication with the Controller in applications where a PC is not available.
User Interface Module	Allows the user to view Controller status using three LED displays including Controller power, shutdown relay, and fault relay
Full Authority Fuel Valve	An electronically actuated, full authority valve used to control fuel flow to the air/fuel carburetor/mixer.
Manifold Temperature Sensor	A thermal resistor used to monitor intake manifold absolute temperature (MAT) to determine M-dot air and calculations (M-dot air is a default air temperature set-point used during engine startup).
Manifold Pressure Sensor	A 5-volt reference pressure sensor used to monitor intake manifold absolute pressure (MAP) from 0 to 43 psia, used as an indicator of engine load.
Engine Speed Sensor	A magnetic pickup (MAG) sensor used to determine engine speed (RPM) by counting pins on the flywheel.
Exhaust Oxygen Sensor	A universal exhaust gas oxygen (UEGO) sensor used to continuously monitor the oxygen concentration in the exhaust gas.
GECO Diagnostic Software	Provides advanced troubleshooting capabilities using diagnostic fault codes, oscilloscope plotting, and data-logging.

Figure 1-2 and Table 1-1 show that the four input variables to the Controller during operation are exhaust gas O_2 content, MAP, MAT, and MAG-pickup. The O_2 signal indicates the excess air level, the MAP signal is used by the Controller to estimate engine load, the MAT signal is used to calculate the M-dot air breakpoint (a pre-programmed exhaust gas O_2 threshold level that disables the Controller during engine startup), and the MAG-pickup sensor monitors engine speed. After all system components are installed on an engine and confirmed to be functional, the Controller must then be programmed to control air/fuel ratios to levels most desirable for a specific engine and application. During programming, the engine air/fuel ratios are varied while monitoring emissions to determine the optimum ratios with respect to engine NO_x emissions. The optimum air/fuel ratio value is identified as Phi-desired. The engine is then operated at a range of loads and, while monitoring the three input variables (O_2, MAT, MAP, and MAG-pickup) to the Controller, the fuel valve is adjusted to achieve Phi-desired at each load. The valve positions and input variables at each operating point are stored by the Controller as the Phi-target table. When in operation, the Controller produces a continuous valve command that controls valve position, and subsequently, the air/fuel ratio.

The Controller can be used in three different modes of operation including open-loop, closed-loop, and manual modes. When the engine is started, the Controller sets the fuel valve to a crank default valve position that can be set a any position. The valve remains in this position until the engine reaches 400 rpm, at which point the Controller goes into open-loop mode and sets valve positions according to a valve learn table. The valve-learn table uses the O_2 and MAT sensor input values to calculate the mdot_air (mass air flow rate to engine) and mdot_fuel (mass fuel flow rate) values.

The Controller will operate in open-loop mode (using the valve-learn table) until the mdot_air reaches a value higher than the mdot_air breakpoint value. The mdot_air breakpoint value is determined during Controller programming as the point where the Controller will go into closed-loop mode of operation. Once in closed-loop mode, the Controller uses input signals for engine speed and air pressure (the MAG-pickup and MAT sensors) to look up the Phi-target valve positions from the pre-programmed valve table, and set the valve at that position to optimize the air/fuel ratio. Manual mode is primarily a troubleshooting tool that allows the user to disable the Controller and manually control the fuel valve to observe the sensor and emissions responses and program the controller during system installation and set-up.

1.4 TEST FACILITY DESCRIPTION

This verification will be hosted by Conoco, Inc. at their Conger Plant near Sterling City, Texas. This facility is an extraction plant where natural gas is extracted and processed for subsequent transport and sale. The plant recovers hydrocarbons of C_2 and heavier from the natural gas, then compresses the methane for sale. The plant has a capacity of approximately 25 million cubic feet per day, and is equipped with five internal combustion engines including two Caterpillar Model 3516-SI re-compressors, two Caterpillar Model 3406 generator sets, and one Caterpillar Model 3508 refrigeration unit.

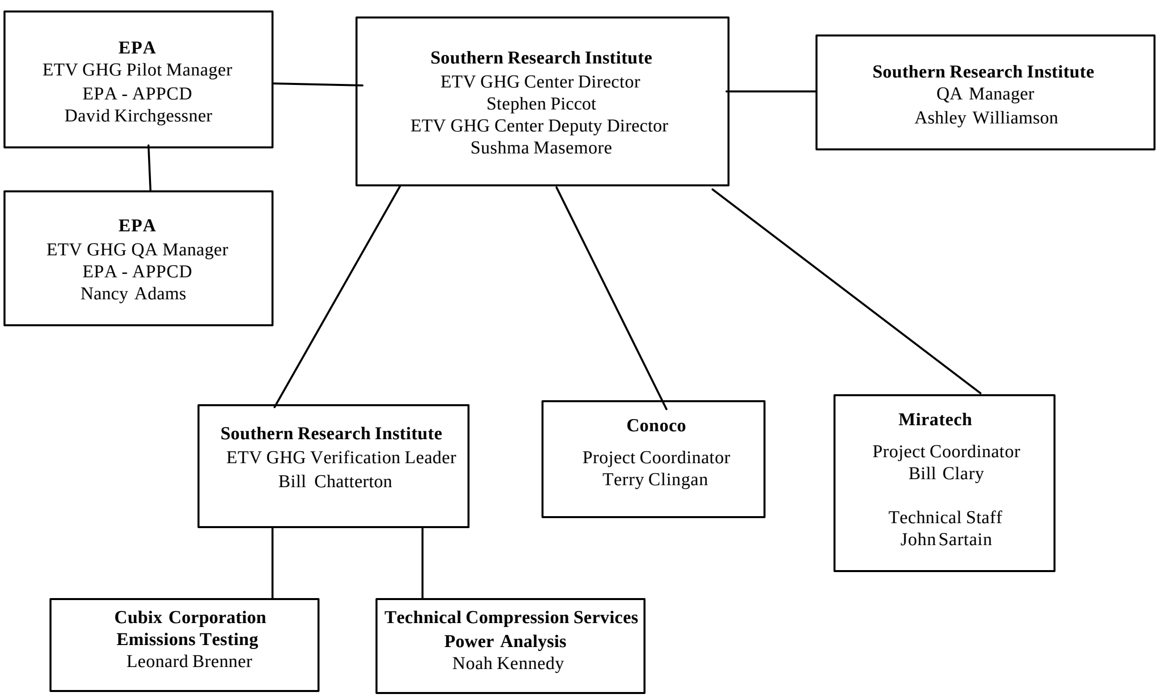
The two Caterpillar 3516-SI lean-burn re-compressor engines will be used to conduct this verification. Unit No. CM-101 will be equipped with the Controller and be designated as the Test Engine. Unit No. CM-102 will be the Control Engine used for comparison of engine oil conditions. Both units were exchanged during a scheduled overhaul with zero-hour units (engine with no run time) the first week of August 2000. Both engines have a rated power output of 1,085 BHp and consume approximately 5,200 cubic feet per hour (cfh) natural gas from a common fuel header during normal operation. The engines are lean-burn design and no additional emission controls are employed. Current permissible emission rates for the engines as mandated by the State of Texas are 1.9 grams per brake horsepower-hour (g/BHp-hr) for NO_x and 1.5 g/BHp-hr for CO (corresponding concentrations are expected to be in the range of 200 to 300 ppm for NO_x and CO).

Both engines drive reciprocating gas compressors that elevate pipeline gas pressure from approximately 250 to 850 psig. The compressors are Ariel Model JGK two-stage units. The two engine/compressor sets operate on the same schedule and load during normal station operation. Engine speed may vary somewhat between the engines depending on inlet gas volumes. Under normal operations, the engines run at or near full capacity with an average annual utilization of approximately 96 percent. Reduced operating loads can be achieved on the engines for short periods in order to facilitate the testing planned for this verification. The station monitors engine operations continuously, but has limited data acquisition capabilities. Therefore, engine operating parameters that are key to this verification will be monitored by the GHG Center using procedures described in Section 2.2.1 of this Plan.

1.5 ORGANIZATION

The project team organization chart is presented in Figure 1-3. A discussion of the functions, responsibilities, and lines of communication between the organizations and individuals associated with this verification test is provided below.

Figure 1-3. Project Organization



Southern Research Institute's Greenhouse Gas Technology Verification Center has overall responsibly for planning and ensuring the successful implementation of this verification test. Mr. William Chatterton will have the overall responsibility as the project manager. He will be responsible for quality assurance at the test site, including determination of DQOs prior to the completion of the test. Mr. Chatterton will follow the procedures outlined in Section 3.0 to make this determination, and will have fully authority to repeat tests as determined necessary. Should a situation arise during the test that could affect the health or safety of any personnel, Mr. Chatterton will have full authority to suspend testing. Mr. Chatterton will be responsible for maintaining communication with MIRATECH, EPA, and Conoco.

Mr. Chatterton will also serve as the Field Team Leader, and will provide field support related to all measurements data collected, including fuel measurements, emissions testing, and efficiency determination. Mr. Chatterton has over 16 years experience in environmental testing with emphasis on emissions testing, flow measurements, field verifications, and project management. He will manage the emissions testing crew and the power measurement contractor to ensure that QA/QC procedures outlined in Sections 3.0 and 4.0 are followed.

Conoco will provide the engines where all testing will be conducted. Conoco technicians will operate the engines, maintain manual operations log, and submit data recorded by the DAS. Conoco will be available on-site to perform instrument checks if the GHG Center determines data collected by measurements instruments are suspect. Mr. Terry Clingan will have the full authority over the activities performed by Conoco technicians, and will coordinate with Mr. Chatterton throughout the test.

The GHG Center's Quality Assurance Manager, Mr. Ashley Williamson, will review and approve the Test Plan, and test results from the verification test. He will conduct an internal Technical Systems Audit and an Audit of Data Quality, as required in the GHG Center's QMP. Further discussion of these audits is provided in Section 5.3.3. Results of the internal audits and corrective actions taken will be reported to Mr. Steve Piccot, the GHG Center Director, and included in the final Verification Report.

EPA's APPCD is the sponsor of this ETV GHG Center, and is providing broad oversight and QA support for this verification. The EPA Pilot Manager, David Kirchgessner, is responsible for obtaining final approval of project Test Plan and reports. The EPA QA Manager reviews and approves the Test Plan and final reports, and has the authority to conduct an external audit of this verification.

MIRATECH and the GHG Center have signed a formal agreement specifying details of financial, technical, and managerial responsibilities. These details are not repeated here. MIRATECH will provide technical guidance and assistance during the installation and programming of the Controller. MIRATECH may participate as an observer during testing, but will not collect any verification data.

1.6 SCHEDULE OF ACTIVITIES

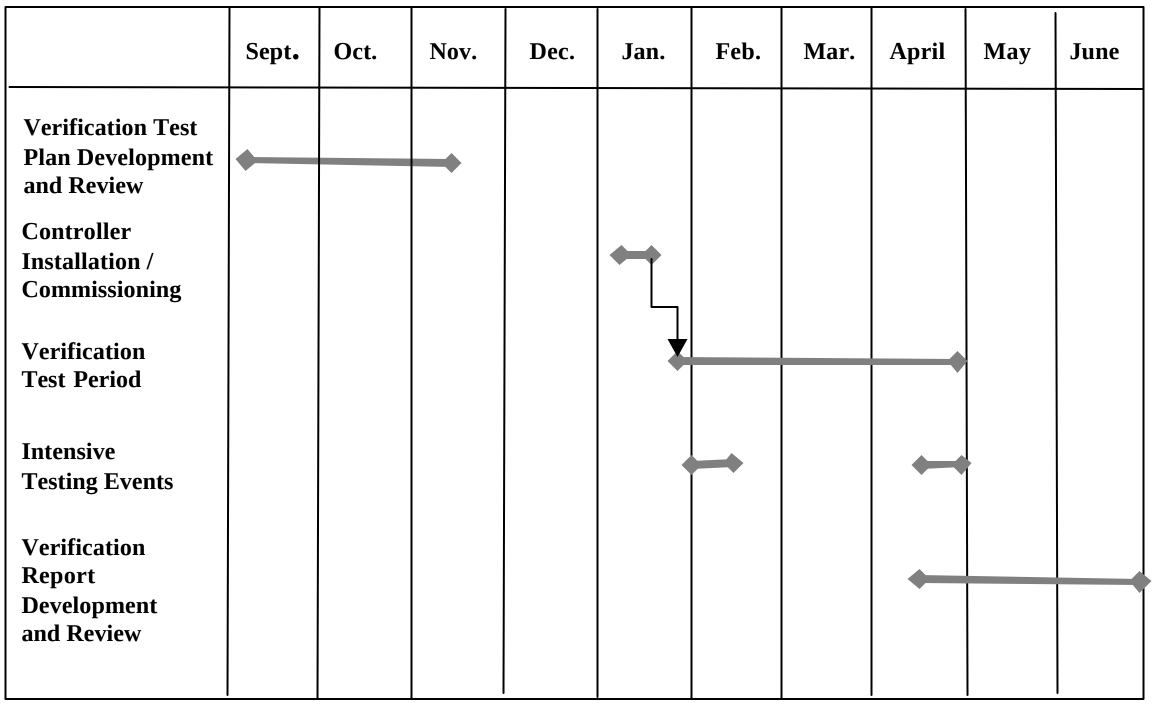
Figure 1-4 presents the schedule of activities for verification testing of the Controller. A site survey visit has already been completed. Field testing is scheduled to begin in February 2001, but the exact date of start-up will depend on installation and programming schedules, and engine availability for these activities.

The first set of performance tests should occur the day after Controller installation and programming is complete and is expected to take 3 days to complete. The Controller will then be allowed to operate normally for the next 3 months during normal Test and Control Engine operations. The second set of performance tests will occur after about 3 months of operation, in April 2001.

A draft verification report is scheduled for completion and review by June 2001. A finalized report and verification statement will be ready for distribution by the end of August.

Although not expected, delays may occur for various reasons, including mechanical failures at the site, weather, and operational issues. Should significant delays occur, the schedule will be updated and all participants will be notified.

Figure 1-4. Verification Schedule



2.0 VERIFICATION APPROACH

2.1 OVERVIEW OF VERIFICATION STRATEGY

This verification is designed to quantify changes in engine fuel consumption rates, criteria pollutant and greenhouse gas (GHG) emissions, and oil degradation rates of the engine while employing the GECO Controller. The GECO Controller is scheduled to be installed on one Caterpillar 3516 lean burn engine at the Conger Plant in January 2001.

The evaluation will characterize, via measurements and other means, the following verification parameters:

Changes in fuel consumption rates (Btu/BHp-hr)
Changes in emissions of criteria pollutants and GHG emissions (g/BHp-hr)
Lubrication Oil Degradation Rates
Controller Installation Requirements (labor and capital)

The evaluation will be conducted over a 3-month period after GECO Controller installation, shake-down, and start-up activities are completed. To verify improvements in engine performance caused by use of the Controller, each of the parameters will be evaluated with and without the use of the Controller. The verification parameters will be evaluated using the following comparisons:

1) Evaluations of fuel savings, engine fuel consumption rate, emissions performance, and emissions reductions will be accomplished by conducting a series of tests with the Controller enabled, and this will then be compared to the performance measured when the engine is operated with the Controller disabled. These evaluations will be conducted twice; once near the beginning of the 3-month verification period and again near the end. During both evaluations, testing will be conducted at three engine operating loads.

