FINAL

Test/QA Plan for the Verification Testing of Catalytica Combustion System, Inc. XONON Flameless Combustion System

EPA Cooperative Agreement No. CR 826152-01-2 with RTI
RTI Subcontract No. 1-93U-7012
MRI Project No. 101494

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Prepared for:

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LIST OF ACRONYMS/ABBREVIATIONS

ADQ	Audit of data quality
ANSI	American National Standards Institute
APCT	Air Pollution Control Technology
ASME	American Society of Mechanical Engineers
CCSI	Catalytica Combustion Systems, Inc.
cfm	Cubic feet per minute
CO	Carbon monoxide
CV	Coefficient of variance
DQO	Data Quality Objective
EED	MRI's Environmental Engineering Division
EPA	Environmental Protection Agency
ETV	Environmental Technology Verification
fpm	Feet per minute
HMI	Human machine interface
IR	Infrared
ISO	International Standards Organization
MRI	Midwest Research Institute
NESHAP	National Emission Standard for Hazardous Air Pollutants
NIST	National Institute of Standards and Technology
NO_X	Nitrogen oxides
PE	Performance evaluation
QA	Quality Assurance
QAO	Quality Assurance Officer
QC	Quality Control
QMP	Quality Management Plan
QSM	Quality System Manual
RH	Relative humidity
RTI	Research Triangle Institute
SOP	Standard operating procedure
TEI	Thermo Enviromental Instruments, Inc. (sometimes identified as TECO)
TSA	Technical systems audit
UHC	Unburned hydrocarbons (same as total hydrocarbons)

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PREFACE

This Test/QA Plan was prepared by Midwest Research Institute (MRI) and Research Triangle Institute (RTI) for the APCT ETC. The Test/QA Plan provides a detailed plan for conducting and reporting results from a verification test of Catalytica Combustion System, Inc. (CCSI) XONON Flameless Combustion System. The plan was reviewed by CCSI, RTI, MRI, and EPA.

SECTION A: PROJECT MANAGEMENT

A1: Project/Task Organization

The US Environmental Protection Agency (EPA) has overall responsibility for the Environmental Technology Verification (ETV) Program for Air Pollution Control Technology (APCT). Research Triangle Institute (RTI) is EPA's verification partner in this effort. Midwest Research Institute (MRI) is the testing organization within the APCT Program. The APCT program has selected the XONON flameless combustion system of Catalytica Combustion Systems, Inc. (CCSI) as a NO_x control technology to be verified.

Management and testing within the NO_x control technology program are performed in accordance with procedures and protocols defined by a series of quality management documents. These include EPA's Quality and Management Plan for the overall ETV program (EPA ETV QMP), MRI's Environmental Engineering Division (EED) Quality System Manual (MRI QSM), the QMP for the overall APCT program (APTC QMP), the Generic Verification Protocol (GVP) for NO_x Control Technologies, and this Test/QA Plan. Table 1 summarizes these documents. The EPA ETV QMP is the primary source for quality management guidance and the APCT's QMP is next.

Midwest Research Institute will, for RTI, conduct a field verification test on the XONON flameless combustion system, analyze data, and prepare a verification report and verification statement. The various quality assurance (QA) and management responsibilities are divided between EPA, RTI, and MRI key project personnel as defined below. The lines of authority between key personnel for this project are shown on the project organization chart in Figure 1.

A1.1 Management Responsibilities

Project management responsibilities are divided among the EPA, RTI, and MRI personnel as listed below.

A1.1.1 EPA Project Manager

The EPA Project Manager, Ted Brna, has overall responsibility for the APCT program. He is responsible for obtaining final approval of project Test/QA plans and reports.

A1.1.2 RTI Project Manager

The RTI Project Manager for the APCT program is Jack Farmer. He has overall responsibility for QA in the APCT program and in technology-specific verification tests. He will assign technology verification task leaders; oversee verifications; review technical panel makeup; and review generic verification protocol and test-specific quality documents. These responsibilities are described in greater detail in Section 2 of the APCT's QMP.

Table 1. Quality Management Documents Applicable to Verification of the XONON Flameless Combustion System

Document	Description
EPA s ETV QMP	EPA's ETV QMP lays out the definitions, procedures, processes, inter-organizational relationships, and outputs that will assure the quality of both the data and the programmatic elements of ETV. Part A of the ETV QMP contains the specifications and guidelines that are applicable to common or routine quality management functions and activities necessary to support the ETV program. Part B of the ETV QMP contains the specifications and guidelines that apply to test-specific environmental activities involving the generation , collection, analysis, evaluation, and reporting of test data. (EPA's Quality and Management Plan for the Pilot Period (1995-2000), May 1998.)
MRI s EED QSM	EED's Quality System Manual describes the quality systems in place for MRI's technical research unit containing the APCT program. EED's quality manuals comply with ANSI/ASQC Standard E4-1994. The scope of these manuals encompasses performance criteria, requirements, and procedures for managing the quality of all work conducted by or on behalf of EED. Therefore, EED's quality manuals apply to all EED staff as well as people who perform work on behalf of EED, such as staff from other MRI research and administrative units, and others who contribute to projects managed by EED.
APCT s QMP	APCT's QMP describes the quality systems in place for the overall APCT program. It was prepared by RTI and approved by EPA. Among other quality management items, it defines what must be covered in the generic verification protocols and Test/QA plans for technologies undergoing verification testing.
Generic Verification Protocols (GVP)	Generic Verification Protocols (GVP) are prepared for each type of technology to be verified. These documents describe the overall procedures to be used for testing a specific technology and define the data quality objectives (DQO). With input from the NO_x Control Technology Technical Panel, RTI and MRI prepared the GVP for NO_x Control Technologies and the document was reviewed and approved by EPA.
Test/QA Plan	The Test/QA Plan describes, in detail, how the verification test will be implemented to meet the requirements of the GVP. The Test/QA Plan addresses issues such as the management organization, test schedule, documentation, analytical method and data collection requirements, calibration traceability, and specifies the QA and QC requirements for obtaining verification data of sufficient quantity and quality to satisfy the DQO of the GVP.

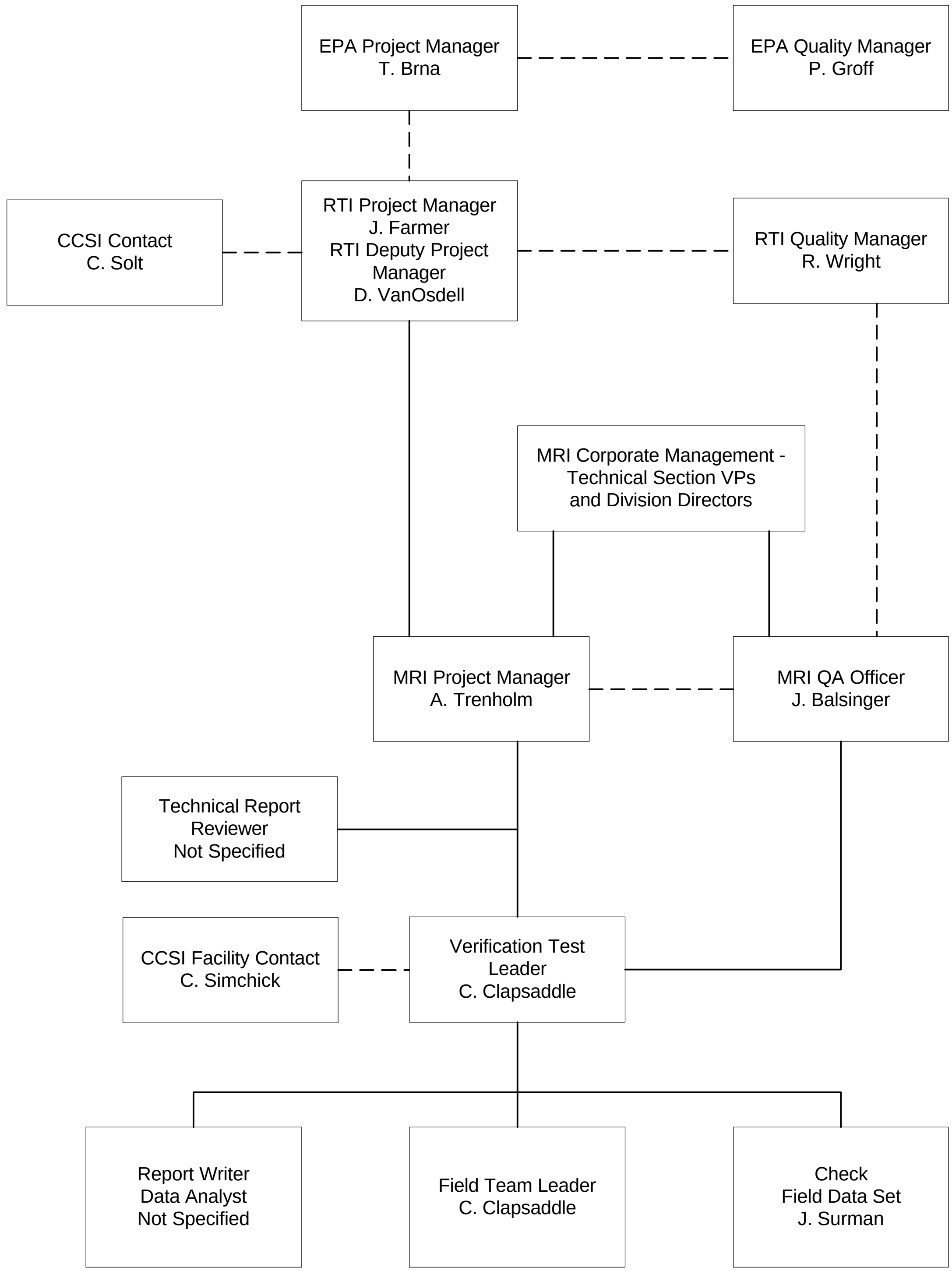

Figure 1. Organizational chart.
(dashed lines indicate organizational independence)

The Deputy Manager, Douglas VanOsdell, reports to the APCT Project Manager and substitutes for the APCT Project Manager if that individual is absent. The Deputy manager is responsible for any functions delegated to him by the APCT Project Manager. For the XONON test he will prepare the draft GVP and provide overall management of the verification test.

A1.1.3 MRI Project Manager

The MRI Project Manager for the XONON verification test in Andrew Trenholn. He will manage MRI's conduct of the XONON technology verification test, select a test leader, develop staffing requirements, and propose a budget for the technology verification test. After a technical assessment, the MRI Project Manager is responsible for developing and implementing corrective actions within MRI. These responsibilities are described in greater detail in Section 1 of MRI's QSM. Mr. Trenholm has more than 30 years of experience in environmental regulation and research with research organizations, private industry, and federal and local regulatory agencies. Mr. Trenholm is deputy Program Manager on MRI's contract with the Emissions Measurement Center of the Emission Monitoring and Analysis Division of EPA's Office of Air Quality Planning and Standards. The program provides technical support for stationary source emission measurement and method evaluation to assist EPA in NESHAP and NSPS development and other measurement activities.

A1.1.4 MRI Task and Field Team Leader

The MRI Task Leader and Field Team Leader for the XONON verification test is Craig Clapsaddle. Mr. Clapsaddle will manage the field testing of the XONON technology, and he has the specific responsibility for quality assurance of the on-site field testing. If test method QC criteria are not met, he has the authority to halt testing until the sampling system is corrected and proven to meet the QC criteria. As the MRI task leader, he will oversee development of this Test/QA Plan and any standard operating procedures (SOPs) that are needed for the XONON verification test and prepare the draft test report. Mr. Clapsaddle is a senior scientist at MRI with more than 11 years of experience in the field of emission monitoring of stationary sources. He specializes in applying NO_x predictive emission monitoring systems to gas turbines. Mr. Clapsaddle has participated in emission testing programs of more than 60 gas turbines.

A1.1.5 Data Reviewer

The MRI data reviewer for the XONON verification test is James Surman. Mr. Surman will be responsible for reviewing, prior to the test, computer spreadsheet workbooks used for recording measurement system calibration and quality control data and emission measurement data. These workbooks are used for computing and reporting quality control and emission results. The purpose of the review is to ensure the workbooks will meet all requirements specific to the project. After the field verification test, he will be responsible for reviewing the field data package for completeness and general data quality. His function will be to serve as the first line, independent data quality reviewer of the XONON verification field test data. Mr. Surman has more than 28 years of direct experience in stationary source emissions testing and related QA/QC procedures.

A1.1.6 Facility Contact

Chuck Simchick, the facility contact, will be responsible for coordinating and collecting data on process conditions during the verification test. These data will be measured using existing plant instrumentation (see Section B2). These data will be passed to the MRI Field Team Leader.

A1.2 Quality Assurance Responsibilities

QA responsibilities are divided among the EPA, RTI, and MRI personnel as listed below:

A1.2.1 EPA Quality Manager

The EPA Quality Manager for the APCT pilot program is Paul W. Groff of EPA's Air Pollution Prevention and Control Division. In general, his responsibilities include:

- Communicate quality systems requirements, quality procedures, and quality issues to the EPA Project Manager and the RTI Project Manager;
- Review and approve APCT quality systems documents to verify conformance with the quality provisions of the ETV quality systems documents;
- Perform technical systems audits (TSAs) and performance evaluations (PEs) of APCT verification tests, as appropriate; and
- Provide assistance to APCT personnel in resolving QA issues

The EPA Quality Manager (or his designee) will perform the following specific activities associated with the verification tests of the XONON flameless combustion system:

- Review and approve the GVP for NO_X control technologies for stationary combustion sources;
- Review and approve the test/QA plan, the verification report, and the verification statement for CCSI's XONON flameless combustion system; and
- Perform a PE of the verification test of CCSI's XONON flameless combustion system.

A1.2.2 RTI Quality Manager

The RTI Quality Manager for the APCT is Robert S. Wright of RTI's Center for Environmental Measurements and Quality Assurance. He is responsible for ensuring that all verification tests are performed in compliance with the QA requirements of the APCT QMP, GVPs, and test/QA plans. He has resources available to ensure conformance with the requirements and ensures that all personnel understand the requirements. Following are the general responsibilities of the RTI Quality Manager:

- Prepare the APCT QMP and assist the RTI Project Manager in the annual review and revision of this document, as needed;
- Communicate with test-specific quality managers for specific verification tests;

- Review and approve the GVPs, test/QA plans, and any needed SOPs that will be developed by technology verification test leaders and test-specific quality managers;
- Oversee test-specific quality training;
- Conduct test-specific TSAs and PEs in cooperation with the EPA Quality Manager and test-specific quality managers;
- Review and approve the test results and the quality control (QC) results from verification tests;
- Store APCT Program Office documentation and data; and
- Prepare the QA section of each verification test report and verification statement.

The RTI Quality Manager will perform the following specific activities associated with the verification tests of the XONON flameless combustion system:

- Review and approve the GVP for NO_X Control Technologies for stationary combustion sources;
- Review and approve the test/QA plan, verification test results, QC results, the verification report, and the verification statement for Catalyticia's XONON flameless combustion system; and
- Perform a TSA of the verification test of Catalyticia's XONON flameless combustion system.

A1.2.3 MRI Task QA Officer

The MRI Task QA Officer for the XONON test is Jack Balsinger. He will handle the QA activities directly associated with MRI's data collection and reporting for the XONON test. These activities will include system and data audits, task-specific data assessments, and reports to management on the quality aspects of the task. He will assist the technology verification task leader in preparing task-specific test/QA plans and SOPs to ensure that technology verification tests are implemented in conformance with these documents. These responsibilities are described in greater detail in Section 1 of the MRI QSM.

Mr. Balsinger is a Senior QA Officer and a member of MRI's Quality Assurance Unit. The QA Unit is a MRI corporate function that reports to senior corporate management and is independent of the section and division generating the data.

A2: Problem Definition/Background

Control of NO_x emissions is of increasing interest, particularly related to the ambient ozone standard. EPA recently issued a new ambient standard for ozone. To that end, EPA recently completed a rulemaking to reduce more than one million tons of NO_x each ozone season and offered to develop and administer a multistate NO_x trading program to assist the affected States.

