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Test and Quality Assurance Plan

Environmental and Sustainable Technology Evaluation - Biomass Co-firing in Industrial Boilers

Prepared by:

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Southern Research Institute

For
U.S. Environmental Protection Agency

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Biomass Co-firing in Industrial Boilers

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Environmental and Sustainable Technology Evaluation

Biomass Co-firing in Industrial Boilers

This Test and Quality Assurance Plan has been reviewed and approved by Southern Research Institute's Quality Assurance Manager, the U.S. EPA APPCD Project Officer, and the U.S. EPA APPCD Quality Assurance Manager.

Signed	10/06	Signed	10/06
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1.0 INTRODUCTION

1.1 BACKGROUND

The U.S. Environmental Protection Agency's Office of Research and Development (EPA-ORD) operates the Environmental and Sustainable Technology Evaluation (ESTE) program to facilitate the deployment of innovative technologies through performance verification and information dissemination. In part, the ESTE program is intended to increase the relevance of Environmental Technology Verification (ETV) Program projects to the U.S. EPA program and regional offices.

The goal of the ESTE program is to further environmental protection by substantially accelerating the acceptance and use of improved and innovative environmental technologies. Congress funds ESTE in response to the belief that there are many viable environmental technologies that are not being used for the lack of credible third-party performance data. With performance data developed under this program, technology buyers, financiers, and permitters in the United States and abroad will be better equipped to make informed decisions regarding environmental technology purchase and use.

The ESTE program involves a three step process. The first step is a technology category selection process conducted by ORD. The second step involves selection of the project team and gathering of project collaborators and stakeholders. Collaborators can include technology developers, vendors, owners, and users and support the project through funding, cost sharing, and technical support. Stakeholders can include representatives of regulatory agencies, trade organizations relevant to the technology, and other associated technical experts. The project team relies on stakeholder input to improve the relevance, defensibility, and usefulness of project outcomes. Both collaborators and stakeholders are critical to development of the project test and quality assurance plan (TQAP), the end result of step two. Step three includes the execution of the verification and quality assurance and review process for the final reports. Should additional collaborators be accepted for participation in this project after publication of this TQAP, addenda will be issued outlining site-specific aspects of those additional tests.

This ESTE project will involve evaluation of co-firing common woody biomass in industrial, commercial or institutional coal-fired boilers. For this project Southern Research Institute (Southern) is the responsible contractor. Client offices within the EPA, those with an explicit interest in this project and its results, include: Office of Air and Radiation (OAR), CHP Partnerships Program, Office of Air Quality Planning and Standards (OAQPS), Combustion Group; Office of Solid Waste (OSW), Municipal and Industrial Solid Waste Division; and ORD's Sustainable Technology Division. Letters of support have been received from the U.S.D.A. Forest Service and the Council of Industrial Boiler Owners (CIBO).

1.2 PROJECT DESCRIPTION AND OBJECTIVES

With increasing concern about global warming and fossil fuel energy supplies, there continues to be an increasing interest in biomass as a renewable and sustainable energy source. Many studies and research projects regarding the efficacy and environmental impacts of biomass co-firing have been conducted on large utility boilers, but less data is available regarding biomass co-firing in industrial size boilers. As such, OAQPS has emphasized an interest in biomass co-firing in industrial-commercial-institutional (ICI) boilers in the 100 to 1000 million Btu per hour (MMBtu/h) range. The reason for this emphasis is to provide support for development of a new Area-Source "Maximum Achievable Control Technology" (MACT) standard. There is also interest in development of a Guidance Memo relating to PM 2.5 emissions reductions.

The focus for this project will be to evaluate performance and emission reductions for ICI boilers as a result of biomass co-firing. The primary objectives of this project are to:

- Evaluate changes in boiler emissions due to biomass co-firing
- Evaluate boiler efficiency with biomass co-firing
- Examine any impact on the value and suitability of fly ash for beneficial uses (carbon and metals content)
- Evaluate sustainability indicators including sourcing and transportation of biomass and disposal of fly ash

Southern utilizes balanced stakeholder groups to guide the activities and priorities. These groups assist in selection and prioritization of technologies to be verified, development of testing protocols, outreach activities, and review of project specific reports and procedures. Previous groups that have guided Southern's activities include an Executive Stakeholders Group, Oil & Gas Industry Stakeholder Group, Electrical Generation Stakeholder Group, and several small technical panels (municipal solid waste, distributed generation, refrigerant systems, and engines and fuels). The Center maintains contact with key members in Stakeholder groups to address issues and provide guidance regarding specific technologies and verification tests.

A Biomass Co-firing Stakeholder Group (BCSG) was assembled for this project. This group, summarized in Appendix A-1 is broad-based and represents key industry, regulatory and research organizations. Together it provides a high degree of expertise in the following areas related to this project:

- operational issues relating to industrial boilers that may influence acceptance and uptake of biomass co-firing in response to regulatory developments
- measurement methods and issues relating to combustion processes, especially to co-firing situations
- data quality requirements and critical factors for data to be used in regulatory guidance
- waste management issues relating to fly ash disposal and beneficial uses of ash and related physical-chemical material requirements
- biomass sources and characteristics
- establishment of sustainability indicators

This document is the Test and Quality Assurance Plan (TQAP) for this ESTE project and has been developed based on the project objectives outlined by client EPA offices and technical expertise provided by the BCGS. This TQAP includes the following components:

- Project organization and responsibilities (§ 1.3)
- Project schedule (§ 1.4)
- Detailed description of the verification approach and parameters (§ 2.0)
- Descriptions of the test locations (§ 2.1)
- Detailed sampling and analytical procedures (§ 2.2)
- Data quality objectives and QA/QC procedures (§ 3.0)
- Data handling and reporting (§ 4.0)

- Health and safety requirements (§ 5.0)

This TQAP has been reviewed by representatives of ORD, OAQPS, OSW, the EPA QA team, and the project stakeholders and collaborators. This TQAP has been prepared to guide implementation of the test and to document planned test operations and is posted on the Web sites maintained by Southern (www.sri-rtp.com) and the ETV program (www.epa.gov/etv).

1.3 PROJECT ORGANIZATION AND RESPONSIBILITIES

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

Southern has overall responsibility for planning and ensuring the successful implementation of this verification test. Southern will ensure that effective coordination occurs, schedules are developed and adhered to, effective planning occurs, and high-quality independent testing and reporting occur.

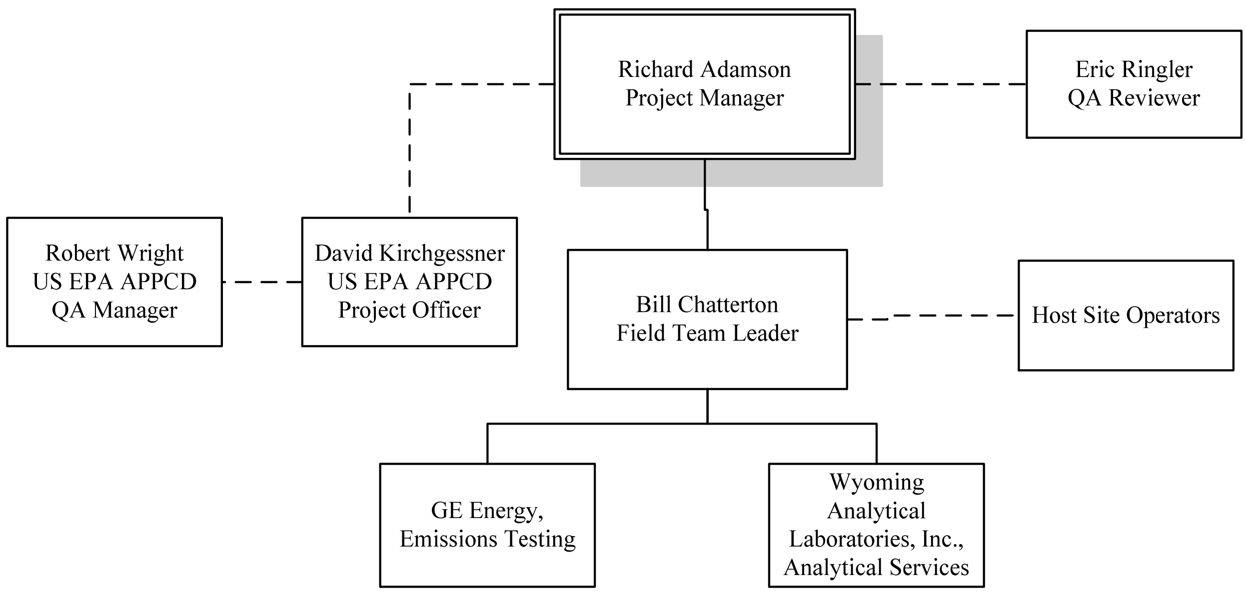


Figure 1-1. Project Organization

Richard Adamson is the Project Manager for Southern. He will ensure the staff and resources are available to complete this verification as defined in this TQAP. He will review the TQAP and Report to ensure they are consistent with ETV operating principles. He will oversee the activities of Southern staff, and provide management support where needed. Mr. Adamson will sign the Verification Statement, along with the EPA-ORD Laboratory Director.

Richard Adamson will also serve as the Project Manager. His responsibilities include:

- Submittal of the TQAP and verification report;
- overseeing the field team leader's data collection activities, and

- ensuring that data quality objectives are met prior to completion of testing.

The project manager will have full authority to suspend testing should a situation arise that could affect the health or safety of any personnel. He will also have the authority to suspend testing if the data quality indicator goals are not being met. He may resume testing when problems are resolved in both cases. He will be responsible for maintaining communication with the EPA client offices, project collaborator/host site personnel, and the BCSG.

Bill Chatterton will serve as the Field Team Leader. Mr. Chatterton will be responsible for ensuring that all personnel and subcontractors at the sites comply with all applicable safety rules specified in Southern's and the sites' safety plans. He will also provide field support for activities related to all measurements and data collected. He will install and operate the measurement instruments, supervise and document activities conducted by the emissions testing contractor, coordinate fuel and fly ash sample collection and analysis with the laboratory, and ensure that QA/QC procedures outlined in this TQAP are followed, including QA requirements for field subcontractors. He will submit all results to the Project Manager, such that it can be determined that the DQOs are met. He will also oversee and manage subcontractor activities and submittals.

Southern's QA reviewer is Eric Ringler, who is responsible for ensuring that the verification is performed in compliance with the QA requirements of the Southern's QMP and this TQAP. He has reviewed and is familiar with each of these documents. He will also review the verification test results and ensure that applicable internal assessments are conducted as described in these documents. He will reconcile the DQOs at the conclusion of testing and will conduct or supervise an audit of data quality. He is also responsible for review and validation of subcontractor activities, review of subcontractor generated data, and confirmation that subcontractor QA/QC requirements are met. Mr. Ringler will report all internal reviews, DQO reconciliation, the audit of data quality, and any corrective action results directly to the to the project manager for corrective action as applicable and citation in the final verification report. He will review and approve the final verification report and statement. He is administratively independent from the Southern's management and maintains stop work authority.

The verification will include the services of two subcontractors. Emissions testing will be conducted by GE Energy with James Tryba serving as project manager. Fuel and fly ash analyses will be conducted by Wyoming Analytical under the management of Monte Ellis.