2) Evaluation of lubrication oil condition will be conducted by comparing the oil characteristics of the engine equipped with the Controller (Engine CM-101) to the oil in an identical engine (Engine CM-102) that is not equipped with a Controller. These evaluations will be conducted periodically throughout the 3-month verification period.

Table 2-1 summarizes the verification approach. More detail regarding evaluation of each of the verification parameters is presented in the following sections.

Table 2-1. Verification Strategy			
Verification Parameters	Data Used to Determine Changes Due to Controller		
	Test Engine with Controller Enabled	Test Engine with Controller Disabled	Control Engine
Fuel Consumption Rates	Fuel/power metering	Fuel/power metering	--
Changes to Criteria Pollutant and GHG Emission Rates	Emission Testing	Emission Testing	--
Installation Requirements	Station Records	--	--
Lube Oil Degradation	Oil Sampling	--	Oil Sampling

2.2 DETERMINATION OF VERIFICATION PARAMETERS

Fuel consumption rates and emissions performance will be evaluated on the engine equipped with the Controller by comparing results of a series of tests conducted with the Controller enabled and disabled. The Controller's closed-loop mode of operation will be used for all of the tests conducted with the Controller enabled. During these tests, fuel flow to the engine will be regulated by the full authority fuel valve according to O_2, MAP, MAT, and MAG-pickup sensor feedback.

The Controller will be disabled to simulate an engine that is not equipped with a Controller. At Conoco, air/fuel ratios are set to meet NO_x emission regulations by manually adjusting the carburetor while monitoring emissions. Typically, these adjustments are made during scheduled engine maintenance or overhauls. Air/fuel ratio will not be adjusted or altered during installation of the Controller. Air/fuel ratios then remain static (but not necessarily optimized) until the carburetor is again manually adjusted. To simulate this during the testing, the Controller will be placed into manual mode and the full authority fuel valve (installed as a component of the Controller) will be placed in full open position. With the Controller disabled, air/fuel ratios will be static, controlled by the carburetor only, and will not be optimized after changes in engine operation, fuel quality, ambient conditions, or any other conditions that might affect engine performance. This will represent operation of the engine without a Controller. Conversely, the Controller (when enabled) is designed to detect changes in engine performance and adjust the air/fuel ratios (using the full authority fuel valve) to optimize engine operation. These two operating conditions provide the basis for conducting an unbiased evaluation of the effectiveness of the Controller.

The pressure drop created by the presence of the open valve is about 0.07 to 0.14 psig. This represents approximately 0.4 percent of the normal fuel pressure of around 20 psig, and is not expected to affect engine operation. Immediately after installation of the Controller and during initial Controller programming, the fuel line pressure will be increased just enough to provide fuel to the carburetor at the same pressure that was observed prior to installation of the full authority fuel valve.

The Controller is designed to stabilize engine performance during normal operation and after engine operating or environmental changes occur. The performance evaluations will be conducted while operating at full load, and after varying engine load, which is the only operational parameter that is fully controllable. Changes in engine performance will be evaluated by changing engine load, allowing the engine to stabilize, and collecting data with the Controller enabled and disabled for comparison. This step-by-step approach is summarized in Table 2-2.

Table 2-2. Illustration of Testing Sequence

Step	Operating Condition	Test Type	Evaluation
1	Full load, Controller disabled	Baseline condition, conduct 1-hour test	Compare fuel consumption rates and emissions performance
2	Maintain full load, Enable Controller	Conduct 1-hour test	
3	Reduce engine load to 75 percent, maintain Controller enabled	Conduct 1-hour test after stabilization	Compare fuel consumption rates and emissions performance
4	Maintain 75 percent load and disable Controller	Conduct 1-hour test after stabilization	
5	Reduce engine load to 50 percent, maintain Controller disabled	Conduct 1-hour test after stabilization	Compare fuel consumption rates and emissions performance
6	Maintain 50 percent load and enable Controller	Conduct 1-hour test after stabilization	

During all of the test periods presented in the table, important engine operational parameters including engine speed, horsepower, fuel pressure, ambient air temperature and humidity, and the fuel lower heating value (LHV) will be monitored using the procedures described in Section 2.2.1 to ensure that they remain relatively constant during each test period, and as the Controller is enabled or disabled. Following guidelines provided in ASME Performance Test Code (PTC) 17 for Reciprocating Internal-Combustion Engines, deviations in these parameters that exceed the limits presented in Table 2-3 during a given test period will necessitate repeating the test.

Table 2-3. Maximum Variability in Operating Parameters During Test Periods

Engine Operating Parameter	Maximum Deviation of Individual Observations From Average Value During Test Period
Engine Power Output (BHp)	± 3 %
Engine Speed (rpm)	± 1 %
Ambient Air Intake Temperature (°F)	± 10 °F
Ambient Air Intake Relative Humidity (%)	n/a*
Fuel Heat Value (Btu/scf)	± 2 %
Fuel Gas Pressure (psig)	± 2 %

* ASME PTC 17 does not specify a maximum deviation for humidity. However, relative humidity will be monitored for informational purposes.

Before conducting each test, Center personnel will confirm that the engine is under steady operations at each of the desired operating set-points by documenting that the engine operating parameters listed in

Table 2-3 are stable (within the deviation criteria listed) for a period of at least 15 minutes. At each test condition, approximately one hour of data will be collected after engine stabilization to determine engine emissions and engine fuel consumption rate with the Controller enabled. The Controller will then be placed in manual mode with the fuel valve fully open (disabled), and another 1-hour test will be conducted.

More detail regarding these tests is provided in Section 2.2.1 through 2.2.3. Equipment calibrations and quality assurance/quality control (QA/QC) procedures for all of the measurements described in these sections are presented in Sections 3.0 (Data Quality) and 4.0 (Sampling, Analytical, and Quality Control Procedures) of this plan.

The full and reduced load testing described above and in Table 2-2 will be conducted in January 2001 soon after Controller installation and shakedown, and again in April to evaluate the effects of ambient conditions (air temperature and humidity) on engine performance. The same engine operating set points used for the initial verification testing will be duplicated as closely as possible for the final test. Historical meteorological data for the Sterling City area, summarized in Appendix B-4, indicate that average temperatures range from 48 ^{o}F in January to 65 ^{o}F in April. Average relative humidity is less variable averaging about 47 percent in January and 41 percent in April. Changes in both of these parameters (ambient temperature and relative humidity) could affect the air/fuel ratios, and subsequently impact engine fuel consumption rates and emissions. Therefore, these parameters will also be monitored and recorded during the test periods to document conditions during each test. Periods when significant changes in ambient temperatures are anticipated (such as early or late in the day) will be avoided for testing to minimize the impact of the temperature changes on engine operation during test periods.

2.2.1 Engine Operation and Power Output

Important engine operating parameters will be recorded throughout the testing to verify stable engine and station operations during the tests, determine net engine power output, and to assist in post-test data analysis. These parameters and the logging frequencies for each variable during the test periods are summarized in Table 2-3.

A primary indicator of engine load and performance is power output as brake-horsepower (BHp). Direct measurement of engine power output can be a difficult and expensive parameter to determine accurately. It is typically conducted by installing a strain-gauge on the engine crankshaft. Instead, gas transmission facilities normally estimate engine BHp mathematically by calculating the work performed by the compressor that the engine is driving. However, this estimation procedure doesn't provide the level of accuracy that is needed for this verification. During this testing, a balanced pressure compressor performance analyzer will be used to make direct and accurate measurements ($\pm$1 percent) of the indicated power (i.e., work being conducted by the compressor), and relate the measured indicated power to net engine power output.

Table 2-4. Summary of Engine Operating Parameters Logged During Testing			
Engine Operating Parameter	**Instrumentation**	**Data Logging Method**	**Frequency of Readings**
Speed (rpm)	GECO Controller MAG-pickup sensor	Logged by Controller internal software	Once per minute
Power (BHp)	Dynalco Model 9240 Compressor Analyzer	Logged by analyzer internal software	1-minute averages, and averaged over test period
Air Manifold Pressure (psig)	GECO Controller MAP sensor	Logged by Controller internal software	Once per minute
Air Manifold Temperature (^oF)	GECO Controller MAT sensor	Logged by Controller internal software	Once per minute
Exhaust Gas O_2 (%)	GECO Controller O_2 sensor	Logged by Controller internal software	Once per minute
Fuel Pressure (psig)	Rosemount 3095 mass flow meter	Meter transmitter/personal computer interface	1-minute averages, and averaged over test period
Fuel Flow (scfm)	Rosemount 3095 mass flow meter	Meter transmitter/personal computer interface	1-minute averages, and averaged over test period
Piplene Gas Temperature (^oF)	Station temperature gauge	Manual gauge readings	Once every 5-minutes, manually
Suction and Discharge Pressures (psig)	Station pressure gauges	Manual gauge readings	Once every 5-minutes, manually
Ambient Temperature and Humidity	Vaisala Model HMP 35C	Logged by Campbell data logger	Once per minute

During each of the tests, engine BHp will be monitored by Technical Compressor Services, Inc. using a Dynalco Recip-Trap Model 9240 Engine/Compressor Analyzer and following guidelines provided by ASME PTC 19.8 titled Measurement of Indicated Power. PTC 19.8 provides guidance for determining indicated engine power as a direct measurement of pressures into and out of the gas compressors. The Dynalco analyzer, coupled with Dynalco's RT software, determines the indicated power using the balanced pressure approach defined in PTC 19.8. The analyzer includes pressure sensors that are mounted on the suction and discharge sides of each compressor cylinder (2 cylinders for the test engine compressor) and then continuously monitors the pressures. The software then calculates the total work performed by the compressor and reports this work as BHp (Appendix A-1). The data will be monitored continuously over each test period, provide real time BHp, and be stored and averaged for each test period. The BHp values will also be used to confirm stable engine load during each test, determine fuel consumption rates, and to normalize measured engine emissions to engine power output.

Engine operating parameters logged by the Controller include exhaust gas O_2, intake air temperature, and intake air manifold pressure. These data will be recorded and stored during each test period using the oscilloscope plotting function built into the Controller software. Pipeline gas temperature and compressor suction and discharge pressures will be logged manually by Center personnel during the test periods at 5-minute intervals on data logs. These data will be used to further document the stability of engine operations during the test periods.

Ambient temperature and humidity will be monitored using a Vaisala Model HMC 35C temperature and humidity probe interfaced with a Campbell data logger. The monitor will be positioned near the engine air intake and will record and store temperature and humidity readings at 1-minute intervals. Meteorological data will not be used in determining the verification parameters, but will document the stability of ambient conditions during each of the test periods. The probe will be factory calibrated to a NIST traceable standard prior to use in this verification, and reasonableness checks will be conducted with a hand held thermocouple and psychrometer.

2.2.2 Fuel Consumption Rate

Evaluation of the Controller's ability to reduce fuel consumption will be a simple comparison of the fuel consumed at each of the operating regimes with the Controller enabled and disabled. Fuel flow to the engine will be monitored continuously during each test period using a Rosemount Model 1195 orifice meter equipped with Model 3095 transmitter. The meter will be mounted in the 1½ -inch inside diameter fuel line at a point in the line upstream of the Controller, and in accordance with Rosemount installation guidelines.

The meter is equipped with a resistance temperature device (RTD) to monitor fuel temperature and a pressure sensor to monitor absolute pressure of the fuel. Fuel flow is continuously temperature and pressure compensated by the meter, providing mass flow output at standard conditions (60 ^{o}F, 14.7 psia). Anticipated fuel flow rate at full engine load is approximately 312,000 standard cubic feet per minute (scfm). The meter is specified for a detection range of 120,000 to 360,000 scfm with a rated accuracy of 1percent of reading within the range.

The response time is 1 second, and the 3095 Transmitter provides 4 to 20 mA output over the meter's range. Output will be wired to a Hart modem (also provided by Rosemount), and using Rosemount's Engineering Assistant software package, interfaced with a portable personal computer where data will be logged and stored. The meter reading in scfh (at calibrated conditions) is given by:

$$scfm = (mA - 4)/16 * 360,000$$

where, mA is the electronic output from the meter electronics and 360,000 is the full-scale reading in scfm. Quality assurance procedures used to confirm meter accuracy are discussed in Section 3.0 of this plan.

Individual 1-second meter signals will be stored in the computer as 1-minute average scfh values. The 1-minute averages will be used to plot engine power and emissions against fuel consumption in the report. The total volume of gas consumed during each 2-hour test period will also be recorded as total standard cubic feet so that the average fuel flow during each test can be calculated.

Fuel consumption rates will be determined as described in ASME PTC 17. Heat input to the engine and engine power output must be determined to verify this parameter. The measured fuel flow rates will be used in conjunction with the lower heating value (LHV, wet basis) of the fuel to determine heat input to the engine during each test period. Fuel composition analyses are conducted by Conoco at the Conger Plant on an hourly basis using an on-site gas chromatograph/mass spectrometer (GC/MS). Conoco has indicated that the LHV of the fuel gas typically does not vary more than 1 percent (approximately 990 to 1,000 Btu/scf) during normal plant operation. However, to evaluate and document small variability in fuel quality that may exist during testing, the fuel will be sampled for LHV at 15-minute intervals during the tests. PTC 17 specifies that the individual LHV values cannot deviate more than 2 percent from the overall average LHV during a test period.

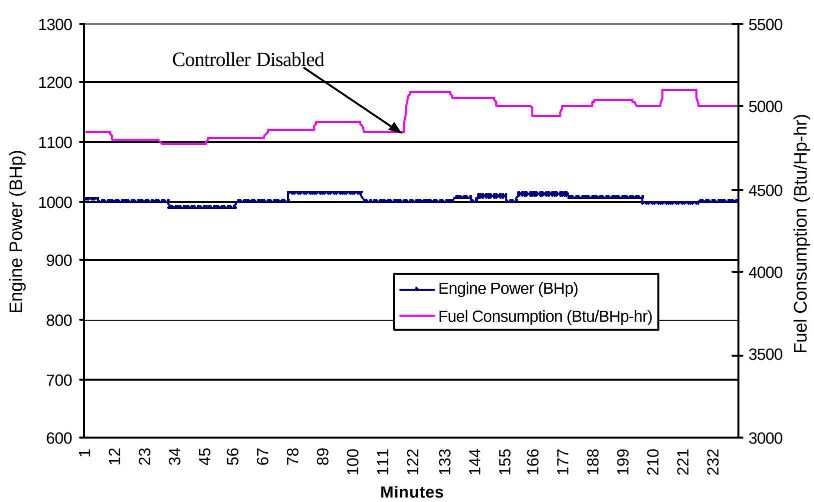
Gas compositional analyses are conducted in accordance with ASTM Specification D1945 with quantification of methane (C1) to hexanes plus (C6+), nitrogen, oxygen, carbon dioxide, and hydrogen sulfide. Sample gas is injected into a gas chromatograph equipped with a flame ionization detector (FID), where gas components are physically separated on the columns and the resultant areas compared to the corresponding calibration data. The useful range of the detectable concentrations (mole percent) is specified in Table 1 of the method (D1945). These data are then used in conjunction with ASTM Specification D3588 to calculate the LHV in units of British thermal units per standard cubic foot (Btu/scf). The 15-minute LHVs will be multiplied by the corresponding fuel flow rate values for that time period to calculate engine heat input in units of Btu/hr.