The objective of the Air Pollution Control Technology ETV Program is to verify, with high data quality, the performance of air pollution control technologies. A subset of air pollution control technologies is NO_x emission control technologies. One of those NO_x emission control technologies is the flameless combustion system known as XONON and developed by CCSI. The XONON flameless system is an advanced combustion process designed for gas turbines to further reduce NO_x emissions below the current level of 8 to 9 ppmv obtainable with dry-low NO_x combustion.

The XONON flameless combustion system will be verified within a specified range of applicability as detailed in Section B1 of this Test/QA Plan, and verification reports and statements will be produced for dissemination to the public. The goal of the verification test is to measure the performance of the XONON flameless combustion system relative to CCSI's statement of capabilities by measuring the NO_x emission concentration. In addition to measuring NO_x emissions, CO and UHC concentration measurements will be made to evaluate potential adverse environmental impacts of operating the technology over the range of gas turbine operating conditions.

A3: Project Description and Schedule

A3.1 Project Description

Testing will be performed on a XONON flameless combustion system installed at a 1.5 megawatt (MW) gas turbine in electric utility service. Performance of the XONON flameless combustion system will be determined in terms of NO_x concentration from the turbine exhaust. The concentration of NO_x in the turbine exhaust will be measured in accordance with EPA Method 20. A total of 12 test runs will be conducted covering the low and high ambient temperature levels available during two test days.

The verification tests will gather information and data for evaluating the performance of the XONON as claimed by CCSI (i.e., NO_x emission concentration). Also, any adverse environmental impacts of operating the technology (i.e., CO and UHC emission concentrations) will be evaluated. All test runs will be conducted under steady-state unit operation. The specific operating conditions used during the verification testing will be documented as part of the verification process. Table 3, in Section B2 of this Test/QA Plan, presents a summary of all measurements that will be made to either (1) evaluate the performance of the XONON flameless combustion system, (2) evaluate any adverse environmental impacts of operating the technology, or (3) document the test conditions.

A3.2 Facility Description

The verification test will be conducted at Silicon Valley Power's Gianera generating station located at 4948 Centennial Road, Santa Clara, California. The XONON flameless combustion system is installed in a Kawasaki Model M1A-13A gas turbine-generator set. The gas turbine at Gianera station operates unattended, 24 hours per day, 7 days per week.

A3.2.1 Process Description

The Kawasaki M1A-13A gas turbine was first introduced in 1989 at an electrical generating capacity of about 1.5 MW. The rated heat input at full load is about 20.8 million British thermal units per hour, and the pressure ratio of the air compressor is 9.4:1. The turbine inlet temperature (following the combustion chamber) is rated at 1,814°F, and the exhaust temperature is about 964°F.

A3.2.2 Control Technology Description

The XONON flameless combustion system is completely contained within the combustion chamber of the gas turbine. The XONON system completely combusts fuel to produce a high temperature gaseous mixture, typically over 2,400°F. Dilution air is added to shape the temperature profile required at the turbine inlet.

The XONON combustor consists of four sections:

1. **Preburner**. The preburner is used for start-up preheat of air before entering the catalyst module and acceleration of the engine. The preburner could be a conventional, diffusion flame burner or could be a dry, low NO_x type (lean, pre-mixed) burner. For this Kawasaki turbine, the preburner is a lean premix burner.

2. **Fuel injection and fuel-air mixing system**. This unit injects the fuel and mixes it with the main air flow to provide a very well-mixed, uniform fuel-air mixture to the catalyst.

3. **XONON catalyst module**. In the catalyst module, a portion of the fuel is combusted without a flame to produce a high temperature gas.

4. **Homogeneous combustion region**. Located immediately downstream of the catalyst module, the homogeneous combustion region is where the remainder of the fuel is combusted, and carbon monoxide and unburned hydrocarbons are reduced to very low levels (also a flameless combustion process).

The overall combustion process in the XONON system is a partial combustion of fuel in the catalyst module followed by complete combustion downstream of the catalyst in the burnout zone. Partial combustion within the catalyst produces no NO_x. Homogeneous combustion downstream of the catalyst usually produces no NO_x, because combustion occurs at a uniformly low temperature. A small amount of fuel is combusted in the preburner to raise the compressed air temperature to about 880°F. NO_x in the turbine exhaust is usually from the preburner.

The design of each XONON combustor is customized to the particular turbine model and operating conditions of the application, and would typically be defined through a collaborative effort with the manufacturer of the engine to integrate the hardware into the design. The footprint will vary depending upon the implementation, although generically the XONON combustion system would likely be somewhat larger than the combustor which is typically supplied as standard equipment by the turbine manufacturer. Each unit could have multiple fuel inputs from separate control valves and additional instrumentation for control and monitoring will be integrated into the control system.

Initial startup and shakedown of the XONON combustion system will be supervised by CCSI personnel, and the requisite training to operate and service the equipment will be provided at that time. Maintenance procedures and spare parts requirements will be identified during design of the combustor for the specific turbine model, and this information will be provided upon delivery of the equipment. Elapsed time between installation and commissioning is expected to be less than one month.

After initial commissioning, the XONON combustion system is expected to require minimal ongoing service. The catalyst module is expected to have a useful life of approximately 8,000 operating hours, requiring a replacement of the module at these intervals.

A3.3 Schedule

The projected schedule for the XONON verification test is as follows:

- Complete site visit on April 17, 2000
- Submit Test/QA Plan for review on May 5, 2000
- Receive comments to the Test/QA Plan by May 30, 2000
- Finalize the Test/QA Plan by June 30, 2000
- Arrive at Gianera generating station by noon on July 17, 2000
- Complete set-up of testing equipment and QA audit entrance meeting on July 17, 2000
- Verification test runs on July 18 and 19, 2000
- Preliminary reconciliation of NO_x DQO at end of testing on July 19, 2000
- Complete verification test data reduction and QA by July 31, 2000
- Complete draft verification test report and verification statement by August 11, 2000
- Receive comments from CCSI and RTI review of draft report and statement by August 22, 2000
- RTI sends draft report and statement for EPA review by August 25, 2000
- Receive EPA comments on draft report and statement by September 15, 2000
- Finalize verification test report and verification statement by September 29, 2000

A4: Quality Objectives and Criteria for Measurement Data

A4.1 Performance of the Technology

As is described in Sections 5 and 6 and illustrated in Appendix C of the NO_x Control Technologies GVP, the performance of the XONON flameless combustion system will be verified using an experiment statistically designed to achieve the data quality objective (DQO) listed below within the performance range tested. For the NO_x emission concentration measurements, sufficient test runs will be made to allow determination of the XONON's overall NO_x emission within ± 10 percent of the mean emission concentration above 5 ppmv, ±25 percent below 5 and above 2 ppmv, and ± 50 percent below 2 ppmv. The DQO will be computed as the half-width of the 95 percent confidence interval of the mean, divided by the mean, or, equivalently, as the product of the standard error of the mean and the appropriate Students-t value divided by the mean. This calculation will be done by the MRI Field Team Leader at the end of the field test using the statistical analysis tool in Microsoft Excel. This DQO is presented in Section 2.3 of the GVP for NO_x Control Technologies. All measurements apply within the performance envelope being verified. The NO_x emission concentration will be measured using EPA Method 20, which is the reference standard for NO_x emissions from gas turbines, and thus each measurement is taken to be without bias. The Method 20 calibration criteria are presented in Section B2.3.1.

The MRI Field Team Leader has the specific responsibility for quality assurance of the on-site field testing. If method QC criteria are not met, he has the authority to halt testing until the sampling system is corrected and proven to meet the QC criteria. See Figure 6 in Section B10.1 for an outline of the on-site field testing QA process.

Should the verification test be conducted and the NO_x DQO not be met due to excessive data variability, RTI and MRI will present the data to CCSI at the end of the last field test day and discuss the relative merit of various options. The two primary options will be either to continue the test to obtain additional data, with resulting increases in cost to all parties, or to terminate the test and report the data obtained. The RTI Project Manager or Deputy Project Manager will make the final decision after consultation with MRI and CCSI.

A4.2 Test Conditions

While not critical, accurate measurement of test conditions such as flow rate and percent of rated capacity is important because the measurements set the boundaries within which the verification applies. As specified in Section B2, plant instrumentation will be used to conduct some of the measurements, while others will be measured using instrumentation supplied by MRI.

A4.3 Associated Environmental Impacts for the Technology

CO and UHC will be measured as potential indications of associated adverse environmental impacts for the XONON flameless combustion system. The Method 10 and 25A calibration criteria are presented in Sections B2.3.2 and B2.3.3, respectively.

A4.4 Associated Resources for the Technology

There are no additional resources (e.g., chemicals, consumable feedstocks, energy) associated with operation of the technology within the performance range to be used during the verification test.

A5: Special Training Requirements/Certification

The field team leader has extensive experience (10+ years) in field testing of air pollutant emissions from gas turbines. He is familiar with the requirements of all of the test methods that will be used in the verification test. Each field crew member is thoroughly familiar with this Test/QA Plan, the measurement equipment, procedures, and methods for their assigned jobs. All field test personnel will receive the required and appropriate safety training and a safety briefing will be given to all test team members by the MRI Field Team Leader. The MRI Field Team Leader and Test Technician both have completed the 40-hour HAZWOPER training and are current on their 8-hour refresher (see 29 CFR Part 1910.120 for the safety information that is part of the HAZWOPER training). Résumés for crew members are provided in Appendix A.

A6: Documentation and Records

Requirements for recordkeeping and data management for the overall APCT program are found in Section 3.6 of the APCT QMP. All verification test data, calibration data, certificates of calibration, assessment reports, verification reports, and verification statements will be retained by MRI's APCT program office for a period of not less than 7 years after the final payment of the assistance agreement as per Part A, Section 5.3 of the EPA ETV QMP.

A6.1 Field Test Documentation

The field team leader will record all field activities. The team leader reviews all data sheets and maintains them in an organized file. The required test information is described in Section B. The field team leader also maintains 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.

Following each test run, the test technician will check the test results and determine whether the run met the method QA criteria. At the end of each test day, the field team leader will collect all of the data from the field team members. This includes data sheets, data printouts, back-up copies of electronic files stored on computer, and the field notebook. These data will be removed from the site each day for security and returned the next day by the field team leader. At the end of the test, the field team leader will copy the electronic data and paper copies. One copy of the electronic data on diskette and the paper data will be returned to MRI and given to the data reviewer. Additionally, a copy of the field data will be provided to the CCSI facility contact. Also, after completing all test runs, the NO_X concentration data will be analyzed by MRI's field team leader to determine if the DQO was met. The DQO analysis will be done using the statistical analysis tool in Microsoft Excel. Following this review and confirmation that the appropriate data were collected, the data reviewer will pass the data to the Task Leader.

A6.2 QC Reports

After the completion of verification tests, control test data, sample inventory logs, calibration records, and certificates of calibration will be stored with the verification test data in MRI's APCT Program Office. Calibration records will include such information as the instrument being calibrated, raw calibration data, calibration equations, analyzer identifications, calibration dates, calibration standards used and their traceabilities, identification of calibration equipment used, and staff conducting the calibration. Final reports of self-assessments and independent assessments (i.e., technical systems audits, performance evaluations, and audits of data quality [TSAs, PEs, and ADQs]) will be retained in the APCT Program Office. Each verification report and verification statement will contain a quality assurance section, which will describe the extent that verification test data comply with the DQO.

A6.3 Verification Reports and Verification Statements

The content and format for the Verification Reports and Verification Statements are specified in the Section 6 of the GVP for NO_x Control Technologies. An outline of the Verification Report is shown below in Section B10.1.D.

Verification reports and verification statements will be prepared by the MRI Task Leader, will be reviewed by the MRI Project Manager and Task QA Officer, and will be submitted to the RTI Task Leader. Procedures for the preparation, review, and dissemination of verification reports and verification statements are described in Sections 6 and 7 of the GVP for NO_x Control Technologies and in Section 2.5 of the APCT's QMP.

SECTION B: MEASUREMENT/DATA ACQUISITION

B1: Sample Process Design (Experimental Design)

The GVP for NO_x Control Technologies provides extended discussions on the experimental design approach for NO_x control technologies verification testing. The specific design for this test is provided below.

The measure of performance for the XONON flameless combustion system will be the level of NO_x emitted in ppmv. The basic experimental design will be to measure the outlet NO_x emission concentration under targeted field test conditions with the XONON flameless combustion system operating at a specified high load and the encountered low and high ambient temperature. The measurement of NO_x concentration is the critical measurement for this verification test. Ambient temperature is an important measurement for establishing the bounds of the verification test design.

A 2 x 1 factorial experimental design will be used with each of the parameters. Two replications of the factorial design (six test runs in each replication) will be used for a total of 12 test runs. While a single replication could be used, at least two replications are recommended to achieve the DQO. Table 2 gives the factorial design with the target values for each parameter. To the extent that it is practical, the order of the runs and the assignment of the low and high levels are randomized. As required by the DQO in Section A4.1, the product of this test design will be the verified mean NO_x emission concentration(s) and the achieved 95 percent confidence interval of the mean for the specified operating range.

The process must be at equilibrium prior to testing. To achieve this, testing will commence only after a period of time equal to twice the time required for the process to reach equilibrium.

Table 2. Verification Test Design (target values)

Test run	Ambient temperature (time of day)	Turbine load
1	Low (predawn)	High (>95 percent maximum load)
2	Low (predawn)	High (>95 percent maximum load)
3	Low (predawn)	High (>95 percent maximum load)
4	High (afternoon)	High (>95 percent maximum load)
5	High (afternoon)	High (>95 percent maximum load)
6	High (afternoon)	High (>95 percent maximum load)
7	Low (predawn)	High (>95 percent maximum load)
8	Low (predawn)	High (>95 percent maximum load)
9	Low (predawn)	High (>95 percent maximum load)
10	High (afternoon)	High (>95 percent maximum load)
11	High (afternoon)	High (>95 percent maximum load)
12	High (afternoon)	High (>95 percent maximum load)

The factorial design allows for statistical significance tests to determine whether the performance measure of the outlet ppmv of NO_x varies significantly with any of the parameters. Further, provided that at least two replicates are done, the significance of interactions between the parameters can also be tested. If the performance does not change significantly with a parameter, then the results are valid for the range of that parameter covered by the test. If the performance does vary significantly with some parameter, then the statement of the results of the test must include information indicating the dependence of the performance on the operating parameter.

The DQO for NO_x emission concentration is met when the 95 percent confidence interval of the mean has the specified width. The confidence interval for the outlet NO_x level depends on several things: the variability of the NO_x measurement, the desired level of confidence, the number of degrees of freedom for error, and the number of runs. The half-width of the confidence interval about the mean NO_x concentration varies with the number of test runs. The half-width is the range on either side of the mean outlet NO_x level within which data points are estimated to fall for the specified confidence level. The independent parameters are taken to be significant, and the NO_x emission concentration mean is computed over all tests. The degrees of freedom are the number of test runs, reduced by 1 for the overall mean and further reduced by 1 for each significant parameter.

The half-width of the confidence interval is then computed as the product of the standard deviation and the Students-t value appropriate for the degrees of freedom divided by the square root of the number of tests.

B2: Sampling Methods Requirements

Table 3 lists all the measurement parameters for this verification test. They are categorized in the table as performance factors (e.g., direct emission measurements), associated impacts (e.g., CO and UHC emissions), and test conditions that will be documented. Table 3 lists the factors to be verified, parameters to be measured for each factor, the measurement method for each parameter, and explanatory comments. A facility contact will provide data for process condition parameters collected from the turbine human machine interface (HMI) computer. Measurement methods and procedures are described in Section B2.3.