Facilities hosting the field testing will assign engineers and boiler operators to assist with field testing, boiler operations, and site safety. They will provide technical assistance, assist in the installation of measurement instruments, and coordinate operation of the boilers with verification activities. Barring unforeseen facility upsets, difficulties, or outages, they will ensure the units are available and accessible to Southern for the duration of the test. Installation of all test and measurement instrumentation will be coordinated and approved by site staff prior to beginning any work at the two sites. Site personnel will also review the TQAP and report and provide written comments.

EPA-ORD will provide oversight and QA support for this verification. The APPCD Project Officer, Dr. David Kirchgessner, is responsible for obtaining final approval of the TQAP and Report. The APPCD QA Manager reviews and approves the TQAP and the final Report to ensure they meet Southern's QMP requirements and represent sound scientific practices.

1.4 SCHEDULE

The tentative schedule of activities for testing is as follows:

TQAP Development

First Stakeholder Teleconference	November 8, 2005
Stakeholder Input Process	November 8 – 30, 2005
Second Stakeholder Teleconference	December 8, 2005
Stakeholder Input Summary Report	December 15, 2005
Host Sites Confirmed	March 31, 2006
Draft TQAP Released for Stakeholder Review	April 14, 2006
EPA Review and Final Editing	September, 2006
Final TQAP Released	September, 2006

Field Testing and Analysis

University of Iowa – Boiler 10	December, 2006
Minnesota Power – Rapids Boiler 5	January, 2007

ESTE Report Development

Internal Draft Development	January, 2007
BCSG Review/Revision	March, 2007
EPA Review/Revision	April, 2007
Final Report Posted	April, 2007

Proposed schedules for field testing are tentative at this time and may be altered depending on circumstances beyond the control of Southern such as biomass availability and host site operating schedules or unexpected outages. Delays in field testing will likely result in similar delays in the report development schedule.

2.0 VERIFICATION APPROACH

This project is designed to evaluate changes in boiler performance due to co-firing woody biomass with coal. On at least two separate boilers, operational performance with regard to efficiency, emissions, and fly ash characteristics will be evaluated while combusting 100 percent coal and then reevaluated while co-firing biomass with coal. The verification will also address site specific sustainability issues associated with biomass co-firing. This TQAP identifies the first two boilers selected for testing (Section 2.1) and contains site specific descriptions and instrumentation plans for each. Separate site specific test plans will be developed based on the TQAP and issued for any additional boilers identified for testing.

The field testing analysis conducted on each of the selected boilers will consist of a simple A/B comparison of boiler performance with the two different fuel mixes. Due to complexities associated with boiler performance using different fuels, the testing will be limited to two operating points. Specifically, the operating points tested will be: the boiler firing coal only at a typical nominal load, and the boiler firing a biomass/coal co-firing mixture at its normal fuel blend and at the same operating load. By limiting the testing to two normal operational points on each boiler, the approach minimizes the chance of other operational changes within the boiler from masking the effects of co-firing.

The project will not include evaluation of the optimum woody biomass co-firing blend on each boiler, but will use the blending rates used during past operations and optimizations by the facility, than compare boiler performance and emissions while co-firing to performance and emissions when firing coal only. The following three step testing approach was developed:

1) Select boilers that are well instrumented and either currently co-firing biomass or configured to do so with minimum modifications. Review operating logs and historic biomass co-firing rates for each boiler selected and define the preferred co-firing rate for each boiler based on past operations.

2) Conduct efficiency, emissions, fuel, and fly ash analyses on the two boilers based on pure coal baseline operations and biomass co-firing at the normal blend for each boiler based on past operations. Analyze test results to evaluate changes in boiler emissions performance attributable to biomass co-firing.

3) Collect data to evaluate sustainability indicators for the two sites selected. It is expected that these indicators will include mode, and distance of transport of fuel and waste material (i.e., ash,).

It is desirable to collect data from a larger number of sites. The total number of units tested will be a function of the amount of collaborator funding or cost sharing that is procured. To this end it is planned to solicit collaborative support from industry partners. The first level of collaboration is to provide access to operational boilers along with some operational data. The second is to provide funding for testing at additional sites.

In addition to the emissions evaluation, this verification will address changes in fly ash composition. There are many beneficial uses of coal combustion fly ash including a component of cement production, structural fill and road materials, soil stabilization, and other industrial uses. An important property that limits the use of fly ash is carbon content. Presence of metals in the ash, particularly Hg, can also be a limiting factor in certain aspects of beneficial use (e.g., cement kiln feed). Biomass co-firing is likely to impact fly ash composition and properties, so testing will be conducted to evaluate changes in fly ash carbon burnout (loss on ignition), minerals content, and metals content.

For each of the boilers tested, the verification parameters listed below will be evaluated. This list was developed based on project objectives cited by the client organizations and input from the BCSG.

Verification Parameters:

- Changes in emissions due to biomass co-firing including:
  - Nitrogen oxides (NO_X)
  - Sulfur dioxide (SO_2)
  - Carbon monoxide (CO)
  - Carbon dioxide (CO_2)
  - Nitrous oxide (N_2O)[1]
  - Total particulates (TPM), PM10, and PM2.5 (including condensable particulates)
  - Primary metals: arsenic (As), selenium (Se), zinc (Zn), and mercury (Hg)
  - Secondary metals: barium (Ba), beryllium (Be), cadmium (Cd), chromium (Cr), copper (Cu), manganese (Mn), nickel (Ni), and silver (Ag)[1]
  - Hydrogen chloride (HCl) and hydrogen fluoride (HF)
- Boiler efficiency during biomass co-firing and normalize emissions to boiler output
- Changes in fly ash characteristics including:
  - Carbon, hydrogen, and nitrogen (CHN), and minerals content
  - Primary metals: arsenic (As), selenium (Se), zinc (Zn), and mercury (Hg)
  - Secondary metals: barium (Ba), beryllium (Be), cadmium (Cd), chromium (Cr), copper (Cu), manganese (Mn), nickel (Ni), and silver (Ag)[1]
  - Potential boiler fouling components: calcium (Ca), sodium (Na), and potassium (K)[1]
  - fly ash fusion temperature
  - RCRA metals TCLP
  - Air entraining agent index
- Sustainability indicators including sourcing and transportation of biomass and ash disposal under baseline (no biomass co-firing) and test case (with biomass co-firing) conditions. Consideration will be given to how the biomass would be disposed of should the co-firing approach not take place.

For each site where testing will occur, careful planning and coordination will be needed to ensure that test results are acceptable and useful, the testing has a minimum impact on host site operations, and field testing is completed within project budgets. The following activities will be planned and managed by Southern:

  - Approval and publishing of this TQAP
  - Identification of host sites
  - Development of Site Profiles

[1] Evaluation of N_2O, secondary metals, and potential boiler fouling components are verification parameters suggested by the BCSG, but not currently funded. These parameters will not be evaluated if additional sources of funding are not secured.

- Confirm that sufficient uniform source of biomass is available for testing
- Testing is scheduled to minimize impact on site operations
- Test locations and safe access are defined and prepared
- Subcontractors and analytical laboratories are properly prepared and managed
- Site specific health and safety plans are in place

2.1 HOST FACILITIES AND TEST BOILERS

Initially, testing will be conducted on two industrial boilers that are capable of co-firing woody biomass. The two units currently committed to hosting tests are identified as Minnesota Power's Rapids Energy Center Boiler 5 (MP-5) which currently co-fires bark with coal, and the University of Iowa Main Power Plant's Boiler 10 (UI-10) which will be co-firing wood derived palletized fuel with coal. Descriptions of the two sites and boilers selected are as follows:

<u>Minnesota Power</u>

Minnesota Power's Rapids Energy Center has two identical Foster Wheeler Spreader Stoker Boilers installed in 1980 (Boilers 5 and 6). This verification will be conducted on Boiler 5. Each boiler has a steaming capacity of approximately 175,000 lb/hour. The boilers can be fired with western subbituminous coal, wood waste, railroad ties, on-site generated waste oils and solvents, and other paper wastes. Particulate emissions from each boiler are controlled by a Zurn multiclone dust collector and cold side electrostatic precipitator. Cleaned flue gas from each boiler exhausts to the atmosphere via a common stack which is 205 feet above elevation and has an inner diameter of 9 feet. Figure 2-1 is a schematic of the boilers.

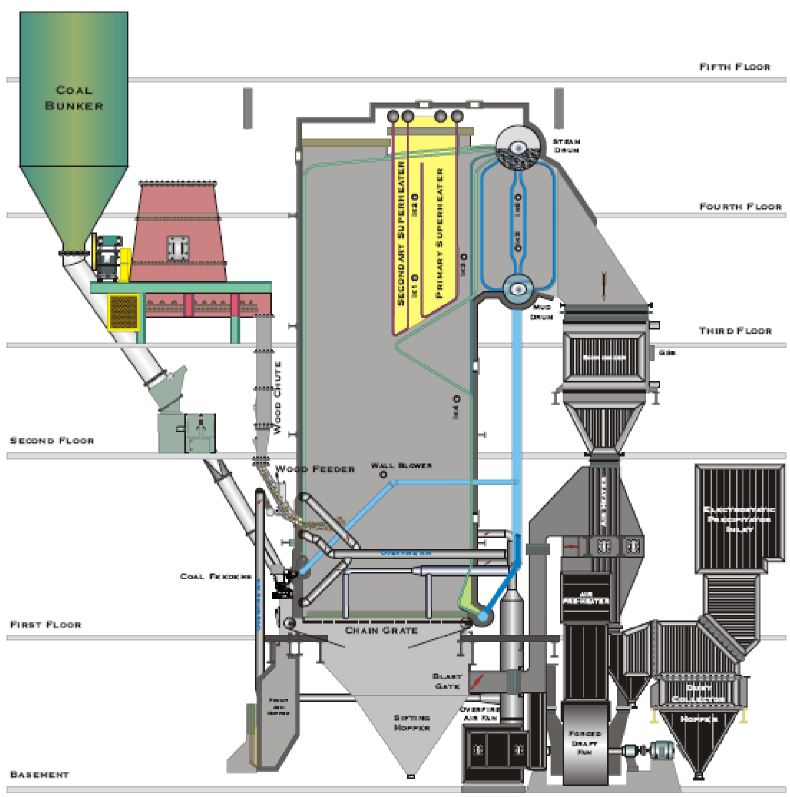


Figure 2-1. Minnesota Power's Foster Wheeler Spreader Stokers

Since both boilers exhaust through a common stack, emission testing for this program will be conducted in the ductwork of the selected boiler upstream of the stack. The testing location and ports are shown in Figure 2-2.

Figure 2-2. Emission Testing Ports for MP-5

Under normal operations, each boiler generates approximately 175,000 lb/hr steam which is used to power a 15 MW steam turbine and provide process steam to a nearby industrial facility. The boilers typically co-fire woody waste, primarily bark, at a coal:biomass fuel ratio of 15:85 percent. The wood waste is of sufficient supply nearly all year long with the exception of spring months. During periods of reduced wood waste supply the facility increases the amount of coal used to fuel the boilers. More details regarding the fuels used for this test is presented in Section 2.2.2.

Fly ash generated by this boiler is collected from the dust collector and precipitator and distributed to farms for crop use as long as the fuel blend is less than 50 percent coal. In 2003, approximately 7,700 tons of ash was distributed to farms. When coal exceeds 50 percent, the ash is landfilled.

The systems data control system (DCS) includes a PI Historian software package that allows the facility to customize data acquisition, storage, and reporting activities. Each boiler is also equipped with continuous emission monitoring systems (CEMS) that record NO_X, SO_2, CO, and O_2 concentrations and emission rates. Table 2-1 summarizes the CEMS on each boiler.