Fuel consumption rates will be determined in units of Btu/BHp-hr using the engine heat input results (Btu/hr) and the measured engine power output (BHp). Determination of BHp on a continuous basis was previously described in Section 2.2. In accordance with PTC 17, the following equation will be used:

Fuel Consumption Rate (Btu/BHp-hr) = [Heat input to engine (Btu/hr) / indicated power (BHp)]

Since both fuel flow rates and engine BHp determinations will be recorded as 1-minute averages, fuel consumption rate will also be reported on a 1-minute basis for each of the test periods (resulting in approximately 60 data points per test). Engine fuel consumption rate data collected with the Controller enabled and disabled will be plotted as Btu/BHp-hr to observe trends in the data sets and to identify any anomalies (see example as Figure 2-1). Anomalous or suspect data points will be discarded, and the data sets will then be tested for normality. The mean of normal data sets will represent the average engine fuel consumption rates for specific test conditions. The standard deviation of each data set will also be reported to indicate data set dispersion.

Figure 2-1. Example Fuel Consumption Rates



The Controller is designed to maintain engine power output while potentially reducing fuel consumption. Fuel flow rate to the engine is the only parameter in the fuel consumption rates equation that is expected to change as a result of enabling or disabling the Controller. Anticipated reductions in fuel consumption as observed on other engines equipped with the Controller are in the range of 3 to 10 percent. This engine normally consumes about 5,200 scfh natural gas while operating at full load. If use of the Controller resulted in a reduction in fuel consumption of 5 percent, for example, the engine would be consuming fuel at a rate of 4,940 scfh. This creates a sensitivity issue because the accuracy of the flow meter is ±1 percent of reading, or in this example, about 50 scfh. In this case, the uncertainty in the reduction of fuel consumption (the difference between the two fuel flow rates) would be 260 ±50 scfh. This level of uncertainty was considered in development of the data quality objectives for this verification that are discussed in Section 3.0 of the plan.

2.2.3 Pollutant Emissions Performance

Testing will be conducted to determine emissions of criteria pollutants including nitrogen oxides (NO_x), carbon monoxide (CO), total hydrocarbons (THC), and greenhouse gases (GHGs) including methane (CH_4) and carbon dioxide (CO_2). Emissions of each pollutant will be determined in units of lb/hr and then normalized to engine power output measured in conjunction with each test to report as g/BHp-hr. Emission rates will also be reported in units of mg/m^3 corrected to 5 percent O_2. The emissions testing will be conducted during each of the 1-hour fuel consumption rates test periods described in the previous section to evaluate emission rates at the three engine loads with the Controller enabled and disabled. Engine BHp, heat input, and operational parameters will be logged during all of the test periods as previously described and will be used to relate engine operations to engine emissions. As with the fuel consumption rate testing, the entire emissions testing sequence will be repeated near the end of the 3-month verification period to evaluate if engine performance is affected by ambient conditions.

The GHG Center intends to contract Cubix Corporation, a qualified emissions testing firm, to conduct the emissions testing. Cubix will provide all test equipment, sampling media, and labor needed to complete the testing and will operate under the supervision of a Center representative. All of the test procedures to be utilized in this verification are U.S. EPA Federal Reference Methods. The Reference Methods are well documented in the Code of Federal Regulations, include detailed procedures, and generally address the elements listed below (40CFR60, Appendix A).

- Applicability and Principle
- Range and Sensitivity
- Definitions
- Measurement System Performance Specifications
- Apparatus and Reagents
- Measurement System Performance Test Procedures
- Emission Test Procedures
- Emission Calculations

Each of the selected methods utilizing an instrumental measurement technique includes performance-based specifications for the gas analyzer used. These performance criteria cover span, calibration error, sampling system bias, zero drift, response time, interference response, and calibration drift requirements. An overview of each test method planned for use is summarized in Table 2-4 and discussed in more detail in Section 4.0

Table 2-5. Summary of Emission Testing Methods			
Pollutant/ Parameter	**Reference Method**	**Principle of Detection**	**Proposed Analytical Range**
O_2	3A	Electrochemical Cell	0-25%
CO_2	3A	NDIR	0-10%
NO_x	20	Chemiluminescence	0-500 ppm
CO	10	NDIR-Gas Filter Correlation	0-500 ppm
CH_4	18	GC/FID	0-1,000 ppm
THC	25A	Flame ionization	0-1,000 ppm

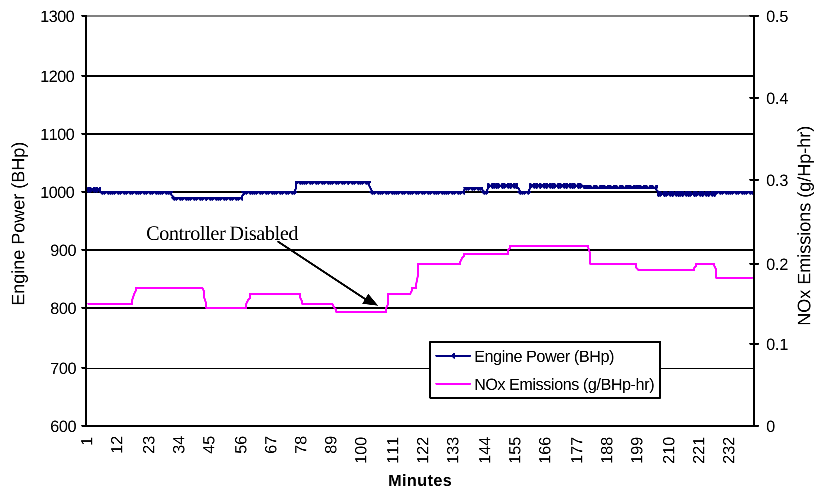
The instrumental testing for CO_2, O_2, NO_x, and CO result in exhaust gas concentrations in units of parts per million by volume, dry (ppmvd). The THC and methane results are quantified as ppmv on a wet basis, but will be corrected to ppmvd based on measured exhaust gas moisture calculations made in conjunction with the testing.

The pollutant concentrations of CO_2, O_2, NO_x, THC, and CO are recorded with a data acquisition system every 5 seconds during testing, averaged at intervals of 1-minute, and stored on a computer. Composite samples will be collected in pre-cleaned stainless steel canisters during each test and shipped to an analytical laboratory for methane analyses. The laboratory will provide one methane result for each 2-hour test period as the average methane concentration in the exhaust gas during each test.

EPA Method 19 provides procedures for converting the ppmvd concentration values of the exhaust gas pollutants to emission rate values in units of lb/hr. For this testing, the lb/hr emission rates also will be normalized to engine output using the corresponding 1-minute engine BHp values and reported as g/BHp-hr. The fundamental principle of this method is based upon "F-factors". F-factors are the ratio of combustion gas volume to the heat content of the fuel. F-factors are calculated as a volume/heat input value, (e.g., standard cubic feet per million Btu). The F-factor will be calculated on a dry basis from measured exhaust gas O_2 values and the gas compositional analyses conducted by Conoco that correspond to each test period (average of the two analyses conducted during the test period).

Changes in emission rates and GHG emissions resulting from Controller operation will be evaluated separately for each pollutant using the g/BHp-hr data only (to account for engine power output). The 1-minute average emission rates generated during each test will result in approximately 60 data points per test. Engine emissions measured with the Controller enabled and disabled will be plotted to observe trends in the data sets and to identify any anomalies (see example as Figure 2-2). Anomalous or suspect data points will be discarded, and the data sets will then be tested for normality. The mean of normal data sets will represent the average pollutant specific engine emissions for each test condition, and the mean values will be compared to identify emission rate reductions resulting from use of the Controller. The standard deviation of each data set will also be reported to quantify data set dispersion.

Figure 2-2. Example NOx Emisson Rates



By stabilizing and optimizing air/fuel ratios in lean-burn engines, NO_x emissions in some applications have been reduced by 25 percent or more. Emission reductions for other pollutants being measured in this verification have not been previously analyzed. The same measurement sensitivity issue discussed in Section 2.2.2 becomes an issue in evaluating emission rate reductions. NO_x concentrations in the engine exhaust are normally around 300 ppmvd during full load operation. If use of the Controller resulted in a 10 percent reduction in NO_x emissions, concentrations would be approximately 270 ppmvd. Therefore, the analyzer must be operated on an analytical range above 300 ppm, but pollutant reductions might be on the order of 30 ppm. This level of uncertainty was considered in development of the data quality objectives for this verification that are discussed in Section 3.0 of the plan.

2.2.4 GECO Controller Installation Requirements

The GHG Center will document installation requirements by verifying the total labor hours expended in the installation, programming, shakedown, and start-up of the GECO controller. The cost of the Controller and components will also be documented. The controller system will be installed by an installation contractor (ISC, Inc.), with supervision and guidance provided by a MIRATECH engineer and Conoco personnel. Labor records and hourly rates will be obtained from ISC, Inc. to document the cost of Controller installation. Center personnel will be on-site throughout the installation and shakedown process, and will document any modifications made or difficulties encountered. The GHG Center will also document key decisions made regarding placement of equipment or adjustments made for site-specific conditions.

MIRATECH will provide an Operator's Manual that provides instructions on start-up activities and routine monitoring and maintenance requirements. For the start-up instructions, the manual lists step-by-step instructions for: initiating controller startup, obtaining and verifying optimum air/fuel ratio, and verifying functionality of integral monitoring sensors. The GHG Center will document any problems encountered or changes made to the start-up and shakedown activities, and report the final procedures in the Verification Report.

2.2.5 Lubrication Oil Analysis

Users of IC engines typically collect oil samples from the engines at routine intervals and analyze the samples for compounds that can corrode and degrade combustion equipment. These analyses are a useful preventive maintenance tool for operators and can help to evaluate the performance and condition of the engines. Conoco performs these oil analyses every 45 days. Poor fuel quality, excessive fuel blow-by (unburned fuel passing the piston rings and entering the crankcase), unstable air/fuel ratios, and fuel mixtures that are too rich or lean can all accelerate the rate of oil degradation. In support of this verification, oil samples will be collected and analyzed for both the Test and Control engines to evaluate if use of the Controller on the Test engine reduces oil degradation and contamination as claimed by MIRATECH.

Both engines were equipped with fresh oil in August 2000 as part of the pre-test overhaul and will receive another oil change prior to the verification period. The first set of samples will be collected prior to installation of the Controller. After commissioning the Controller, samples will be collected on a monthly basis for the duration of the 3-month verification period to enable the development of oil degradation profiles. Engine operators will collect the samples from a sampling port in each engine oil system located at a point between the oil filters and the oil cooler. Each month, duplicate samples will be collected from both the Test and Control Engines. Duplicate analyses will be conducted on each sample collected by a certified laboratory (Petroleum Products Monitoring, Inc. of Athens, GA) to quantify the parameters listed in Table 2-6. Station operating logs will be procured and reviewed to document the operating hours of both engines during the verification period. In order to make a meaningful comparison of oil degradation rates on the two engines, operating hours will need to be similar. Typically, the engines operate on the same schedule so long as equipment malfunctions do not occur.

Table 2-6. Lubrication Oil Analyses

Analyte	Reference Method	Principle of Analysis	Reporting Units
Oxidation and Nitration	Not Specified	Fourier-Transform Infra-Red Spectroscopy	angstrom per centimeter (A/cm)
Viscosity @ 40°C	ASTM-D445	Kinematic	centistokes (cSt)
Total Acid Number	ASTM-D2896-88	Potentiometric Titration	mg KOH/g
Total Base Number	ASTM-D664-959	Potentiometric Titration	mg KOH/g

The analytes listed in the table are indicators of oil condition and often times related. Oil nitration, quantified in units of angstrom per centimeter (A/cm), occurs when piston blow-by occurs and fuel and/or combustion products mix with the engine oil. The products of nitration are highly acidic and therefore have an obvious impact on total acid and base numbers, but also can increase or accelerate the effects of oxidation, and increase the oil viscosity. Oxidation, also quantified as A/cm, is a chemical change in oil composition caused by nitration and high temperature operation. Oxidation can also increase oil viscosity and reduce the oil's ability to lubricate.

Viscosity, quantified as centistokes (cSt) is a measure of the thinness of the oil and is used as a primary indicator of the oil's lubricating abilities. Abnormally high or low oil viscosity can be caused by dilution, contamination, or oxidation and can be damaging to engine components. Total base and total acid numbers are also indicators of oil condition and contamination. Most oils contain alkaline additives to help neutralize the effects of acidic products that accumulate in the oil over time. In an engine experiencing excessive blow-by, improper air to fuel ratios, or poor fuel quality, the total acid number can increase dramatically over time, thereby reducing the base number, or the ability of the oil to maintain neutral pH.

Samples will be collected from a tap installed by the facility specifically for oil sampling. The tap is located at a point in each engine system that is between the oil filters and the oil coolers. Samples will be collected in pre-cleaned containers provided by the laboratory and expressed shipped on the day of collection and analyzed for the above listed parameters on the following day.

The trends observed in the viscosity, oxidation, nitration, total acid, and total base levels between the oil in the two engines will be used to develop degradation profiles, and identify differences that may develop between the Test and Control Engines. The GHG Center recognizes that, in a 3-month period, oil degradation may not be severe enough to observe conclusive trends regarding how use of the Controller impacts the condition of the oil, or reduces oil degradation. However, the host facility normally changes oil after approximately 2,000 hours of operation, when nitration levels in the oil are elevated. Providing the Test and Control engines operate according to normal utilization rates (around 96 percent), the 3-month verification test period should be sufficient to observe changes in oil quality.

It is possible that changes in oil characteristics may be slight during the 3-month verification period. Although the analyses outlined in Table 4-3 are highly precise, duplicate samples will be collected during each sampling event to minimize uncertainty and increase the size of the data set. In addition, duplicate analyses will be conducted on each sample collected. All of the QA/QC procedures specified in the above referenced analytical methods will be followed by the laboratory, including instrument calibrations and performance checks. Copies of the QA/QC results from the laboratory will be reviewed by Center personnel for integrity. Any analyses not meeting the method specifications will be repeated.