Table 3. Summary of Measurements

Factors to be verified	Parameter to be measured	Measurement method	Comments
Performance Factors			
NO_x emissions	Outlet NO_x conc., ppmv	EPA Ref. Method 20	MRI provides and operates analyzer
Associated Impacts			
CO emissions	Outlet CO conc., ppmv	EPA Ref. Method 10	MRI provides and operates analyzer
UHC emissions	Outlet THC conc., ppmv(wet basis)	EPA Ref. Method 25A	MRI provides and operates analyzer

Table 3. (continued)

Factors to be verified	Parameter to be measured	Measurement method	Comments
O_2/CO_2 emissions	Outlet O_2/CO_2 conc., percent	EPA Ref. Method 20	MRI provides and operates analyzer
Test Conditions Documentation			
Percent of turbine's rated capacity	Electrical power ÷ turbine rating	Electrical meter	MRI collects data from facility contact
Fuel type	---	---	Natural gas
Fuel flow	Fuel flow rate	Coriolis-type flow meter	Facility contact provides data from turbine HMI computer
Fuel sample results	Natural gas composition	GCMS	From fuel sample results obtained from CCSI
Ambient conditions	Air temperature	Thermocouple or Thermohygrometer following EPA QA handbook for air pollution measurement systems, Volume IV: Meteorological Measurements	MRI conducts temperature, pressure, and humidity measurements concurrently
	Air pressure	ASTM D3631-95: aneroid barometer or equivalent	
	Air humidity	Thermohygrometer equivalent to ASTM E337-84(1996)e1	
Compressor parameters	Inlet temperature	Array of thermocouples on turbine	Facility contact provides data from turbine HMI computer
	Discharge temperature	Array of thermocouples on turbine	Facility contact provides data from turbine HMI computer
	Discharge pressure	Absolute pressure on turbine	Facility contact provides data from turbine HMI computer
Catalyst inlet condition	Temperature at catalyst inlet	Array of thermocouples on turbine	Facility contact provides data from turbine HMI computer
Catalyst outlet condition	Temperature out of the catalyst	Array of thermocouples on turbine	Facility contact provides data from turbine HMI computer
Catalyst hours of operation	Hours of operation since catalyst installed	Clock counter	Information provided by CCSI facility contact
Exhaust temperature	Exhaust gas temperature	Array of thermocouples on turbine	Facility contact provides data from turbine HMI computer
Compressor/turbine status	---	Pressure ratio compared to rated value	Information provided by CCSI facility contact

B2.1 Sampling Locations

Sample locations will be chosen so that they meet the minimum specified sample location criteria of the sample methods used or will yield a representative sample.

B2.1.1 Turbine Exhaust Sampling Location

Parameters to be measured at the exhaust of the turbine include the NO_x concentration, CO concentration, UHC concentration, the O_2 and CO_2 concentrations, and the turbine exhaust temperature. The sampling location for the turbine exhaust is identified in Figure 2. Two sets of sampling ports are available, but neither meets Method 20 criteria (see Section B2.3.4 for an explanation). MRI judged the top set of sampling ports as the most likely to yield a representative sample; therefore, the top sampling ports will be used.

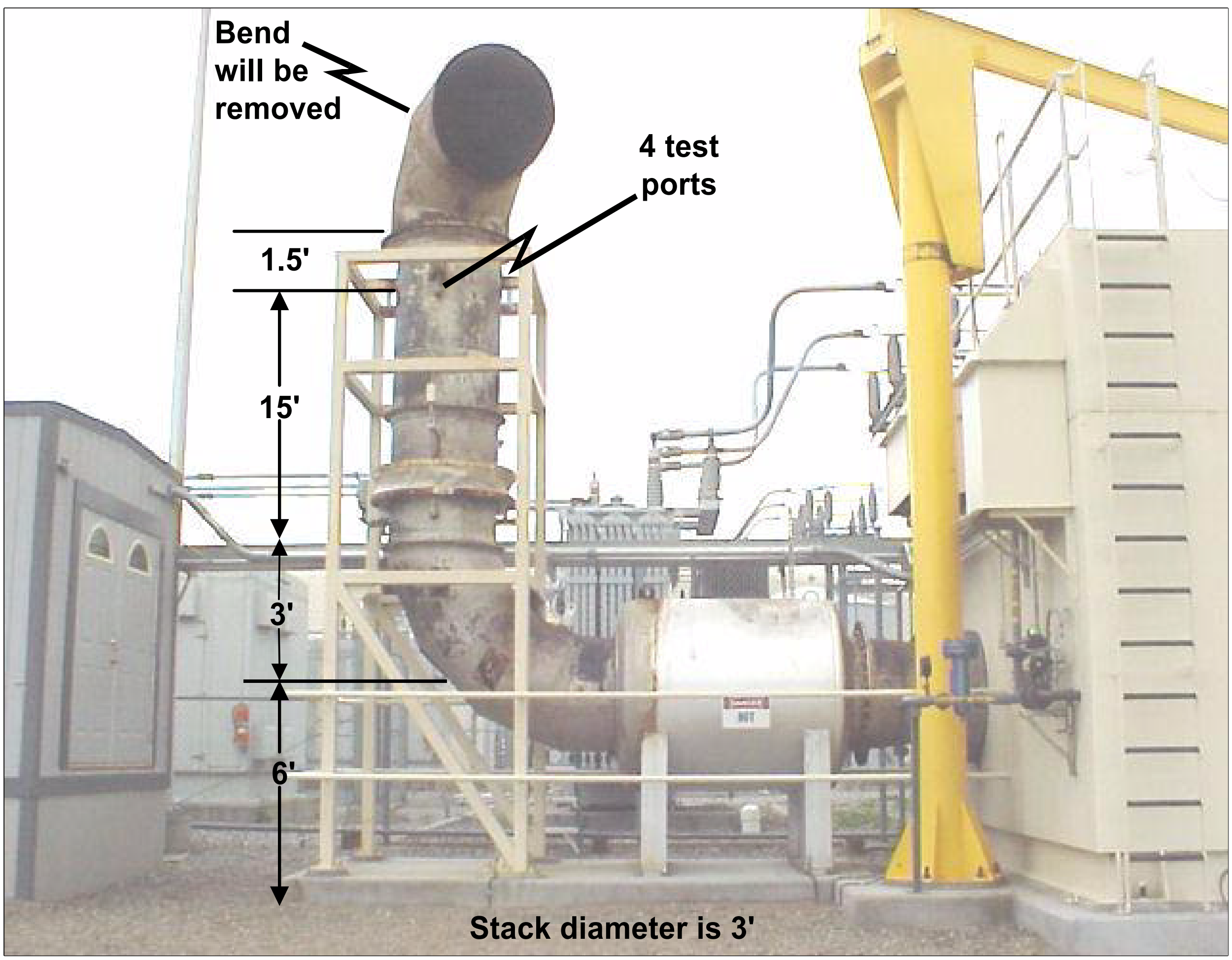

Figure 2. Turbine exhaust sampling location.

B2.1.2 Process Conditions Sampling Locations

Several parameters related to the operating conditions of the gas turbine during the verification test runs will be recorded. These include electric power output, fuel flow rate, inlet temperature to the compressor, static pressure at the discharge of the compressor, and the outlet temperature of the combustion unit. The sampling locations for these parameters are identified in Figure 3 and are located in relation to where the measurements are taken in the gas turbine.

B2.1.3 Ambient Conditions Sampling Location

Parameters related to the ambient conditions during the verification test runs include the ambient air temperature, ambient air pressure, and ambient relative humidity. The sampling location for ambient conditions is shown in Figure 4. The temperature, pressure, and relative humidity measurement devices will be placed on the platform just below the gas turbine air inlet filters. In this location, the measurements will be representative of the inlet air conditions (as recommended in Section 4.3.4 of EPA Quality Assurance Handbook for Air Pollution Measurement Systems, Volume IV: Meteorological Measurements, March 1995). An aspirated radiation shield will be used to prevent biases caused by direct sunlight exposure.

B2.2 Performance Factors and Associated Impacts Sampling Methods/Procedures/ Equipment

Turbine exhaust gas sampling for NO_x, CO, and UHC will be conducted using EPA reference methods (see Section B2.3). All sampling will follow the requirements of the specific test method being used unless otherwise stated in this document or approved by RTI prior to the verification test. The analytical systems will be calibrated before and after each 32-minute test run following the procedures in each applicable EPA reference method.

A diagram of the extractive gaseous measurement system to be used for the testing is shown in Figure 5. Two independent sampling systems will be used; one for CO, O_2, CO_2, and NO_x and another for UHC. All analyzers, calibration gases, and the sampling manifold will be housed in an environmentally controlled trailer. The sampling system components will be stainless steel (SS), Teflon, or glass. These components have been proven to be inert for the gases of interest.

The sampling system for measurement of CO, O_2, CO_2, and NO_x consists of the following:

- Unheated SS probe; ½-inch outside diameter (OD) (since the stack gas temperature is ~ 950^{o}F, the probe will not be heated)
- Heated (~ 250^{o}F) glass-fiber filter to remove particles with a diameter > 1 µm
- Heated (~ 250^{o}F) Teflon sample line (~ 10 feet long and 3/8-inch OD) to transport the sample gas to the moisture removal condenser; temperature of the sample line is regulated with a thermostatic heat controller
- Chiller condenser system submerged in an ice bath to condense and remove moisture in the sample gas; the condenser is a two-pass impinger type system to condense moisture while minimizing the liquid-air interface; a peristaltic pump is used to continually remove condensed water vapor; the water vapor dew point after the chiller is estimated to be ~ 38^{o}F

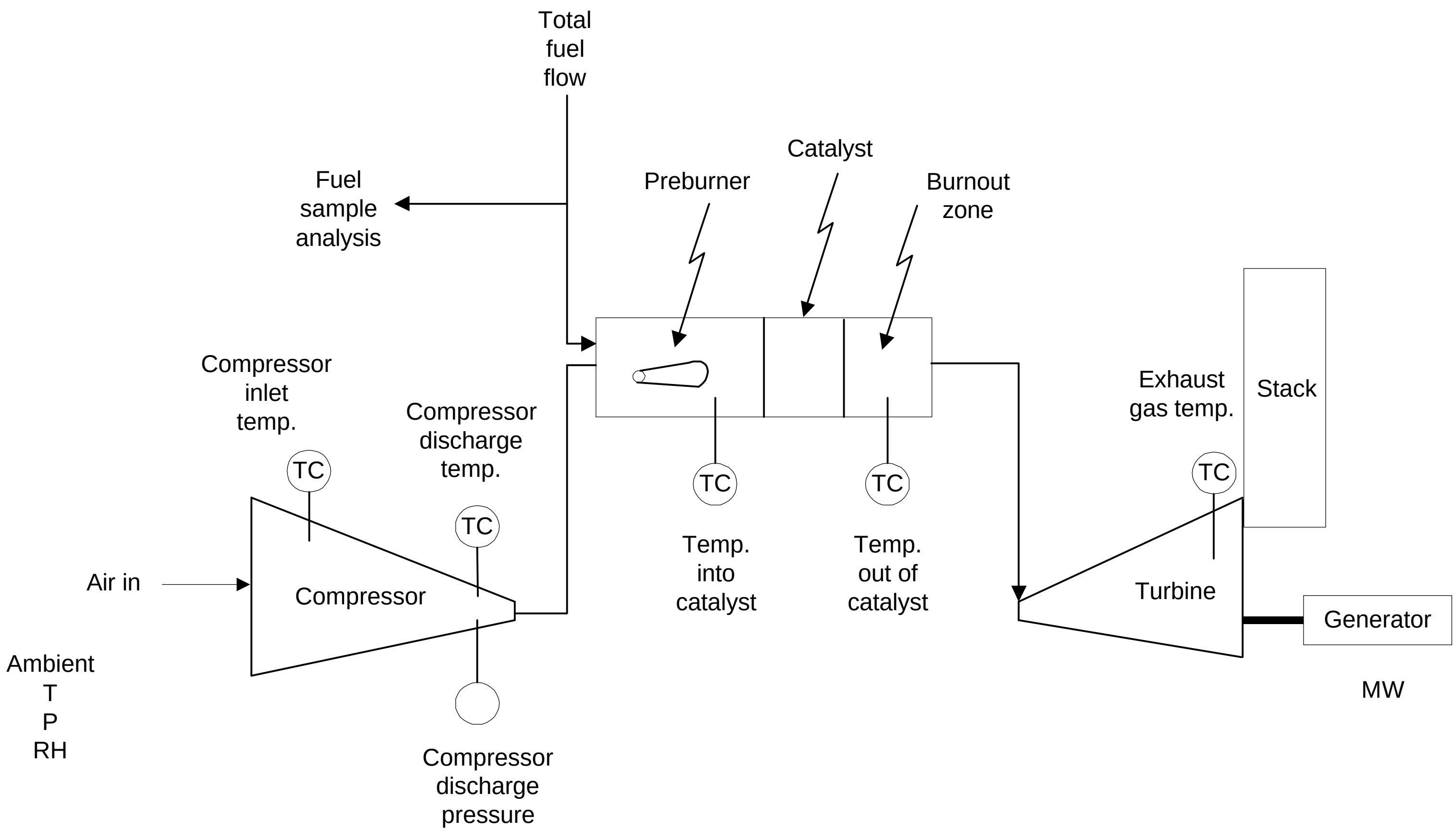

Figure 3. 1.5 MW gas turbine.

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Figure 3. 1.5 MW gas turbine.

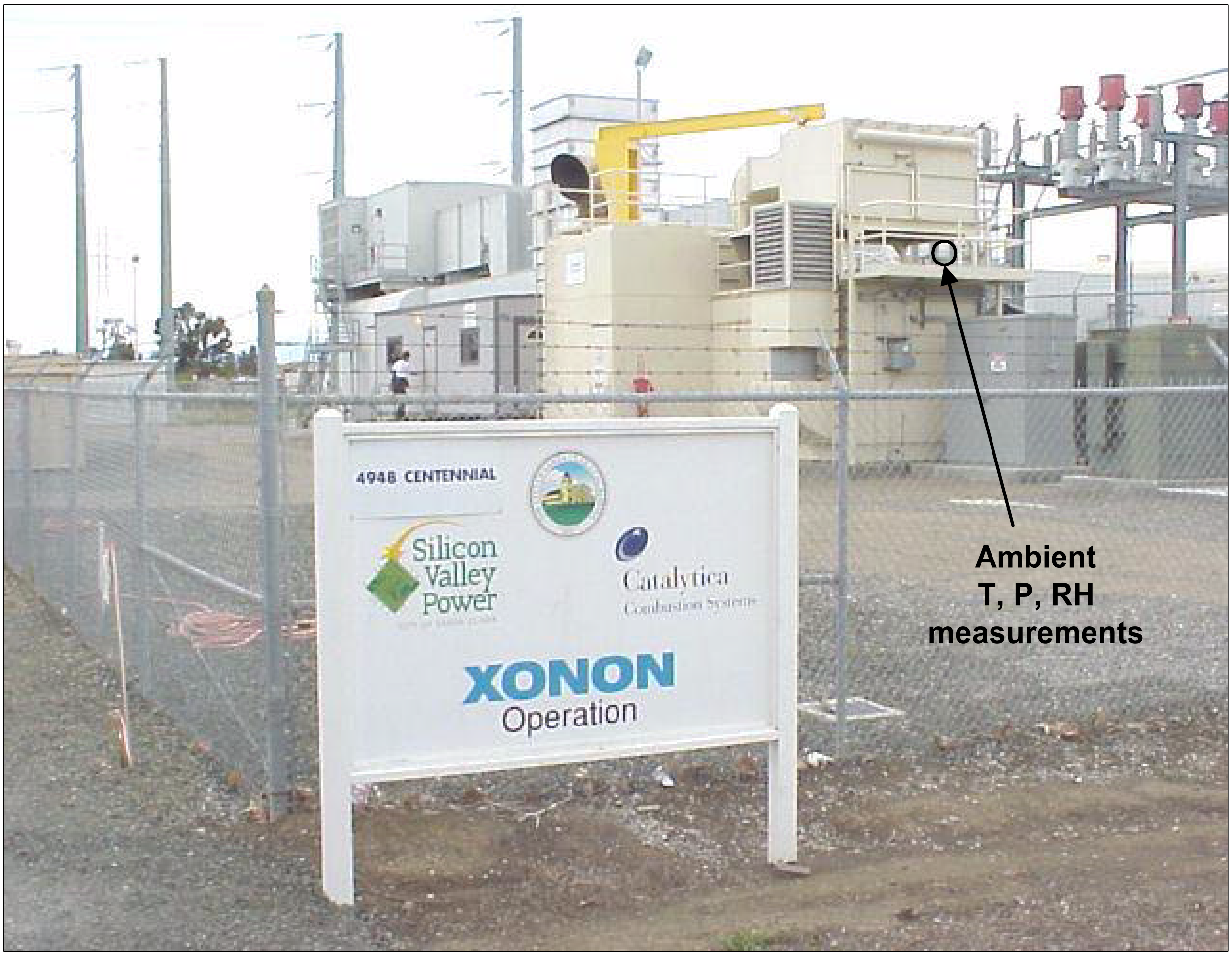

Figure 4. Ambient conditions sampling location.

