SRI/USEPA-GHG-QAP-44
April 2008

Test and Quality Assurance Plan

OfficePower, Inc.
Elliott Microturbine DG / CHP Installation

Prepared by:

Greenhouse Gas Technology Center

Operated by
Southern Research Institute

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

and

Under Agreement With
New York State Energy Research and Development Authority

EPA REVIEW NOTICE

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Greenhouse Gas Technology Center

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

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

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Test Plan Final: April 2008

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ACRONYMS AND ABBREVIATIONS

A	ampere
Btu/h	British thermal units per hour
Btu/scf	British thermal units per standard cubic foot
CHP	combined heat and power
CO_2	carbon dioxide
CO	carbon monoxide
CT	current transformer
DG	distributed generation
DG / CHP	distributed generation / combined heat and power
DQO	data quality objective
EPA	Environmental Protection Agency
ETV	Environmental Technology Verification
gpm	gallons per minute
HR_{LHV}	heat rate, LHV basis, Btu/kWh
Hz	Hertz
kW	kilowatt
KVA	kilovolt-ampere
KVAR	kilovolt-ampere reactive
lb/h	pounds per hour
lb/kWh	pounds per kilowatt-hour
LHV	lower heating value
MQO	measurement quality objective
MTG	microturbine
NO_X	nitrogen oxides
NYSERDA	New York State Energy Research and Development Authority
O_2	oxygen
ppmv	volume parts per million
QA / QC	quality assurance / quality control
RTD	resistance temperature device
SCADA	supervisory control and data acquisition
THC	total hydrocarbons
THD	total harmonic distortion
T_r	return temperature
T_s	supply temperature
^oF	degrees Fahrenheit
η	efficiency, percent

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1.0 INTRODUCTION

The intent of this Test and Quality Assurance Plan (test plan) is to guide the planning, execution, data analysis, and reporting for performance verification of an Elliott Microturbine (MTG) distributed electrical generation and combined heat and power (DG / CHP) installation owned and operated by OfficePower, Inc.

OfficePower has installed eight natural gas-fired Model TA 100 kilowatt, (kW) machines into two arrays of four MTG each in a 39-story office building located at 110 East 59th Street in New York City, NY. Appendix B provides MTG specifications while Figure 2-2 shows an overall layout schematic.

The MTG arrays operate in response to building electrical demand; power is not exported to the grid. The installation recovers substantial amounts of thermal energy from the MTG exhaust which the building uses for space heating and cooling. Design specifications indicate that the recovered energy will displace up to 4.7 million British thermal units per hour of the high pressure steam purchased from the local utility. Parasitic loads include booster compressors to raise the as-delivered natural gas pressure to approximately five pounds per square inch, heat transfer fluid circulation pumps, and a separate fan-cooled radiator for emergency use during upsets. The as-built system collects all parasitic loads into a single cabinet for control and quantification by a revenue-quality power meter. Revenue-quality meters also measure power and thermal energy production, providing 5-minute data points for system operations use and 15-minute averages for billing purposes.

The test campaign will determine the emissions performance, electrical performance, and electrical efficiency of MTG unit number 6 during a "controlled test period". A two-week "long-term monitoring period" will quantify the power production, recovered CHP thermal energy (heat) production, electrical efficiency, thermal efficiency, and total efficiency of the as-dispatched system.

1.1. PURPOSE

The New York State Energy Research and Development Authority (NYSERDA) and the U.S. Environmental Protection Agency (EPA) Environmental Technology Verification (ETV) program have commissioned this test campaign. Test results also are of interest to the ETV program because previous verifications have not included either the Elliott MTG or multi-microturbine arrays.

1.2. PARTICIPANTS, ROLES, AND RESPONSIBILITIES

Southern Research Institute (Southern) will manage the test campaign. Responsibilities include:

- test strategy development and documentation
- coordination and execution of all field testing, including:
  - installation, operation, and removal of emissions testing equipment
  - providing electrical power monitoring and datalogging equipment
  - subcontract management for installation and removal of electrical power monitors
- inspection of calibrations, performance of crosschecks, and other activities to verify the host facility's as-built sensors and monitoring equipment performance
- data validation, quality assurance and quality control (QA / QC), and reporting

OfficePower's installation at 110 East 59th Street in New York City will serve as the host facility. Southern will work closely with OfficePower personnel to ensure reasonable access to the host facility and minimal effects on the facility's normal operations.

Figure 1-1 lists test participants and their titles.