3.0 DATA QUALITY

3.1 DEFINITION OF DATA QUALITY OBJECTIVES

In verifications conducted by the GHG Center and EPA's Office of Research and Development, measurement methodologies and instrumentation are selected to ensure that desired level of data quality occurs in the final results. Data quality objectives (DQO) are stated for key verification parameters before testing commences. To help ensure the data are of sufficient quality to support conclusions reached from the measurements. Section 2.0 presented the approaches that will be used to evaluate each of the verification procedures. The section also introduced the sampling and analytical methods that will be used, required instrumentation, and data reduction and reporting procedures. For some verification parameters such as fuel flow monitoring and emissions testing, additional details regarding the installation and use of test instrumentation is provided in Section 4.0. This section presents the DQO's for each verification parameter, followed by a discussion of the Data Quality Indicators (DQIs) for each of the critical measurement variables that will be used to determine if the DQOs were met.

The process of establishing data quality objectives starts with determining the desired level of confidence in the primary verification parameters (e.g., fuel consumption and engine emission rates). The next step is to identify all measured values that impact the primary verification parameters and estimate the level of error that can be tolerated. Error propagation is used to estimate the cumulative effect of all measured variables on the data quality of the verification parameters. This allows individual measurement methods and instruments to be chosen which perform well enough to satisfy the DQO for each verification parameter. The technique used to determine if data quality objectives are met is to identify DQIs. The DQIs define the accuracy and completeness goals for each measured variable.

In this verification, the primary quantitative objectives are to verify the performance of the Controller with respect to savings or reductions in engine fuel consumption and NO_x emissions. Based on input from MIRATECH, reductions are anticipated to be in the range of 3 to 10 percent for fuel consumption and 10 percent or greater for NO_x emissions. DQO's were developed based on these anticipated levels of reduction, and quantifying reductions lower than these values may result in higher levels of uncertainty. Uncertainty will vary depending on the magnitude of reductions measured and this is illustrated in the examples presented in Table 3-1. As the reductions in fuel consumption or NO_x emissions improve, the level of uncertainty decreases as a percent of the total reduction. Table 3-1 shows that the uncertainties in the rate of reduction are much greater than the uncertainty in the actual measured values.

The examples of uncertainty presented in Table 3-1 were developed by propagating the maximum error in each of the measurement used to determine the reductions. A statistical t-test was used to calculate the variance in each of the measurements based on the cumulative errors inherent with each of instruments used to perform the measurements. For example, the uncertainties presented in the table for engine fuel consumption rate improvements were propagated using the maximum error expected for fuel flow, gas heat content, and engine power output measurements (the DQI's for each of these measurements).

Table 3-1. Examples of Overall Uncertainty in Fuel Consumption and Emission Rate Reductions					
Verification Parameter	**Instrument Accuracy**	**Uncertainty in Individual Measured Values**	**Uncertainty at Various Levels of Reduction Through Use of Controller**		
			3% Reduction	**5% Reduction**	**10% Reduction**
Fuel Consumption	±1% of reading	5200 ±52 scfh (1%)	170 ±58 scfh (34%)	260 ±48 scfh (18%)	520 ±47 scfh (9%)
Engine Fuel Consumption Rate	±1% of reading for fuel flow and horsepower	5096 ±102 Btu/Hp-hr (2%)	167 ±60 Btu/Hp-hr (36%)	255 ±52 Btu/Hp-hr (20%)	510 ±56 Btu/Hp-hr (11%)
Emission Rates (NO_x)	±1% of span for NOx, ±1% of reading for horsepower	1.90 ±0.04 g/BHp-hr	0.06 ±0.022 g/BHp-hr (37%)	0.10 ±0.022 g/Bhp-hr (22%)	0.17 ±0.022 g/Bhp-hr (13%)

Based on the examples provided in Table 3-1 and assuming a 5 percent reduction in fuel consumption and a 10 percent reduction in emissions, the data quality objectives listed in Table 3-2 are targeted for these parameters.

Table 3-2. Data Quality Objectives		
Verification Parameter	**Units**	**DQO**
Changes in Fuel Consumption Rates	Btu/BHp-hr	± 20 %
Emission Reductions (NO_x)	g/BHp-hr	± 13 %
Emission Reductions (CO_2, CO, THC, CH_4)	g/BHp-hr	± 24 %

Actual uncertainties in each of the verification parameters will be calculated at the end of the verification and presented in the final report. The GHG Center has not included a DQO for oil degradation parameters because typical degradation rates vary widely for specific engines and, being that the test engines were recently overhauled, expected degradation rates are unknown. Instead, the GHG Center will report DQIs for each of the oil analysis parameters to ensure that the measurements are accurate.

Table 3-3 summarizes the DQIs for each critical measured variable that will be used to determine the measurement uncertainty in each test result. Achievement of each DQI will ensure that the DQOs can also be achieved. A discussion of the DQIs for each verification parameter is provided in the following sections.

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

Measurement Variable		Instrument Specifications			Data Quality Indicators		
Measurement Variable		Instrument Type / Manufacturer	Instrument Accuracy	Frequency of Measurements	Accuracy	Complete-ness	How Verified / Determined
Engine Operation	Engine Power Output	Dynalco Recip-Trap Compressor Analyzer	± 1.0% reading	1-minute readings	± 1.0%	100%	Review manufacturer calibration certificates, Perform function checks in field.
	Fuel Flow Rate	Mass Flow Meter / Rosemount 3095 Integral Orifice (0.748 in. dia.) or equiv.	± 1.0% reading	once per min	± 1.0% of reading	90%	Review manufacturer calibration certificates, Perform function checks in field before and after verification period.
	Fuel Pressure	Pressure Transducer / Rosemount or equiv.	± 0.15% FS (FS = 100 psig)	once per min	± 0.15% FS		
	Fuel LHV	FGT - Dual Column Daniels Chromatograph Certified Laboratory – HP Gas Chromatograph	± 0.2% reading	two per hour	± 0.2%		Review Conoco and laboratory calibration records.
Engine Emissions	NO_x Levels	Chemilumunescense / TECO Model 10	± 1% FS (FS = 500 ppm)	1-minute readings	± 1% FS (includes sampling system bias corrections)	100%	Follow EPA Method calibration and system performance check criteria.
	CO Levels	NDIR / TECO Model 48	± 1% FS (FS = 500 ppm)		± 2% FS (includes sampling system bias corrections)		
	THC Levels	FID / JUM Mode 3-100	± 1% FS (FS = 1000 ppm)		± 5% FS		
	CO_2 / O_2 Levels	Servomex 1400 NDIR	± 0.5% FS (FS = 20%/25%)		± 2% FS (includes sampling system bias corrections)		
	CH_4 content	GC / FID HP Model 5890	± 0.1% FS (FS = 1000 ppm)		± 2% FS		
	H_2O content	Gravimetric / NA	± 0.2% FS (FS = 100%)	Daily	± 5% FS		
Lube Oil Analyses	Viscosity	Kinematic Capillary Viscometer	±0.05 cSt	Monthly	+0.05 cSt	90%	Review laboratory calibration records.
	Oxidation/ Nitration	Nicolet FTIR Spectrometer	±1 A/cm		±1 A/cm		
	Total Acid Number	Automatic KF Titrator	±0.5%		3 Replicates within 5% of mean		Review laboratory replicate titration records.
	Total Base Number	Automatic KF Titrator	±0.5%		3 Replicates within 5% of mean		

3.2 DETERMINATION OF DATA QUALITY INDICATORS

The following subsections describe the DQIs that will be used to evaluate the accuracy and completeness of each of the key verification measurements. The sections discuss the methods to be used to document DQIs and procedures for operation and calibration of measurement instrumentation. Table 3-4 summarizes the calibration procedures and QC checks that will be used to evaluate the DQIs for each of the key measurements. Additional detail regarding QC procedures for each of these critical measurements is presented in Section 4.0 of this plan.

Table 3-4. 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
Fuel Flow Rate		Instrument Calibration by Manufacturer	Beginning and end of test	± 1.0% reading	Identify cause of any problem and correct, or replace meter
		Sensor Diagnostics	Beginning, middle, and end of test	Pass	Identify cause of any problem and correct, or replace meter
Fuel Heating Value		Calibration with gas standards by certified laboratory	Prior to analysis of each lot of samples submitted	± 0.2% for CH_4 concentration	Repeat analysis
Engine Operating Parameters		Sensor diagnostics	Prior to initial testing	No error conditions	Identify cause of error and request host and/or MIRATECH to correct
Indicated Power		Calibration of pressure sensors	Before and after each intensive sampling period	No error condition	Identify cause of any problem and correct
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
		Analyzer calibration error test	Daily before testing	±1% of analyzer span	Repair or replace analyzer
		System bias checks	Before each test	±5% of analyzer span	Correct or repair sampling system
		Calibration drift test	After each test	±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	±5% of analyzer span	Correct or repair sampling system
		Calibration drift test	After each test	±3% of analyzer span	Repeat test
	THC	System calibration error test	Daily before testing	±5% of analyzer span	Correct or repair sampling system
		System calibration drift test	After each test	±3% of analyzer span	Repeat test
	CH_4	Calibration with gas standards by certified laboratory	Prior to analysis of each lot of samples submitted	± 2% for CH_4 concentration	Repeat analysis
Oil Analyses		Instrument Calibrations	Before each analysis	+/- 5% of measurement range	Repeat analysis

3.2.1 Engine Power Output and Operating Parameters

The Dynalco analyzer to be used for power output measurements has been tested by the manufacturer and found to be accurate within 0.5 percent on BHp calculations provided the pressure sensors are calibrated and correct compressor data such as cylinder bore, stroke, rod length, and connecting rod center distances are used. Following the guidelines in PTC 19.8, each of the 4 pressure sensors will be calibrated using a NIST traceable standard before and after the two verification test periods. The contractor conducting the power output measurements will provide calibration certificates for the pressure sensors that will be reviewed by the GHG Center. In addition, the key compressor specifications used in the analyzer software will be verified using compressor manufacturer specifications.

MIRATECH will provide calibration certificates for the MAP, MAT, and O_2 sensors that are supplied with the Controller and will be used during the test periods to monitor air manifold pressure, air manifold temperature, and exhaust gas O_2 concentration. The sensors should not require re-calibration over the duration of the test.

The engine operational parameters monitored by the host include engine speed, compressor gas temperature, and compressor suction and discharge pressures. These gauges are not routinely calibrated by the facility after installation and are used primarily as indicators of engine performance and for troubleshooting purposes. During the verification period, these parameters will be used only as indicators of stable engine operation and will not be used directly in calculating key verification parameters. Initial factory calibration certificates for each of the sensors will be obtained from the host where possible, although many of these calibrations may be dated.

3.2.2 Fuel Consumption Rates

The mass flow rate of the fuel supplied to the engine will be determined using an integral orifice meter (Rosemount Model 3095). The meter will contain a 0.512 inch orifice which will enable flow measurements to be conducted at the ranges expected during testing (2600 to 5200 scfh natural gas). The meter will be temperature and pressure compensated, providing mass flow output at standard conditions (60 ^{o}F, 14.7 psia). The meter will continuously monitor flows during the test periods at a rate of one reading per minute, and will be capable of providing an accuracy of $\pm$ 1 percent reading. Rosemount's Engineering Assistant (EA) Software will be used wired to interface meter output with a personal computer.

Prior to testing, the Rosemount will be factory calibrated, and a calibration certificate traceable to NIST will be obtained and reviewed to ensure the required instrument rating of ±1 percent accuracy. The factory certified calibration are reported to be valid for 3 years, and thus will not require re-calibration over the duration of the test, provided manufacturer specified installation and set-up procedures are followed. Specifically, the transmitter electronics are programmed in the field to enable the meter to calculate mass from differential pressure across an integral orifice element. Rosemount's EA Software which is interfaced to the transmitter via a HART protocol serial modem, is used to input information about the gas being metered and its operating conditions. Specific setup parameters required in the EA are discussed in Section 4.1. The GHG Center testing personnel will maintain field logs of all data entered into the EA, and subsequently transmitted to the instrument. An electronic copy of the configuration file will be maintained.

To validate the performance of the meter in the field, certain QC checks will be performed. Sensor diagnostic checks consists of zero flow verification by isolating the meter from the flow, equalizing the pressure across the differential pressure (DP) sensors using a crossover valve on the orifice assembly, and reading the pressure differential and flow rate. The sensor output must read 0 flow during these checks. Transmitter analog output checks will also be conducted at the beginning, middle, and end of the test. In this loop test, a current of known amount will be checked against a DMM to ensure that 4 mA and 20 mA signals are produced. The procedures for conducting sensor diagnostic checks are provided in Section 4.1.2. Provided that the meter is properly installed and meets all of the required QC checks, the accuracy of flow rates achieved will be reported as the accuracy certified by the manufacturer.

In addition to fuel consumption rates, the GHG Center will quantify heat input to the engine and engine power output. To calculate heat input, the fuel lower heating value (LHV) will be determined. The host uses a gas analyzer to determine gas composition and calculates LHV in accordance with ASTM methodology. The accuracy of this procedure for LHV is approximately 1.2 Btu per thousand cubic feet, or about 0.1 percent, and is low enough that it was not included in the error propagation calculations. Quality control procedures for the gas analysis are provided in Section 4.2 of this plan.

Any test runs where unstable engine operation are encountered (due to station upsets or changes in demand) will be discarded and repeated. Other data anomalies, errors, or problems may be discovered after leaving the site, and therefore a 10 percent allowance in completeness is included. Thus, the completeness goal for fuel consumption is 90 percent.

3.2.3 Emissions Measurements

EPA Reference Methods, listed earlier in Table 2-3, will be used to quantify emission rates of criteria pollutants and greenhouse gases. The 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 instrument and sampling system 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 determinations conducted here are considered to be of acceptable quality if all Reference Method calibrations, performance checks, and concentration corrections specified in the Reference Methods have been successfully conducted. As such, a DQI of 2 percent of full scale is assigned for emissions of CO_2, CH_4, CO, and THC emission rate measurements as detailed in the first bullet item below. Emissions of NO_x are a primary concern of IC engine operators and therefore, DQI ± 1 percent of full scale is assigned for NO_x.

Emissions of NO_x, CO, and CO_2 and O_2 will be determined in accordance with Methods 7E, 10, and 3A, respectively. QC criteria for CO measurements are not well defined in Method 10. Methods 3A and 7E refer to EPA Method 6C (determination of sulfur dioxide emissions) for QC criteria, and these criteria will be followed for this testing. The criteria specified in Method 6C include determination of analyzer calibration error, sampling system bias, and calibration drift. The calibration error checks are conducted once per day of testing to verify proper instrument function. The system bias checks are conducted before and after each test run to determine overall sampling system accuracy. These pre- and post-test system calibrations are also used to determine sampling system drift during each test period. In accordance with Method 7E for determination of NO_x emissions, additional QC requirements include an analyzer interference response check and an NO_2 converter efficiency test. The interference and NO_2 converter efficiency tests are conducted once prior to the start of testing to verify proper analyzer function. All calibrations are conducted using EPA Protocol 1 calibration gas standards.