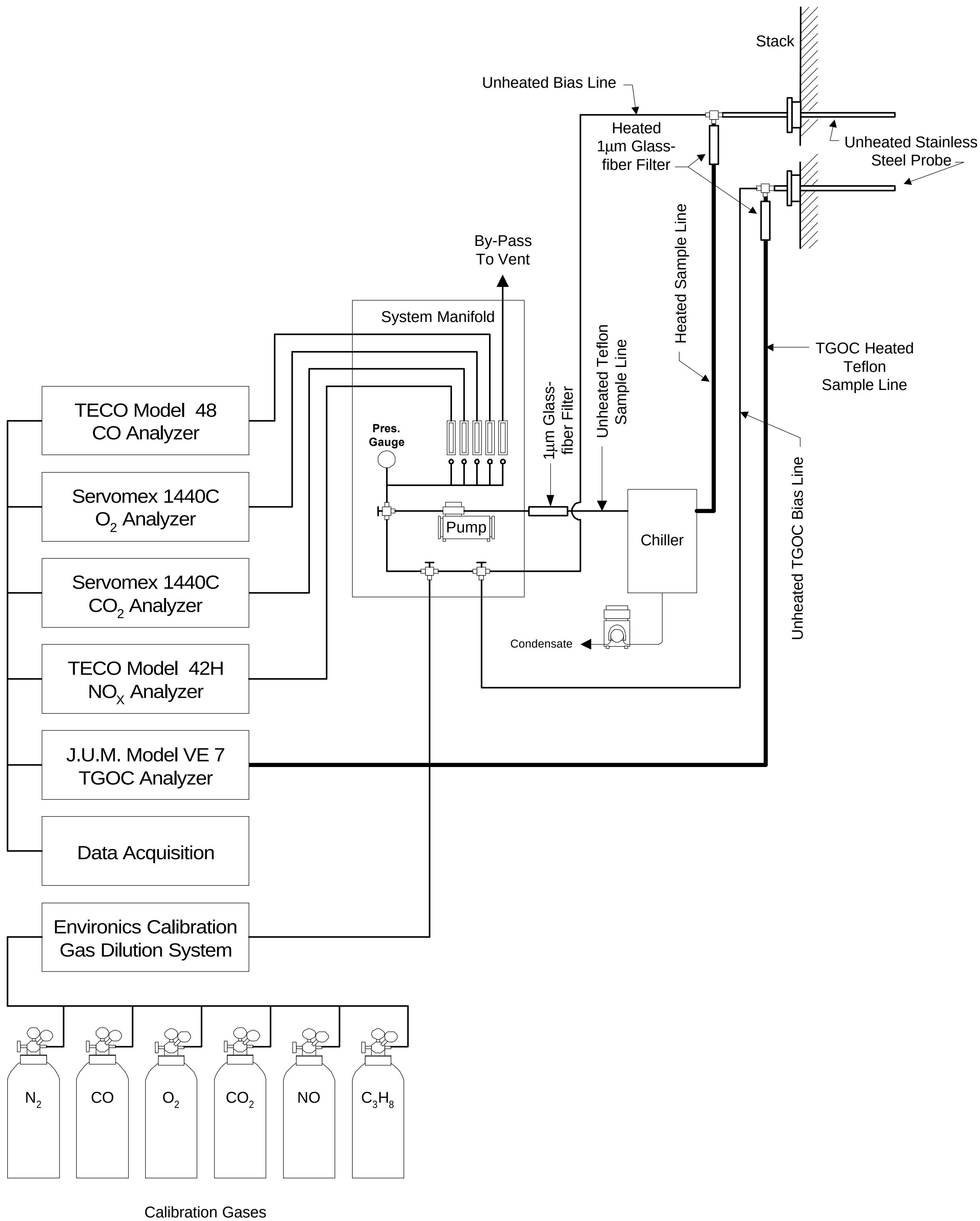

Figure 5. Extractive sampling system.

- Unheated Teflon sample line (~ 75 feet long and 3/8-inch OD) to transport the sample gas from the Chiller (probably located on the scaffold platform near the sample ports) to the sample manifold; just upstream of the sample extraction pump is a second glass-fiber filter that may be installed in some applications
- Teflon-lined sample pump to extract sample gas from the stack; sampling rate will be ~ 8-10 liters per minute (lpm)
- Individual rotameters regulate the sample flow to each analyzer and excess sample gas is dumped through the by-pass

The sampling system for measurement of UHC consists of the following:
- Unheated SS probe; ½-inch OD
- Heated (~ 250^{O}F) glass-fiber filter to remove particles with a diameter > 1 µm
- Heated (~ 250^{O}F) Teflon sample line (~ 75 feet long and 1/4-inch OD) to transport the sample gas directly to the J.U.M.; temperature of the sample line is regulated with a thermostatic heat controller
- Sample gas is extracted by a heated pump contained within the J.U.M.

Calibration of the sampling system is accomplished by directing each calibration gas to the probe through an unheated Teflon tube. The probe is “flooded” with calibration gas, and the sample pump pulls as much of the calibration gases needed to the system manifold. Excess calibration gas is dumped out the probe. This process of calibrating the system does not pressurize the sampling system and mask any leaks.

Calibration gases will be generated with an Environics gas dilution system. The Environics consists of four electronic mass flow controllers (MFC). MFC 1 is used for the nitrogen dilution gas. MFC 2 (0 - 10 lpm), MFC 3 (0 - 1 lpm), and MFC 4 (0 - 0.1 lpm) are used in combination with MFC 1 to generate the specified calibration gas concentration by diluting a high concentration standard gas. The Environics is calibrated at the factory each year. Also, the calibration of the combined MFCs that will be used for this test (e.g., 1 & 2 and 1 & 3) will be checked in accordance with EPA Method 205 the day before the field test begins.

A list of the reference analyzers to be used for quantifying the gaseous concentrations is shown in Table 4. The table also includes a description of the analyzer and its measurement ranges. Operator manuals for each of the gaseous pollutant analyzers will be kept by the instrument operator.

Table 4. Reference Analyzers and Measurement Ranges

Pollutant	Reference analyzer	Measurement range	Description
NO_x	Thermo Environmental Instruments (TEI) 42H	0-20 ppm	Uses the principle of chemiluminescence to measure the concentration of NO_x in the sample stream. The instrument will use a heated can NO_2 converter.
CO	Thermo Environmental Instruments (TEI) 48	0-50 ppm	Uses the principle of gas filter correlation and non-dispersive infrared (GFC-NDIR) to measure the concentration of CO in the sample stream.
UHC	J.U.M VE 7	0-100 ppm	Uses the principle of flame ionization detection (FID) to measure the concentration of hydrocarbons in the sample stream.
O_2/CO_2	Servomex 1440C	0-25 / 0-20%	The O_2 detector uses the principle of paramagnetic technique, and the CO_2 detector uses a single beam, dual-wavelength IR technique.

B2.3 Measurement Methods Requirements

Each of the sampling methods has different criteria that have to be met to assure the quality of the sample and the data collected. Each method has been broken out by general and calibration requirements, and these requirements are presented below. For this test program, the measurement span for each instrument is listed in Table 5 (and also in Table 4 above).

Table 5. Analyzer Measurement Spans

	NO_x	O_2	CO_2	CO	UHC
Span	20 ppm	25%	20%	50 ppm	100 ppm

B2.3.1 NO_X, O_2, and CO_2 by Method 20

General Requirements

- Initial interference checks completed before first use of instrument
- NO_2 to NO converter efficiency check
- Response time check
- Preliminary O_2 traverse
- Sample duration

For the interference test, the gases listed in Table 6 will be injected into the NO_X analyzer. For acceptable analyzer performance, the sum of the interference responses to all of the interference gases must be $\leq$2 percent of the analyzer span value.

Table 6. Analyzer Interference Test Gas Concentrations

CO	SO_2	CO_2	O_2
500±50 ppm	200±20 ppm	10±1%	20.9±1%

For the NO_2 converter efficiency test, a clean, leak-free Tedlar bag will be filled half full with the mid-level NO calibration gas. The bag will then be filled with 20.9 percent O_2 gas. The bag will then be attached directly to the NO_x analyzer sample inlet. After approximately a 2-minute stabilization period, 30 1-minute average NO_x analyzer readings will be recorded. For an acceptable converter, the 1-minute average response at the end of 30 minutes shall not decrease more than 2.0 percent of the highest peak 1-minute value. An alternative procedure, using an EPA protocol cylinder of NO_2 in N_2 instead of the bag procedure, for doing the converter efficiency test is acceptable.

To determine the response time, the zero gas (i.e., N_2) will be injected into the sampling system at the probe. When all the analyzers' readings are stable, the zero gas will be turned off so as to sample effluent. When a stable reading is obtained, the upscale response time will be determined as the time required for the recording device (computer readout) to record a 95 percent step change from the zero reading to the stable effluent concentration. Then the high-level calibration gas for each monitor will be injected to the sampling system at the probe. When all the analyzers are stable, high-level gas will be turned off so as to sample effluent. When a stable reading is obtained, the downscale response time will be determined as the time required for the recording device (computer readout) to record a 95 percent step change from the calibration gas reading to the stable effluent concentration. This procedure will be repeated until three upscale and three downscale response times are completed. The longest of all the upscale and downscale response times will be reported as the system response time.

Typically, a preliminary O_2 traverse is conducted at multiple sample points across the stack's crossectional area to determine the eight lowest O_2 concentration sampling points for the individual test runs. However, since this stack has a cross-sectional area of 7.1 ft^2, only eight traverse points would be used for the preliminary O_2 traverse. Therefore, a preliminary O_2 traverse will NOT be done, and the eight sampling points will be selected in accordance with EPA Method 1 (i.e., four points will be sampled from each of the two sampling ports).

When sampling, the probe will be positioned at the first of the eight traverse points. The minimum sampling time at each traverse point will be at least 1-minute plus the system response time. At the conclusion of sampling at each point, the probe will be moved to the next traverse point for a period of at least 1-minute plus the system response time until all eight traverse points have been sampled.

Calibration Requirements

- Calibration error check ± 2 percent of span
- Drift ± 2 percent of span

Table 7 lists the acceptable calibration gas concentrations for the Method 20 testing. EPA protocol gas will be used to calibrate the monitors.

Table 7. Calibration Gas Concentrations

Calibration point	O_2	CO_2	NO_x
Zero	Pure N_2	Pure N_2	0 - 0.25% of span
Low-level	NA	NA	20 - 30% of span
Mid-level	11 - 15%	2 - 5%	45 - 55% of span
High-level	20.9%	8 - 12%	80 - 90% of span

The NO_x calibration gas will be NO in a balance of N_2. The O_2 calibration gas will be O_2 in a balance of N_2. The CO_2 calibration gas will be CO_2 in a balance of air. Copies of the calibration gas certifications will be available on-site. A gas dilution system (e.g., Environics Model 2020) will be used to make the targeted gas concentration levels from a single, high concentration EPA protocol gas. Dilution mass flow controller calibration results will be available on site.

For calibration error checks of both the NO_x and diluent analyzers, the zero gas and mid-level gas will be separately introduced into the sampling system at the calibration gas valve. Each analyzer's response will be adjusted to the appropriate level. Then, the remainder of the calibration gases will be introduced into the sampling system, one at a time. The response of the instrument to each calibration gas must be within ±2 percent of span.

At the conclusion of a test run, the zero and mid-level calibration gases will be separately introduced into the sampling system. Both the zero drift and calibration drift, calculated in accordance with equation B-1, must be within ±2 percent of span. If a drift is greater than 2 percent of span, the test run will be considered invalid, and the measurement system will be repaired before additional test runs are conducted.

Percent drift = (Final response - Initial response) / Span value * 100 B-1

B2.3.2 CO by Method 10

General Requirements

- Sample duration
- CO_2 removal tube

Because the CO measurement will be made from sample gas extracted as part of the NO_x sampling system, the same sample duration applied to the NO_x measurement will be applied to the CO measurement.

Method 10 requires that CO_2 be removed from the sample gas that is sent to the CO analyzer. The CO_2 is removed because a standard non-dispersive infrared technique instrument for measurement of CO exhibits an interference from CO_2. However, the TECO Model 48 incorporates the technique of gas filter correlation to eliminate the CO_2 interference from the measurement of CO. Since the TEI Model 48 does not have a CO_2 interference, the CO_2 trap will not be used.

Calibration Requirements

- Calibration error check ± 2 percent of span
- System bias determination ± 5 percent of span
- Drift ± 3 percent of span

Table 8 lists the acceptable calibration gas concentrations for the Method 10 testing. EPA protocol gas will be used to calibrate the monitors. The CO calibration gas will be in a balance of N_2. Copies of the calibration gas certification will be available on-site. A gas dilution system (e.g., Environics Model 2020) will be used to make the targeted gas concentration levels from a single, high concentration EPA protocol gas. Dilution mass flow controller calibration results will be available on site.

Table 8. Method 10 CO Calibration Gas Concentrations

Calibration point	CO
Zero	Pure N_2
Low-level	30% of span
Mid-level	60% of span
High-level	90% of span

Daily analyzer calibration error checks will be conducted before the start of each day's testing. The calibration error check will be conducted (after final calibration adjustments are made) by separately injecting each of the four calibration gases (zero, low-, mid-, and high-level) directly into each analyzer and recording the response. If the calibration error is greater than 2 percent, the analyzer will be repaired or replaced and recalibrated to an acceptable calibration error limit before proceeding.

Zero and upscale calibration checks will be performed both before and after each test run to quantify reference measurement system calibration drift and sampling system bias. Upscale will be either the mid- or high-level gas, whichever most closely approximates the sample gas concentration level. During these checks, the calibration gases will be introduced into the sampling system at the probe so that they are sampled and analyzed in the same manner as the sample gas. Drift is defined as the difference between the pre- and post-test run system calibration check responses. Sampling system bias is the difference between the system calibration check response and the initial calibration error response (direct analyzer calibration) at the zero and upscale calibration gas levels. If acceptable bias check results are obtained (system bias $\leq$5 percent of the analyzer span value) but the zero or upscale drift result exceeds the drift limit (3 percent of the analyzer span value), the test run result will be considered valid; however, the analyzer calibration error and bias check procedures will be repeated before conducting the next test run. If the post-test zero or upscale system bias check result exceeds the specification, the test run will be considered invalid.

B2.3.3 UHC by Method 25A

General Requirements
- Response time check
- Sample duration

For EPA Method 25A, only an upscale response time test will be done. To determine the upscale response time, the zero gas will be injected into the sampling system at the probe. Then, the high-level calibration gas will be injected into the sampling system. The upscale response time will be determined as the time required for the recording device (computer readout) to reach 95 percent of the high-level calibration gas reading. This procedure will be repeated three times, and the average will be reported as the response time.

UHC measurements will be made using a separate sampling system apart from the NO_x testing. The sample will be maintained at a temperature above the moisture dew point to prevent condensation in the sample line. The same sample duration applied to the NO_x measurement will be applied to the UHC measurement.

Calibration Requirements
- Calibration error check ± 5 percent of calibration gas value
- Drift ± 3 percent of span

Table 9 lists the acceptable calibration gas concentrations for Method 25A. EPA protocol gas will be used to calibrate the monitors.

Table 9. Method 25A Calibration Gas Concentrations

Calibration Point	**UHC**
Zero	purified air
Low-level	25 - 35% of span
Mid-level	45 - 55% of span
High-level	80 - 90% of span

The UHC calibration gas will be propane in a balance of nitrogen. Copies of the calibration gas certification will be available on-site. A gas dilution system (e.g., Environics Model 2020) will be used to make the targeted gas concentration levels from a single, high concentration EPA protocol gas. Dilution mass flow controller calibration results will be available on site.

For calibration error checks, the zero gas and high-level gas will be separately introduced into the sampling system at the probe. The UHC analyzer's response will be adjusted to the appropriate level. Then, the low- and mid-level calibration gases will be introduced into the sampling system, one at a time. The response of the instrument to each calibration gas must be within ±5 percent of the calibration gas value.