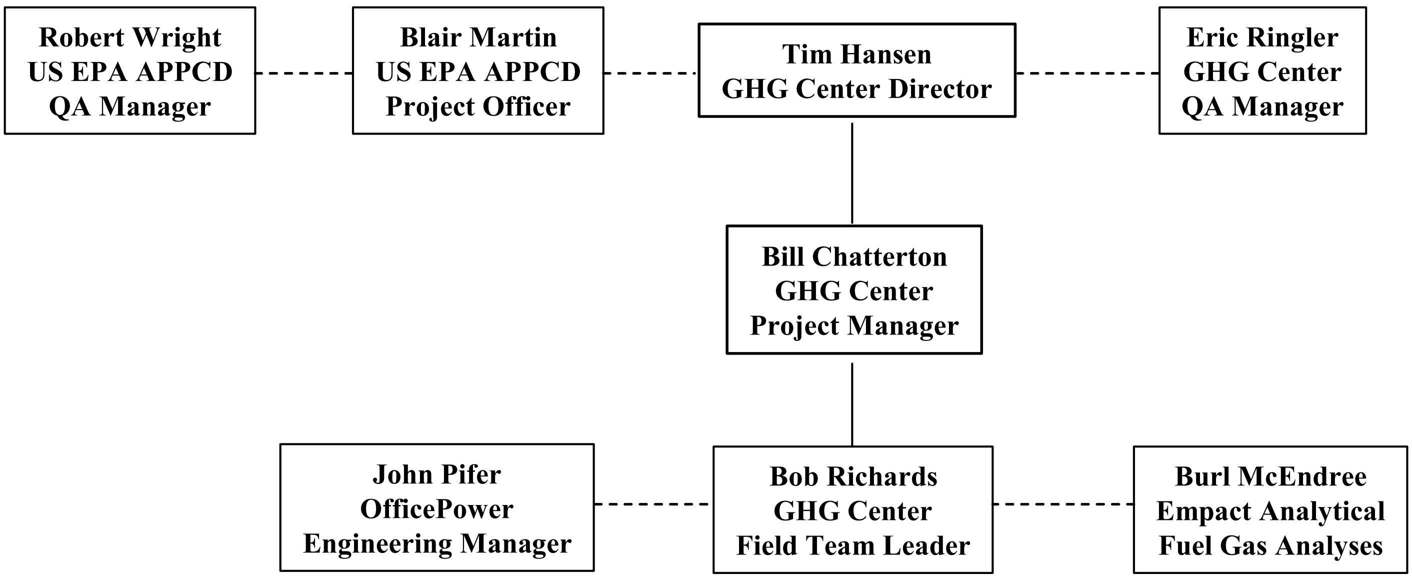

Figure 1-1. Test Participants

Tim Hansen is the GHG Center Director. He will:

- ensure the resources are available to complete this verification
- review the test plan and verification report to ensure they conform to ETV principles
- oversee GHG Center staff and provide management support where needed
- sign the verification statement, along with the EPA-ORD laboratory director.

Bill Chatterton will serve as the Project Manager for the GHG Center. He will have authority to suspend testing in response to health or safety issues or if data quality indicator goals are not met. His responsibilities also include:

- drafting the test plan and verification report
- overseeing the field team leader's data collection activities
- ensuring that data quality objectives (DQO) are met prior to completion of testing
- maintaining effective communications between all test participants

Bob Richards will serve as the Field Team Leader. He will:

- provide field support for activities related to all measurements and data collected
- install and operate the measurement instruments
- collect gas samples and coordinate sample analysis with the laboratory
- ensure that QA / QC procedures outlined in this test plan are followed
- submit all results to the Project Manager to facilitate his determination that DQOs are met

Southern's GHG Center QA Manager, Eric Ringler, is administratively independent from the GHG Center Director and the field testing staff. Mr. Ringler will:

- ensure that all verification tests are performed in compliance with the QA requirements of the GHG Center quality management plan, the generic protocol [1], and this test plan
- review the verification test results and ensure that applicable internal assessments are conducted as described in the test plan
- reconcile the DQOs at the conclusion of testing
- conduct or supervise an audit of data quality
- review and validate subcontractor-generated data
- report all internal reviews, DQO reconciliation, the audit of data quality, and any corrective action results directly to the GHG Center Director, who will provide copies to the project manager for corrective action as applicable and citation in the final verification report
- review and approve the final verification report and statement

Fuel gas analyses will be conducted by Empact Analytical of Brighton, Colorado under the management of Burl McEndree.

EPA-ORD will provide oversight and QA support for this verification. The APPCD Project Officer, Blair Martin, is responsible for obtaining final approval of the Test Plan and Report. The APPCD QA Manager will review this test plan and the final Report to ensure they meet the GHG Center Quality Management Plan requirements and represent sound scientific practices.

OfficePower will collect data during the long term monitoring period from the as-built host facility sensors and equipment. John Pifer of OfficePower will coordinate transfer of these data files.

1.3. TEST SCHEDULE

The host facility's electrical design normally requires that all eight MTG be in service to meet the expected demand. The design demand occurs during regular office hours. The automated control system normally shuts down most or all of the MTG on nights or weekends because of reduced thermal demand.

The controlled test runs will occur on unit 6 only. This means that the other 7 MTG must be shut down and not dispatched during the controlled test period. Normal dispatching will resume as soon as this test period is finished. Also, Southern will install MTG and parasitic load electric power monitoring equipment for use during the controlled test period. This will require de-energizing the electrical feed briefly during installation and removal.

Figure 1-2 shows the intended test schedule. OfficePower and Southern will specify the test dates upon completion of the installation and commissioning process.