In accordance with Method 25A for determination of THC emissions, QC requirements include sampling system calibration error and drift tests before and after each test conducted. The calibrations are direct assessments of sampling system accuracy using EPA Protocol 1 gas standards. Methane samples will be collected and analyzed using a GC/FID following the guidelines of EPA Draft Method 0040. The GC will be calibrated prior to sample analysis using certified methane standards, and the accuracy of the methane analysis is $\pm$ 2 percent. The THC and methane test results for each test period will be used to calculate VOC concentrations as THC less methane. Therefore, the DQO for VOC is 10 percent because two separate measurements are involved. Actual calibration data from the THC sampling system calibrations and the GC/FID calibrations for the methane analyses will be used to propagate error in the calculated VOC concentrations.

3.2.4 Lubrication Oil Sampling

Evaluation of lubrication oil will be conducted by reviewing oil analyses on a monthly basis. The analyses, conducted by Petroleum Products Monitoring, Inc. of Athens, Georgia will be conducted using the DQIs listed in the Table 3-3 for each of the parameters. The completeness goal for the oil analyses is 90percent. Duplicate analyses will be conducted on each sample collected and individual parameter results will be averaged for the two analyses. Table 3-4 summarizes the instrument calibrations and QC checks that will be used to confirm the DQIs.

4.0 SAMPLING, ANALYTICAL, AND QUALITY CONTROL PROCEDURES

This section provides additional detail regarding the instrumentation, procedures, and quality control measures to be used during the verification testing for the fuel consumption rate and emission rate determinations.

4.1 FUEL CONSUMPTION RATES

4.1.1 Installation and Set-Up

Manufacturer's installation checks: Field installation procedures are well documented in Rosemount's "Model 3095 MV Product Manual", and will not be repeated here in entirety. Center testing personnel will follow all required procedures to ensure that checks for process connections, leaks, field wiring, and ground wiring are conducted properly. The Product Manual will be made available during installation. Following manual specifications, meter installation will be conducted using the following considerations:

- The meter will be installed vertically in the 1-1/2-inch diameter fuel line in a safe, accessible, and vibration free section of pipe.
- Installation will include sufficient straight run of pipe (no less than 10 diameters) upstream and downstream of the meter.
- Temperature sensors will be installed in the piping and wired to the transmitters for continuous temperature compensation.
- All mechanical connections will be leak checked.
- All electrical connections will be made following manufacturer specifications and tested.

4.1.2 Sensor Diagnostics

Manufacturer's setup and start-up checks: In each flow sensor element, a transmitter calculates mass from differential pressure across an integral orifice element. To perform this calculation, the transmitter electronics must be programmed with information on the gas being metered and the operating conditions. This is accomplished using Rosemount's Engineering Assistant (EA) Software, which is interfaced to the transmitter via a HART protocol serial modem. Specific setup parameters required in the EA are listed in Appendix B-2. The GHG Center testing personnel will maintain field logs of all data entered into the EA, and subsequently transmitted to the instrument. An electronic copy of the configuration file will be maintained. Detailed guidelines are provided in the Product Manual.

Sensor function checks: A series of meter and transmitter function checks will be conducted before the verification period begins and again at the end of the testing. The following checks will be included.

- Power supply test to document that the meter is receiving sufficient power (no less than 11 vDC) to the transmitter.
- Analog output checks where a current of known amount will be checked against a secondary device to ensure that 4 mA and 20 mA signals are produced.
- Reasonableness checks will be performed by ensuring that the mA signal produced at the transmitter is recorded correctly in the EA.

- Zero checks will be conducted by isolating the transmitter from the differential pressure taps using valves built into the meter, and recording the transmitter output. The sensor output must read 0 flow during these checks.

Procedures for performing these checks are documented in the Product Manual. Appendix B-3 identifies the records to be logged.

4.1.3 Instrument Calibration

Prior to installation in the field, the flow meter will be sent to the factory for calibration. Although the meter should not require re-calibration over the duration of the test, the meter will be sent out for post-test calibration at the conclusion of the verification test period. Calibration certificates traceable to national standard will be obtained, and verified to ensure they met the accuracy goals specified in Table 3-2.

4.2 FUEL HEATING VALUE MEASUREMENTS

Fuel heating value measurements are made by Conoco at the test site twice every hour. The gas analyzer used for these measurements is calibrated weekly as a continuing calibration verification check using a certified natural gas standard. Instrument accuracy is 0.2 percent full scale, but allowable method errors vary among gas constituents as listed below.

Gas Constituent	Allowable Error (% Diff.)
nitrogen	2.0
methane	0.2
carbon dioxide	3.0
ethane	1.0
propane	1.0
isobutane, n-butane	2.0
isopentane, n-pentane	3.0

To ensure accurate analyses, the instrument is re-calibrated whenever its performance is outside of the listed acceptance limits. Calibration records will be obtained and reviewed by the Center. Records of the natural gas calibration standard will also be obtained.

4.3 ENGINE POWER OUTPUT MEASUREMENTS

The Dynalco analyzer to be used for power output measurements has been tested by the manufacturer and found to be accurate within 0.5 percent on BHp calculations provided the pressure sensors are calibrated and correct compressor data such as cylinder bore, stroke, rod length, and connecting rod center distances are used.

Quality control procedures for this measurement will be conducted following the guidelines in PTC 19.8. Each of the 4 pressure sensors will be calibrated using a NIST traceable standard (dead weight tester) before and after the two verification test periods. The contractor conducting the power output measurements will provide calibration certificates for the pressure sensors that will be reviewed by the GHG Center. In addition, the key compressor specifications used in the analyzer software will be verified using compressor manufacturer specifications.

4.4 EMISSION RATE MEASUREMENTS

The methods to be used to determine emission rates from the engine exhaust were introduced in Section 2.2.6. Data quality objectives for these measurements were described in Section 3.2.3. The following sections provide additional detail regarding instrumentation to be used, sampling procedures, and quality control procedures.

4.4.1 Gaseous Sample Collection, Conditioning, and Handling

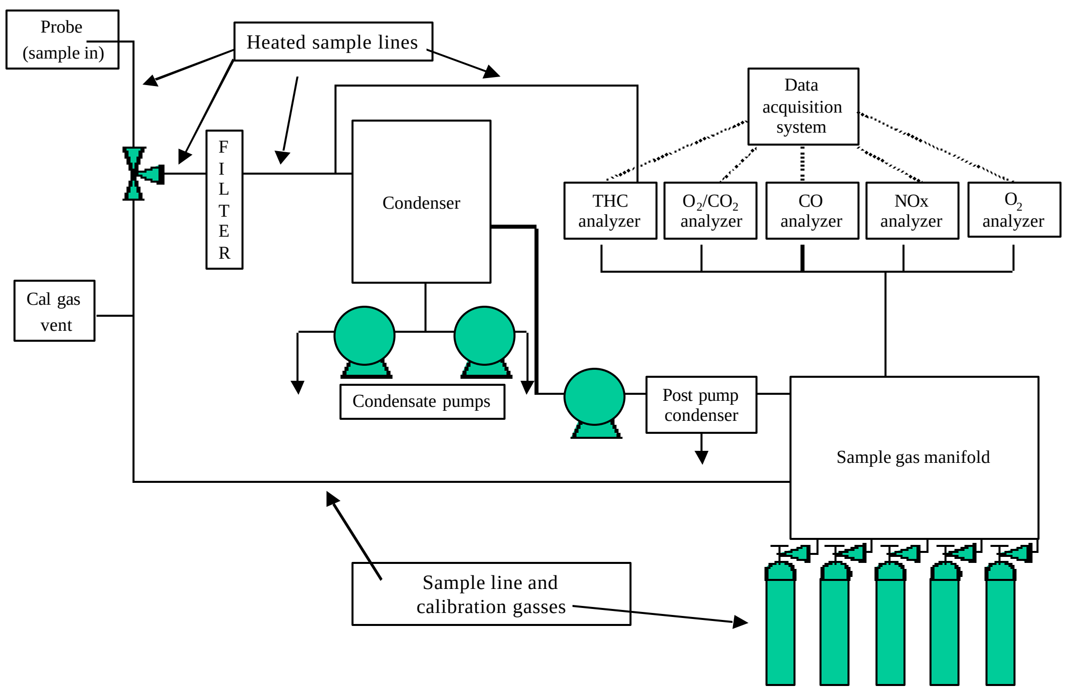
A schematic of the sampling system to be used for determination of concentrations of CO_2, O_2, NO_x, CO, and THC is presented as Figure 4-1. In order for the CO_2, O_2, NO_x, and CO instruments used to operate properly and reliably, the flue gas must be conditioned prior to introduction into the analyzer. The gas conditioning system is designed to remove water vapor and/or particulate from the sample. All interior surfaces of the gas conditioning system are made of stainless steel, Teflon™, or glass to avoid or minimize any reactions with the sample gas components. Gas is extracted from the engine exhaust gas stream through a heated stainless steel probe, filter, and sample line and transported to two ice-bath condensers on each side of the sample pump. The condensers remove 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. Calibration gases can be routed 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.

The THC and methane analyzers are both equipped with flame ionization detectors (FIDs) as the method of detection. These detectors analyze gases on a wet, unconditioned basis. Therefore, a second heated sample line is used to deliver unconditioned exhaust gases directly to these analyzers.

4.4.2 Gaseous Pollutant Sampling Procedures

For CO_2 and O_2 determination, a continuous sample will be extracted from the emission source and passed through instrumental analyzers. For determination of CO_2 a Milton Roy 3300 non-dispersive infrared (NDIR) analyzer will be used. 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 10 percent.

Figure 4-1. Gas Sampling and Analysis System



Oxygen will be analyzed using a Teledyne 320A fuel cell-analyzer. 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) and serves 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.

NO_x concentrations will be determined on a continuous basis, utilizing a Thermo Environmental Model 10S chemiluminescence analyzer. 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. The efficiency of the catalytic converter in making the changes in chemical state for the various nitrogen oxides is checked 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 conducted, the NO and NO_2 fractions of the overall NO_x concentration will be checked. The NO_x analyzer range 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.

For CO determinations, a Thermo Environmental Model 48 gas filter correlation analyzer 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. Based on site-specific data collected during preliminary measurements, the CO analyzer range 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.

Total hydrocarbons vapors in the exhaust gas will be measured using a JUM Model VE-7 flame ionization analyzer. 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. Concentrations of THC measured on a wet basis will be converted to a dry basis using calculated exhaust gas moisture data. 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. The THC analyzer range will be set at or near the 0 to 1,000 ppm range (as methane).

Concentrations of methane in the exhaust gas will be determined in accordance with EPA Method 18. A slipstream of the Method 25A unconditioned gas stream will be collected in precleaned stainless steel canisters and shipped to a certified laboratory where analysis will be conducted using a GC equipped with a flame ionization detector. Each sample will be injected into the GC three times to determine methane concentrations. The GC/FID will also be calibrated with appropriate certified calibration gases.

Measured pollutant concentrations will be converted to mass rates as lb/hr using Method 19. The lb/hr emission rates will be normalized to engine output and reported as g/BHp-hr. Measured pollutant concentrations as ppmvd will first be converted to pounds per dry standard cubic foot (lb/dscf) using the following unit conversion factors:

CO_2: 1 ppmvd = 1.142E-07 lb/dscf
NO_x: 1 ppmvd = 1.194E-07 lb/dscf
CO: 1 ppmvd = 7.264E-08 lb/dscf
THC: 1 ppmvd = 4.15E-08 lb/dscf (THC emissions are quantified as methane)
CH_4: 1 ppmvd = 4.15E-08 lb/dscf

Emission rates for each pollutant can then be calculated using the following equation:

$$\text{Emission rate (g/BHp-hr)} = [Ci * 453.593 * HI * \text{F-factor} * (20.9/(20.9-O_2))] / BHp$$

Where:
Ci = pollutant concentration (lb/dscf)
453.359 = units conversion lb to g
HI = average engine heat input during test (Btu/hr)
F-factor = calculated fuel F-factor (dscf/MMBtu)
O_2 = average measured exhaust gas O_2 concentration (percent)
BHp = average engine power output during test (BHp)

4.4.3 Calibrations and Quality Control Checks

Analyzer and sampling system calibrations and other QC check criteria specified in the Reference Methods for emissions determinations were identified in Section 3.2.3 and Table 3-3. These QC procedures will be used to determine if overall DQOs for emissions were met during the verification. All of these procedures are detailed in the corresponding Reference Methods and will not be repeated here in entirety. However, the specific procedures to be conducted during this test are outlined below.

<u>NO_x Analyzer Interference Test</u>

In accordance with Method 20, an interference test will be conducted on the NO_x analyzer once before the testing begins. This test is conducted by injecting the following calibration gases into the analyzer:

- CO – 500 $\pm$ 50 ppm in balance nitrogen (N_2)
- SO_2 – 200 $\pm$ 20 ppm in N_2
- CO_2 – 10 $\pm$ 1 % in N_2
- O_2 – 20.9 $\pm$ 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.

<u>NO_2 Converter Efficiency Test</u>

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.

<u>Calibration Error, System Bias, and Calibration Drift Tests</u>

These calibrations will be conducted to verify accuracy of NO_x, CO, CO_2, and O_2 measurements. The calibration error test is conducted at the beginning of each day of testing. A suite of calibration gases is introduced directly to the analyzer and analyzer responses are recorded. EPA Protocol 1 calibration gases must be used for these calibrations. Three gases are used for NO_x, CO_2, and O_2 including 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 $\pm$2 percent of span.

Before and after each test conducted during the day, the zero and mid-level calibration gases are introduced to the sampling systems at the probe and the response is recorded. System bias is then calculated by comparing the system responses to the calibration error responses recorded earlier. System bias must be less than $\pm$ 5 percent of span for the sampling system to be acceptable.

These bias values are used to adjust CEMS concentrations after field operations are completed using the following equation.

$$C_{gas} = (C_{avg} – C_o) * [C_{ma} / (C_m – C_o)]$$

Where:
C_{gas} = Corrected gas concentration
C_{avg} = Average gas concentration measured during the test
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 A-4 provides an example calibration records sheet.

THC Sampling System Calibration Error and Drift

The sampling system calibration error test must be conducted prior to the start of the first test on each day of testing on the THC sampling system. 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. Calibrations will be conducted on all analyzers using Protocol No. 1 calibration gases. Four calibration gases of methane are required including zero, 20 to 30 percent of span, 40 to -60 percent of span, and 80 to 90 percent of span. 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.

4.4.4 Data Collection and Reporting

Data measurement and collection activities for emissions rate determinations will consist of initial pretest QA steps to the passing of the data to the Field Team Leader. Cubix will use a Data Acquisition System (DAS) to record the concentration signals from the individual monitors. The DAS records instrument output at 1-second intervals, and will average those signals into 1-minute averages (Appendix A-3). At the conclusion of a test run, the pre-and post-test calibration results and test run values will be electronically transferred from the DAS into a Microsoft Excel spreadsheet for data calculations and averaging. The Field Team Leader will be informed of the results. Measurement system calibration and gaseous pollutant concentration measurements will be recorded on forms similar to the examples shown in Appendices A-2 through A-4 (these examples do not represent expected emissions at the test site).