At the conclusion of a test run, the zero and mid-level calibration gases will be separately introduced into the sampling system. Both the zero drift and calibration drift, calculated in accordance with equation B-1 (under Section B2.3.1), must be within ±3 percent of span. If a drift is greater than 3 percent of span, the test run will be considered invalid, and the measurement system will be repaired before additional test runs are conducted.

B2.3.4 Sample Location by Method 20 and Traverse Point Selection by Method 1

General Requirements

- Select sample location as close to the turbine exhaust as practical but no closer than 5 feet from the discharge to atmosphere
- Select the eight traverse points from Figure 1-2 of 40 CFR 60, appendix A

Two sets of sampling ports are available on the turbine exhaust stack. One set is located immediately after a slow 90^{o} horizontal-to-vertical upward bend in the stack. The second set is located approximately 15 feet (5 duct diameters) downstream of the 90^{o} horizontal-to-vertical upward bend and 1.5 feet upstream (0.5 duct diameters) of the stack exit. Neither of these port locations is ideal; however, the top ports will be used (see Figure 2). A total of eight traverse points will be sampled (four points per port), see Table 10 for point locations.

Table 10. Traverse Points

Point #	Percent of stack diameter	Distance from stack wall (in.)
1	6.7	2.4
2	25.0	9
3	75.0	27
4	93.3	33.6

Calibration Requirements

None applicable.

B2.4 Process Data Collection

Process data will be collected by a facility contact or from the turbine control's HMI computer to document the test conditions. Table 3 identifies the parameters that will be measured and the party responsible. The test condition documentation parameters taken from the HMI computer will be retrieved at 15-second intervals for each test run.

B2.4.1 Electrical Power Generation by Turbine

To determine the operating rate of the turbine during the verification test, the electrical power production from the electrical generator will be recorded. This measurement is taken with a wattducer that determines the electrical power supplied at the generator terminals. Currently, CCSI is not aware of any calibration of this device since commissioning of the site in October 1998.

B2.4.2 Fuel Flow Rate

The fuel flow rate into the combustion system will be measured for use in calculating the heat input to the turbine. The type of device to be used is a Coriolis-mass flow meter. The flow meter was calibrated for natural gas at the factory and has not been recalibrated since installation in October 1998. (The flow meter is periodically compared to the City of Santa Clara's main turbine flow meter.)

B2.4.3 Compressor Inlet Temperature

Compressor inlet temperature (also referred to as "ambient temperature" by the facility) is measured with two 1/8-inch diameter sheathed K-type thermocouples located in the inlet air duct. These devices are calibrated on a semi-annual basis using a calibrated thermowell device.

B2.4.4 Compressor Discharge Pressure

Compressor discharge pressure is measured using two pressure taps and two absolute pressure transducers. The transducers were originally calibrated at the factory and have been periodically re-calibrated by CCSI personnel using specially maintained and calibrated pressure sensing devices.

B2.4.5 Catalyst Inlet/Catalyst Outlet Temperatures

The air temperature just upstream of the catalyst and the gas temperature just downstream of the catalyst are measured by separate thermocouple arrays. The catalyst outlet temperature is measured with a series of 4 to 8 thermocouples installed at the exit from the catalyst bed. The thermocouples are calibrated by CCSI personnel whenever the thermocouple hardware is changed.

B2.4.6 Turbine Exhaust Temperature

The turbine outlet temperature is measured by four 1/8-inch diameter sheathed K-type thermocouples installed at the exit of the turbine, just upstream of the stack's silencer. These thermocouples were factory calibrated, were re-calibrated by CCSI personnel upon receiving, and were re-calibrated upon installation.

B2.5 Ambient Conditions Sampling

Three ambient air conditions will be measured for each test run: temperature, pressure, and relative humidity. Temperature and humidity will be measured using an equivalent technique to ASTM E337-84(1996)e1. ASTM E337-84(1996)e1 uses an aspirated wet-bulb and dry-bulb device to determine humidity, but MRI will be using a thermohygrometer to obtain the relative humidity and ambient temperature. Pressure will be measured using ASTM D3631-95. Ambient pressure will be measured with a mechanical pressure device (aneroid barometer). The accuracy of the thermohygrometer measurements are ±3 percent for relative humidity and ±0.7°F for ambient temperature. The relative humidity is detected using the principle of changes in the capacitance of the sensor as its thin polymer film absorbs water molecules. Temperature is measured with a type N thermocouple.

B3: Sample Handling and Custody Requirements

Because all of the data collection and analysis will be done on-site, no samples will be transported to a laboratory. Therefore, sample handling and custody requirements are not part of this verification test program.

B4: Analytical Methods

Table 4 contains the analytical measurement technique for each of the gaseous pollutant monitors.

B5: Quality Control

The quality control procedures for the concentration measurement of NO_x, O_2, CO_2, CO, and UHC are found in the EPA reference methods specific to each gaseous pollutant and summarized in Section B2.3. The QC criteria for the methods are summarized in Table 11.

B6: Instrument Testing, Inspection, and Maintenance Requirements

The equipment used to make the measurements described in Section B2.3 will be subject to the pre- and post-test QC checks required in each applicable EPA Reference Method. In addition, before the equipment leaves MRI's shop, it will be assembled exactly as anticipated to be used in the field and fully tested for functionality. That is, all pumps, controllers, flow meters, computers, instruments, and other subcomponents of the entire measurement system will be operated and calibrated as required by the reference methods. Any faulty subcomponents will be repaired or replaced before being transported to the field measurement site. A small amount of consumables

Table 11. Reference Method QC Criteria

Method	Check	Criteria
Method 20	Interference	≤ 2% of span
	NO_2 converter efficiency	98%
	Response time	< 30 sec.
	Calibration error	± 2% of span
	Drift	± 2% of span
Method 10	Calibration error	± 2% of span
	System bias	± 5% of span
	Drift	± 3% of span
Method 25A	Calibration error	± 5% of gas value
	Drift	± 4% of span
Method 1	Traverse Point	± 1 inch

and frequently needed spare parts will be maintained in the testing trailer. Major subcomponent failures will be handled on a case-by-case basis (e.g., by renting replacement equipment or buying replacement parts).

The equipment used to make the process operating measurements described in Section B2.4 will not be tested, inspected, or maintained by the verification testing contractor as part of this program. CCSI must provide assurance that the values reported for the process data are of acceptable quality.

The equipment used to make the ambient conditions measurements described in Section B2.5 are carefully maintained by MRI's Field Measurements section. The instrumentation will be calibrated according to MRI SOPs; 0721 - Calibration of Thermocouple Probes, Thermocouple Indicators and Digital Thermometers, 0722 - Calibration of Pressure Guages, and 0729 - Qualification and Calibration of Hygrometers at MRI's laboratory before being transported to the field measurement site.

B7: Instrument Calibration and Frequency

The procedures for calibrating the analyzers and sampling system for measuring gaseous pollutants were presented in Section B2.3. The results of each calibration will be entered into Microsoft Excel spreadsheets similar to those presented in Appendix B, pages B4 - B6, B11, and B13. Also, the concentration of the calibration gas standards for each of the EPA methods were presented throughout Section B2.3 (see Tables 7, 8, and 9). As discussed in Section B2.2, an Environics gas dilution system will be used to generate the targeted calibration gas points from high concentration EPA Protocol standard gases. The Environics' MFCs are factory calibrated once each year. Also, the Environics will be verified in the field before the test program according to EPA Method 205 - Verification of Gas Dilution Systems for Field Instrument Calibrations.

Test runs for the XONON flameless combustion system verification test will be 32 minutes in duration. The gaseous pollutant measurement system will be calibrated before and after each test run. Also, no test run will start more than 2 hours after a pre-test calibration and all post-test calibrations will be competed within 1 hour of the end of a test run.

Calibration of the process monitoring instrumentation and frequency of those calibrations are presented throughout Section B2.4.

Calibration of the ambient monitoring instrumentation is done according to MRI SOPs as discussed at the end of Section B6. This instrumentation will be calibrated before the test program. Documentation of the calibration results will be contained on standard forms as noted in the SOP.

B8: 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 Tables 7, 8, and 9 will be generated from high concentration gases for each target compound using a dilution system. 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.

B9: Data Acquisition Requirements (Non-Direct Measurements)

Data to document the process operating conditions of the turbine and XONON will be recorded by the turbine's HMI computer. These data will be provided by the facility contact to MRI's Field Team Leader in electronic format after each 3-run test series.

Data to document the ambient conditions will be recorded by hand on the sheet shown in Appendix B (see page B15).

Data for the gaseous pollutant measurement system calibration and gaseous pollutant concentration measurements will be recorded on sheets shown in Appendix B.

B10: Data Management

B10.1 Data Flow

A. Data origination from test site:

Data measurement and collection activities for NO_X are shown in Figure 6. This flow chart includes all data activities from the initial pretest QA steps to the passing of the data to the Task Leader. Data for other gas pollutants tested under this verification test will be collected and handled in the same manner as the NO_X data.

MRI will use Labtech Notebook to record the concentration signals from the individual monitors. Labtech Notebook will be the data acquisition system for the EPA instrumental test methods. Labtech Notebook records the instrument output at 1-second intervals and will average those signals into 1-minute averages. At the conclusion of a test run, the pre- and post-test calibration results and test run values will be electronically transferred from Labtech Notebook into a Microsoft Excel spreadsheet for data calculations and averaging (see Appendix B for examples of the spreadsheet pages).

B. Data Reduction:

Data from measurements for NO_x from the verification test will be reported in:

- Parts per million by volume (ppmv), and
- ppmv corrected to 15 percent O_2.

One-minute average NO_x concentration values will be recorded by Labtech Notebook. Test run averages will be calculated from the valid readings at each of the eight traverse points.

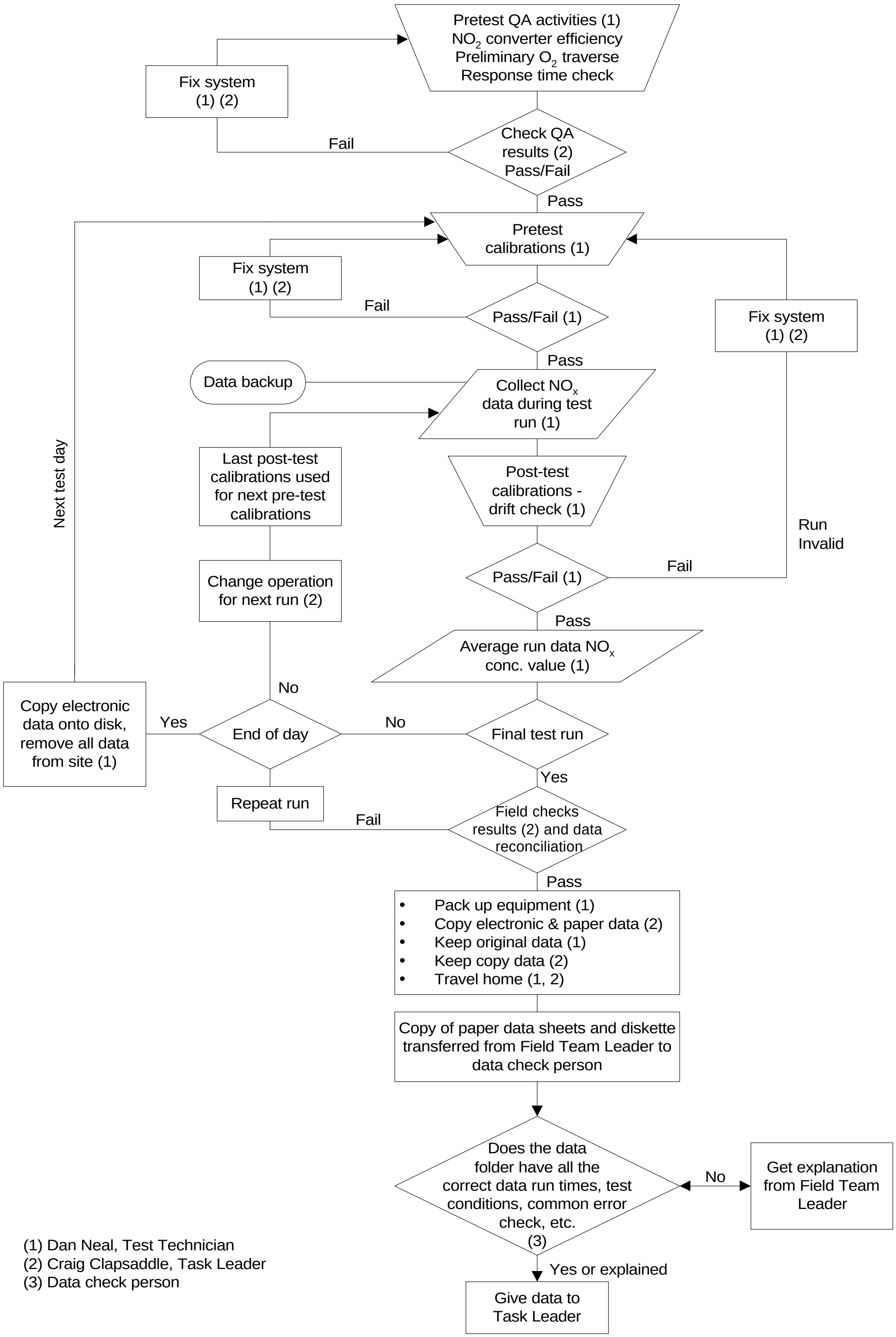

Figure 6. Method 20 NO_x/O_2 gas turbine emissions measurement.

C. Statistical Analysis of Verification Data:

This section describes the statistical analysis of the verification test data. The measured values from the verification test will be compared to the performance capability range specified by CCSI. The hypothetical Test/QA plan targets will be those claimed by CCSI, but the values actually achieved in the field may be slightly different. This sort of variability is to be expected in field tests. Some parameters can be closely controlled; others cannot. The verification range is the range actually tested, not the range specified by CCSI.

The first step in the statistical analysis is to perform the analysis of variance including the only factor: ambient temperature. This step will confirm if the ambient temperature is a significant factor, with P-values below 0.05.

It is assumed that the effect of ambient temperature will be significant enough to be of interest. Two approaches can be used for the final analysis. One is to fit a model with ambient temperatuare as the only parameter. The estimated performance results would be presented separately for the low and high ambient temperature levels. Confidence intervals for the OUT NO_x level can be calculated by taking the mean for each ambient temperature level and adding and subtracting the t-value for 10 degrees of freedom and a 95 percent confidence interval times the standard error indicated in the table. The t-value can be found in standard statistical texts. The verification claim in this case would be that the outlet NO_x concentration is X ± x ppmv at an ambient temperature value of low and Y ± y ppmv at an ambient temperature value of high.

The second approach to estimating the performance of the XONON flameless combustion system is to perform a regression of OUT NO_x on ambient temperature. The result is an equation of the form

$$\text{OUT } NO_x = a + b\,(\text{Ambient T})$$

that can be used to predict the OUT NO_x as a function of ambient temperature. This linear equation would be applicable over the tested ranges of ambient temperatures. Outside these ranges it might be useful, but such use has not been verified.

In some cases, the difference in OUT NO_x values for the low and high ambient temperature levels may be too small to be of practical importance. For example, if the OUT NO_x differed by only 0.5 ppmv between the low and high ambient temperature levels, then one would not likely make a distinction in performance based on the ambient temperature level. For such a case, the overall mean OUT NO_x would be calculated and reported along with the appropriate confidence interval.

D. Outline of the Verification Test Report:

- Verification statement
  - APCT manufacturer/vendor information
  - APCT vendor claim of performance
  - Summary of verification test program
  - Results of the verification test
  - Any limitations of the verification results.
  - Brief QA statement
- Introduction
- Description and identification of the XONON Flameless Combustion System
- Procedures and methods used in testing
- Statement of operating range over which the test was conducted
- Summary and discussion of results
  - Results supporting verification statement
  - Deviations and explanations from test plan
  - Discussion of QA and QA statement
- Conclusions and recommendations
- References
- Appendices
  - QA/QC activities and results
  - Raw test data
  - Equipment calibration results

E. Draft Report Preparation:

At the conclusion of the field sampling effort, a copy of all electronic and paper data will be made and retained by the Field Team Leader. A copy also will be provided to the CCSI facility contact. The original electronic and paper data will be returned to Kansas City. The Field Team Leader will inspect the data for completeness and make a copy of all data to be reviewed by a data reviewer.