Test Schedule

Day 1	Day 2	Day 3
Arrive at site Conduct orientation, safety, and other conferences Unpack Southern's test equipment, mobilize, and perform preliminary setups	Install exhaust duct test ports Install PEMS and accessory emissions test equipment Warmup PEMS and perform preliminary calibrations Prepare unit 6 and parasitic load electric power monitors for installation Install Ts, Tr cross-check sensors in building water line "Pete's plugs." Conduct Ts, Tr cross-checks during normal operations	De-energize unit 6 control and parasitic load cabinets Connect electric power monitors (use contract electrician, if required) Re-energize unit 6 and resume normal operations Perform all remaining cross-checks and review all site sensor calibrations Configure SCADA and verify data collection capability for controlled test and long-term monitoring periods

Day 4	Day 5
Withdraw both MTG arrays from normal dispatching and shut them down Start unit 6 and load it at 100 % of capacity Perform 3 controlled test runs, 1 hour each on unit 6 Collect natural gas samples, if required Verify data collection, permissible variations, pre- and post-test PEMS calibrations, etc. Remove unit 6 and parasitic load electric power monitors Restore normal dispatching	Begin 2-week long term monitoring period Remove and de mobilize all Southern's test equipment Pack for shipping and closeout

Figure 1-2. Test Schedule

2.0 TEST PROCEDURES

The ETV program has published the Distributed Generation and Combined Heat and Power Field Testing Protocol [1] (generic protocol). The generic protocol contains detailed test procedures, instrument specifications, analytical methods, and QA / QC procedures. This test campaign will generally conform to the generic protocol specifications, with modifications or special considerations as listed in the following subsections. Appendix A provides field data forms as derived from the generic protocol.

2.1. TEST CONCEPTS AND OBJECTIVES

The test campaign will proceed in two phases:

- controlled test period
- two-week long-term monitoring period

2.1.1. Controlled Test Period

Southern test personnel will be on-site during the controlled test period to perform the following determinations on MTG unit 6:

- electrical performance (see generic protocol §2.0 for parameters and specifications; Appendix D1 for definitions and equations)
- electrical efficiency (see generic protocol §3.0 for parameters and specifications; Appendix D2 for definitions and equations)
- gaseous carbon monoxide (CO), carbon dioxide (CO_2), nitrogen oxides (NO_X) and total hydrocarbons (THC) emissions performance (see generic protocol §5.0)

The controlled test period will consist of three (3) test runs, each one (1) hour long, while unit 6 operates at 100 percent capacity. The generic protocol also recommends testing at 25, 50, and 75 percent capacity, but the host facility is not designed for that capability.

Southern will coordinate the installation of independent electrical power analyzers on the unit 6 output bus and at the central parasitic load control cabinet. Parasitic loads include:

- glycol loop circulation pump
- cooling radiator fan
- booster compressors
- chiller loads (not yet installed)

The loads are likely to consume up to approximately 10 percent of the full array's power output. Figure 1 shows the instrument locations. The analyzers will record the electrical performance parameters at 1-minute intervals or shorter.

Southern will determine gaseous emissions as CO, CO_2, NO_X, and THC concentrations with a Horiba OBS-2200 portable emissions monitoring system. Test personnel will temporarily install the PEMS and two volumetric flow test ports on the unit 6 exhaust stack. They will conduct one Title 40 CFR 60 Appendix A, Method 2 volumetric flow traverse during each test run while the PEMS gathers emissions concentrations. The mean concentration for each gas, integrated with the mean volumetric flow rate will yield the gaseous emission rate in pounds per hour. Note that facility operators will set the unit 6 bypass damper to the bypass position during the controlled test period. CHP heat recovery data will be collected during long-term monitoring only.

Southern will log natural gas consumption data directly from the two utility revenue meters located in the building basement. Test personnel will collect natural gas samples for lower heating value (LHV) analysis.