Table 2-1. MP-5 CEMS

Parameter	Instrument Make/Model	Instrument Range	Reporting Units
NO_X	Teledyne Monitor Labs (TML) 41-H-O2	0 – 500 ppm	lb/MMBtu
SO_2	TML 50-H	0 – 1000 ppm	lb/MMBtu
CO	TML 30-M	0 – 5000 ppm	lb/MMBtu
O_2	TML 41-H-O2	0 – 25 %	%

Operational parameters that will be recorded during this test program include the following:

- Steam flow (lb/hr)
- Steam pressures (psig)
- Air temperatures (^{o}F)
- Power output (MW)
- Heat input for coal, wood, and total, (Btu/hr)
- Coal and wood feed rates via belt scales, (lb/hr)
- NO_X, SO_2, and CO emissions (lb/MMBtu)
- Multiclone pressure drop (in. w.c.)
- ESP variables (volts, amperes, fields on line)

Data recorded during each test period will be averaged over the test period and reported to document boiler operations during the testing, co-firing rates, and boiler efficiency.

University of Iowa

The University of Iowa Main Power Plant is a combined heat and power (CHP) facility serving both the University main campus and the University of Iowa Hospitals and Clinics. The plant operates continuously supplying steam service and cogenerating electric power. There are four operational boilers at the facility, one stoker unit (Boiler 10), one circulating fluidized bed boiler (Boiler 11), and two gas package boilers (Boilers 7 and 8). Three controlled extraction turbine generators with an accredited capacity of 24.7 MW that cogenerate about 30 percent of the University and Hospital facilities total electric needs. Figure 2-3, a control room screen snapshot, provides a depiction of the plant's configuration. For this program, testing will be conducted on the stoker unit – Boiler 10.

Boiler 10 is a Riley Stoker Corporation unit rated at 170,000 lb/hr steam (206 MMBtu/hr heat input) at 750°F at 600 psi. This unit normally operates in pressure control (swing) mode on a multi-boiler header at a typical operating range of 120,000 to 140,000 lb/hr steam. The unit can be base loaded up to its rated capacity or swing down to a minimum load of 90,000lb/hr.

Currently, this boiler is fired with coal only. However, UI has been very successful in converting the fluidized bed boiler at the facility to a co-firing unit using an oat hull product generated at a nearby food processing plant. In keeping with the economic and environmental benefits realized through this effort, UI is interested in introducing biomass co-firing on Boiler 10 as well. A pelletized wood product manufactured from woody biomass by Renewafuels, LLC in Minnesota has been identified as a suitable fuel to be co-fired with coal in Boiler 10. More details regarding the fuels used for this test is presented in Section 2.2.2.

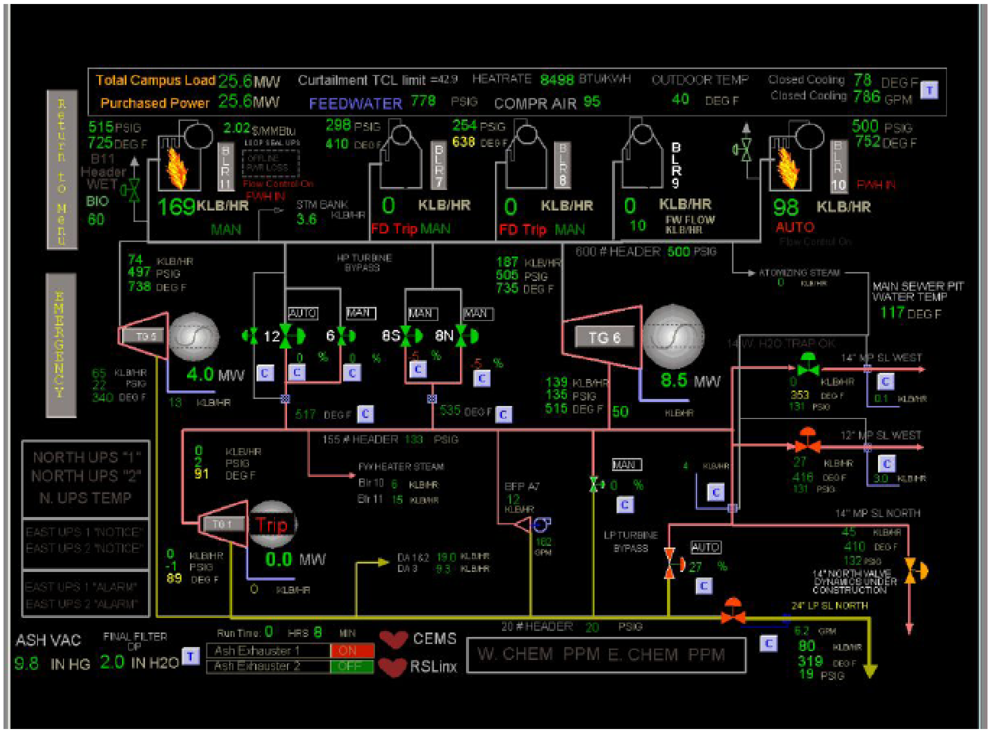


Figure 2-3. University of Iowa Main Power Plant Configuration

Emissions testing for this program will be conducted in the ductwork of the selected boiler upstream of the stack. The testing location and ports are shown in Figure 2-4.

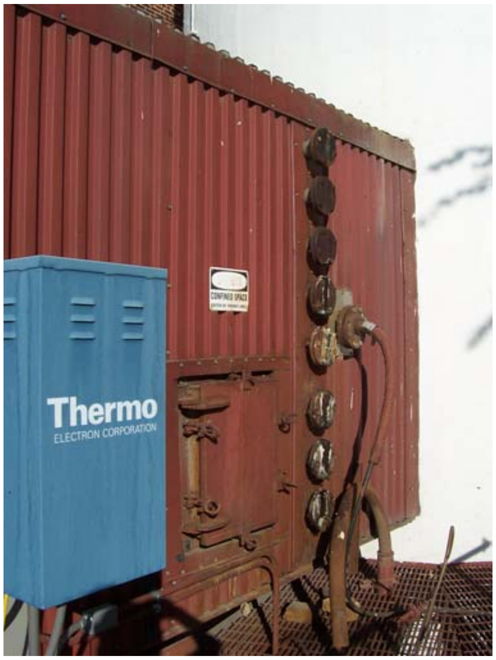


Figure 2-4. Test Port Locations for UI-10

The facility includes a mechanical dust collector and electrostatic precipitator to control particulate emissions. Bottom ash and fly ash generated by Boilers 10 and 11 are collected, blended, and shipped to a nearby limestone quarry where it is mixed with water, solidified, and used to build roads or fill.

Boiler 10 is equipped with a CEMS that monitors SO_2 and O_2 concentration in the flue gas. Table 2-2 summarizes the CEMS for Boiler 10.

Table 2-2. UI-10 CEMS

Parameter	Instrument Make/Model	Instrument Range	Reporting Units
SO_2	TML 50-H	0 – 1000 ppm	lb/MMBtu
O_2	TML 41-HO2	0 – 25 %	%

The facility has a fully equipped control room that continuously monitors boiler operations. The systems DCS includes a PI Historian software package that allows the facility to customize data acquisition, storage, and reporting activities. A partial list of parameters monitored by the DCS includes:

- Heat input, (Btu/hr)
- Steam flow (lb/hr)
- Steam pressures (psig) and temperatures (^oF)
- Air flows (lb/hr) and temperatures (^oF)
- Power output (MW)
- SO_2 emissions (lb/MMBtu)
- ESP variables (volts, amperes, fields on line), recorded manually

Data recorded during each test period will be averaged over the test period and reported to document boiler operations during the testing, co-firing rates, and support the boiler efficiency determinations.

2.2 FIELD TESTING

2.2.1 Field Testing Matrix

Field testing will be conducted on both of the boilers selected to evaluate each of the verification parameters cited. On each unit, a set of three replicate tests will be conducted while firing coal and a second set of three tests will be conducted while co-firing biomass and coal. The test matrix for each boiler also includes a third optional test scenario should funding be secured to cover costs associated with these optional tests. Specifically, the Minnesota Power test matrix includes an option to evaluate boiler performance and emissions at a fuel blend with less biomass (approximately 40 percent) than that normally fired at this facility. This will provide data for users that might not have availability to as large a supply of biomass that this site has. The University of Iowa test matrix includes a second set of co-firing tests using pelletized blend of wood and agricultural biomass. This fuel will be comprised of a mix of woody biomass and processed corn stover, a promising renewable energy source for the Midwestern US. A claimed benefit of this blended fuel over straight wood pellets is improved mechanical binding. These optional tests will only be conducted if additional sources of funding are available to support the project.

Other than changes in fuel composition, all other boiler operations will be replicated as closely as possible during test sets. Test and sampling procedures will also be consistent between sets of tests. Table 2-3 summarizes the test matrix.

All testing will be conducted during stable boiler operations. A representative of Southern will coordinate testing activities with boiler operators to ensure that all testing is conducted at the desired boiler operating set points and the boiler operational data needed to calculate efficiency is properly logged and stored. Southern will also either conduct or supervise the field testing activities. A log form such as the example in Appendix B-1 will be used to document test periods and conditions.

At the conclusion of field testing, results will be analyzed to evaluate changes in boiler performance and fly ash characteristics between the two sets of tests on each boiler. A statistical analysis (t-test) will be conducted to verify the statistical significance of any observed changes in emissions or efficiency.

Table 2-3. ESTE Biomass Co-firing Program Test Matrix

<table>
<tr><th>Boiler ID</th><th>Fuel</th><th>Operating Load</th><th>Test Parameters[a]</th><th>Test Durations and Sampling Frequency[a]</th></tr>
<tr><td rowspan="3">MP-5</td><td>100 percent sub bituminous coal</td><td rowspan="3">Nominal 175,000 lb/hr steam at each fuel condition</td><td rowspan="6">- Boiler efficiency
- Boiler emissions
- Fly ash analysis
- Fuel analysis[b]</td><td rowspan="6">- 3 one hour tests
- 3 one hour tests
- 3 integrated samples
- 3 composite samples</td></tr>
<tr><td>Co-fired blend of nominal 15% coal and 85% woody biomass</td></tr>
<tr><td>Co-fired blend of nominal 55% coal and 45% woody biomass (Optional test)</td></tr>
<tr><td rowspan="3">UI-10</td><td>100 percent sub bituminous coal</td><td rowspan="3">Nominal 130,000 lb/hr steam at each fuel condition</td></tr>
<tr><td>Co-fired blend of nominal 75% coal and 25% woody biomass</td></tr>
<tr><td>Co-fired blend of nominal 75% coal and 25% agricultural biomass (Optional test)</td></tr>
</table>

[a] Test parameters, durations, and frequencies will be the same for each set of tests.
[b] Fuel analyses will include both coal and biomass separately.

2.2.2 Boiler Operations and Fuels

MP-5

Minnesota Power's Boiler 5 co-fires woody biomass (primarily bark) with sub bituminous coal at a fuel blend of approximately 85 percent biomass to 15 percent coal. This plant employs belt scales to gravimetrically measure the consumption of both types of fuels. The scales will be used to measure fuel consumption and co-firing rates during all test periods, and to calculate boiler heat input with the fuel heat content analyses. The fuels are not premixed and are fed to the boiler separately.

The facility has agreed to operate the boiler on coal only for a duration of time sufficient to conduct the baseline testing. During the baseline testing, heat input will be maintained at a level that produces the nominal 155,000 lb/hr steam typically produced by the boiler. During co-firing, fuel inputs will be maintained to replicate boiler output during the baseline test.