The data reviewer will review the data packets for completeness and conduct spot checks for common source testing errors. The common error checks will be based on the data reviewer's experience conducting source tests.

The Task Leader or designated assistant, under the guidance of the Task Leader, will prepare the draft verification test report following the format presented in Section B10.1.D above. After the draft verification test report is completed by the MRI Task Leader, the report will be first reviewed by the MRI Project Manager and then by the MRI Task QA Officer. Following all reviews by MRI, the draft verification test report will be transferred to the RTI Task Leader for RTI's and CCSI's review. After comments from RTI and CCSI, the draft report will be sent for EPA's review.

F. Example Verification Statement:

Appendix D of the GVP for NO_x Control Technologies contains an example verification statement for a NO_x control technology. An example verification statement for CCSI's XONON Flameless Combustion System NO_x control technology is presented in Appendix C of this Test/QA Plan. It is intended to show the form of a verification statement that can be expected from the planned verification test.

G. Long-term Storage:

All verification test data, calibration data, certificates of calibration, assessment reports, verification reports, and verification statements will be retained by MRI's APCT Program Office for a period of not less than 7 years after the final payment of the assistance agreement as per Part A, Section 5.3 of the EPA ETV QMP.

B10.2 Data Recording

Data for this task will be collected by computer and by handwritten entries. Observations and test run sheets will be recorded manually in lab notebooks kept exclusively for this task. The printed output will be secured into the lab notebook.

B10.3 Data Quality Assurance Checks

Data quality assurance checks have been discussed in Sections A1.2 and B10.1.

B10.4 Data Analysis

The statistical analysis of the verification data will be done using STATA®. The NO_x DQO will be calculated using the statistical analysis tool in Microsoft Excel.

B10.5 Data Storage and Retrieval

After the completion of a verification test, labeled three-ring binders containing manually recorded information and data output generated from instrumentation will be stored by MRI's APCT Program Office with a copy retained by the Task Leader. After the completion of a verification test, a computer diskette containing spreadsheet data files will be stored by MRI's APCT Program Office with a copy retained by the test analyst.

All data, verification reports, and verification statements will be retained by MRI's APCT Program Office for a period of not less than 7 years per Part A, Section 5.3 of the EPA ETV QMP.

SECTION C: ASSESSMENT/OVERSIGHT

The quality of the project and associated data are assessed within the project by the project personnel, project leader, and 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 program and department management and independently by the quality assurance officer.

C1: Assessments and Response Actions

The effectiveness of implementing the Test/QA Plan and associated SOPs for a project are assessed through project reviews, in-phase inspections, audits, and data quality assessment.

C1.1 Project Reviews

The review of project data and the writing of project reports are the responsibility of the Task Leader, 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 Task Leader who must assure that overall the project activities meet the measurement and data quality objectives. The second review is an independent assessment by a technical peer reviewer. The peer review is conducted by a technically competent person who is familiar with the technical aspects of the project but not involved in the conduct of project activities. The peer reviewer presents to the Task Leader and program management an accurate and independent appraisal of the technical aspects of the project. The third review of the project is performed by the Program Manager, who is responsible for ensuring that the project's activities adhere to the requirements of the program. The Program Manager's review of the project also will include an assessment of the overall project operations to ensure that the Task Leader has the equipment, personnel, and resources to complete the project as required and to deliver data of known and defensible quality. The final review is that of the division director, who is responsible for assuring that the program management systems are established and functioning as required by division procedures and corporate policy. The division director is the final MRI reviewer and is responsible for assuring that contractual requirements have been met.

C1.2 Inspections

Inspections may be conducted by the project leader, program manager, or quality assurance officer. Inspections assess activities that are considered important or critical to key activities of the project. These critical activities may include, but 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/QA Plan, SOPs, or other established methods, and are documented in the field records. The results of the inspection are reported to the Task Leader, Program Manager, and quality assurance officer. 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). This report is discussed later in this section.

C1.3 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, performance evaluation audits, and data audits 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 Task QA Officer is responsible for ensuring that audits are conducted as required by the Test/QA Plan. Audit reports that describe problems and deviations from the procedures are prepared and distributed through management. Any problems or deviations need to be corrected. The Task Leader is responsible for evaluating corrective action reports, taking appropriate and timely corrective actions, and informing the Task QA Officer and Program Manager of the action taken. The Task QA Officer 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 Program Manager at MRI and the QA Manager at RTI.

C1.3.1 Technical System Audit

The technical system (TSA) audit will be conducted by the RTI Quality Manager prior to the start of the project activities. This audit will evaluate 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 plan, and procedures. This review includes personnel qualifications, adequacy and safety of the facilities and equipment, standard operating procedures (SOPs), 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. During the system audit, the Task QA Officer or designee will inspect the analytical activities and determine they adherence to the SOPs and the Test/QA Plan. The RTI Quality Manager or a designee reports any area of nonconformance to the project leader, program manager, and division director 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.

C1.3.2 Performance Audit

The performance evaluation sample (PES) is designed to check the operation of the analytical system. The performance samples, obtained from the EPA QA Manager, will contain analytes at a known (determined) concentration and will be presented to the analyst in such a manner as to have the concentration of the PES unknown (blind) to the analyst. Upon receiving the analytical data from the analyst, the EPA QA Manager will evaluate the performance data for compliance with the requirements of the project. The performance evaluation will occur on-site during the field test.

The method performance also will be assessed using the internal quality control samples: inserted into the analytical scheme. The specific measurement and data quality objectives for method performance samples have been described earlier.

C1.3.3 Data Audit

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

The data audit, 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 leader and the peer reviewer.

C2: Reports to Management

During the different activities on this project, the reporting of information to management is critical. To insure the complete transfer of information to all parties involved in this project, a system of reports to management is described below.

C2.1 Status and Activity Reports

The status of the project will be reported to the Task Leader on a regular basis by the project staff. Project status will be reported to the MRI Project Manager and MRI Task QA Officer at regularly scheduled meetings and monthly to the RTI Project Manager in the project status report.

Any problems found during the analytical process requiring corrective action will be reported immediately by the project staff to the Task Leader, Project Manager, and the Task QA Officer through the investigation and corrective action documentation. The results of the inspection by the Task Leader or program management will be documented in the project files and reported to the Task QA Officer. Inspections conducted by the Task QA Officer will be reported to the Task Leader and program management in the same manner as other audits.

The results of system audits, inspections, performance evaluations, and data audits conducted by the Task QA Officer will be routed to the project leader for review, comments, and corrective action. The results of the performance evaluations will be documented in the project records. The control and an assessment of the data will be sent for management review. The performance evaluations, issues, and corrective action responses covered by the audit reports will be reviewed and approved by the task and Program Manager, section manager, and division directors. The results of all assessments, audits, inspections, and corrective actions for the task will be summarized and included in a quality assurance/quality assessment section in the final report.

C2.2 Corrective Action 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 Task Leader, the Project Manager, and the Task QA Officer. In cases involving the analytical process, the corrective action will also involve the analyst. A written report (Figure 7) is required on all corrective actions.

Since the tasks of this study involve a validation process to ensure data quality for pollution control technologies, 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 an 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 Task Leader will be notified of the problem immediately. The Task Leader will then take and document appropriate action. The Task Leader is responsible for and is authorized to halt the work if it is determined that a serious problem exists.

The Task Leader is responsible for and is authorized to implement any procedures to prevent the recurrence of problems.

C2.3 Verification and Assessment Reports

The MRI Task Leader will notify RTI's Project Manager, Task QA Officer, and QA Manager when the field test of the XONON flameless combustion system is being conducted. The RTI Project Manager will submit the draft verification reports and verification statements to the RTI Quality Officer. After technical assessments, the RTI Quality Manager will submit the assessment Report to the RTI Project Manager. The RTI Project Manager will submit verification reports and verification statements to the EPA Project Manager and will submit assessment reports to the EPA Project Manager for informational purposes.

Project No.:________________
Date:________________

Corrective Action Report

Project Title/Description: ____
____

Description of Problem:

Originator: ____________________________ Date:________________

Investigation and Results:

Investigator: ____________________________ Date:________________

Corrective Action Taken:

Originator: ____________________________ Date:________________

Reviewer/Approval: ____________________________ Date:________________

cc: Project Leader, Program Manager, Division Manager, QA Unit

Figure 7. Corrective action report.

SECTION D: DATA VALIDATION AND USABILITY

D1: Data Review, Validation, and Verification Requirements

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

- On site following each test run – by the Test Technician
- On site following completion of the test program – by the Field Team Leader
- Before writing the draft verification test report – by the Data Reviewer
- During QA review of the draft report and audit of the data – by the MRI Task QA Officer and Project Manager

The criteria used to review and validate the data will be the QA/QC criteria specified in each test method (see Table 11) and the DQO analysis of the NO_x test data (see Section A4.1). Those individuals responsible for onsite data review and validation are noted in Figure 6, Section B10, and above. The project leader is responsible for verification of data with all written procedures. Finally the QA Manager reviews and validates the data and the draft report using the Test/QA Plan, test methods, general SOPs, and project-specific SOPs.

The data review and data audit will be conducted in accordance with MRI SOP 0208 – "Review and Audit of Data and Study Reports." The procedures that will be followed are summarized in Sections C1.3.3 and C2 of this Test/QA Plan. Form MRI-86 ("blue sheet") will be used for Verification Report review/approval/distribution within MRI. A copy of Form MRI-86 is included in Appendix D.

D2: Validation and Verification Methods

The process for validating and verifying data has been described in Sections A6.1, B10.1, and D1. If the test is found to not meet the DQO, the process described in Section A4.1 will be followed. Results of the testing are conveyed to the data users through the ETV Verification Statements and Verification Reports. Examples of these are presented in the GVP for NO_x Control Technologies.

D3: Reconciliation with Data Quality Objectives

Stakeholder requirements for the DQO have been defined in the GVP for NO_x Control Technologies. This reconciliation step is an integral part of the test program and will be done at the test site. Attainment of the NO_x DQO is confirmed by statistically analyzing the NO_x test data as described in the middle of the first paragraph in Section A4.1. The statistical analysis to determine the NO_x DQO will be done by MRI's Field Team Leader at the conclusion of all 12 scheduled test runs. The statistical analysis will be done using Microsoft Excel's "Descriptive Statistics" package in the data analysis tool. The DQO is calculated as the 95 percent confidence interval divided by the mean.

The reconciliation of the results with the DQO will be evaluated using the data quality assessment process. This process started with the review of the DQO and the sampling design to assure that the sampling design and data collection documentation are consistent with those needed for the DQO. When the preliminary data is collected, the data will be reviewed to ensure that the data are consistent with what was expected and to identify patterns, relationships, and potential anomalies. The data will be summarized and analyzed using appropriate statistical procedures to identify the key assumptions. The assumptions will be evaluated and verified with all deviations from procedures assessed as to their impact on the data quality and the DQO. Finally, the quality of the data will be assessed in terms of precision, bias, and statistical significance as they relate to the measurement objectives and the DQO.

Results from verification testing of the XONON flameless combustion system will be presented in a Verification Statement and a Verification Report as described in Section B10.1.D.

Review/Revision History

Date	Pages	Revision
6/2/00	Complete document	Initial issue
7/5/00	Complete document	1

Appendix A

Résumé of Craig A. Clapsaddle

Résumé of Daniel O. Neal

Craig A. Clapsaddle

Senior Environmental Scientist
Midwest Research Institute

Education

B.S., Meteorology, Millersville University of Pennsylvania, 1986
M.S., Meteorology, The Pennsylvania State University, 1989

Specialties

- Continuous emission monitoring and predictive emission monitoring; CEMS performance evaluations, monitoring plans, QA plans, program audits; PEMS development for boilers, turbines, and engines; PEMS performance evaluations, QA plans, and regulatory acceptance.
- Source emission testing; emission control equipment performance evaluation testing, compliance with NSPS and State permit limits, and boiler performance analysis and combustion characterization.
- Emission monitoring policy analysis and issues; CEM regulatory comparisons and emission testing protocols.

Experience

Senior Environmental Scientist, 1998-Present
(Staff Scientist 1996-1998)
Midwest Research Institute, Cary, North Carolina

Provides emission monitoring-related technical support and source testing on MRI contracts with EPA and industrial clients. Experience includes:

- Task Lead for EPA's PM CEMS demonstration project on a coal-fired boiler exhaust. Activities included specification and procurement of three PM monitors; installation, startup, and operation of three PM CEMs; PM CEMS data analysis and correlation equation development; and commenting on PS-11 for EPA.
- Task Lead for EPA document "Current Knowledge of Particulate Matter (PM) Continuous Emission Monitoring." Objective of this document was to provide detailed information on the current knowledge of PM CEMS, primarily for State permitting authorities and Regional EPA personnel.
- Project Manager for a Part 75, Appendices D, E, and G, DAHS installation and compliance testing on two GE Frame 7 gas turbines located in Wisconsin. This project is being performed for Burns & McDonnell.
- Project Leader on a statistical evaluation of the potential system errors in a continuous emission rate monitoring system (CERMS) project. Activities involved (1) evaluating the uncertainty in the Reference Method flow rate measurement, (2) calculating the bias and imprecision of four example ultrasonic flow rate monitors, and (3) estimating the uncertainty

in the NO_x mass emission rate reported by a CERMS at a municipal waste combustor facility.

- Project Leader on a source testing project at two asphalt roofing facilities. Objective of project was to obtain emissions data for MACT standard development.
- Task Leader on Air Pollution Control Technology Evaluation Center subcontract to RTI. Responsibility includes developing verification testing protocols.
- Responsible for MRI's PEMS activities. Project Manager for implementing EPRI's gas turbine PEMS project. Activities included regulatory acceptance of the PEMS and oversight of the PEMS development and performance evaluation. Also served as principal investigator for an AGA/PRCI project to determine the natural gas transmission industry's experience with gas turbine PEMS.
- Project Leader on an EPA/EMC project to finalize the opacity CEM PS-1 Federal Register package. Activities included addressing public comments on proposed revisions to PS-1, preparing the docket for the rule, incorporating ASTM D6216-98 into the specification, and revising into Plain English.
- Task Leader on an EPA/EMC project to redesign and update EPA's CEMS Cost Model. Activities included revising the equations based on experience in the field of continuous emission monitoring and information gathered from CEMS vendors, CEMS users, and instrument manufacturers. In addition to revising the existing cost model, the cost for particulate matter monitors was incorporated into the CEMS Cost Model, and a new module for estimating the cost of an FTIR CEM was added to the CEMS Cost Model.
- Task Leader for Open Market Trading Rule Guidance. Activities involved developing generic quantification protocols for NO_x and VOC DER use and generation credits.
- Project Leader on an EPA/EMC project to evaluate two alternative methods to EPA Method 25. Responsibilities included conducting the site survey, preparing the test plan, organizing the field test program, and producing the final evaluation report.
- Continues to conduct source testing activities as needed to support MRI projects. Evaluates source test reports for MACT standard development.
- Participated in an EPA/EMC project to develop a guidance manual for baghouse bag leak detection monitoring.

Project Manager and Department Manager, 1993-1996
Kilkelly Environmental Associates, Raleigh, North Carolina

Managed numerous source testing projects, CEMS consulting projects, and PEMS development and implementation projects. Also responsible for source testing business development. Experience includes the following activities.

CEMS Consulting

- Served as a CEMS consultant to oversee the procurement and installation of a Part 75 CEMS for a municipal utility in Nebraska. Responsibilities included developing a bid specification document, evaluating five CEMS vendor proposals, conducting a best and final meeting with two CEMS vendors, participating in contract negotiations, and oversight of installation and startup.

- Served as a CEMS consultant to the Gas Research Institute. Responsibilities included serving as project manager for two CEMS procurement projects for two gas transmission companies, conducting a CEMS experience survey of three gas transmission companies, and principal technical advisor for a CEMS guideline manual for the gas transmission industry.
- Served as a CEMS consultant to an Engineering firm in New York. Responsibilities included specifying a Part 503 CEMS for a sewage sludge incinerator.
- Served as a CEM consultant to PSE&G for a project involving developing comparison tables between state and federal CEM record keeping and reporting regulations for the utilities boilers and combustion turbines. Responsibilities included summarizing the record keeping and reporting requirements for the state regulations, NSPS regulation, and acid rain regulation.