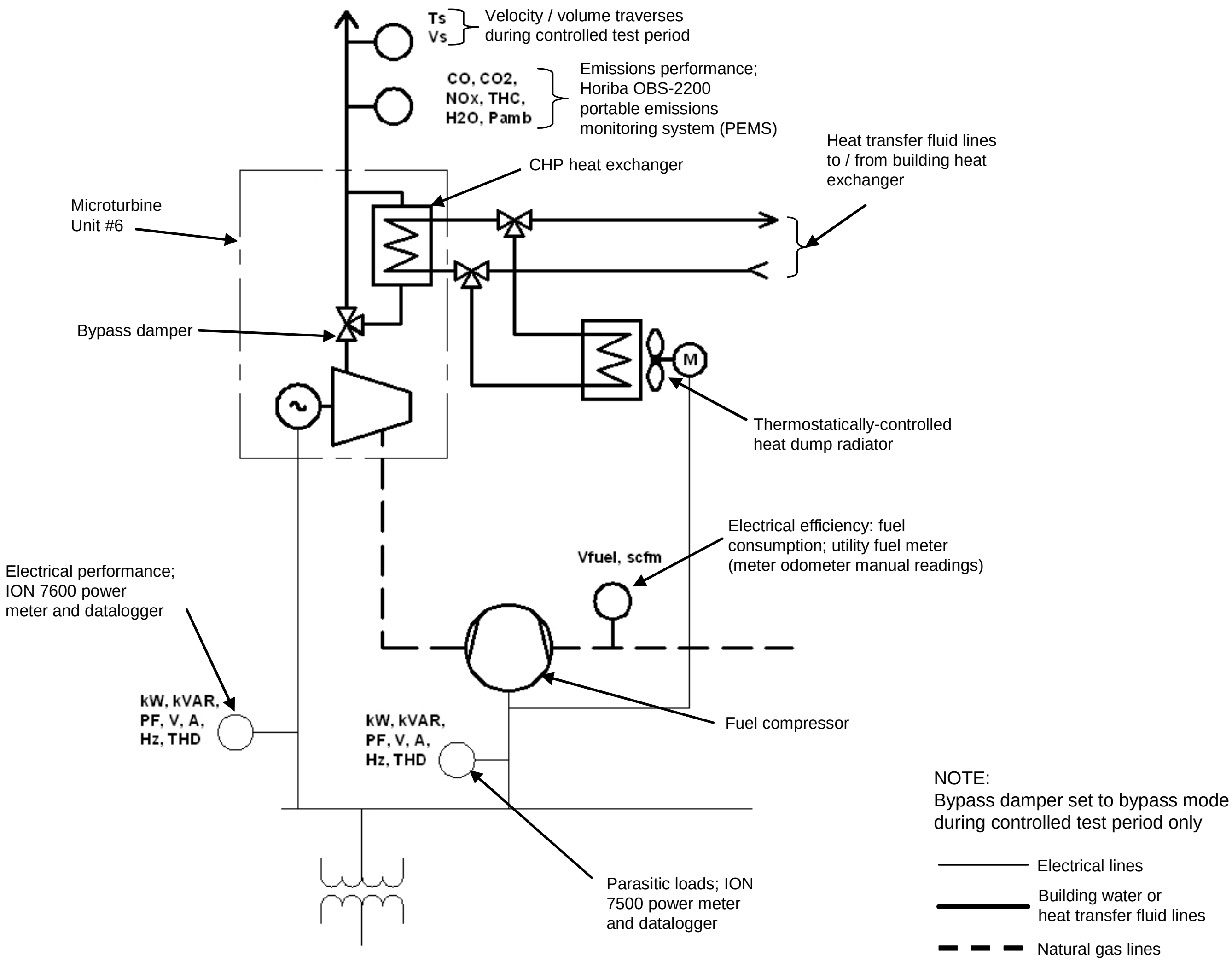

Figure 2-1. Controlled Test Instrument Locations

2.1.2. Long-term Monitoring Period

The long-term monitoring period will provide assessments of the following for the two banks of four MTG each:

- electric power production, net
- electrical efficiency
- CHP thermal performance (see generic protocol §4.0 for parameters and specifications, Appendix D3 for definitions and equations)

- CHP and total efficiency (see generic protocol Appendix D3 for definitions and equations)

The host facility has installed a well-designed suite of revenue service-capable power and thermal energy monitors with their associated sensors, signal conditioners, dataloggers, and support equipment. These meet the generic protocol accuracy and precision specifications for the electrical and heat recovery parameters of interest. The host facility supervisory control and data acquisition (SCADA) system is capable of recording the required parameters in MicroSoft Excel worksheet format with timestamps. NIST-traceable calibration certificates, manufacturer specifications, and independent cross checks to be performed by Southern (see §3.5) will support the use of data from these instruments. Figure 2 provides an instrument location schematic.