Table 2-4 summarizes typical fuel characteristics. More detailed fuel analyses will be conducted during the tests.

Table 2-4. MP-5 Fuel Characteristics

Fuel	Heat Content (Btu/lb)	Fly ash (%)	Sulfur (%)	Moisture (%)
Coal	9,260	4.9	0.4	27
Wood	4,900	1.9	< 0.1	50

UI-10

Boiler 10 at the UI site typically fires coal only, but will co-fire pelletized wood product during this program. Boiler operations can be controlled using three methods including manually controlling fuel feed rate, controlling fuel feed using a steam header pressure set point, or controlling fuel feed using a steam mass flow control point. For this testing, the site has recommended that boiler operations be controlled using steam flow. During the baseline testing, steam flow will be set at nominal 130,000 lb/hr. During co-firing, fuel inputs will be controlled by this set point to maintain the desired steam flow present during the baseline test.

The pelletized biomass will be provided by Renewafuel, LLC. Renewafuel produces a range of renewable composite biofuel pellets from renewable feedstock. Use of the fuel is expected to result in lower emissions of criteria pollutants greenhouse gases compared to coal. Densified pellets allow for better handling, storage and blending with existing fuels. The products also are consistent in size, heat value and moisture content.

The two Renewafuel pellets that will be used for the proposed biomass emission evaluation study are: (1) a wood-based composite pellet; and (2) a wood and corn-stover based pellet (optional testing). The pellets can be produced in various sizes, but typically are cubed and approximately 1 ¼ x 1 ¼ x 2 inches and have a density of 25-30 lb/ft3. Moisture content of the fuels is approximately 12 percent and the fuels have a higher heating value of approximately 8,200 Btu/pound (at 12% moisture). Feedstock woods for Renewafuel's pellets come from industrial and agricultural entities. Corn stover comes from local farms. Table 2-5 summarizes typical fuel characteristics for this site.

Table 2-5. UI–10 Fuel Characteristics

Fuel	Heat Content (Btu/lb)	Fly ash (%)	Sulfur (%)	Moisture (%)
Coal	12,100	< 10	0.8 – 1.5	10
Pelletized wood	8,200	1.0	< 0.05	12
Pelletized corn stover	8,200	3.7	< 0.05	12

The biomass used in the pellets for the study will come from within a 150-mile radius of Renewafuel's research and development facility in Battle Creek, Michigan and will be transported to the coal yard of the University's coal supplier (River Trading Company). Coal and biomass will be blended at the suppliers' coal yard at a rate of 25 percent biomass, then hauled by truck to the University. The field team will collect blended fuel samples just ahead of the stoker to validate the fuel blending rate by evaluating the compositions of the coal, wood, and blended fuels separately.

At the time of development of this draft TQAP, the method for measuring fuel feed rates and subsequently heat input is not finalized. It is expected that a method of gravimetrically measuring the fuel consumption will be developed using either batch or continuous feed procedures. An addendum to this TQAP will be issued when the procedures are finalized.

2.3 BOILER PERFORMANCE METHODS AND PROCEDURES

Conventional field testing protocols and reference methods will be used to determine boiler efficiency, emissions, and fly ash properties during the testing programs to maximize the overall data quality. Details regarding the protocols and methods proposed are provided in Sections 2.3.1 through 2.3.4.

2.3.1 Boiler Efficiency

During each test run performed, testing will be conducted to evaluate boiler efficiency. The data will be used to document efficiencies during biomass co-firing and to normalize measured emission rates to boiler output. Boiler efficiency will be determined following the Btu method in the B&W Steam manual [1]. The efficiency determinations will also be used to estimate boiler heat input during each test period. An example spreadsheet is included as Appendix B-2. Using this procedure, a number of boiler operational parameters must be logged during the test periods. Table 2-6 summarizes the parameters needed and the likely source of the data.

Both facilities are well instrumented and log all of the data required for determination of boiler efficiency on a regular basis. Southern will verify the accuracy of as many facility logged data points as possible by taking independent spot readings using calibrated sensors (details regarding these QC checks are provided in Section 3.1). Other parameters such as ambient conditions and flue gas temperatures will be independently measured by the Southern. The following subsections provide details regarding the measurements required for efficiency determinations.

Table 2-6. Summary of Boiler Efficiency Parameters

Operational Parameter	Source of Data	Logging Frequency
Intake air temperature, ^oF Flue gas temperature at air heater inlet, ^oF	Southern measurements	Five minute intervals
Fuel temperature, ^oF Moisture in air, lb/lb dry air	Southern measurements	Twice per test run
Fuel consumption, lb/hr Combustion air temperature, ^oF Steam flow, MMBtu/h or lb/h Steam pressure, psig Steam temperature, ^oF Supply water pressure, psig Supply water temperature, ^oF Power generation, kW	Facility operational data	One minute averages
Fuel ultimate analyses, both wood and coal Fuel heating value, Btu/lb Unburned carbon loss, %	Analytical laboratory	One composite biomass, coal, mixed fuel (UI – 10), and fly ash samples per test (3 total for each condition)

2.3.1.1 Data Logged by Host Facilities

Prior to testing, instrumentation that currently exists on site and is available for collecting test data will be inventoried and the following information collected:

1. Operational parameter
2. Description of operating principle (e.g. 'orifice plate flow meter')
3. Manufacturer
4. Model number
5. Range
6. Accuracy
7. Response time for sample interval
8. Date of calibration and calibration documentation
9. Measurement location

Wherever possible, cross-checks will be performed between Southern instruments and host-site equipment. (For example a pressure gauge check at an available valve port, or temperature checks at thermo-well or using a strap-on sensor.)

2.3.1.2 Data Logged by Southern

Southern will independently measure values contributing to efficiency calculations wherever placement of measurement devices is feasible. Table 2-7 summarizes some of the measurements that Southern expects to conduct independently, and the instruments that will be used. If possible, additional measurements from the list in Table 2-6 (facility logged data) will be conducted or at least verified by Southern.

Table 2-7. Summary of Boiler Efficiency Parameters Logged by Southern

Operational Parameter	Instrument	Instrument Range	Instrument Accuracy
Fuel temperature, °F	Hobo Model H12 with Type K thermocouple	0 – 932 °F	± 6 °F
Flue gas temperature at air heater inlet, °F			
Intake air temperature, °F	Hobo Model U10 Data Logger	-20 to 158 °F	± 1 ° F
Moisture in air, lb/lb dry air		25 to 95 % relative humidity	± 3.5 %

The Hobo sensors are equipped with data loggers that will be programmed to log data at 5 minute intervals throughout the verification. Data logged during each test period will be averaged and the means used in the efficiency determinations.

2.3.1.3 Fuel Sampling and Analyses

Fuel samples will be collected during each test run. These samples will undergo ultimate and heating value analysis. A composite of grab samples of coal and biomass (or individual samples of coal and biomass if fed separately) will be prepared during co-firing test runs and submitted to Wyoming Analytical Laboratories, Inc. in Laramie, Wyoming for the analyses shown in Table 2-8. Fuel analyses will be conducted following ASTM standard methods [2].

Table 2-8. Summary of Fuel Analyses

Parameter	Method
Ultimate analysis	ASTM D3176
Gross calorific value	ASTM D5865 (coal) ASTM E711-87 (biomass)

At Minnesota Power, coal and biomass will be sampled separately. Grab samples of each fuel will be collected at 30 minute intervals during each test run and combined. One composite sample of each fuel will be generated for each test run and submitted for analysis. Collected composite samples will be labeled, packed and shipped to Wyoming Analytical along with completed chain-of-custody documentation for off-site analysis.

At the UI site, coal samples and blended fuel samples will be collected in a similar matter during each test run. However, because the blended fuel is delivered premixed, biomass samples will be collected at the fuel blending facility (coal yard). These samples will be submitted to the field team leader for subsequent analysis.

Finally, the efficiency analysis requires the unburned carbon loss value, or carbon content of fly ash. Integrated fly ash samples will also be collected during each test run and submitted for analysis. Details regarding the collection, handling, and analysis of fly ash samples are provided in Section 2.3.3.

The ultimate analysis will report the following fuel constituents as percent by weight:

- carbon
- water
- ash
- sulfur
- nitrogen
- hydrogen
- oxygen

Results of these fuel analyses will be used to complete the combustion gas calculations in the Btu method. For tests conducted during biomass co-firing, weighted average results of the biomass and coal fuel analyses will be used in the calculations.

The sensitivity of the boiler efficiency analyses will be a function of the accuracy of all of the contributing measurements. Southern will quantify the error in each of the measurements. By determining the propagated overall error, the Southern will be able to estimate the sensitivity of the analysis (that is, how small of a change in efficiency can be quantified). More detail regarding the DQOs for this analysis are provided in Section 3.1 of this TQAP.

2.3.2 Boiler Emissions

Testing will be conducted on each boiler to determine emissions of the following atmospheric pollutants:

- nitrogen oxides (NO_x)
- sulfur dioxide (SO_2)
- nitrous oxide (N_2O), optional
- carbon monoxide (CO)
- carbon dioxide (CO_2)
- primary metals (As, Hg, Se, Zn)
- particulate matter (total, PM10, and PM2.5)
- secondary metals (optional)
- acid gases (HCl, HF)

A total of three replicate test runs will be conducted on each boiler tested under both the baseline (coal only) and co-firing operating conditions. Each test run will be approximately 60 minutes in duration. The emissions testing will be conducted simultaneously with the efficiency evaluations.

Measurements required for emissions tests include:

- fuel heat input, Btu/h (via boiler efficiency, Section 2.3.1)
- pollutant and O_2 concentrations, parts per million (ppm), grains per dry standard cubic foot (gr/dscf), or percent
- flue gas molecular weight, pounds per pound-mole (lb/lb-mol)
- flue gas moisture concentration, percent
- flue gas flow rate, dry standard cubic feet per hour (dscfh)

The average concentrations established as part of each test run will be reported in units of ppmvd for NO_X, CO, SO_2, HCl, and HF, and percent for CO_2. Concentrations of total particulate matter (TPM), PM10 and PM2.5 will be reported as grains per dry standard cubic foot (gr/dscf). The average emission rates for each pollutant will also be reported in units of pounds per hour (lb/hr), and pounds per million Btu (lb/MMBtu).

The fuel heat input and boiler output values will be determined during the efficiency determinations. The remainder of the required measurements will be determined through emissions testing. All testing will be conducted following EPA Reference or Conditional Methods or for emissions testing [3]. Table 2-9 summarizes the reference methods to be used and the fundamental analytical principle for each method.

Table 2-9. Summary of Emission Test Methods and Analytical Equipment

Parameter or Measurement	U.S. EPA Reference Method	Principle of Detection
NO_X	7E	Chemiluminescence
CO	10	Non-dispersive infrared (NDIR)-gas filter correlation
SO_2	6C	Pulse fluorescence or NDUV
CO_2	3A	NDIR
O_2	3A	Paramagnetic or electrochemical cell
TPM	5	Gravimetric
PM10,PM2.5/con-densable PM	CTM040/202	Gravimetric
Metals	29	ICP/CVAAS
HCl, HF	26	Ion chromatography
Moisture	4	Gravimetric
Flue gas flow rate	2	Pitot traverse

GE Energy, an organization specializing in air emissions testing will be contracted to perform all stack testing. The testing contractor will provide all equipment, sampling media, and labor needed to complete the testing and will operate under the supervision of Southern's Field Team Leader. The reference methods provide detailed procedures for selecting measurement system performance specifications and test procedures, quality control procedures, and emission calculations and are not repeated here.