PEMS Development and Evaluation

- Involved with developing PEMS models, evaluating PEMS performance, and PEMS regulatory approval. Responsible for developing 13 utility boiler PEMS for two electric utility companies in New Jersey. Activities included developing monitoring plans for PEMS, negotiating PEMS performance requirements and QA/QC requirements with utility and state regulatory agency, collecting field data for model development, supervising the generation of PEMS models, and supervising certification testing of PEMS.
- Conducted a performance evaluation of a SoLoNOx PEMS for a natural gas transmission company. Activities included developing a spreadsheet to calculate a statistical evaluation of the PEMS data, supervising development of additional models to evaluate the significance of the PEMS parameters, identifying acceptable PEMS performance criteria and evaluated the PEMS performance against the established criteria, producing a report summarizing the results of the PEMS performance evaluation, and meeting with industry and vendor representatives to discuss the project results and to determine future objectives.

Project Manager and/or Field Team Leader for source testing projects

- Served as the project manager and field team leader to conduct compliance emission testing on numerous engines and gas turbines for CNG Gas Transmission. Served as the project manager and field team leader for a compliance emission test on three boilers at a Campbell Soup plant. Served as the project manager for a compliance emission test on six gas turbines for Savannah Electric. Responsibilities for these projects included maintaining project budgets, developing test protocols, conducting and supervising field testing, data evaluation, and final reports.
- Served as the field team leader on more than 15 Part 75 CEMS certification tests.

Project Manager and CEM Group Manager, 1989-1993
Galson Corporation, Syracuse, New York

Conducted source testing for compliance and engineering purposes. Supervised field testing crews. Managed source testing and CEMS certification projects. Responsible for overall operation of CEM testing services within the Source Testing Department, including equipment maintenance, staff training, and staff supervision. Experience included:

- As a field team leader or project manager, conducted more than 75 source emission testing projects to determine compliance with permitted emission limits or evaluate pollution control equipment. Sources tested include electric utility and industrial boilers, medical waste incinerators, municipal waste combustors, combustion turbines, and internal combustion engines. Control equipment included carbon adsorption units, thermal oxidizers, selective and non-selective catalytic reduction devices, wet and dry scrubbers, baghouses, and electrostatic precipitators.
- As a field team leader or project manager, conducted more than 20 CEMS certifications.
- Project manager responsibilities included overall technical and financial management of projects, including initial client contact, project budgets and proposal preparation, contact with regulatory agencies and protocol development, staff training, field testing, and data management and final report preparation.

Publications and Papers

Clapsaddle, C. A., and D. Lamb, "The Sorption Behavior of SO_2 on Ice at Temperatures Between -30° ανδ –5°Χ," *Geophys. Res. Lett.* (1989).

Clapsaddle, C. A., M. A. Acree, and K. D. Steckley, "Development of a Parametric NO_x Emission Estimation Correlation for Oil- and Gas-Fired Boilers," in *Proceedings of the Air and Waste Management Association Annual Conference*, *94-TP29B.05*, Air and Waste Management Association, Pittsburgh (1994).

Clapsaddle, C. A., "Comparison of NO_x Emission Rates Estimated by 40 *CFR* Part 75, Appendix E, Procedures and Parametric Emission Models with Reference Method CEM Measurements," in *Proceedings of the Air and Waste Management Association Annual Conference, 95-MP16A.05*, Air and Waste Management Association, Pittsburgh (1995).

Clapsaddle, C. A., and M. B. Cunningham, "Performance Evaluation of Parametric Emission Monitoring System for Boilers," in *Proceedings of the Air and Waste Management Association Continuous Compliance Monitoring Under the Clean Air Act Amendments Conference*, Air and Waste Management Association, Pittsburgh (1995).

Clapsaddle, C. A., "Performance Evaluation of CEMS Installed on Non-Utility Sources," in *Proceedings of the Air and Waste Management Association Annual Conference, 96-MP16A.05*, Air and Waste Management Association, Pittsburgh (1996).

Clapsaddle, C. A., “Monitoring Beyond Part 75—The Effect of the NO_x Budget Rule on Northeastern Electric Utilities,” in *Proceedings of the May 1997 CEM Users Group Meeting*, Electric Power Research Institute, Palo Alto, California (1997).

Clapsaddle, C. A., and D. G. Bivins, “An Update to the Environmental Protection Agency’s CEMS Cost Model,” in *Proceedings of the Air and Waste Management Association Annual Conference, 98-TPC.01*, Air and Waste Management Association, Pittsburgh, Pennsylvania (1998).

Clapsaddle, C. A., P. M. Romberg, and G. H. Quentin, “The First-Principle-Based EPRI Turbine PEMS,” in *Proceedings of the May 1998 CEM Users Group Meeting*, Electric Power Research Institute, Palo Alto, California (1998).

Bivins, D. G., C. A. Clapsaddle, and P. Westlin, “U.S. Environmental Protection Agency’s Evaluation and Applicability Determination Process for Particulate Matter Continuous Emission Monitoring Systems,” in *Proceedings of the CEM99 International Conference on Emission Monitoring, Paper No. 13*, IEA Coal Research, London, UK (1999).

Daniel O. Neal
Principal Technician
Midwest Research Institute

MRI

Education

Undergraduate Studies, Kansas State University, Johnson County Community College, and Longview College

Experience

Principal Technician, 1996-Present
(Senior Technician, 1993-1996)
Midwest Research Institute, Kansas City, Missouri

Based in the Field Measurements Section of MRI's Applied Engineering Division, provides technical support on programs for environmental monitoring, sampling, and analysis.

- Responsibilities include operation and maintenance of CEMS analyzers; operation, calibration, and maintenance of manual methods test equipment; purchase of equipment and supplies; staging and destaging equipment for field tests; analysis by Orsat; and setup and operation of equipment, including operating stack probe and running Method 5 console. Skilled in collection of emission samples of particulates, metals, Cr^{+6}, organics, and PCDDs/PCDFs.

- Conducted emissions tests at a variety of facilities: brick manufacturing, iron and steel foundary, ferroalloy, wool fiberglass, chromium refractories, coal calcining, asphalt cement, nutritional yeast, asphalt roofing, secondary aluminum, and the Drake chemical Superfund site. Emission testing also performed for RCRA miniburns and trial burns, and for compliance tests at hazardous waste and infectious waste incinerators. Also assists in cooling tower compliance and performance tests.

Route Salesperson, 1991-1993
Kansas City Periodical, Inc., Lenexa, Kansas

Salesperson, 1984-1991
Shamrock Cabinet and Appliance Company, Raytown, Missouri

Design Detailer and Drafting Supervisor, 1976-1984
Burns and McDonnell Engineers, Architects and Consultants, Kansas City, Missouri

- Worked in the Power Division developing design and layout for electrical power substations.

Appendix B

Data Summary Sheets

Final Data Report

Job No. ________________________ Operator: ________________________

Client: ________________________ Date: ________________________

Plant: ________________________ Run No. ________________________

Location: ________________________ Condition: ________________________

Corrected to: _________ $\%O_2$

Measurement Results

Test method	3A	3A	6C	7E	20	10	25A
Emission component	O_2	CO_2	SO_2	NO_X	NO_X*	CO*	TGOC*
Initial system zero	#REF!	0	0	0			
Final system zero	#REF!	0	45	0			
Initial system upscale	#REF!						
Final system upscale	#REF!						
Upscale calibration gas value							
Raw average							
Corrected average	#REF!						

*** Values not corrected**

Volumetric Flow Rate _________ **dscfm**

Fuel F-Factor _________ **dscf/10^6 Btu**

Emission concentration and rate results

Emission component	O_2	CO_2	SO_2	NO_X - 7E	NO_X - 20	CO	TGOC**
ppm as measured			N/A	N/A	N/A	N/A	N/A
ppm corr. to N/A $\%O_2$			N/A	N/A	N/A	N/A	N/A
lb/hr			N/A	N/A	N/A	N/A	N/A
lb/10^6 Btu			N/A	N/A	N/A	N/A	N/A

**** Measured as propane**

N/A = Not applicable

Raw Data

Job No. ______________________ Operator: ______________________

Client: ______________________ Date: ______________________

Plant: ______________________ Run No. ______________________

Location: ______________________ Condition: ______________________

Sample	Test Method and Emission Component					
Time	20	20	20	6C	10	25A
24-Hr	O_2	CO_2	NO_X	SO_2	CO	TGOC

NO_x Analyzer Calibration Data By Method 20

Job No:	0	Operator:	0
Client:	0	Date:	00-Jan-00
Plant:	0	Run No.:	0
Location:	0	Condition:	

Instrument:	NOx	Manufacturer:	Thermo Environmental Intru., Inc.
Instr. Span:	____ ppm	Model No.:	42H
		Serial No:	42H-41111-264

Calibration Error Determination

Calibration Time	Calibration Gas Range	Calibration Gas: Cal Value	Calibration Gas: Cylinder Number	Analyzer Calib. Response Value	Difference As % span	Pass/Fail
	Zero	0.0			#DIV/0!	#DIV/0!
	Mid				#DIV/0!	#DIV/0!
	High				#DIV/0!	#DIV/0!
	Low				#DIV/0!	#DIV/0!

Fail Criteria is greater than +/- 2% of the calibration gas value

1st Drift Check - Zero (Zero Gas) and Span (Mid-Level Gas)

Calibration Time	Initial Value	Zero Drift Check Value	Difference As % span	Pass/Fail
	0.0		#DIV/0!	#DIV/0!

Calibration Time	Initial Value	Span Drift Check Value	Difference As % span	Pass/Fail
	0.0		#DIV/0!	#DIV/0!

Fail Criteria is greater than +/- 2% of the span value

2nd Drift Check - Zero (Zero Gas) and Span (Mid-Level Gas)

Calibration Time	Initial Value	Zero Drift Check Value	Difference As % span	Pass/Fail
	0.0		#DIV/0!	#DIV/0!

Calibration Time	Initial Value	Span Drift Check Value	Difference As % span	Pass/Fail
	0.0		#DIV/0!	#DIV/0!

Fail Criteria is greater than +/- 2% of the span value

O_2 Analyzer Calibration Data By Method 20

Job No. ______________________ Operator: ______________________

Client: ______________________ Date: ______________________

Plant: ______________________

Location: ______________________

Analyzer Type: **O_2**

Analyzer Span: **25** %O_2

Zero Gas: Prepurified nitrogen

High-level Gas: Oxygen in nitrogen

Mid-level Gas: Oxygen in nitrogen

Analyzer Manufacturer: ______________________

Model No. ______________________

Serial No. ______________________

Calibration Check Data

Run No.	**Load Condition:**							
Calibration Ending Time	**Calibration Gas**			**Analyzer Response Value, %O_2**		**Response Agreement with Curve[a]**	**Difference (Drift) After Run, %O_2**	**Drift Check Result[b]**
	Concentration Level	**Value, %O_2**	**Cylinder ID Number**	**Before Run**	**After Run**			
	Zero Gas	0.0		**0.0**	**0.0**		**0.0**	**Pass**
	High-level	20.9		**20.9**	**20.9**	**Pass**	**0.0**	**Pass**
	Mid-level	12.5		**12.5**	**12.5**		**0.0**	**Pass**
Predicted value from linear curve, %O_2 :			20.9	**Difference, %O_2 :**		0.0		

a. High-level response before run must agree with predicted value on linear curve within 2% of the span value.

b. Drift check must not exceed ±±2% of the span value.

$$\text{Percent Drift} = \frac{\text{Absolute difference}}{\text{Span}} \times 100$$

Response Time Determination

Reading	Downscale Response, seconds		Upscale Response, seconds	
1				
2				
3		Average:		Average:
System Response Time (slower average time) =				**seconds**

Calibration Check Data

Run No.			**Load Condition:**					
Calibration Ending Time	**Calibration Gas**			**Analyzer Response Value, %O_2**		**Response Agreement with Curve**	**Difference (Drift) After Run, %O_2**	**Drift Check Result**
	Concentration Level	**Value, %O_2**	**Cylinder ID Number**	**Before Run**	**After Run**			
	Zero Gas	0.0					0.0	
	High-level	20.9					0.0	
	Mid-level	12.5					0.0	
Predicted value from linear curve, %O_2 :				**Difference, %O_2 :**				

CO_2 Analyzer Calibration Data By Method 20

Job No. ____________________ Operator: ____________________

Client: ____________________ Date: ____________________

Plant: ____________________

Location: ____________________

Analyzer Type: **CO_2**

Analyzer Span: **20** $\%CO_2$

Zero Gas: Prepurified nitrogen

High-level Gas: Carbon dioxide in nitrogen

Mid-level Gas: Carbon dioxide in nitrogen

Analyzer Manufacturer: ____________________

Model No. ____________________

Serial No. ____________________

Calibration Check Data

Run No.	**Load Condition:**							
Calibration Ending Time	**Calibration Gas**			**Analyzer Response Value, $\%CO_2$**		**Response Agreement with Curve[a]**	**Difference (Drift) After Run, $\%CO_2$**	**Drift Check Result[b]**
	Concentration Level	**Value, $\%CO_2$**	**Cylinder ID Number**	**Before Run**	**After Run**			
	Zero Gas	0.0		0.0	0.0		0.0	**Pass**
	High-level	12.0		12.0	12.0	**Pass**	0.0	**Pass**
	Mid-level	5.0		5.0	5.0		0.0	**Pass**
Predicted value from linear curve, $\%CO_2$:			12	**Difference, $\%CO_2$:**		0.0		

a. High-level response before run must agree with predicted value on linear curve within 2% of the span value.

b. Drift check must not exceed ±±2% of the span value.

$$\text{Percent Drift} = \frac{\text{Absolute difference}}{\text{Span}} \times 100$$

Response Time Determination

Reading	Downscale Response, seconds	Upscale Response, seconds
1		
2		
3	Average:	Average:
System Response Time (slower average time) =		**seconds**

Calibration Check Data

Run No.	**Load Condition:**							
Calibration Ending Time	**Calibration Gas**			**Analyzer Response Value, $\%CO_2$**		**Response Agreement with Curve**	**Difference (Drift) After Run, $\%CO_2$**	**Drift Check Result**
	Concentration Level	**Value, $\%CO_2$**	**Cylinder ID Number**	**Before Run**	**After Run**			
	Zero Gas	0.0					0.0	
	High-level	12.0					0.0	
	Mid-level	5.0					0.0	
Predicted value from linear curve, $\%CO_2$:				**Difference, $\%CO_2$:**				

Response Time

Operator: **0**
Date: **00-Jan-00**
Instr. Span: **0** ppm

Instrument: **NOX**
Manufacturer: **Thermo Environmental Intru., Inc.**
Model No.: **42H**
Serial No: **42H-41111-264**

	Downscale Response Time	Upscale Response Time	
Reading 1			(Seconds)
Reading 2			(Seconds)
Reading 3			(Seconds)
Maximum	**0**	**0**	(Seconds)

Response time = **0** (Seconds)

Analyzer Interference Test

Operator: **0**
Date: **00-Jan-00**
Instr. Span: ________ ppm

Instrument: **NOX**
Manufacturer: **Thermo Environmental Intru., Inc.**
Model No.: **42H**
Serial No: **42H-41111-264**

Analyzer Interference Determination			
Calibration Gas	**Concentration**	**Interference Value**	**Interference as % of Span**
CO	500 +/- 50 ppm		#DIV/0!
SO_2	200 +/- 20 ppm		#DIV/0!
CO_2	10% +/- 1%		#DIV/0!
O_2	20.9 +/- 1%		#DIV/0!
		Total Interference as % of Span	#DIV/0!
		Fail criteria is greater than +/- 2% of span value	**#DIV/0!**

Analyzer Interference Test

Operator: ____________________ Analyzer Type: O_2

Date: ____________________ Analyzer Manufacturer: ____________________

Analyzer Span: 25 % Model No. ____________________

Serial No. ____________________

Analyzer Interference Determination

Test Gas		Analyzer Output Response As $\%O_2$	Interference as % of Span
Component Tested	Component Concentration		
CO	500 ppm		0.0%
SO_2	200 ppm		0.0%
CO_2	10%		0.0%
		Total Interference as % of Span	0.0%
Sum of interferences must not exceed ±±2% of span value.		Result:	Pass

Analyzer Interference Test

Operator: ____________________
Date: ____________________
Analyzer Span: **20** %

Analyzer Type: **CO_2**
Analyzer Manufacturer: ____________________
Model No. ____________________
Serial No. ____________________

Analyzer Interference Determination

Test Gas		Analyzer Output Response As %O_2	Interference as % of Span
Component Tested	**Component Concentration**		
CO	500 ppm		0.0%
SO_2	200 ppm		0.0%
O_2	20.9%		0.0%
		Total Interference as % of Span	0.0%
Sum of interferences must not exceed ±±2% of span value.		**Result:**	**Pass**

NO_2 To NO Converter Efficiency

Job No: 0
Client 0
Plant: 0

Operator: 0
Date: 00-Jan-00

Instrument: NOx
Instr. Span: 100 ppm

Manufacturer: Thermo Environmental Intru., Inc.
Model No.: 42H
Serial No: 42H-41111-264

Calibration Error Determination

Calibration Time	Calibration Gas Range	Calibration Gas: Cal Value	Calibration Gas: Cylinder Number	Analyzer Calib. Response Value	Difference As % span	Pass/Fail
	Zero				#DIV/0!	**#DIV/0!**
	High				#DIV/0!	**#DIV/0!**
	Mid				#DIV/0!	**#DIV/0!**

Fail Criteria is greater than +/- 2% of the span value

Mid-level N0 in N2 calibration gas diluted approximately 1:1 with ambient air.