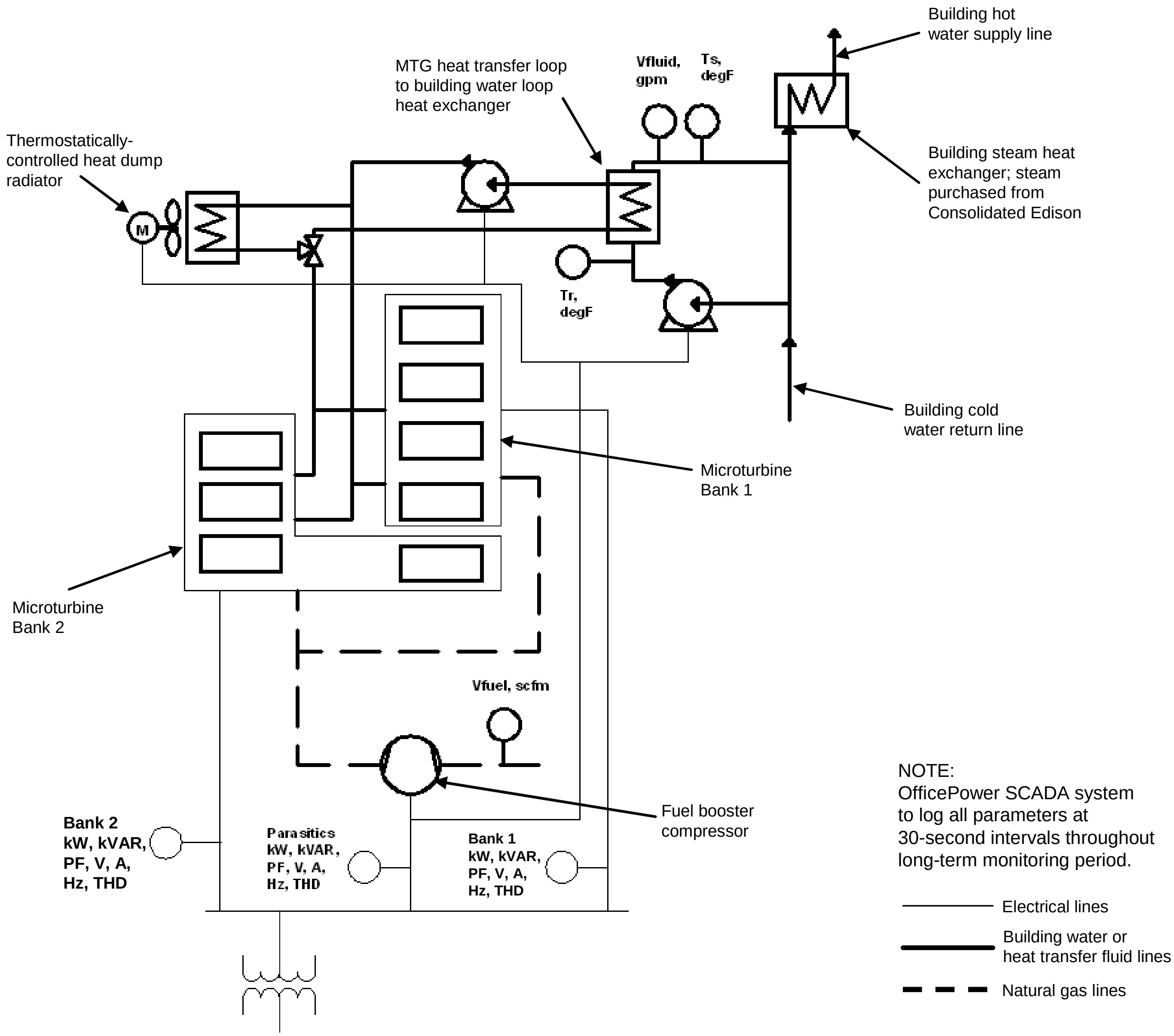

Figure 2-2. Long-Term Monitoring Instrument Locations

The electrical, thermal, and total efficiency determinations require fuel LHV data. Analysts will use the mean laboratory LHV results from the samples collected during the controlled test period for the efficiency calculation.

OfficePower representatives will configure the SCADA system to record the long-term monitoring data at five-minute intervals during normal daily operations. Table 2-1 provides a tag list and descriptions

Table 2-1. Long-Term Monitoring Tag List

Item	Description	Units	Tag_ID
1	Timestamp	mm/dd/yyyy hh:mm:ss	n/a
2	MTG array #1 energy production	kWh	WTA1
3	MTG array #2 energy production	kWh	WTA2
4	Building heat exchanger water flow rate	gpm	FGL
5	Building water supply temperature	°F	TGLS
6	Building water return temperature	°F	TGLR
7	Natural gas consumption, meter 1	scf	FGM1
8	Natural gas consumption, meter 2	scf	FGM2

2.1.3. Instrument Specifications

The generic protocol provides detailed specifications for all instruments or analyses. Table 2-2 provides a synopsis.

Table 2-2. Instrument and Analysis Accuracy Specifications[a]

Parameter	Accuracy
Voltage	± 0.5 %
Current	± 0.4 %
Real Power	± 0.6 %
Reactive power	± 1.5 %
Frequency	± 0.01 Hz
Power Factor	± 2.0 %
Voltage THD	± 5.0 %
Current THD	± 4.9 % to 360 Hz
CT	± 0.3 % at 60 Hz
CT	± 1.0 % at 360 Hz
Temperature	± 1 °F
Barometric pressure	± 0.1 in. Hg (± 0.05 psia)
Gas flow	± 1.0 %[b]
LHV analysis by ASTM D1945 [8] and D3588 [9]	± 1.0 %
Heat transfer fluid flow	± 1.0 %
T_{supply}, T_{return} temperature sensors	± 0.6 °F
Gaseous emissions concentrations	± 2.0 % of span[c]
Method 2 volumetric flow rate	± 5.0 %

[a]All accuracy specifications are percent of reading unless otherwise noted.
[b]Utility gas meter is temperature- and pressure-compensated.
[c]PEMS conforms to or exceeds Table 1 of Title 40 CFR 1065.915 specifications.

2.2. SITE-SPECIFIC CONSIDERATIONS

Section 6.0 of the generic protocol lists step-by-step procedures for the controlled test period. This subsection considers site-specific testing, safety, or other actions which the field team will implement. Appendix A of this test plan provides the necessary field data forms.

Emissions testing

Unit 6 has a ½" NPT male test port at the base of its exhaust stack. Southern will temporarily install the PEMS test probe at this port.

The vertical exhaust ducts have a 10" inner flue, 14" outer sheath, and 2" thick insulation. The volumetric flow traverses will require two ½" diameter test ports at the locations shown in Figure 2-3.

Test personnel will first temporarily secure a plank laid along the structural steel for staging. They will then remove the retaining clamp for access to the inner flue. The two ½" diameter holes for the test ports must be at 90^{o} around the circumference of the flue from each other. When tests are finished, test personnel will install a 10" diameter sheet metal clamp around the flue, sealing it with high-temperature gasket material. They will then re-install the retention clamp and remove the staging.

The staging will be approximately 12' above the floor level. Southern test personnel will wear safety harnesses and tethers secured to the structure while working at elevated heights.