All emissions tests will be conducted under steady state boiler operations and for durations of approximately 60 minutes each. Steady state operations will be confirmed by the operator based on achievement of desired nominal fuel and steam flow rates without undue variability. The testing will be conducted downstream of the pollution control devices at each site as described in detail in the Site Profiles.:

For isokinetic testing procedures at MP-5 (Methods 5, CTM040/202, and 29), the five ports shown in Figure 2-2 will be used to conduct a 25 point duct traverse during each test. On UI-10, the eight ports shown in Figure 2-3 will be used to conduct 32 point traverses. Testing for all other pollutants will be conducted at a single point near the center of each duct.

Where available, the use of continuous emission monitoring systems (CEMS) will be used to measure gaseous components such as NO_X, SO_2, CO, CO_2, or O_2 in lieu of reference methods. Where CEMS are available (see Section 2.1), current audit materials will be reviewed to document CEMS accuracy and functionality. Collected samples for determination of TPM, PM10, PM2.5, metals, HCl, and HF will be recovered on-site at the conclusion of each test run, and then shipped to the emissions tester's analytical laboratory along with completed chain-of-custody documentation for off-site analysis. All sample handling and analysis will be conducted following reference method specifications. Appendix B-3 provides an example chain of custody form.

Details regarding the DQOs for emissions performance testing are provided in Section 3.1.1 of the TQAP.

2.3.3 Fly ash Characteristics

Fly ash samples will be collected during the efficiency and emissions testing periods to evaluate the impact of biomass co-firing on ash composition. On MP-5, fly ash samples will be collected at the air heater outlet during each test run following EPA Reference Method 17 procedures. Depending on particulate loadings encountered at each test site, fly ash collection testing will be of a duration that allows testers to obtain ash samples of sufficient mass for the analytical procedures. This approach is not logistically feasible on IU-10. Alternately, fly ash samples will be collected from hoppers on the mechanical collector and ESP. Collected samples will be submitted to Wyoming Analytical along with completed chain-of-custody documentation for determination of carbon, hydrogen, and nitrogen (CHN) content, minerals content, and TCLP for RCRA metals including arsenic, barium, cadmium, chromium, lead, mercury, selenium, and silver. The laboratory will also conduct tests to evaluate ash fusion temperature, and air-entraining agents index. Results will be compared to the Class F (bituminous and anthracite) or Class C (lignite and subbituminous) fly ash specifications. Table 2-10 summarizes the analytical methods that will be used.

Table 2-10. Summary of Fly ash Analyses

Parameter	Method
CHN	ASTM D5373 [2]
minerals	ASTM D4326-04 [2]
RCRA metals	SW-846 3052/6010 [4]
Metals TCLP	SW-846 1311/6010 [4]
Air-entraining agents index	Foam Index Test
Fly ash fusion temperature	ASTM D1857 [2]

The laboratory will report method precision using repeatability checks so that Southern can evaluate the sensitivity of the analysis and level of change in each of the parameters that is quantifiable. More detail regarding the DQOs for ash analyses is provided in Section 3.1 of the TQAP.

2.4 SUSTAINABILITY INDICATORS AND ISSUES

Sustainability is an important consideration regarding use of woody biomass as a renewable fuel source. This project will evaluate certain sustainability issues for the two sites selected for field testing. The following sustainability related issues will be examined:

- Estimated daily and annual woody biomass consumption at the nominal co-firing rate
- Biomass delivery requirements (distance and mode)
- Coal delivery requirements (distance and mode)
- Fly ash composition, use, and waste disposal including delivery distance and mode.

Biomass Consumption, Type, and Source

The projected daily and annual biomass consumption rate will be useful in determining whether the supply of biomass is sustainable. Biomass consumption rates measured during the testing conducted at each site will be used as the basis to estimate daily and annual biomass consumption for each site. Estimates will be compared for reasonableness with site records if available. The source, type, and compositional analyses of the biomass will also be documented during testing. If more than one source is used, the sources and proportions used will be documented in the Site Profile and confirmed from site documentation during testing.

Associated Biomass NO_X Emissions

By evaluating the average biomass consumption rate at each site, upstream NO_X and CO_2 emissions associated with the biomass supply can be estimated for each site. The distance between the biomass sources and the units tested along with NO_X emission factors for the modes of transportation used to deliver the biomass will be used to complete this analysis. Emission factors will be determined based on EPA's AP 42 Emission Factors Database [5].

The same analysis will be conducted for delivery of an equivalent amount of coal (based on heat input) that the biomass will offset, enabling analysts to determine if mining, processing, and transportation related emissions are expected to increase or decrease as a result of co-firing biomass at each facility. This type of analysis however is likely to be very complex and beyond the scope of this project. Reporting the estimated NO_X emissions associated with biomass delivery will provide the first step for analysts wishing to complete the entire emissions offset estimation.

At the Minnesota Power site, the biomass is a combination of wood byproducts generated at a neighboring industrial facility, a second industrial facility within 5 miles, and other sources up to 75 miles from the site. Therefore, emissions associates with biomass delivery to the generator are expected to provide a significant environmental benefit over coal-only operations.

For the University of Iowa however, the pelletized biomass is produced offsite, shipped to a fuel blending facility, then shipped again to the power plant. Emissions associated with the delivery scenarios will be estimated. The following data will be recorded for each plant:

- Mass of coal offset by co-firing (based on biomass heat input)
- Fuel source to generator distance, mode of transport, and mass per load for coal
- Fuel source to generator distance, mode of transport, and mass per load for biomass
- NO_X emission factors for each transport type

An alternate scenario in which processing is performed locally using local biomass sources will also be considered. This is representative of what is likely to occur should UI choose to switch to this fuel.

Solid Waste Issues

Results of the baseline coal fly ash analyses and the co-fired fuel fly ash analyses will be compared to determine if co-firing biomass has a measurable impact on the carbon content of the ash with respect to ASTM C618-05 [2] standards for cement admixtures. In addition, results of the RCRA metals analyses for the baseline and co-fire ash will be compared to evaluate impact on metals content. The metals TCLP analytical results will be used to examine if co-firing impacts fly ash characteristics with respect to the TCLP standards cited in 40 CFR 261.24 [6].

3.0 DATA QUALITY OBJECTIVES

Under the ETV program, Southern specifies data quality objectives (DQOs) for each primary verification parameter before testing commences as a statement of data quality. The DQOs for this verification were developed based on input from EPA's ETV QA reviewers, and input from the BCSG. As such, test results meeting the DQOs will provide an acceptable level of data quality for technology users and decision makers.

The DQOs for this verification are qualitative in that the verification will produce emissions performance data that satisfy the QC requirements contained in the EPA Reference Methods specified for each pollutant, and the fuel and fly ash analyses will meet the QA/QC requirements contained in the ASTM Methods being used. The verification report will provide sufficient documentation of the QA/QC checks for all of these determinations to evaluate whether the qualitative DQOs were met. These QA/QC checks are described in Sections 3.1.1 and 3.1.2.

This verification will not include a stated DQO for boiler efficiency determinations. It is likely that for certain measurements provided by the facility (e.g., steam flow, steam pressure, and steam temperature), validation of measurement accuracy may not be possible. Confirmation of the availability of traceable calibration and accuracy data will be contained in the final reports. Southern will attempt to validate the accuracy of as many contributing measurements as possible as described in Section 3.1.3. Accuracies for the boiler efficiency contribution will be propagated to estimate the overall uncertainty in reported boiler efficiencies.

3.1.1 Emissions Testing QA/QC Checks

Each of the EPA Reference Methods proposed here for emissions testing contains rigorous and detailed calibrations, performance criteria, and other types of QA/QC checks. For instrumental methods using gas analyzers, these performance criteria include analyzer span, calibration error, sampling system bias, zero drift, response time, interference response, and calibration drift requirements. Methods 5, 29, CTM040, and 202 for determination of particulates and metals also include detailed performance requirements and QA/QC checks. Details regarding each of these checks can be found in the methods and are not repeated here. However, results of certain key QA/QC checks for each method will be included in the verification report as documentation that the methods were properly executed. Key emissions testing QA/QC checks are summarized in Table 3-1. Appendix C-1 provides an example emissions analyzer calibration form. Where facility CEMS are used, up to date relative accuracy test audit (RATA) certifications and quarterly cylinder gas audits (CGAs) will serve be used in to document system accuracy and will be reported. CEMS not meeting acceptable RATA and CGA criteria will not be used.

In addition to these internal QA/QC checks for each parameter, Southern will issue two independent audits which will serve as performance evaluation audits (Section 4.5.4). A known concentration of NO_X procured from a reputable supplier of calibration gases will be submitted for blind analysis during field testing. A NO_X Protocol 1 calibration gas with a concentration near the range of readings found at the site will be selected for the audit. A blind audit will also be submitted for the Hg analysis. A Hg standard of known concentration will be procured from Accustandard and submitted to the analytical laboratory along with the collected Hg samples for analysis.

The emissions testing completeness goal for this verification is to obtain valid data for 90 percent of the test periods on each boiler tested.

Table 3-1. Summary of Emission Testing Calibrations and QA/QC Checks

Parameter[a]	Calibration/QC Check[b]	When Performed/Frequency	Allowable Result	Response to Check Failure or Out of Control Condition
NO_X, CO, CO_2, O_2, SO_2	Analyzer calibration error test	Daily before testing	± 2 % of analyzer span	Repair or replace analyzer
	System bias checks	Before each test run	± 5 % of analyzer span	Correct or repair sampling system
	System calibration drift test	After each test run	± 3 % of analyzer span	Repeat test
NO_X	NO_2 converter efficiency	Once before testing begins	98 % minimum	Repair or replace analyzer
TPM, PM10, PM2.5, Metals	Percent isokinetic rate	After each test run	90 - 110 % for TPM and metals, 80 – 120% for PM10, PM2.5	Repeat test run
	Analytical balance calibration	Daily before analyses	± 0.0002 g	Repair/replace balance
	Filter and reagent blanks	Once during testing after first test run	< 10 % of particulate catch for first test run	Recalculate emissions based on high blank values
	Sampling system leak test	After each test	<0.02 cfm	Repeat test
	Dry gas meter calibration	Once before and once after testing	± 5 %	Recalculate emissions based on average calibration factor
	Sampling nozzle calibration	Once for each nozzle before testing	± 0.01 in.	Select different nozzle
Metals	ICP/CVAAS	Analysis of prepared QC standards	± 25% of expected value	Repeat calibration curve
HCl, HF	Sampling system leak test	After each test	<0.02 cfm	Repeat test
	Dry gas meter calibration	Once before and once after testing	± 5 %	Recalculate emissions based on average calibration factor
	Ion chromatograph	Analysis of prepared QC standards	± 10% of expected value	Repeat calibration curve

[a] EPA reference methods are used to determine each parameter as listed in Table 2-4.
[b] Definitions and procedures for each of the calibration and QC checks specified here are included in the applicable reference method and not repeated here.

3.1.2 Fly ash and Fuel Analyses QA/QC Checks

The laboratory selected for analysis of collected fuel and fly ash samples (Wyoming Analytical Laboratory Services, Inc) operates under a strict internal quality assurance protocol, a copy of which is maintained at Southern. Each of the analytical procedures used here (Tables 2-8 and 2-10) include detailed procedures for instrument calibration and sample handling. They also include QA/QC checks in the form of analytical repeatability requirements or matrix spike analyses. Table 3-2 summarizes the key QA/QC checks for the ash and fuel analyses.