Upon completion of the field test activities, Cubix will provide copies of records of calibration, pre-test checks, and field test data to Field Team Leader prior to leaving the site. A formal report will be prepared by Cubix and submitted to Center Field Team Leader within 3 weeks of completion of the field activities. The report will describe the test conditions, documentation of all QA/QC procedures, including copies of calibrations, certificates of calibration gases, and the results of the testing. Field data will be included as an appendix and an electronic copy of the report will be submitted. The submitted information will be stored at the GHG Center's RTP office per guidelines defined in the QMP.

4.5 LUBRICATION OIL ANALYSES

Evaluation of lubrication oil will be conducted by reviewing oil analyses on a monthly basis. The sampling procedures and analytical procedures for each of the test parameters (oxidation and nitration, viscosity, total acid number, and total base number) were detailed in Section 2.2.5 and summarized in Table 2-6.

Specific QA/QC procedures will be used during the testing and analysis to verify the integrity of the oil analysis results and are summarized in the following paragraphs.

Oil sampling will be conducted by collecting the samples in containers that are pre-cleaned at the laboratory. Each time sampling is conducted (samples will be collected at the beginning of the verification period and monthly thereafter), duplicate samples will be collected from each engine to verify repeatability of the analyses.

During analysis, the QA/QC procedures specified in each of the analytical methods specified in the above table will be followed. For the total acid and base number determinations, these QA/QC procedures include the following:

- The meter/electrode combination used for the titrations will be tested prior to analyses to verify that the potential between electrodes changes by at least 590mV when exposed to the base and then acid buffer solutions.
- Reagent purity specifications listed in the method will be met or exceeded.
- For each set of electrodes used, daily meter readings will be obtained and recorded for each set of electrodes at the acidic and basic buffer solution end points.
- One duplicate and one blank titration will be conducted and recorded for each set of samples analyzed.

For the viscosity determinations,

- The capillary viscometer used for these analyses is factory calibrated and has a certified accuracy of $\pm$0.05 cSt. The viscometer is also calibrated with a fluid standard at the laboratory on a daily basis. Duplicate analyses will be conducted on each sample submitted.

For the oxidation and nitration determinations using FTIR,

- The FTIR carries a factory accuracy rating of $\pm$1A/cm.

Copies of the QA/QC results from the laboratory will be reviewed by Center personnel for integrity. Any analyses not meeting the method specifications will be repeated.

4.6 INSTRUMENT TESTING, INSPECTION, AND MAINTENANCE REQUIREMENTS

The equipment 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 or testing laboratories, each instrument will be assembled as anticipated for use in the field and fully tested for functionality. For example, all pumps, controllers, flow meters, computers, instruments, and other sub-components of the entire stack testing measurement system will be operated and calibrated as required by the reference methods. Any faulty sub-components will be repaired or replaced before being transported to the test site. A small amount of consumables and frequently needed spare parts will be maintained in the testing trailer. Major sub-component failures will be handled on a case-by-case basis (e.g., by renting replacement equipment or buying replacement parts).

The meter used to make fuel flow measurements has been serviced and re-calibrated for this verification. It will be inspected at the GHG Center's laboratory prior to installation in the field to ensure all parts are in good condition. The mass flow meters, temperature sensor, and gas pressure sensor will all be calibrated by the manufacturer prior to being transported to the test site.

4.7 INSPECTION/ACCEPTANCE OF SUPPLIES AND CONSUMABLES

EPA Protocol gases will be used to calibrate the gaseous pollutant measurement system. Calibration gas concentrations meeting the levels stated in Section 4.2 are generated by the gas manufacturer from high concentration gases for each target compound using a dilution system, and then analyzed at the factory. Per EPA Protocol gas specifications, the actual concentration must be within ± 2 percent of the certified tag value. Copies of the EPA Protocol gas certifications will be available on-site.

5.0 DATA VALIDATION AND REPORTING

5.1 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
- On-site following completion of each load testing – by the Field Team Leader
- Before writing the draft verification test report – by the Project Manager
- During QA review of the draft report and audit of the data – by Center QA Manager

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 specified in Table 3-4 and determination of DQI goals discussed in Section 3.2. In general, valid results are based on measurements meeting data quality objectives, and that were collected when an instrument was verified as being properly calibrated. Often anomalous data are identified in the process of data review. All outlying or unusual values will be investigated in the field for control testing and weekly for continuous testing. 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. The reasons for excluding any data will be justified in the report. 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 and QA Manager. Based on this, a decision will be made to either continue the test or collect additional data or terminate the test and report the data obtained.

Those individuals responsible for onsite data review and validation are noted in Figure 1-3. The QA Manager reviews and validates the data and the draft report using the Test/QA Plan and test methods. The data review and data audit will be conducted in accordance with Center's QMP. The procedures that will be followed are summarized in Section 5.3.

5.2 RECONCILIATION WITH DATA QUALITY OBJECTIVES

The reconciliation of the results with the DQO will be evaluated using the DQI process. When the primary data is collected, the data will be reviewed 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 quality of the data will be assessed in terms of accuracy and statistical significant as they relate to the stated DQI goals. Attainment of the DQI accuracy goals will be confirmed by analyzing the test data as described in Section 3.2. The statistical analysis will be done by the Project Manager at the conclusion of each load testing using Microsoft Excel's "Descriptive Statistics" routine. The accuracy will be calculated as the 95 percent confidence interval divided by the mean (unless an alternative scheme is specified.) If the accuracy goals were satisfied, it will be concluded that DQOs are met. Emissions testing DQOs will be met because tests will be repeated unless the DQI goals are not achieved.

Results from verification testing of the Controller will be presented in a Verification Statement and a Verification Report as described in Section 5.4.4. All data and analyses performed will be transparent in the final report and the statement. In addition, potential limitations in the use of the data will be discussed, and correction actions taken in the field and its impact on data quality will be discussed.

5.3 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/QA Plan are assessed through project reviews, in-phase inspections, audits, and data quality assessment.

5.3.1 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.

The draft document is then reviewed by MIRATECH, followed by an independent review by selected Stakeholders (minimum of 2 industry experts). The external peer reviews are conducted by technically competent persons who are familiar with the technical aspects of the project, but not involved with the conduct of project activities. 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.

5.3.2 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).

5.3.3 Audits

Independent systematic checks to determine the quality of the data will be performed on the activities of this project. These checks will consist of a system audit and a data audit as described below. In addition, the internal quality control measurements will be used to assess the performance of the analytical methodology. The combination of these audits and the evaluation of the internal quality control data allow the assessment of the overall quality of the data for this project.

The QA Manager is responsible for ensuring the audits are conducted as required by the Test/QA Plan. Audit reports that describe problems and deviations from the procedures are prepared and distributed to the Field Team Leader. Any problems or deviations need to be corrected. The Field Team Leader is responsible for evaluating corrective action reports, taking appropriate and timely corrective actions, and informing the QA Manager of the action taken. The QA Manager is then responsible for ensuring that the corrective action was taken. A summary report of the findings and corrective actions is prepared and distributed to the Project Manager and Center Director.

5.3.3.1 Technical System Audit

The technical system audit (TSA) will be conducted by the QA Manager. This process begins during the project planning process and continues until completion of all data collection and testing activities. Before beginning the test, the audit will include evaluation of all components of the data gathering and management system to determine if these systems have been properly designed to meet the quality assurance objectives for this study. The TSA includes a careful review of the experimental design, the Test/QA Plan, and procedures. This review includes personnel qualifications, adequacy and safety of the facility and equipment, and the data management system.

The TSA begins with the review of study requirements, procedures, and experimental design to ensure that they can meet the data quality objectives for the study. After completion of the testing and data collection activities, the QA Manager or designee will inspect the analytical activities conducted and determine their adherence to the Test/QA Plan. This inspection can include verification that all planned tests were executed, changes to planned activities are documented and archived, raw data are complete, properly stored and recorded, and that planned test procedures were followed. The QA Manager or a designee reports any area of nonconformance to the Field Team Leader through an audit report. The audit report may contain corrective action recommendations. If so, follow-up inspections may be required and should be performed to ensure corrective actions are taken.

5.3.3.2 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 processing the data. 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.

5.4 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.

5.4.1 Field Test Documentation

The Field Team Leader will record all field activities. The Test Leader reviews all data sheets and maintains them in an organized file. The required test information was described earlier in Section 5.1. 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, and originals will be stored in the project records, as required by the QMP.

5.4.2 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.

5.4.3 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 recurrent 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.

5.4.4 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 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 the Controller, 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
MIRATECH Corporation GECO Air/Fuel Ratio Controller
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 Technical and Performance Data from MIRATECH Corporation

References

6.0 TRAINING, HEALTH, AND SAFETY REQUIREMENTS

6.1 TRAINING AND QUALIFICATIONS

The GHG Center's Field Team Leader has extensive experience (+15 years) in field testing of air emissions from gas engines, and Field Support person has over +20 years experience conducting power measurements. 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 performed numerous field verifications under the ETV program, and 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.

The nature of the tests to be performed do not require formal certifications by state, federal, or local authorities. However, special software training was obtained from Rosemount, Power Measurements, and Rochester to install, configure, and operate their instruments. The GHG Center has used the Rosemount mass flow meter in past verifications, and is familiar with its operation and QA/QC requirements.

6.2 HEALTH AND SAFETY REQUIREMENTS

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

Since the site is part of a pipeline facility, Conoco's safety policies are regulated in part by the US Department of Transportation. The GHG Center previously provided a scope of work equivalent to the scope of this plan to the National Compliance Management Service Company, which is a compliance and safety program management company specializing in DOT regulated industries. Their assessment, which is on-site at the GHG Center, is that the GHG Center's on-site job function is not covered by the Research and Special Programs Administration, DOT pipeline safety regulations covered by 49 CFR Parts 192, 193, and 195. If the scope of work changes significantly, this determination would be re-evaluated.

Southern staff will comply with all known Conoco, state/local and Federal regulations relating to safety at Conoco's Conger compressor station. This includes use of personal protective gear (flame resistant clothing (specifically NOMEX), safety glasses, hearing protection, safety toe shoes) as required by Conoco and completion of site safety orientation (i.e., site hazard awareness, alarms and signals).

Other than normal industrial hazards, the most significant hazard at the Station is the potential for explosive concentrations of natural gas. Southern plans to use only intrinsically safe apparatus in the compressor building. Should use of any equipment not so rated be required, Southern will not use this equipment until advised by site personnel that it is safe to do so.

7.0 REFERENCES

Southern Research Institute. *Environmental Technology Verification Greenhouse Gas Technology Verification Quality Management Plan.* Research Triangle Park, NC. October, 1998.

American Society of Mechanical Engineers, *Performance Test Code on Reciprocating Internal Combustion Engines (PTC-17-1997)*, New York, New York, 1997.

American Society of Mechanical Engineers, *Performance Test Code on Measurement of Indicated Power (PTC-19.8-1985)*, New York, New York, 1985.

Code of Federal Regulations, Title 40, Part 60 (Appendix A), *Reference Methods for Determination of Emissions Rates*, United Environmental Protection Agency, Washington, D.C. 1999.

APPENDIX A

Example Field Data

Appendix A-1. Calculation of Indicated Horsepower

Overview of how indicated horsepower is calculated

Click here for an overall discussion about horsepower calculations

Indicated horsepower is calculated from the area within the pressure-volume curve. Indicated horsepower for an entire engine or compressor is the sum of the indicated horsepower for each cylinder.

How RTwin calculates indicated horsepower

DETERMINE FORCE

Consider a pressure, P, acting on the face of a piston of area Ap. The force, Fp, acting on the piston is:

$$Fp = P * Ap$$

DETERMINE WORK

Work is equal to the force applied over a distance. So, if the piston moves a distance, dx, the amount of work, W is:

$$W = (P * Ap)dx$$

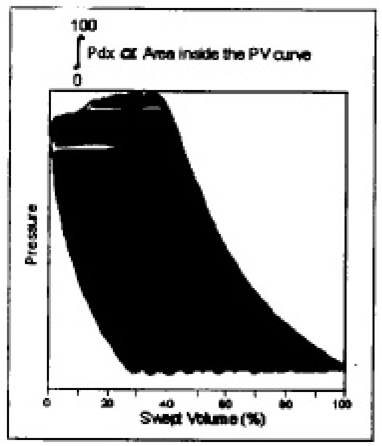
This work is positive if the piston moves in the same direction as the force. Positive work means that work is being done by the gas. The work will be negative if the piston moves in the opposite direction to the force; this means that work is being done on the gas.

During one period, some of the work is positive and some of the work is negative.

To determine the total amount of work done during one complete period, sum all of the increments of work for each increment of motion over 100% of the period, dx

$$W = Ap \int_0^{100\%} Pdx$$

($\int_0^{100\%} Pdx$) is the area contained in power or compressor cylinder PV curve.



DETERMINE POWER

Power is the rate of doing work. Multiply the work per period by the number of periods per minute and divide this number by a constants to express the power in horsepower units. The result is called indicated horsepower (IHP):

$$IHP = \frac{\text{work per period} * \frac{\text{periods}}{\text{min}}}{\text{constant}}$$

$$= \frac{Ap * PVarea * \frac{\text{periods}}{\text{min}}}{33{,}000}$$

for compressors and 2-stroke engines:

$$\frac{\text{periods}}{\text{min}} = \text{rpm}$$

for 4-stroke engines:

$$\frac{\text{periods}}{\text{min}} = \frac{\text{rpm}}{2}$$

Another way of looking at how horsepower is calculated

An alternative way of looking at how RTwin determines horsepower is to consider the equation:

$$\text{Horsepower} = \frac{P.L.A.N.}{33{,}000} \text{ where } P.L.A. \text{ is } = Ap \int_0^{100\%} Pdx$$

where:

P is the mean effective pressure

is the length of the stroke entered in setup (or

L is the length of the stroke entered in setup (or calculated for articulated engines)

A is the piston area entered in the setup (cylinder bore)

N is the periods per minute

33,000 is the factor that converts the value to horsepower units.