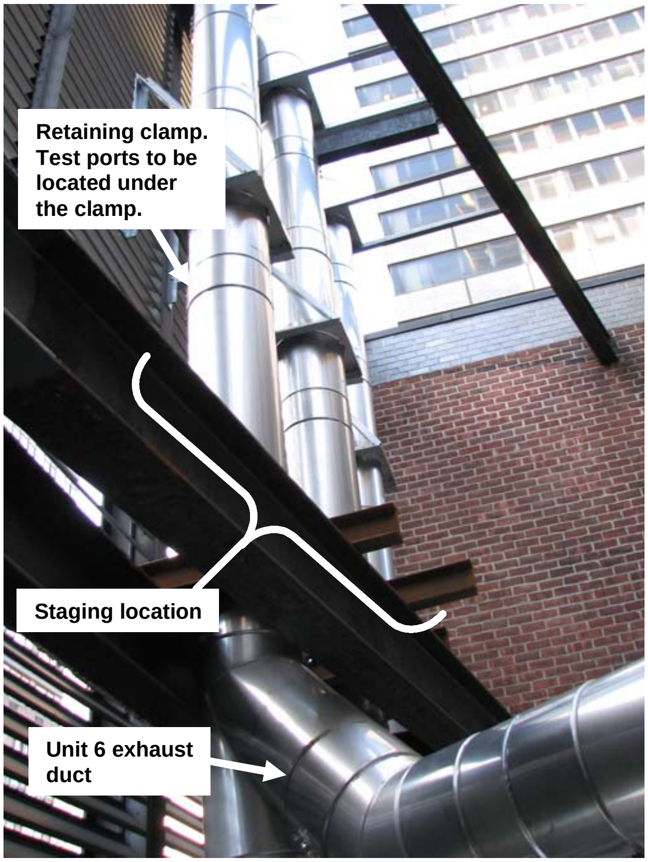

Figure 2-3. Volumetric Flow Testing Location

Electrical power monitors

Southern will coordinate the temporary installation of the unit 6 and parasitic load electric power monitors by a qualified electrician. The generic protocol, Figure F-1 of Appendix F2, provides a wiring schematic. Southern will provide the power monitors, shorting switches, current transmitters (CT), and miscellaneous supplies. These tests will employ split-core CTs which can be installed without disturbing the MTG bus conductors. The power meters will, however, require direct voltage connection to each phase. The MTG and parasitic load electrical feed must be shut down briefly during the connection procedure and while installing the CTs.

Natural gas sampling

Southern will collect at least three natural gas samples during the controlled test period and three additional samples at the end of the long-term monitoring period. The sampling location is on the MTG side of the fuel gas booster. Expected pressure is five pounds per square inch, gauge. Test personnel will connect an evacuated sample bottle to the sample port and purge it for at least 30 seconds prior to capping and sealing during each sampling event. Analysts will compare the mean LHV between the two sets of samples to evaluate potential changes in the gas supply. They will also use the mean LHV in the electrical and CHP efficiency determinations. Appendices A6 and A7 provide a sampling log and chain of custody form, respectively

Building water system supply and return temperature crosschecks

Section 3.1 describes the building supply and return temperature crosschecks. The supply and return pipelines incorporate the CHP heat recovery temperature sensors (see Figure 2-2). The building water piping includes 1/8" diameter "Pete's Plugs" adjacent to the as-built supply temperature (T_s) and return temperature (T_r) sensors. These self-sealing fittings allow insertion of check thermometers and other devices while the system remains under pressure. Test personnel will install 1/8" diameter platinum resistance temperature device (RTD) probes in these locations for the crosschecks.

3.0 DATA QUALITY

Southern operates the Greenhouse Gas Technology Center (GHG Center) for the U.S. Environmental Protection Agency's Environmental Technology Verification program. Southern's analysis and QA / QC procedures generally conform to the Quality Management Plan, Version 1.4, developed for the GHG Center.

3.1. DATA ACQUISITION

Test personnel will collect the following electronic data files:

- controlled test power output and power quality parameters (power meter number 1)
- controlled test parasitic loads (power meter number 2)
- controlled test emissions concentrations (PEMS)
- heat transfer fluid temperature crosschecks (datalogger)
- long-term monitoring period power output, parasitic loads, and fuel consumption (SCADA)

The two controlled test power meters will poll their sensors once per second. They will then calculate and record one-minute averages. The field team leader will download the one-minute data directly to a laptop computer during the short-term tests. The SCADA system will record each parameter at 5-minute intervals during the controlled test and long-term monitoring periods.

Test personnel will record printed or written documentation on the log forms provided in Appendix A, including:

- daily test log, including test run starting and ending times, notes, etc.
- appendix A forms which show the results of QA / QC checks
- copies of calibrations and manufacturers' certificates

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

3.2. DATA REVIEW, VALIDATION, AND VERIFICATION

The project manager will initiate the data review, validation, and analysis process. Analysts will employ the QA / QC criteria specified in §3.5 to classify all collected data as valid, suspect, or invalid.

In general, valid data results from measurements which:

- meet the specified QA / QC checks
- were collected when an instrument was verified as being properly calibrated
- are consistent with reasonable expectations, manufacturers' specifications, and 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 or laboratory deliverables,
- before writing the draft report -- by the project manager, and
- during draft report QA review and audits -- by the GHG Center QA Manager.