Table 3-2. Fuel and Fly ash Analytical QA/QC Checks

Analysis	Calibration/QC Check[a]	When Performed	Allowable Result	Response to Check Failure
Fuel ultimate analysis (D3176)	Duplicate analysis	2 samples	± 10 % difference	When allowable results are exceeded, analysts will investigate the problem, repeat the QA/QC check, and repeat completed analyses
Fuel Calorific Value (D5865)				
Ash CHN (D5373)				
Ash fusion temperature (D1857)				
Ash metals (3052/6010) and metals TCLP (1311/6101)	Matrix spike analysis	Once per batch of samples	Results ± 25 % of expected value	
	Duplicate analysis	2 samples	± 20 % difference	

[a] Definitions and procedures for each of the calibration and QC checks specified here are included in the applicable reference method and not repeated here.

3.1.3 Boiler Efficiency QA/QC Checks

Table 3-3 summarizes the contributing measurements for boiler efficiency determination, measurement quality objectives (MQOs) for each, and the primary method of evaluating the MQOs. Factory calibrations, sensor function checks, and reasonableness checks in the field will document achievement of the MQOs. After each test run and upon receipt of the laboratory results, analysts will review the data and classify it as valid or invalid. All invalid data should be associated with a specific reason for its rejection, and the report should cite those reasons.

Table 3-3. Boiler Efficiency QA/QC Checks

Measurement / Instrument	QA/QC Check	When Performed	MQO
Fuel temperature, °F	NIST-traceable calibration	Upon purchase and every 2 years	± 6 °F
Flue gas temperature at air heater inlet, °F			
Air temperature, °F	NIST-traceable calibration		± 1 °F
Moisture in air, lb/lb dry air	NIST-traceable calibration		± 3.5 %
Combustion air temperature, °F	Cross check with NIST-traceable standard	Annually	± 6 °F
Steam flow, MMBtu/h or lb/h	Orifice calibration	Upon installation	± 5 % reading
Steam pressure, psig	Cross check with NIST-traceable standard	Annually	± 5 psig
Steam temperature, °F			± 6 °F
Supply water pressure, psig			± 5 psig
Supply water temperature, °F			± 2 % of reference standard
Power generation, kW			± 5 % reading
Fuel feed rate, lb/hr	NIST-traceable calibration	Annually	± 5 % reading
Fuel ultimate analyses, both wood and coal	ASTM D1945 duplicate sample analysis and repeatability	2 samples	Within D1945 repeatability limits for each fuel component
Fuel heating value, Btu/lb	ASTM D1945 duplicate sample analysis and repeatability		Within D1945 repeatability limits for each fuel component
Unburned carbon loss, %	Benzoic acid standard calibration	Weekly	± 0.1 % relative standard deviation

The table lists the MQOs for each of the measurements. However, the actual measurement errors determined using the QA/QC checks will be used to conduct the parameter uncertainty evaluation for boiler efficiency. The uncertainty evaluation will be conducted by propagating the measurement errors using the procedures detailed in Appendix D-1

3.2 INSTRUMENT TESTING, INSPECTION, AND MAINTENANCE

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

3.3 INSPECTION/ACCEPTANCE OF SUPPLIES, CONSUMABLES, AND SERVICES

The procurement of purchased items and services that directly affect the quality of environmental programs defined by this TQAP will be planned and controlled to ensure that the quality of the items and services is known, documented, and meets the technical requirements and acceptance criteria herein. For this verification, this includes services provided by Wyoming Analytical for fuel and ash analyses and GE Energy for emissions testing services.

Procurement documents shall contain information clearly describing the item or service needed and the associated technical and quality requirements. The procurement documents will specify the quality system elements of the TQAP for which the supplier is responsible and how the supplier's conformity to the customer's requirements will be verified.

Procurement documents shall be reviewed for accuracy and completeness by the project manager and QA manager as noted in Sections 1.4 and 4.2. Changes to procurement documents will receive the same level of review and approval as the original documents. Appropriate measures will be established to ensure that the procured items and services satisfy all stated requirements and specifications.

3.4 DATA QUALITY OBJECTIVES RECONCILIATION

A fundamental component of all verifications is the reconciliation of the collected data with its DQO. In this case, the DQO assessment consists of evaluation of whether the stated methods were followed. The field team leader and project manager will initially review the collected data to ensure that they are valid and are consistent with expectations. They will assess the data's accuracy and completeness as they relate to the stated QA / QC goals. If this review of the test data shows that QA / QC goals were not met, then immediate corrective action may be feasible, and will be considered by the project manager. DQOs will be reconciled after completion of corrective actions. As part of the internal audit of data quality, the Southern QA Manager will include an assessment of DQO attainment.

3.5 TRAINING AND QUALIFICATIONS

This test does not require specific training or certification beyond that required internally by the test participants for their own activities. Southern's field team leader has approximately 20 years experience in field testing of air emissions from many types of sources and will directly oversee field activities. He is familiar with the test methods and standard requirements that will be used in the verification test.

The field team leader has performed numerous field verifications under the ETV program, and is familiar with EPA and Southern quality management plan requirements. The QA Manager is an independently appointed individual whose responsibility is to ensure Southern's conformance with the EPA approved QMP.

4.0 DATA HANDLING AND REPORTING

4.1 DATA ACQUISITION AND DOCUMENTATION

Test personnel will acquire the following electronic data and generate the following documentation during the verification:

Boiler Operational Data

Boiler operations will be monitored for the following measurements:

- Generator power output power quality parameters (if applicable)
- Steam flow, temperature, and pressure
- Intake air temperature and moisture
- Flue gas and combustion air temperature
- Supply water pressure and temperature
- transfer fluid flow, supply temperature, and return temperature (if applicable)
- ambient temperature and barometric pressure

Data collected using Southern instrumentation will be recorded as one-minute averages throughout all tests and stored on a laptop computer. Data collected by the facilities will be downloaded in the format and frequencies available and also stored on the laptop computer. Manually logged boiler data will be stored in a field notebook.

Emissions Testing Data

Emissions testing will result in both electronic and manually recorded data. Southern personnel will obtain copies of the electronic data from the emission testing contractor prior to leaving the site including one-minute average pollutant values during test runs, pre- and post-test instrument calibrations, and emission rate calculations. The contractor will also provide copies of manually recorded data, QA/QC checks, and sample chain of custody records. After field testing, the contractor will submit to Southern a comprehensive emissions testing report including descriptions of methods and instrumentation, dates of analysis, test team participants, test results, sample chain of custody documentation, and all analytical QA/QC procedures, calibrations, and results. The reports will be reviewed for completeness and maintained at Southern.

Laboratory Reports

Laboratory reports will be obtained with results of the submitted fuel, fly ash, and emissions testing samples. These reports will include analytical methods, dates of analysis, analyst names, sample results, sample chain of custody documentation, and all analytical QA/QC procedures, calibrations, and results. The reports will be reviewed for completeness and maintained at Southern.

Documentation

Printed or written documentation will be recorded on the log forms and will include:

- Daily test log including test participants, test conditions, starting and ending times for test runs, notes, etc.
- Forms which show the results of QA / QC checks

- Copies of calibrations and manufacturers' certificates

Southern will archive all electronic data, paper files, analyses, and reports at their Research Triangle Park, NC office in accordance with their quality management plan.

4.1.1 Corrective Action and Assessment Reports

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

The field team leader will most frequently identify the need for corrective actions. In such cases, he or she will immediately notify the project manager. The field team leader, project manager, QA Manager and other project personnel, will collaborate to take and document the appropriate actions. Appendix C-2 includes a corrective action report form.

Note that the project manager is responsible for project activities. He is authorized to halt work upon determining that a serious problem exists. The field team leader is responsible for implementing corrective actions identified by the project manager and is authorized to implement any procedures to prevent a problem from recurring.

4.2 DATA REVIEW, VALIDATION, AND VERIFICATION

The project manager will initiate the data review, validation, and analysis process. At this stage, analysts will classify all collected data as valid, suspect, or invalid. Southern will employ the QA/QC criteria specified in Section 3.0 and the associated tables. Source materials for data classification include factory and on-site calibrations, maximum calibration and other errors, subcontractor deliverables, etc.

In general, valid data results from measurements which:

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

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

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

- on site -- by the field team leader,
- upon receiving subcontractor deliverables,
- before writing the draft report -- by the project manager, and
- during draft report QA review and audits -- by Southern's QA Manager.

The field team leader's primary on-site functions will be to install and operate the test equipment. He will review, verify, and validate certain data (QA / QC check results, etc.) during testing.

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

4.3 ASSESSMENTS AND RESPONSE ACTIONS

The field team leader, project manager, QA Manager, Southern's Program Director, and technical peer-reviewers will assess the project and the data's quality as the test campaign proceeds. The project manager and QA Manager will independently oversee the project and assess its quality through project reviews, inspections if needed, a technical systems audit, an audit of data quality, and performance evaluation audits.

4.3.1 Project Reviews

The project manager will be responsible for conducting the first complete project review and assessment. Although all project personnel are involved with ongoing data review, the project manager must ensure that project activities meet measurement and DQO requirements. The project manager is also responsible for maintaining document versions, managing the review process, and ensuring that updated versions are provided to reviewers and tracked.

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

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

Client organizations and select members of the BCSG will then review the report. Finally, Southern's Program will submit the draft report to EPA QA personnel, and the project manager will address their comments as needed. Following this review, the report will undergo EPA management reviews, including Southern's Program Director, EPA ORD Laboratory Director, and EPA Technical Editor.

4.3.2 Technical Systems Audit

The technical systems audit (TSA) will be conducted by the QA Manager during all phases of 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 DQOs for this test. The TSA includes a review of the experimental design, the Test Plan, and planned field procedures prior to field activities. The review also includes an assessment of personnel qualifications, adequacy and safety of the facility and equipment, and the data management system.

During field testing activities, the QA Manager or his designee will inspect the analytical activities and determine their adherence to the Test Plan. The auditor reports any area of nonconformance to the Field Team Leader through an audit report. The audit report may contain corrective action recommendations. If so, follow-up inspections may be required to ensure that corrective actions are taken.

4.3.3 Audit of Data Quality

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

The QA Manager will route audit results to the project manager for review, comments, and possible corrective actions. The ADQ will result in a memorandum summarizing the results of custody tracing, a study of data transfer and intermediate calculations, and review of the QA/QC data. The ADQ report will include conclusions about the quality of the data from the project and their fitness for the intended use. The project manager will take any necessary corrective action needed and will respond by addressing the QA Manager's comments in the verification report.

4.3.4 Performance Evaluation Audit

Two PEAs are designed to check the accuracy of the Hg analyses conducted by GE Energy's analytical laboratory and the NO_X determination in the field conducted by GE's field testing crew. As discussed in Section 3.0, Hg and NO_X audit samples will contain analytes of a known concentration. At the invitation of the QA Manager, the Field Team Leader will conduct the PEAs. He will submit the audit materials to the laboratories in such a manner as to have the concentration of the PEAs unknown or blind to the analyst. Upon receiving the analytical data from the analyst, the Field Team Leader will evaluate the performance data for compliance with the requirements of the project, and report the findings to the QA Manager.