Conversion Efficiency Check (1 min Average Readings)

Time 24 Hrs.	Time (min) Elapsed	NO_x Reading	Time 24 Hrs.	Time (min) Elapsed	NO_x Reading	Time 24 Hrs.	Time (min) Elapsed	NO_x Reading
	1		0:10	**11**		0:20	**21**	
0:01	**2**		0:11	**12**		0:21	**22**	
0:02	**3**		0:12	**13**		0:22	**23**	
0:03	**4**		0:13	**14**		0:23	**24**	
0:04	**5**		0:14	**15**		0:24	**25**	
0:05	**6**		0:15	**16**		0:25	**26**	
0:06	**7**		0:16	**17**		0:26	**27**	
0:07	**8**		0:17	**18**		0:27	**28**	
0:08	**9**		0:18	**19**		0:28	**29**	
0:09	**10**		0:19	**20**		0:29	**30**	

Highest Reading = 0

Converter Efficiency = #DIV/0! %

Fail criteria is less than 98% efficiency: #DIV/0!

Calibration Drift
Final Values

Calibration Time	Calibration Gas Range	Analyzer Calibration Response	Drift % of Span	Pass/Fail
	Zero Gas		**#DIV/0!**	**#DIV/0!**
	High		**#DIV/0!**	**#DIV/0!**
	Mid		**#DIV/0!**	**#DIV/0!**

Fail Criteria for drift check is greater than +/- 3% of the span value

CO Analyzer Calibration Data By Method 10

Job No: 0
Client: 0
Plant: 0
Location: 0

Operator: 0
Date: 0-Jan-00
Run No.: 0
Condition: 0

Instrument: CO
Instr. Span: ________ ppm

Manufacturer: Thermo Environmental Intru., Inc.
Model No.: 48
Serial No: 48-29095-233

Calibration Error Determination

Calibration Time	Calibration Gas Range	Calibration Gas: Cal Value	Calibration Gas: Cylinder Number	Analyzer Calib. Response Value	Difference As % span	Pass/Fail
	Zero	0.0			#DIV/0!	#DIV/0!
	High				#DIV/0!	#DIV/0!
	Mid				#DIV/0!	#DIV/0!
	Low				#DIV/0!	#DIV/0!

Fail Criteria is greater than +/- 2% of the span value

System Calibration Bias and Drift

Initial Values

Calibration Time	Calibration Gas Range	Analyzer Calibration Response	System Calibration Response	System Cal. Bias % of Span	Pass/Fail
	Zero Gas	0.0		#DIV/0!	#DIV/0!
	Upscale Gas			#DIV/0!	#DIV/0!

Final Values

Calibration Time	Calibration Gas Range	System Calibration Response	System Cal. Bias % of Span	Pass/Fail	Drift % of Span	Pass/Fail
	Zero Gas		#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
	Upscale Gas		#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!

Fail Criteria for system bias check is greater than +/- 5% of the span value
Fail Criteria for drift check is greater than +/- 3% of the span value

$$\text{System Calibration Bias} = \frac{\text{System Cal. Response} - \text{Analyzer Cal. Response}}{\text{Span}} \times 100$$

$$\text{Drift} = \frac{\text{Final System Cal. Response} - \text{Initial System Cal. Response}}{\text{Span}} \times 100$$

Response Time

Operator: 0
Date: 0-Jan-00
Instr. Span: 0 ppm

Instrument: CO
Manufacturer: Thermo Environmental Intru., Inc.
Model No.: 48
Serial No: 48-29095-233

	Downscale Response Time	Upscale Response Time	
Reading 1			(Seconds)
Reading 2			(Seconds)
Reading 3			(Seconds)
Maximum	0	0	(Seconds)

Response time = 0 (Seconds)

Obtain Sample Readings after: 0 (Seconds)

THC Analyzer Calibration Data By Method 25A

Job No: 0
Client: 0
Plant: 0
Location: 0

Operator: 0
Date: 0-Jan-00
Run No.: 0
Condition: 0

Instrument: THC
Instr. Span: ______ ppm

Manufacturer: J.U.M. Engineering
Model No.: VE 7
Serial No: 102011192

Calibration Error Determination

Calibration Time	Calibration Gas Range	Calibration Gas: Cal Value	Calibration Gas: Cylinder Number	Analyzer Calib. Response Value	Difference As % span	Pass/Fail
	Zero	0.0			#DIV/0!	#DIV/0!
	High				#DIV/0!	#DIV/0!
	Mid				#DIV/0!	#DIV/0!
	Low				#DIV/0!	#DIV/0!

Fail Criteria is greater than +/- 5% of the calibration gas value

1st Drift Check - Zero (Zero Gas) and Span (Mid-Level Gas)

Calibration Time	Initial Value	Zero Drift Check Value	Difference As % span	Pass/Fail
	0.0		#DIV/0!	#DIV/0!

Calibration Time	Initial Value	Span Drift Check Value	Difference As % span	Pass/Fail
	0.0		#DIV/0!	#DIV/0!

Fail Criteria is greater than +/- 3% of the span value

2nd Drift Check - Zero (Zero Gas) and Span (Mid-Level Gas)

Calibration Time	Initial Value	Zero Drift Check Value	Difference As % span	Pass/Fail
	0.0		#DIV/0!	#DIV/0!

Calibration Time	Initial Value	Span Drift Check Value	Difference As % span	Pass/Fail
	0.0		#DIV/0!	#DIV/0!

Fail Criteria is greater than +/- 3% of the span value

Response Time

Operator: 0
Date: 0-Jan-00
Instr. Span: 0 ppm

Instrument: THC
Manufacturer: J.U.M. Engineering
Model No.: VE 7
Serial No: 102011192

	Upscale Response Time	
Reading 1		(Seconds)
Reading 2		(Seconds)
Reading 3		(Seconds)
Maximum	0	(Seconds)

Response time = 0 (Seconds)

Ambient Conditions Data Summary*

Date: ______				
	Time	**Temperature, °F**	**Pressure, mm Hg**	**Relative humidity, %**
Run 1	______ ______ ______	______ ______ ______	______ ______ ______	______ ______ ______
Run 2	______ ______ ______	______ ______ ______	______ ______ ______	______ ______ ______
Run 3	______ ______ ______	______ ______ ______	______ ______ ______	______ ______ ______

*** Ambient measurements to be taken every 10 minutes for each 30-minute run.**

Appendix C

Example Verification Statement for the CCSI
XONON Flameless Combustion System NO_x Control Technology

The following is an example verification statement for the Catalytica Combustion Systems, Inc. XONON Flameless Combustion System NOx control technology. It is intended to show the form of a verification statement that can be expected from the planned verification test.

THE ENVIRONMENTAL TECHNOLOGY VERIFICATION PROGRAM

U.S. Environmental Protection Agency

Research Triangle Institute

ETV Joint Verification Statement

TECHNOLOGY TYPE:	**NOx AIR POLLUTION CONTROL TECHNOLOGY**
APPLICATION:	**A PROCESS INHERENT NOx EMISSION CONTROL SYSTEM FOR GAS TURBINE APPLICATIONS**
TECHNOLOGY NAME:	**XONON FLAMELESS COMBUSTION SYSTEM**
COMPANY:	**CATALYTICA COMBUSTION SYSTEMS, INC.**
ADDRESS:	**430 FERGUSON DRIVE PHONE: (650) 934-6504** **MOUNTAIN VIEW, CA FAX: (650) 968-5184**
WEB SITE:	**http://www.catalytica-inc.com**

The U.S. Environmental Protection Agency (EPA) has created the Environmental Technology Verification (ETV) Program to facilitate the deployment of innovative or improved environmental technologies through performance verification and dissemination of information. The goal of the ETV Program is to further environmental protection by substantially accelerating the acceptance and use of improved and cost-effective technologies. ETV seeks to achieve this goal by providing high quality, peer reviewed data on technology performance to those involved in the design, distribution, financing, permitting, purchase, and use of environmental technologies.

ETV works in partnership with recognized standards and testing organizations; stakeholder groups which consist of buyers, vendor organizations, permitters, and other interested parties; with the full participation of individual technology developers. The program evaluates the performance of innovative technologies by developing test plans that are responsive to the needs of stakeholders, conducting field or laboratory tests (as appropriate), collecting and analyzing data, and preparing peer reviewed reports. All evaluations are conducted in accordance with rigorous quality assurance protocols to ensure that data of known and adequate quality are generated and that the results are defensible.

The Air Pollution Control Technology (APCT) program, one of 12 technology areas under ETV, is operated by the Research Triangle Institute (RTI), in cooperation with EPA's National Risk Management Research Laboratory. The APCT program has evaluated the performance of a NOx control technology utilizing flameless catalytic combustion for stationary gas turbines, XONON.

VERIFICATION TEST DESCRIPTION

All tests were performed in accordance with general guidance given by the APCT program "Generic Verification Protocol for NOx Control Technologies for Stationary Combustion Sources" and the specific technology test plan "Verification Test/QA Plan for XONON Flameless Combustion System." These documents include requirements for quality management, quality assurance, auditing of the test laboratories, and test reporting format.

The XONON Flameless Combustion System was tested as installed and operating on a Kawasaki M1A-13A gas turbine generator set (1.5 MW) using stack test methods. NOx concentrations were measured using continuous emissions monitors (CEMs) following EPA Reference Method 20 for gas turbines. Other gaseous emissions were monitored using the applicable EPA test method. Other process variables were monitored using calibrated plant instrumentation.

Tests were conducted to meet primary quality assurance goals of a 95% confidence interval with a width of ±10% or less of the mean NOx emission concentration for concentrations above 5 ppmvd, ±25% or less below 5 ppmvd and above 2 ppmvd, and ±50% or less below 2 ppmvd. The verification test is valid only for the stated performance envelope of ambient temperature at full turbine operating load.

A single test run consisted of setting the primary variable, ambient temperature, at either its low point or high point (i.e., early morning or late afternoon), allowing the process to reach steady-state at full turbine load, and then measuring outlet NOx concentration over a 32-minute steady-state process condition. The test design was a 2 x 1 factorial using two levels of ambient temperature and a single level of turbine load. The limits of the performance envelope within which the verification is valid are set by the values of these independent variables, as shown in Table 1.

Table 1. Verification test performance envelope

	Ambient Temperature	**Turbine Load**
Low	45^{o}F *(example value)*	100% *(example value)*
High	85^{o}F *(example value)*	99% *(example value)*

In addition to outlet NOx concentration and the primary process variables, carbon monoxide and unburned hydrocarbon emission concentrations were also measured using EPA reference methods, and the installation efforts, site modifications, staffing, maintenance requirements, and similar issues were noted qualitatively.

TECHNOLOGY DESCRIPTION

This verification statement is applicable to the XONON flameless combustion system for gas turbine applications absent the air management system. The XONON flameless combustion system is completely contained within the combustion chamber of the gas turbine. The XONON system completely combusts fuel to produce a high temperature mixture, typically about 2,400°F. Dilution air is added to shape the temperature profile required at the turbine inlet.

The XONON combustor system consists of four sections:

- The **preburner** for start-up and acceleration of the engine. The preburner tested as part of this verification was a lean, pre-mixed combustor.
- The **fuel injection and fuel-air mixing system**. This unit injects the fuel and mixes it with the main air flow to provide a very well-mixed, uniform fuel-air mixture to the catalyst.
- The **XONON catalyst module**, where a portion of the fuel is combusted without a flame to produce a high temperature gas.
- The **homogeneous combustion region**, immediately downstream of the catalyst module, where the remainder of the fuel is combusted, and carbon monoxide and unburned hydrocarbons are reduced to very low levels (also a flameless combustion process).

The overall combustion process in the XONON system is a partial combustion of fuel in the catalyst module followed by complete combustion downstream of the catalyst in the burnout zone. Partial combustion within the catalyst produces absolutely no NOx. Homogeneous combustion downstream of the catalyst produces only 1 to 2 ppm NOx, because combustion occurs at a uniformly low temperature. A small amount of fuel is combusted in the preburner to raise the compressed air temperature to about 880°F.

This verification statement covers application of the XONON flameless combustion system to small gas turbines operated at full load when combusting natural gas.

VENDOR S STATEMENT OF PERFORMANCE

The XONON flameless combustion system is capable of achieving a NOx emission concentrations of less than 3 ppmvd when operated over an ambient temperature range of 32^{o}F to 105^{o}F at turbine full load conditions. Additionally, CO emission concentrations should not exceed 6 ppmvd.

VERIFICATION OF PERFORMANCE

Verification testing of the XONON flameless combustion system was performed on July 18 and 19, 2000, at an installation on a 1.5 MW Kawasaki M1A-13A gas turbine loacted in Santa Clara, California. The results are given in Table 2.

XONON Flameless Combustion System

Table 2. NOx control performance

Ambient Temperature	Turbine Load	Mean Outlet NOx Concentration ppmvd*	Half-Width of 95% Confidence Interval on Mean Outlet NOx ppmvd*
45^{o}F	100% *(example)*	1.8 *(example)*	0.3 *(example)*
85^{o}F	99% *(example)*	1.5 *(example)*	0.2 *(example)*

* **ppmvd = parts per million by volume dry basis**

The APCT quality assurance (QA) Officer has reviewed the test results and quality control data and has concluded that data quality objectives given in the NOx Control Technology generic verification protocol and test/QA Plan have been attained. During the verification tests, EPA and/or APCT quality assurance staff conducted technical assessments at the field test site, which confirm that the verification test was conducted in accordance with the MRI's EPA-approved test/QA Plan.

This verification statement verifies the NOx emissions characteristics of the XONON flameless combustion system within the stated range of application. Extrapolation outside that range should be done with caution and an understanding of the scientific principles that control the performance of the XONON flameless combustion system. Gas turbine users with NOx control requirements should also consider other performance parameters such as service life and cost when selecting a NOx control system.

In accordance with the NOx Control Technology generic verification protocol, this verification report is valid indefinitely for application of the XONON flameless combustion system within the range of applicability of the statement.

____

Director Date
National Risk Management Research Laboratory
Office of Research and Development
United States Environmental Protection Agency

____

Jack R. Farmer Date
Program Manager
Air Pollution Control Technology Program
Research Triangle Institute

Appendix D

Form MRI-86
Report Review/Approval/Distribution

Report review/approval/distribution **Project No.** (task and subtasks):

Form MRI-86 starts in the technical department office and is circulated with the document through production and review. The completed original form is attached to the Archives copy and sent to the Records Center by the Word Processing Center. The Records Center sends a copy of the completed form to Contracts for deliverable tracking. Form MRI-86 is used for letter reports, monthly reports, interim reports, QA plans, test plans, draft and final reports, and other internally generated project documents. All portions must be filled in. If an information item is not needed, cross it out, initial, and date it. *Documents will not be mailed until this form is properly completed.* THIS FORM SHOULD BE PRINTED ON **BLUE** PAPER.

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