3.3. INSPECTION AND ACCEPTANCE OF SUPPLIES, CONSUMABLES, AND SERVICES

Procurement documents shall contain information clearly describing the item or service needed and the associated technical and quality requirements. Consumables for this verification will primarily consist of NIST-traceable calibration gases. Fuel analysis will be the only purchased service. The procurement documents will specify the QA / QC requirements for which the supplier is responsible and how conformance to those requirements will be verified.

Procurement documents shall be reviewed for accuracy and completeness by the project manager and QA manager. Appropriate measures will be established to ensure that the procured items and services satisfy all stated requirements and specifications.

3.4. DATA QUALITY OBJECTIVES

The generic protocol [1] provides the basis for the DQOs to be achieved in this verification. Previous DG / CHP verifications and peer-reviewed input from EPA and other stakeholders contributed to the development of those specifications. Tests which meet the following quantitative DQOs will provide an acceptable level of data quality to meet the needs of technology users and decision-makers.

Verification Parameter	DQO (relative uncertainty)
electrical performance as generated power	± 2.0 %
electrical efficiency	± 2.5 %
CHP thermal efficiency	± 3.5 %

Each test measurement that contributes to a verification parameter has stated measurement quality objectives (MQO) which, if met, ensure achievement of that parameter's DQO. Table 2-2 summarizes the generic protocol MQOs as accuracy specifications for each instrument or measurement.

The gaseous emissions DQO is qualitative in that this verification will produce emission rate data that satisfies the QA / QC requirements for EPA reference methods. The verification report will provide sufficient documentation of the QA / QC checks to evaluate whether the qualitative DQO was met.

The completeness goal for this verification is to obtain valid data for 90 percent of each controlled test period.

A fundamental component of all verifications is the reconciliation of the collected data with its DQO. The DQO reconciliation will consist of evaluation of whether the stated methods were followed, MQOs achieved, and overall accuracy is as specified in the generic protocol and this test plan. The field team leader and project manager will initially review the collected data to ensure that they are valid and are consistent with expectations. They will assess the data's accuracy and completeness as they relate to the stated QA / QC goals. If this review of the test data show that QA / QC goals were not met, then immediate corrective action 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 GHG Center QA Manager will include an assessment of DQO attainment.

3.5. CALIBRATIONS AND PERFORMANCE CHECKS

Sections 7.1 through 7.3 of the generic protocol specify a variety of technical system audits and QA / QC checks for the electrical performance, electrical efficiency, and CHP performance determinations. This test campaign will perform those that are applicable to the host facility. The final test report will cite the results for each QA / QC check.

In addition to the CHP data validation procedures cited in §7.3 of the generic protocol, Southern will conduct a cross-check of the building water supply and return temperature sensors. Test personnel will insert calibrated RTDs into the pipeline adjacent to the as-built sensors through self-sealing fittings. They will record steady-state temperature data from the SCADA display and RTDs at least once per minute for at least ten minutes while the MTG array is idle. The temperatures during normal, steady-state operations will also be recorded while the system is delivering CHP energy to the building. The mean steady-state temperatures should agree within ± 0.98 ^{o}F for each as-built temperature sensor and the adjacent RTD.

The electrical power monitoring equipment installed for the controlled test period will serve as a cross-check for the SCADA power instruments. Analysts will compare the electrical performance data logged from the two sources for each test run. Mean values, in general, should agree within approximately ± 2 percent for generated power and ± 7 percent for total harmonic distortion. If possible, OfficePower will dispatch the entire MTG array for at least ½ hour to enable comparisons at full power output.

The generic protocol specifies Title 40 CFR 60 Appendix A source test methods to determine gaseous pollutant emissions. This test campaign, however, will employ a Horiba OBS-2200 PEMS that meets Title 40 CFR 1065 [2] specifications. Southern will also deploy a Testo 350 multi-gas combustion analyzer as a backup instrument. Test personnel will conduct the technical system audits, calibrations, performance checks, and cross checks listed in Table 3-1.

Table 3-1. Recommended Calibrations and Performance Checks

System or Parameter	Description / Procedure	Frequency	Meets Spec.?	Date Completed
Pressure transducers	NIST-traceable[a] calibration	Within 12 months	☐	
Temperature transducers (T_{intake}, T_{exh})			☐	
All instrumental analyzers	11-point linearity check	Within 12 months	☐	
CO_2 (NDIR detectors)[b]	H_2O interference	Within 12 months	☐	
CO (NDIR detectors)	CO_2, H_2O interference		☐	
Hydrocarbon analyzer (FID)[c]	Propane (C_3H_8) calibration		☐	
	FID response optimization		☐	
	C_3H_8 / methyl radical (CH_3) response factor determination		☐	
	C_3H_8 / CH_3 response factor check		☐	
	Oxygen (O_2) interference check		☐	
NO_X analyzer	CO_2 and H_2O quench (CLD)[d]		☐	
NO_X analyzer	Non-methane hydrocarbons (NMHC) and H_2O interference (NDUV detectors)[e]	Within 12 months	☐	
	Ammonia interference and NO_2 response (zirconium dioxide		☐	