4.4 VERIFICATION REPORT AND STATEMENT

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

The project manager will submit the draft report and Verification Statement to the QA Manager and Southern's Director for review. A preliminary outline of the report is as follows:

Preliminary Outline
Environmental and Sustainable Technology Evaluation – Biomass Co-firing in Industrial Boilers

Verification Statement

Section 1.0:	*Verification Test Design and Description* *Description of the ESTE Program* *Test Facility and Boiler Descriptions* *Overview of the Verification Parameters and Evaluation Strategies*
Section 2.0:	*Results* - *Boiler performance* - *Boiler emissions* - *Fly ash characteristics* - *Sustainability issues*
Section 3.0:	*Reconciliation of Data Quality Objectives*
Section 4.0:	*References*
Appendices:	*Raw Verification or Other Data* *Site Profiles*

5.0 HEALTH AND SAFETY PLAN

This section applies to Southern personnel and subcontractors. Other organizations involved in the project have their own health and safety plans which are specific to their roles in the project.

Southern staff will comply with all known host, state/local and Federal regulations relating to safety at the test facilities. This includes use of personal protective gear (such as safety glasses, hard hats, hearing protection, safety toe shoes) as required by the host and completion of site safety orientation. Southern's site safety plan for this verification will include adoption and adherence to the Facility's Site Specific Safety Plans.

Both facilities maintain strict Site Specific Safety Plans that identify of key site personnel, location of nearby medical facilities, required personal protective equipment, potential site hazards, and hazard response activities. Should it be required by the host site or the Project Manager, test personnel will undergo a safety briefing regarding site policies and procedures. While on-site, the Field Team Leader will be responsible for ensuring compliance with site safety plans and will maintain a safety log form such as the example in Appendix D-2.

6.0 REFERENCES

[1] Babcock & Wilcox, *Steam – it's Generation and Use – 40th Edition,* The Babcock & Wilcox Company, Barberton, Ohio, 1992.

[2] ASTM, *ASTM Standards Catalog 2005,* *www.astm.org*, American Society for Testing and Materials, West Conshohocken, PA. 1999.

[3] Code of Federal Regulations (Title 40 Part 60, Appendix A) *Test Methods (Various)*, http://www.gpoaccess.gov/cfr/index.html, U.S. Environmental Protection Agency, Washington, DC, 2005.

[4] U.S. EPA, *SW-846 – Test Methods for Evaluating Solid Waste, Physical/chemical Methods,* *http://www.epa.gov/epaoswer/hazwaste/test/sw846.htm*, U.S. Environmental Protection Agency Office of Solid Waste, Washington D.C., 2005.

[5] U.S. EPA, *AP-42, Compilation of Air Pollutant Emission Factors,* *http://www.epa.gov/oms/ap42.htm*, U.S. Environmental Protection Agency Office of Transportation and Air Quality, Washington D.C., 2005.

[6] Code of Federal Regulations (Title 40 Part 261.24) *Identification and Listing of Hazardous Waste – Toxicity Characteristic*, http://www.access.gpo.gov/nara/cfr/waisidx_05/40cfr261_05.html, U.S. Environmental Protection Agency, Washington, DC, 2005.

Appendix A-1.
Biomass Co-firing Stakeholder Group

Dr. Jim Cobb, University of Pittsburgh

Kim Crossman, U.S. EPA, CHP Partnerships

Keith Cummer, Black & Veatch

Jim Eddinger, U.S. EPA, OAQPS

Dennis Kennedy, Duke University

Dr. David Kirchgessner, U.S. EPA, ORD

Dr. Alex Livnat, U.S. EPA, Office of Solid Waste

Bob Morrow, Detroit Stoker

Bill Perdue, American Furniture Mfr's Association

Donna Perla, U.S. EPA, ORD Sustainable Development

Dr. John Pinkerton, NCASI

John Steinhoff, Envise

Bryce Stokes, Forest Service, Vegetation Mgmt

Tom Tucker, Envise

Appendix B-1
Test Log Form

Project ID:_______________________ Location (city, state):_______________________

Date:_______________________ Signature:_______________________

Unit Description:_______________________ Run ID:_______________________

Clock synchronization performed (Initials):_______________________

	Start	**End**
Time		
Boiler Load Setting		
Biomass Blend Rate, %		
Steam Flow, MMBtu/hr		
Steam Pressure, psig		
Steam Temperature, °F		
Combustion Air Temp., °F		
Ambient Temp., °F		
Ambient Pressure, psia		
Generating Rate, kW		

Notes:____

____

____

____

____

Appendix B-2
Boiler Efficiency Calculations

Table 13A
Combustion Calculations - Btu Method

	INPUT CONDITIONS - BY TEST OR SPECIFICATION	
1	Excess air: at burner/leaving boiler/econ, % by weight	20/20
2	Entering air temperature, F	80
3	Reference temperature, F	80
4	Fuel temperature, F	80
5	Air temperature leaving air heater, F	350
6	Flue gas temperature leaving (excluding leakage), F	390
7	Moisture in air, lb/lb dry air	0.013
8	Additional moisture, lb/100 lb fuel	0
9	Residue leaving boiler/economizer, % Total	85
10	Output, 1,000,000 Btu/h	285.6
	Corrections for sorbent (from Table 14 if used)	
11	Additional theoretical air, lb/10,000 Btu Table 14, Item [21]	0
12	CO_2 from sorbent, lb/10,000 Btu Table 14, Item [19]	0
13	H_2O from sorbent, lb/10,000 Btu Table 14, Item [20]	0
14	Spent sorbent, lb/10,000 Btu Table 14, Item [24]	0

FUEL - *Bituminous coal, Virginia*

	15 Ultimate Analysis		16 Theo Air, lb/100 lb fuel		17 H_2O, lb/100 lb fuel	
	Constituent	% by weight	K1	[15] x K1	K2	[15] x K2
A	C	80.31	11.51	924.4		
B	S	1.54	4.32	6.7		
C	H_2	4.47	34.29	153.3	8.94	39.96
D	H_2O	2.90			1.00	2.90
E	N_2	1.38				
F	O_2	2.85	− 4.32	− 12.3		
G	Ash	6.55				
H	Total	100.00	Air	1072.1	H_2O	42.86

18	Higher heating value (HHV), Btu/lb fuel		14,100
19	Unburned carbon loss, % fuel input		0.40
20	Theoretical air, lb/10,000 Btu	[16H] x 100 / [18]	7.604
21	Unburned carbon, % of fuel	[19] x [18] / 14,500	0.39

COMBUSTION GAS CALCULATIONS, Quantity / 10,000 Btu Fuel Input

			A At Burners	B Infiltration	C Leaving Furnace		D Leaving Blr/Econ	
22	Theoretical air (corrected), lb/10,000 Btu	[20] − [21] x 1151 / [18] + [11]						7.572
23	Residue from fuel, lb/10,000 Btu	([15G] + [21]) x 100 / [18]						0.049
24	Total residue, lb/10,000 Btu	[23] + [14]						0.049
25	Excess air, % by weight		20.0	0.0		20.0		20.0
26	Dry air, lb/10,000 Btu	(1 + [25] / 100) x [22]				9.086		9.086
27	H_2O from air, lb/10,000 Btu	[26] x [7]			0.118	0.118	0.118	0.118
28	Additional moisture, lb/10,000 Btu	[8] x 100 / [18]			0.000	0.000	0.000	0.000
29	H_2O from fuel, lb/10,000 Btu	[17H] x 100 / [18]			0.304		0.304	
30	Wet gas from fuel, lb/10,000 Btu	(100 − [15G] − [21]) x 100 / [18]				0.660		0.660
31	CO_2 from sorbent, lb/10,000 Btu	[12]				0.000		0.000
32	H_2O from sorbent, lb/10,000 Btu	[13]			0.000	0.000	0.000	0.000
33	Total wet gas, lb/10,000 Btu	Summation [26] through [32]				9.864		9.864
34	Water in wet gas, lb/10,000 Btu	Summation [27] + [28] + [29] + [32]			0.422	0.422	0.422	0.422
35	Dry gas, lb/10,000 Btu	[33] − [34]				9.442		9.442
36	H_2O in gas, % by weight	[100] x [34] / [33]				4.28		4.28
37	Residue, % by weight	[9] x [24] / [33]				0.42		0.42

EFFICIENCY CALCULATIONS, % Input from Fuel

	Losses			
38	Dry gas, %	0.0024 x [35D] x ([6] − [3])		7.02
39	Water from fuel, as-fired % — Enthalpy of steam at 1 psi, T = [6]	H_1 = (3.958E−5 x T + 0.4329) x T + 1062.2	1237.1	
40	Enthalpy of water at T = [3]	H_2 = [3] − 32	48.0	
41		[29] x ([39] − [40]) / 100		3.61
42	Moisture in air, %	0.0045 x [27D] x ([6] − [3])		0.16
43	Unburned carbon, %	[19] or [21] x 14,500 / [18]		0.40
44	Radiation and convection, %	ABMA curve, Chapter 22		0.40
45	Unaccounted for and manufacturers margin, %			1.50
46	Sorbent net losses, % if sorbent is used	From Table 14 Item [41]		0.00
47	Summation of losses, %	Summation [38] through [46]		13.09
	Credits			
48	Heat in dry air, %	0.0024 x [26D] x ([2] − [3])		0.00
49	Heat in moisture in air, %	0.0045 x [27D] x ([2] − [3])		0.00
50	Sensible heat in fuel, %	(H at T[4] − H at T [3]) x 100 / [18]	0.0	0.00
51	Other, %			0.00
52	Summation of credits, %	Summation [48] through [51]		0.00
53	**Efficiency, %**	100 − [47] + [52]		86.91

	KEY PERFORMANCE PARAMETERS		Leaving Furnace	Leaving Blr/Econ
54	Input from fuel, 1,000,000 Btu/h	100 x [10] / [53]		328.6
55	Fuel rate, 1000 lb/h	1000 x [54] / [18]		23.3
56	Wet gas weight, 1000 lb/h	[54] x [33] / 10	324.1	324.1
57	Air to burners (wet), lb/10,000 Btu	(1 + [7]) x (1 + [25A] / 100) x [22]	9.205	
58	Air to burners (wet), 1000 lb/h	[54] x [57] / 10	302.5	
59	Heat available, 1,000,000 Btu/h	[54] x [([18] − 10.30 x [17H]) / [18] − 0.005		
	H_a = 66.0 Btu/lb	x ([44] + [45]) + H_a at T[5] x [57] / 10,000]	335.2	
60	Heat available/lb wet gas, Btu/lb	1000 x [59] / [56]	1034.2	
61	Adiabatic flame temperature, F	From Fig. 3 at H = [60], % H_2O = [36]	3560	

Appendix B-3
Southern Research Institute Chain-of-Custody Record

Important: Use separate Chain-of-Custody Record for each laboratory and/or sample type.