Appendix A-2. Example of Emission Rate Results

Example Summary of Results
Turbine Generator

Company: XYZ
Plant: Power Prodcution Facility
Location: Florida
Technicians: LJB, RPO, DLD
Source: a Solar Centaur T-4500 Gas Turbine Generator Set

Test Number	1C-1	1C-2	1C-3	
Date	xx/xx/xx	xx/xx/xx	xx/xx	
Start Time	xx:xx	xx:xx	xx:xx	
Stop Time	xx:xx	xx:xx	xx:xx	
Power Turbine Operation				*Averages*
Generator Output (kW, kilowatts)	2820	2830	2820	*2823*
Percent Load (% of mfg.'s rated capacity of 2970 kW)	94.9	95.3	94.9	*95.1*
Ammeter (AC Amperes)	386	386	390	*387*
Voltmeter (AC Volts)	437	433	433	*434*
Frequency Meter (Hz, herz)	60.4	60.4	60.4	*60.4*
Power Factor Meter (Below 100 is lag)	96.4	96.6	96.4	*96.5*
Engine Speed (%, NGP)	100.2	100.1	100.1	*100.1*
Engine Compressor Discharge Pressure (psia, PCD)	130.0	129.5	130.0	*129.8*
Mean Turbine Exhaust Temperature (°F, T-5)	1161	1160	1160	*1160*
Turbine Fuel Data (Landfill Gas)				
Fuel Heating Value (Btu/SCF, HHV)	631.6	631.6	631.6	*631.6*
Fuel Specific Gravity	0.8817	0.8817	0.8817	*0.8817*
O_2 "F-factor" (DSCFex/MMBtu @ 0% excess air)	9150	9150	9150	*9150*
CO_2 "F-factor" (DSCFex/MMBtu @ 0% excess air)	1501	1501	1501	*1501*
Fuel Flow (scfm, landfill gas)	1167.2	1164.3	1164.8	*1165.4*
Heat Input (MMBtu/hr, Higher Heat Value)	44.23	44.12	44.14	*44.17*
Heat Input (MMBtu/hr, Lower Heat Value)	39.8	39.7	39.7	*39.7*
Brake-specific Fuel Consumption (Btu/kW-hr)	14,117	14,032	14,088	*14,079*
Ambient Conditions				
Atmospheric Pressure ("Hg)	29.93	29.93	29.89	*29.92*
Temperature (°F): Dry bulb	83.4	83.1	80.1	*82.2*
(°F): Wet bulb	69.9	69.9	69.0	*69.6*
Humidity (lbs moisture/lb of air)	0.0122	0.0123	0.0123	*0.0123*
Measured Emissions				
NO_x (ppmv, dry basis)	31.03	31.15	31.28	*31.15*
NO_x (ppmv, dry @ 15% O_2)	46.1	47.2	46.3	*46.5*
SO_2 (ppmv, dry basis via EPA Method 6c)	1.10	1.13	1.28	*1.17*
SO_2 (ppmv, dry @ 15% O_2)	1.63	1.71	1.89	*1.75*
CO (ppmv, dry basis)	9.94	9.80	9.81	*9.85*
THC (ppmv, wet basis)	1.62	1.63	1.75	*1.67*
Visible Emissions (% opacity)		0		0
H_2O (% volume, from Method 4 sample train)	5.55	5.37	5.30	5.41
O_2 (% volume, dry basis)	16.93	17.01	16.91	*16.95*
CO_2 (% volume, dry basis)	3.26	3.29	3.25	*3.27*
Stack Volumetric Flow Rates				
via EPA Method 2, pitot tube (SCFH, dry basis)	2.17E+06	2.12E+06	2.22E+06	*2.17E+06*
via O_2 "F_d-factor" (SCFH, dry basis)	2.13E+06	2.17E+06	2.12E+06	*2.14E+06*
via CO_2 "F_c-factor" (SCFH, dry basis)	2.04E+06	2.01E+06	2.04E+06	*2.03E+06*
Calculated Emission Rates (via M-19 O_2 "F-factor")				
NO_x (lbs/hr)	8.05	7.90	8.29	*8.08*
CO (lbs/hr)	1.57	1.51	1.58	*1.56*
THC (lbs/hr)	0.16	0.15	0.17	*0.16*
SO_2 (lbs/hr)	0.40	0.40	0.47	*0.42*
NO_x (tons/yr)	35.3	34.6	36.3	*35.4*
CO (tons/yr)	6.88	6.63	6.93	*6.82*
THC (tons/yr)	0.68	0.00	0.75	*0.48*
SO_2 (tons/yr)	1.74	1.75	2.07	*1.85*

Testing by Cubix Corporation - Austin, Texas - Gainesville, Florida

Appendix A-3. Example of Raw Emission Measurements Data

Unit R-2, Logged Data Records

Run Number	Date	Time	NO_x (ppmv)	O_2 (% vol)	CO_2 (% vol)	AVE NO_x (ppmv)	AVE O_2 (% vol)	AVE CO_2 (% vol)
START Run 2C-3	4/10/2000	1:51:57 PM	8.22	16.41	2.58	8.22	16.41	2.58
Run 2C-3	4/10/2000	1:52:57 PM	8.22	16.42	2.60	8.22	16.41	2.59
Run 2C-3	4/10/2000	1:53:57 PM	8.10	16.42	2.58	8.18	16.41	2.59
Run 2C-3	4/10/2000	1:54:57 PM	8.22	16.43	2.56	8.19	16.42	2.58
Run 2C-3	4/10/2000	1:55:57 PM	8.26	16.43	2.56	8.21	16.42	2.58
Run 2C-3	4/10/2000	1:56:57 PM	8.09	16.38	2.58	8.19	16.41	2.58
Run 2C-3	4/10/2000	1:57:57 PM	8.17	16.39	2.59	8.18	16.41	2.58
Run 2C-3	4/10/2000	1:58:57 PM	8.24	16.30	2.64	8.19	16.40	2.59
Run 2C-3	4/10/2000	1:59:57 PM	8.30	16.31	2.62	8.20	16.39	2.59
Run 2C-3	4/10/2000	2:00:57 PM	9.68	16.08	2.75	8.35	16.35	2.61
Run 2C-3	4/10/2000	2:01:56 PM	9.41	16.07	2.74	8.45	16.33	2.62
Run 2C-3	4/10/2000	2:02:56 PM	10.38	16.07	2.74	8.61	16.31	2.63
Run 2C-3	4/10/2000	2:03:56 PM	10.29	16.07	2.74	8.74	16.29	2.64
Run 2C-3	4/10/2000	2:04:56 PM	10.68	16.11	2.72	8.88	16.28	2.64
Run 2C-3	4/10/2000	2:05:56 PM	11.11	16.11	2.72	9.02	16.27	2.65
Run 2C-3	4/10/2000	2:06:56 PM	11.53	16.15	2.71	9.18	16.26	2.65
END Run 2C-3	4/10/2000	2:07:56 PM	11.87	16.15	2.71	**9.34**	**16.25**	**2.65**
START Run 2C-4	4/10/2000	2:17:36 PM	15.32	16.07	2.79	15.32	16.07	2.79
Run 2C-4	4/10/2000	2:18:36 PM	14.96	16.09	2.83	15.14	16.08	2.81
Run 2C-4	4/10/2000	2:19:36 PM	15.01	16.09	2.83	15.10	16.09	2.82
Run 2C-4	4/10/2000	2:20:36 PM	14.58	16.09	2.85	14.97	16.09	2.82
Run 2C-4	4/10/2000	2:21:36 PM	14.46	16.09	2.86	14.87	16.09	2.83
Run 2C-4	4/10/2000	2:22:36 PM	13.85	16.11	2.84	14.70	16.09	2.83
Run 2C-4	4/10/2000	2:23:36 PM	13.65	16.11	2.83	14.55	16.09	2.83
Run 2C-4	4/10/2000	2:24:36 PM	13.08	16.16	2.80	14.36	16.10	2.83
Run 2C-4	4/10/2000	2:25:36 PM	12.95	16.17	2.79	14.21	16.11	2.83
Run 2C-4	4/10/2000	2:26:36 PM	12.54	16.24	2.76	14.04	16.12	2.82
Run 2C-4	4/10/2000	2:27:36 PM	12.27	16.25	2.76	13.88	16.14	2.81
Run 2C-4	4/10/2000	2:28:36 PM	12.42	16.31	2.73	13.76	16.15	2.81
Run 2C-4	4/10/2000	2:29:36 PM	12.18	16.32	2.74	13.64	16.16	2.80
Run 2C-4	4/10/2000	2:30:36 PM	12.38	16.37	2.70	13.55	16.18	2.79
Run 2C-4	4/10/2000	2:31:36 PM	12.33	16.37	2.73	13.46	16.19	2.79
Run 2C-4	4/10/2000	2:32:36 PM	12.50	16.41	2.70	13.40	16.20	2.79
END Run 2C-4	4/10/2000	2:33:35 PM	12.29	16.41	2.69	**13.34**	**16.22**	**2.78**
START Run 2C-5	4/10/2000	2:42:03 PM	12.46	16.40	2.74	12.46	16.40	2.74
Run 2C-5	4/10/2000	2:43:03 PM	12.16	16.40	2.76	12.31	16.40	2.75
Run 2C-5	4/10/2000	2:44:04 PM	12.35	16.41	2.75	12.33	16.40	2.75
Run 2C-5	4/10/2000	2:45:03 PM	12.38	16.37	2.77	12.34	16.40	2.75
Run 2C-5	4/10/2000	2:46:03 PM	12.30	16.37	2.77	12.33	16.39	2.76
Run 2C-5	4/10/2000	2:47:03 PM	12.45	16.34	2.77	12.35	16.38	2.76
Run 2C-5	4/10/2000	2:48:03 PM	12.43	16.34	2.76	12.36	16.37	2.76
Run 2C-5	4/10/2000	2:49:03 PM	12.76	16.29	2.79	12.41	16.36	2.76
Run 2C-5	4/10/2000	2:50:03 PM	12.27	16.29	2.77	12.40	16.36	2.76
Run 2C-5	4/10/2000	2:51:03 PM	13.47	16.21	2.80	12.50	16.34	2.77
Run 2C-5	4/10/2000	2:52:03 PM	13.47	16.20	2.78	12.59	16.33	2.77
Run 2C-5	4/10/2000	2:53:03 PM	14.57	16.16	2.92	12.76	16.31	2.78
Run 2C-5	4/10/2000	2:54:03 PM	14.43	16.14	2.81	12.89	16.30	2.78
Run 2C-5	4/10/2000	2:55:03 PM	14.62	16.14	2.82	13.01	16.29	2.79
Run 2C-5	4/10/2000	2:56:03 PM	14.59	16.15	2.80	13.11	16.28	2.79
Run 2C-5	4/10/2000	2:57:03 PM	14.84	16.16	2.79	13.22	16.27	2.79
END Run 2C-5	4/10/2000	2:58:03 PM	15.35	16.17	2.79	**13.35**	**16.27**	**2.79**

Appendix A-4. Example of Emission Measurements Calibration Data

Unit R-2, Logged QA Calibration Records

Run 2C-3 4/10/2000 1:51:56 PM 2:07:56 PM

Initial Linearity Test	Zero	Low	Mid	Span	L-Lin	M-Lin	S-Lin
NOx (ppmv)	0	13.57	45.92	23.52	0.22	-0.84	-0.06
O2 (%)	0.09	4.64	12.03	20.68	-0.69	-0.07	0.47
CO2 (%)	0	8.01	12.45	4.57	-0.14	0.55	-0.34

Initial and Final Bias and Drift	I-Zero	I-Span	F-Zero	F-Span	Z-Bias	S-Bias	Z-Drift	S-Drift
NOx (ppmv)	0.08	24.14	0.07	24.34	0.14	1.64	0.02	-0.4
O2 (%)	0.25	20.83	0.24	20.84	0.58	0.63	0.06	-0.03
CO2 (%)	-0.15	4.28	-0.24	4.23	-1.63	-2.3	0.64	0.36

Run Results and Cal Gases Used	Raw	Corrected	Ranges	Low Gas	Mid Gas	Span Gas
NOx (ppmv)	9.34	9.01	50	13.68	45.5	23.49
O2 (%)	16.25	16.17	25	4.47	12.01	20.8
CO2 (%)	2.65	2.89	15	7.99	12.53	4.52

Run 2C-4 4/10/2000 2:17:35 PM 2:33:35 PM

Initial Linearity Test	Zero	Low	Mid	Span	L-Lin	M-Lin	S-Lin
NOx (ppmv)	0	13.57	45.92	23.52	0.22	-0.84	-0.06
O2 (%)	0.09	4.64	12.03	20.68	-0.69	-0.07	0.47
CO2 (%)	0	8.01	12.45	4.57	-0.14	0.55	-0.34

Initial and Final Bias and Drift	I-Zero	I-Span	F-Zero	F-Span	Z-Bias	S-Bias	Z-Drift	S-Drift
NOx (ppmv)	0.07	24.34	0.09	24.45	0.18	1.86	-0.04	-0.22
O2 (%)	0.24	20.84	0.28	20.89	0.75	0.81	-0.17	-0.18
CO2 (%)	-0.24	4.23	-0.15	4.35	-1.03	-1.44	-0.6	-0.86

Run Results and Cal Gases Used	Raw	Corrected	Ranges	Low Gas	Mid Gas	Span Gas
NOx (ppmv)	13.34	12.81	50	13.68	45.5	23.49
O2 (%)	16.22	16.11	25	4.47	12.01	20.8
CO2 (%)	2.78	3.00	15	7.99	12.53	4.52

Testing by Cubix Corporation - Austin, Texas - Gainesville, Florida

R2-2

APPENDIX B

Field Data Logs

Appendix B-1. Gas Flowmeter Readings Data Log

Date: ______________

Engine ID: ______________

Engine Speed: ______________

Engine Load: ______________

GECO Mode: ______________

Barometric Pressure: ______________

Ambient Temp: ______________

Synchronize clocks: ______________

Operator(s): ______________

Flow Rate Measurements

Run 1		Run 2		Run 3		Totalizer Values	
Time	Flow (scfm gas)	Time	Flow (scfm gas)	Time	Flow (scfm gas)	Time	Volume (scf gas)
Avg.		Avg.		Avg.		Total	

Appendix B-2. Flow Meter Setup Parameters

MODEL 3095 MV CONFIGURATION DATA SHEET

00806-0100-4716
English
Rev. AA

Complete this form to define a Custom Flow Configuration for the Model 3095 MV.
Unless specified, the Model 3095 MV will ship with the default values identified by the ★ symbol.

For technical assistance in filling out this CDS, call Rosemount Customer Central at 1-800-999-9307.

NOTE: Any missing information will be processed with the indicated default values.

OPTION CODE C2

Customer: ____________________

Customer P.O. No.: ____________________

Customer Line Item: ____________________

Model No.:(1) ____________________

Tag Type: ☐ SST Wire-on Tag (85 characters maximum) ☐ Stamped on Nameplate (65 characters maximum)

Tag Information: ____________________

TRANSMITTER INFORMATION (optional)

Software Tag: |__|__|__|__|__|__|__|__| (8 characters)

Descriptor: |__|__|__|__|__|__|__|__|__|__|__|__|__|__|__|__| (16 characters)

Message: |__|__|__|__|__|__|__|__|__|__|__|__|__|__|__|__|
|__|__|__|__|__|__|__|__|__|__|__|__|__|__|__|__| (32 characters)

Date: |__|__| (dd) |__|__|__| (mmm) |__|__| (yy)

TRANSMITTER INFORMATION (required)

Failure Mode Alarm Direction (select one): ☐ Alarm High ★ ☐ Alarm Low

(1) A complete model number is required before Rosemount Inc. can process this custom configuration order.