Project ID:____________________________ Location (city, state):__________________________________

Originator's signature:____ Unit description:________________

Sample description & type (gas, liquid, other.):____

Laboratory:___________________________ Phone:________________ Fax:__________________

Address:______________________________ City:__________________ State:_________ Zip:_____

Sample ID	Date, Time Collected	Sample Matrix	Sample Temp. (°F)	Analyses Req'd

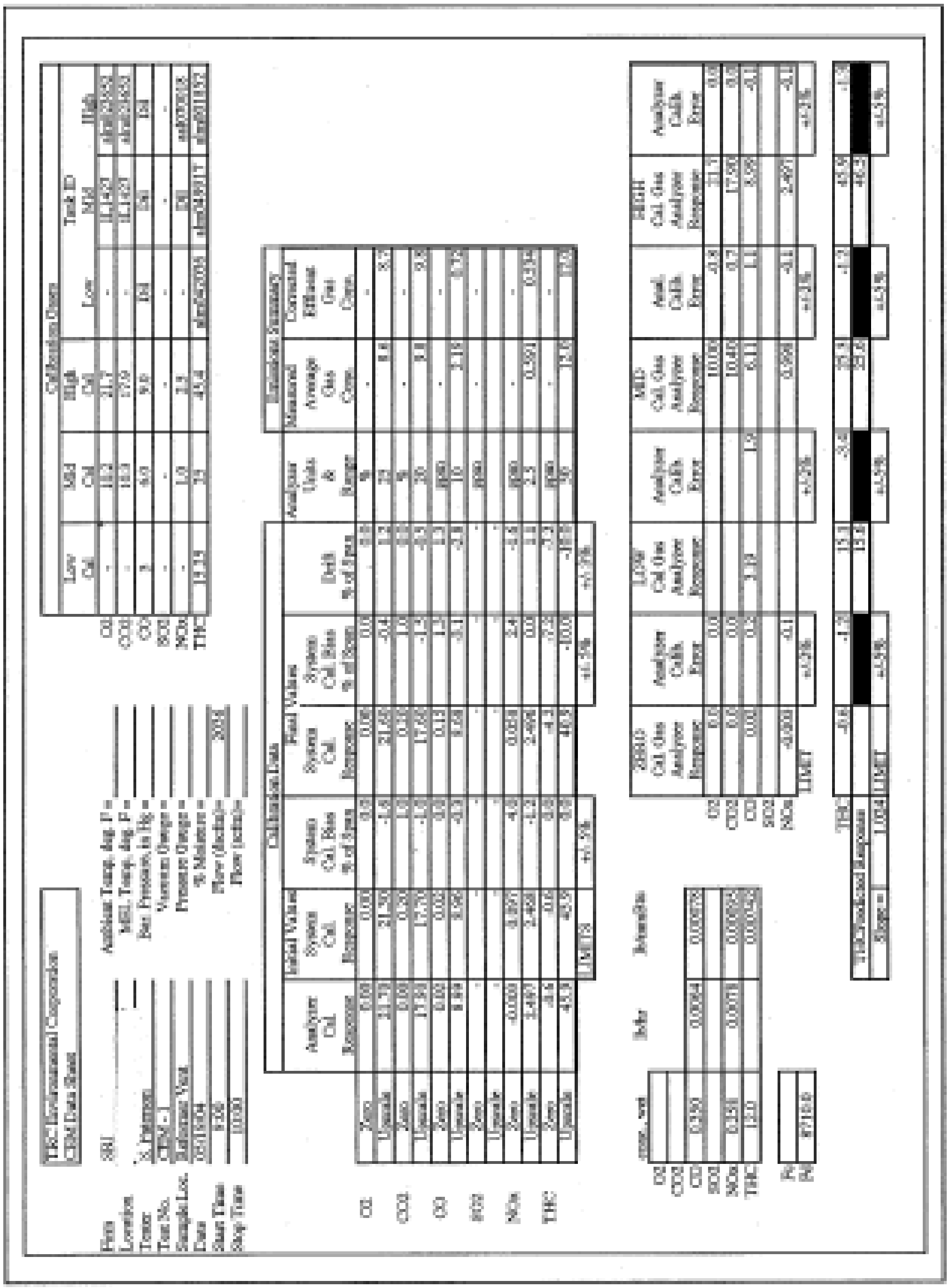
Relinquished by:_______________________ Date:__________________ Time:__________________
Received by:___________________________ Date:__________________ Time:__________________

Relinquished by:_______________________ Date:__________________ Time:__________________
Received by:___________________________ Date:__________________ Time:__________________

Relinquished by:_______________________ Date:__________________ Time:__________________
Received by:___________________________ Date:__________________ Time:__________________

Notes: (shipper tracking #, other)____
____
____
____
____

Appendix C-1
Example Emissions Testing Calibrations



Appendix C-2. Corrective Action Report

Corrective Action Report

Verification Title:____

Verification Description:____

Description of Problem:____

Originator:_________________________ Date:_____________

Investigation and Results:____________________________________

Investigator:_________________________ Date:_____________

Corrective Action Taken:______________________________________

Originator:_________________________ Date:_____________
Approver:__________________________ Date:_____________

Appendix D -1. Uncertainty Estimation

This Appendix presents compounded error estimation procedures for quantities which are developed from two or more instruments (or analyses) with individual measurement errors. In addition to following the specified procedures to evaluate data quality, evaluation and reporting of the achieved uncertainty is an important aspect of this TQAP. Where applicable, two methods of uncertainty evaluation are acceptable.

For boiler efficiency determinations, the achieved parameter uncertainty may be calculated based on actual measurement instrument calibration data, actual laboratory error, field conditions, and other uncertainties determined as described in the TQAP. Analysts may compound the measurement errors to determine the achieved uncertainty (or relative error) for the parameter of interest using the methods specified below.

Measurement Error

This Appendix defines measurement error, uncertainty, or accuracy as the combination of all contributing instrument errors and instrument precision. It makes no effort to separate the two or to quantify sampling error. An instrument manufacturer's accuracy specification (or laboratory analysis accuracy statement, etc.) is sufficient if it is accompanied, at a minimum, by current applicable National Institutes of Standards and Technology (NIST)-traceable calibration(s), appropriate QA/QC checks, or other supporting documents which support the accuracy statements.

Absolute and Relative Errors

Absolute measurement error is an absolute value compared to a given value or operating range. An example is: "± 0.6 ^{o}F between 100 and 212 ^{o}F" for a temperature meter.

Relative measurement error, generally stated as a percentage, is:

$$err_{rel} = \frac{err_{abs}}{reading}100 \qquad \text{Eqn. G-1}$$

Where:

err_{rel} = relative error, percent
err_{abs} = absolute error, stated in the measurement's units
reading = measurement result, stated in the measurement's units

The reference basis for relative accuracy statements can be either the instrument's full scale or span or the measurement reading. The following examples show the relationships between relative and absolute measurement errors.

Relative Error Accuracy Statement	FS (or span)	Absolute Error
"Temperature accuracy is ± 1.0 %, FS"	120 ^{o}F	± 1.2 ^{o}F at 60 ^{o}F
"Temperature accuracy is ± 1.0 % of reading"	n/a	± 0.6 ^{o}F at 60 ^{o}F

Compounded Error for Added and Subtracted Quantities

For added or subtracted quantities, the absolute errors compound as follows:

$$err_{c,abs} = \sqrt{err_{abs1}^{\ 2} + err_{abs2}^{\ 2}} \qquad \text{Eqn. G-2}$$

Where:

$err_{c,abs}$ = compounded error, absolute
err_1 = error in first added or subtracted quantity, absolute value

err_{abs2} = error in second subtracted quantity, absolute value

As an example, a heat transfer fluid ΔT is defined as the difference between T_{supply} and T_{return}. The uncertainties in each temperature measurement compound together to yield the overall ΔT uncertainty. If the absolute error for each temperature meter is ± 0.6 °F, from 100 to 212 °F. The resulting ΔT absolute error is constant at $\sqrt{0.6^2 + 0.6^2}$, or ± 0.85 °F. Relative error will vary with the actual ΔT found during testing.

Compounded Error for Multiplied or Divided Quantities

For two multiplied or divided quantities, the relative errors compound to yield the overall error estimate:

$$err_{c,rel} = \sqrt{err_{1,rel}{}^2 + err_{2,rel}{}^2} \qquad \text{Eqn. G-3}$$

Where: $err_{c,rel}$ = compounded relative error, percent
$err_{1,\,rel}$ = relative error for first multiplied quantity, percent
$err_{2,\,rel}$ = relative error for second multiplied quantity, percent

For example, a power meter measures the current (CT) output and applies the appropriate scaling factor by multiplication. For a meter with current THD accuracy of ± 4.9 percent at 360 Hz, compounded with the specified ± 1.0 percent CT accuracy at that frequency, the overall current THD accuracy is $\sqrt{4.9^2 + 1.0^2}$ or ± 5.0 percent.

Appendix D-2. Site Safety Log Form
Site Safety Plan

Site Name: ______________________________
Address:_________________________________
Contact Name: ___________________________
Contact Phone: __________________________

Company Contact Name: ______________________
Company: ________________________________
Contact Phone: ____________________________

Work Dates: ____________________________

Southern Research Site Personnel:
Name1: ______________________________________
Home Phone: ___________ CellPhone: ______________
Name2: ______________________________________
Home Phone: ___________ CellPhone: ______________

Local Hospital Name: ___________________________
Address: ____________________ Phone: ____________

Signature1/date: ________________________________
Signature2/date:________________________________

Southern Research Safety Officer signature/date: ________________________________

Southern Research Office Contact: ___________________________

Backup Contact: _________________________

Work Description:
This project will require extended presence in industrial setting and close proximity to industrial boilers. Collection of coal, wood, and fly ash samples and supervision of emissions testing crews.

Expected Hazards, Hazardous Conditions, or Potentially Hazardous Systems:

- ☒ Flying fragments, dust, or dirt
- ☐ Illumination or work lighting
- ☒ Climbing, scaffolding, or access
- ☒ Lifting or material moving
- ☒ Handling hot objects
- ☒ Falling objects, bumps, pinchpoints
- ☒ Noise
- ☒ Breathing or atmospheric hazard
- ☐ Extreme ambient heat or cold
- ☐ Splashes or spills

- ☐ Electrical wiring
  - ☐ Power systems; VAC __
  - ☐ Control/DAS systems; VDC
- ☐ Plumbing
  - ☐ Water; °F _ psig ______
    - ☐ Potable ☐ Black / gray
  - ☐ Liquid; °F ________ psig __________
    - Description: ____________________
  - ☒ Gas; °F ___750___ psig __________
    - Description: ____Flue gases______

Engineering, Personal Protective Equipment, or other methods to address each expected hazard checked above:

IMPORTANT: During field execution of this project, all Southern Research field personnel must wear hard hats, safety glasses, hearing protection, long sleeve shirts, trousers, and leather or other hard closed-toe shoes (not tennis or running shoes) during testing. Rings and other jewelry should be removed during field activities. Head coverings are recommended at all times.

-- Southern Research site personnel will check in with the site contact upon arrival and at the start of each work day and will abide by all site safety requirements not specified here.

-- *Flying fragments, dust, or dirt*: Southern Research site personnel will wear safety glasses with side shields while dismounting, disassembling, and packing test equipment and collecting fuel and ash samples.

-- *Climbing, scaffolding, or access*: Southern Research site personnel will use only existing ladders, platforms, and scaffolds that are approved by the facility safety manager to access sampling points.

-- *Lifting or material moving*: Manual handling of the equipment is unavoidable, and some may be heavy. Southern Research site personnel will seek local assistance if necessary to lift or move heavy equipment. They will also review the NC "Guide to Manual Materials Handling and Back Safety" and undergo a training session at the RTP office prior to departure.

-- *Handling hot objects:* Test personnel will use high temperature gloves and great caution when removing hot probes from contact with hot flue gases. Probes will be allowed to cool a minimum of 30 minutes prior to disassembly or sample recovery.

-- *Noise:* Hearing protection is required when working at or near the boilers.

-- *Breathing or Atmospheric Hazards:* Fitted half mask respirators will be available near work sites for respiratory protection should excess dust or fumes be evident.