★ ***Indicates default value.***

For RMD internal use only:

House Order No: ____________________

Line Item No: ____________________

Transmitter Serial No: ____________________

RCC Tech: ____________________

6-18

LCD Meter Configuration

Process Variables displayed on LCD:

☐ Absolute Pressure
☐ Analog Output Current
☐ Differential Pressure
☐ Flow
☐ Flow Total
☐ Gauge Pressure
☐ Percent of Range
☐ Process Temperature

Number of seconds to display each variable:____________________
(available ranges from 2–10 seconds, in one second increments)

FLOW CONFIGURATION (required)

Select units for each Process Variable, then enter *sensor* Lower Trim Value (LTV) and *sensor* Upper Trim Value (UTV).
Note: LTV and UTV must be within the range limits stated in the Range Limits Table (see page 6-26).

Differential Pressure:

DP Units ☐ inH_2O–68 °F★ ☐ inHg–0 °C ☐ ftH_2O–68 °F ☐ mmH_2O–68 °F ☐ mmHg–0 °C ☐ psi
☐ bar ☐ mbar ☐ g/SqCm ☐ Kg/SqCm ☐ Pa ☐ kPa
☐ torr ☐ Atm ☐ inH_2O–60 °F

Trim Values LTV:________________(0 ★) UTV:________________(URL inH_2O–68 °F ★)

Static Pressure:

Static Units ☐ inH_2O–68 °F ☐ inHg–0 °C ☐ ftH_2O–68 °F ☐ mmH_2O–68 °F ☐ mmHg–0 °C ☐ psi ★
☐ bar ☐ mbar ☐ g/SqCm ☐ Kg/SqCm ☐ Pa ☐ kPa
☐ torr ☐ Atm ☐ MPa ☐ inH_2O–60 °F

Trim Values(2) LTV:________________(0 ★) UTV:________________(URL psi ★)

Process Temperature:

PT Units ☐ °F ★ ☐ °C

Trim Values LTV:________________(–300 ★) UTV:________________(1500 °F ★)

Flow Rate:

Flow Units: ☐ StdCuft/s ☐ StdCuft/min ☐ StdCuft/h ☐ StdCuft/d ☐ StdCum/h
☐ StdCum/d ☐ lbs/sec ☐ lbs/min ☐ lbs/hour ★ ☐ lbs/day
☐ grams/sec ☐ grams/min ☐ grams/hour ☐ kg/sec ☐ kg/min
☐ kg/hour ☐ NmlCuM/hour ☐ NmlCuM/day ☐ Special (see Flow Rate Special Units)

Flow Rate Special Units (use if "Special" is checked in Flow Rate above):

NOTE: Flow Rate Special Units = Base Flow Unit multiplied by Conversion Factor.

Base Flow Units (select from above Flow Rate units): ____________________

Conversion Factor: ____________________

Display As: |__|__|__|__|__| *(available units A–Z, 0–9)*

Flow Rate Output:

Low PV (4 mA) ________________(0.00 ★) High PV (20 mA)________________

FLOW CONFIGURATION CONT. (required)

Flow Total:

Flow Units: ☐ Grams ☐ Kilograms ☐ Metric Tons ☐ Pounds ☐ Short Tons
☐ Long Tons ☐ Ounces ☐ NmlCuM ☐ Normal Liters ☐ StdCuM
☐ StdCuFt ☐ Special (see Flow Total Special Units)

Flow Total Special Units (use this section if "Special" is checked in Flow Total above):

NOTE: Flow Rate Special Units = Base Flow Unit multiplied by Conversion Factor.

Base Flow Units (select from above Flow Total units): ______________________________

Conversion Factor: ______________________________

Display As: |___|___|___|___|___| *(available units A–Z, 0–9)*

Flow Total Output:

Low PV (4 mA) ___________________________(0.00 ★) High PV (20 mA)______________________________

Damping: Enter a damping value for each variable (valid range: 0.1 – 29 seconds).
(Transmitter will round to nearest available damping value.)

Differential Pressure = ______________(0.864★) Temperature = ______________(0.864★)

Static Pressure = ______________(0.864★)

(2) If absolute pressure module, then lower static pressure values must be ≥ 0.5 psia (3.45 kPa).

★ ***Indicates default value.***

NOTE ***The information on Pages 6-21–6-25 can be sent in on a floppy disk by creating a .MFL file with the EA Software or EA Demo Disk. Call 1-800-999-9307 for more information.***

PRIMARY ELEMENT INFORMATION

Select Differential Producer (Select One)

- ☐ 1195 Integral Orifice
- ☐ Annubar® Diamond II+/Mass ProBar+
- ☐ Nozzle, Long Radius Wall Taps, ASME
- ☐ Nozzle, Long Radius Wall Taps, ISO
- ☐ Nozzle, ISA 1932, ISO
- ☐ Orifice, 2½D & 8D Taps
- ☐ Orifice, Corner Taps, ASME
- ☐ Orifice, Corner Taps, ISO
- ☐ Orifice, D & D/2 Taps, ASME
- ☐ Orifice, D & D/2 Taps, ISO
- ☐ Orifice, Flange Taps, AGA3
- ☐ Orifice, Flange Taps, ISO
- ☐ Small Bore Orifice, Flange Taps, ASME
- ☐ Venturi Nozzle, ISO
- ☐ Venturi, Rough Cast/Fabricated Inlet, ASME
- ☐ Venturi, Rough Cast Inlet, ISO
- ☐ Venturi, Machined Inlet, ASME
- ☐ Venturi, Machined Inlet, ISO
- ☐ Venturi, Welded Inlet, ISO

Selecting Area Averaging Meter or V-Cone® requires a constant value for discharge coefficient: ____________________

☐ Area Averaging Meter ☐ V-Cone

Primary Element Minimum Diameter (d) ________________ ☐ in. ☐ mm at ____________ ☐ °F ☐ °C in. at 68 °F ★

or

Diamond II Sensor Series No. _______ (see table on page 6-26)

Differential Producer Material (Select One) ☐ Carbon Steel ☐ SST 304 ☐ SST 316★ ☐ *Hastelloy C* ☐ *Monel*

Pipe Tube Diameter (Pipe ID) (D) ________________ ☐ in. ☐ mm at ____________ ☐ °F ☐ °C in. at 68 °F ★

Pipe Tube Material: ☐ Carbon Steel★ ☐ SST 304 ☐ SST 316 ☐ *Hastelloy C* ☐ *Monel*

PROCESS OPERATING CONDITIONS

Operating Pressure Range ____________ to ____________ ☐ psia ☐ psig ☐ kPa (absolute) ☐ kPa (gage) ☐ bar

Operating Temperature Range ____________ to ____________ ☐ °F ☐ °C

For fixed process temperatures (Model Code = 0), enter value ____________________.
Valid range: –459 to 3500 °F (–273 to 1927 °C)

NOTE: For steam applications, temperatures must be equal to or greater than the saturation temperature at the given pressures.

ATMOSPHERIC PRESSURE

Atmospheric Pressure = ____________ ☐ psia ☐ kPa(absolute) ☐ bar 14.696 psia ★

STANDARD REFERENCE CONDITIONS

NOTE: This information is only required if any of the following flow units were selected: StdCuft/s, StdCuft/min, StdCuft/h, StdCuft/d, StdCum/h, StdCum/d

Standard Reference Conditions:

Standard Pressure = ________________ ☐ psia ☐ bar ☐ kPa(absolute) 14.696 psia ★
(gas/steam only)

Standard Temperature = ________________ ☐ °F ★ ☐ °C 60 °F ★ (For Steam, 212 °F ★)

★ ***Indicates default value.***

FLUID TYPE (Select One)

☐ Gas ☐ Liquid

FLUID INFORMATION (Complete one section only)

☐ **Steam (ASME) Saturated and/or Superheated**

☐ **Natural Gas**

NOTE: If you selected Natural Gas, complete the information on page 6-23.

☐ **Gas or Liquid from AIChE database**: Circle **ONE** fluid name below:

Acetic Acid
Acetone
Acetonitrile
Acetylene
Acrylonitrile
Air
Allyl Alcohol
Ammonia
Argon
Benzene
Benzaldehyde
Benzyl Alcohol
Biphenyl
Carbon Dioxide
Carbon Monoxide
Carbon Tetrachloride
Chlorine
Chlorotrifluoroethylene
Chloroprene
Cycloheptane
Cyclohexane
Cyclopentane
Cyclopentene
Cyclopropane
Divinyl Ether
Ethane
Ethanol
Ethylamine
Ethylbenzene
Ethylene
Ethylene Glycol/Ethylene Oxide
Fluorene
Furan
Helium–4
Hydrazine
Hydrogen
Hydrogen Chloride
Hydrogen Cyanide
Hydrogen Peroxide
Hydrogen Sulfide
Isobutane
Isobutene
Isobutylbenzene
Isopentane
Isoprene
Isopropanol
Methane
Methanol
Methyl Acrylate
Methyl Ethyl Ketone
Methyl Vinyl Ether
m–Chloronitrobenzene
m–Dichlorobenzene
Neon
Neopentane
Nitric Acid
Nitric Oxide
Nitrobenzene
Nitroethane
Nitrogen
Nitromethane
Nitrous Oxide
n–Butane
n–Butanol
n–Butyraldehyde
n–Butyronitrile
n–Decane
n–Dodecane
n–Heptadecane
n–Heptane
n–Hexane
n–Octane
n–Pentane
Oxygen
Pentafluorothane
Phenol
Propane
Propadiene
Pyrene
Propylene
Styrene
Sulfer Dioxide
Toluene
Trichloroethylene
Vinyl Acetate
Vinyl Chloride
Vinyl Cyclohexane
Water
1–Butene
1–Decene
1–Decanal
1–Decanol
1-Dodecene
1–Dodecanol
1–Heptanol
1–Heptene
1–Hexene
1–Hexadecanol
1–Octanol
1–Octene
1–Nonanal
1–Nonanol
1–Pentadecanol
1–Pentanol
1–Pentene
1–Undecanol
1,2,4–Trichlorobenzene
1,1,2–Trichloroethane
1,1,2,2–Tetrafluoroethane
1,2–Butadiene
1,3–Butadiene
1,3,5–Trichlorobenzene
1,4–Dioxane
1,4–Hexadiene
2–Methyl–1–Pentene
2,2–Dimethylbutane

☐ **Custom Gas or Liquid**

Enter your custom fluid name ______________________

NOTE: If you are defining a custom fluid, complete the density and viscosity information on page 6-25.

★ ***Indicates default value.***

NOTE ***Only fill out this page if you selected natural gas.***

COMPRESSIBLITY FACTOR INFORMATION:

Choose desired characterization method, and only enter values for that method:

☐ Detail Characterization Method, (AGA8 1992)

			Mole	Valid Range
CH4	Methane mole percent	______	%	0–100 percent
N2	Nitrogen mole percent	______	%	0–100 percent
CO2	Carbon Dioxide mole percent	______	%	0–100 percent
C2H6	Ethane mole percent	______	%	0–100 percent
C3H8	Propane mole percent	______	%	0–12 percent
H2O	Water mole percent	______	%	0–Dew Point
H2S	Hydrogen Sulfide mole percent	______	%	0–100 percent
H2	Hydrogen mole percent	______	%	0–100 percent
CO	Carbon Monoxide mole percent	______	%	0–3.0 percent
O2	Oxygen mole percent	______	%	0–21 percent
C4H10	i-Butane mole percent	______	%	0–6 percent (1)
C4H10	n-Butane mole percent	______	%	0–6 percent (1)
C5H12	i-Pentane mole percent	______	%	0–4 percent (2)
C5H12	n-Pentane mole percent	______	%	0–4 percent (2)
C6H16	Hexane mole percent	______	%	0–Dew Point
C7H16	n-Heptane mole percent	______	%	0–Dew Point
C8H18	n-Octane mole percent	______	%	0–Dew Point
C9H20	n-Nonane mole percent	______	%	0–Dew Point
C10H22	n-Decane mole percent	______	%	0–Dew Point
He	Helium mole percent	______	%	0–3.0 percent
Ar	Argon mole percent	______	%	0–1.0 percent

(1) The summation of i-Butane and n-Butane cannot exceed 6 percent.
(2) The summation of i-Pentane and n-Pentane cannot exceed 4 percent.

☐ Gross Characterization Method, Option 1 (AGA8 Gr-Hv-CO2)

			Valid Range
Specific gravity at 14.73 psia and 60 °F	______		0.554–0.87
Volumetric Gross Heating Value at Base Conditions	______	BTU/SCF	477–1150 BTU/SCF
Carbon dioxide mole percent	______	%	0–30 percent
Hydrogen mole percent	______	%	0–10 percent
Carbon monoxide mole percent	______	%	0–3 percent

☐ Gross Characterization Method, Option 2 (AGA8 Gr-CO2-N2)

			Valid Range
Specific Gravity at 14.73 psia and 60 °F	______		0.554–0.87
Carbon dioxide mole percent	______	%	0–30 percent
Nitrogen mole percent	______	%	0–50 percent
Hydrogen mole percent	______	%	0–10 percent
Carbon monoxide mole percent	______	%	0–3 percent

★ ***Indicates default value.***

Appendix B-3. Gas Flowmeter Meter QA/QC Checks

<u>SENSOR FUNCTION CHECKS</u>

1) Analog Loop Test

Date ___________

Time ___________ ___________ ___________ ___________

Meter Output (mA) ___________ ___________ ___________ ___________

Master Reading mA) ___________ ___________ ___________ ___________

% Difference ___________ ___________ ___________ ___________

Corrective Action ____

<u>CALIBRATION CHECKS</u>

1) Bench Calibration

Date ___________ Time ___________

Absolute Pressure Offset Trim Point (psi) ________________________

Absolute Pressure Slope Trim Point (psi) ________________________

Absolute Temperature Offset Trim Point (°F) ________________________

Absolute Temperature Slope Trim Point (°F) ________________________

Corrective Action ____

2) Zero Check

Date ___________

Time ___________

Initial reading ___________mA ___________lbs/hr

Reading after adjustment ___________mA ___________lbs/hr (should be 0, enter n/a if no adjustment)

Corrective Action ____

Appendix B-4. Meteorological Data Summary for Midland-Odessa International Airport Area Elevation - 2861.1 ft above sea level (1999)

	Temperature (^oF)			Relative Humidity (%)			Barometric Pressure (in.)
	Daily Min.	Daily Max.	Avg. Monthly	Daily Min.	Daily Max.	Avg. Monthly	Avg. Monthly
24 HOUR DAILY AVERAGES							
January	32.3	63.6	48.0	29	65	47.2	27.06
February	38.4	71.2	54.8	17	54	35.4	27.09
March	42.7	69.0	55.9	35	75	56.2	27.03
April	50.3	79.7	65.0	25	61	41.2	26.96
6:00 AM – 6:00 PM AVERAGES							
January	17	81	50	12	100	44	27.06
February	20	84	58	9	100	32	27.09
March	26	86	58	8	100	52	27.03
April	32	94	69	9	100	38	26.96

Source: National Climatic Data Center