Table 3-1. Recommended Calibrations and Performance Checks

System or Parameter	Description / Procedure	Frequency	Meets Spec.?	Date Completed
	detectors)			
	Chiller NO_2 penetration (PEMS with chillers for sample moisture removal)		☐	
	NO_2 to NO converter efficiency	Within 6 months or immediately prior to departure for field tests	☐	
Complete PEMS	Comparison against laboratory CVS system	At purchase / installation; after major modifications	☐	
	Zero / span analyzers (zero ≤ ± 2.0 % of span, span ≤ ± 4.0 % of point)	Before and after each test run	Refer to Appendix A2, "Test Run Record"	
	Perform analyzer drift check (≤ ± 4.0 % of cal gas point)	After each test run		
	NMHC contamination check (≤ 2.0 % of expected conc. or ≤ 2 ppmv)	Once per test day		
	100 ppm CO cal gas crosscheck with Testo	At least once per test day		
Testo (if used)	Zero / span analyzers (zero ≤ ± 2.0 % of span, span ≤ ± 4.0 % of point)	Before and after each test run	☐	
	Perform analyzer drift check (≤ ± 4.0 % of cal gas point)	After each test run	☐	
	100 ppm CO cal gas crosscheck with PEMS	At least once per test day	☐	
Exhaust gas or intake air flow measurement device	Differential pressure line leak check (ΔP stable for 15 seconds at 3 "H_2O)	Once per test day	☐	

[a]National Institutes of Standards and Technology (NIST)
[b]non-dispersive infrared (NDIR)
[c]flame ionization detector (FID)
[d]chemilumenescence detector (CLD)
[e]non-dispersive ultra violet (NDUV)

3.6. AUDITS OF DATA QUALITY

The reported results will include many contributing measurements from numerous sources. Data processing will require different algorithms, formulae, and other procedures. Original datalogger ASCII text files, the host facility's SCADA system Excel-format file outputs, signed logbook entries, and signed field data forms will be the source for all Excel worksheets used as analysis tools. The GHG Center QA manager will:

- manually calculate each reported result based on ten percent of the raw data files, including the applicable engineering conversions
- compare the manually-calculated result with the worksheet file and the draft report
- in the event that errors are found, manually calculate a higher proportion of each reported result and resolve any problems.

3.7. INDEPENDENT REVIEW

The GHG Center QA manager will examine this test plan, the report text, and all test results. The analyst or author who produces a result table or text will submit it (and the associated raw data files) to him or to an independent technical or editorial reviewer. Reviewers will be Southern employees with different lines of management supervision and responsibility from those directly involved with test activities.

4.0 ANALYSIS AND REPORTS

The test report will summarize field activities and present results. Attachments will include sufficient raw data to support the findings and allow reviewers to assess data trends, completeness, and quality. The report will clearly characterize the test parameters, their results, and supporting measurements as determined during the test campaign. It will present raw data and analyses as tables, charts, or text as is best suited to the data type.

The report will group the results separately for the controlled test runs and long-term monitoring period. The long term monitoring period results will likely fall into three subgroups:

- both MTG arrays operating with eight units
- one MTG array operating with four units
- overall mean results including downtime

Reported results will include:

- run-specific mean, maximum, minimum, and standard deviation
- run-specific assessment of the permissible variations within the run for the controlled test period
- overall mean, maximum, minimum, and standard deviation for all valid test runs
- ambient conditions (temperature, barometric pressure) observed during each controlled test run and a comparison between the observed conditions and the standard conditions at which the manufacturer rated the DG (usually ISO standard of 60 ^{o}F, 14.696 psia)
- description of measurement instruments and a comparison of their accuracies with those specified in the generic protocol
- summary of data quality procedures, results of QA/QC checks, the achieved accuracy for each parameter, and the method for citing or calculating achieved accuracy
- copies of laboratory QA documentation, including calibration data sheets, duplicate analysis results, etc.
- results of data validation procedures including a summary of invalid data and the reasons for its invalidation
- information regarding any variations from the procedures specified in this test plan
- narrative description of the DG installation, site operations, and field test activities including observations of site details that may impact performance. These include thermal insulation presence, quality, mounting methods that may cause parasitic thermal loads etc.

The following subsections itemize the reported parameters. Appendix D of the generic protocol provides the relevant definitions and equations.

4.1. ELECTRICAL PERFORMANCE

The electrical performance test reports will include:

- total real power without external parasitic loads, kW
- total reactive power, kilo-volt-ampere reactive (kVAR)
- total power factor, percent

- voltage (for each phase and average of all three phases), volts (V)
- current (for each phase and average of all three phases), amperes (A)
- frequency, Hertz (Hz)
- Voltage total harmonic distortion (THD) (for each phase and average of all three phases), percent
- Current THD (for each phase and average of all three phases), percent
- apparent power consumption for the external parasitic loads, kilo-volt-amperes (kVA)
- total real power including debits from all external parasitic loads, kW

4.2. ELECTRICAL EFFICIENCY

Electrical efficiency test reports will include:

- electrical generation efficiency ($\eta_{e,LHV}$) without external parasitic loads
- electrical generation efficiency ($\eta_{e,LHV}$) including external parasitic loads
- heat rate (HR_{LHV}) without external parasitic loads
- heat rate (HR_{LHV}) including external parasitic loads
- total kW
- heat input, British thermal units per hour (Btu/h) at a given electrical power output
- fuel input, standard cubic feet per hour (scfh)

The report will quote all laboratory analyses for the fuel LHV in British thermal units per standard cubic foot (Btu/scf).

Note that electrical generation efficiency uncertainty should be reported in absolute terms. For example, if $\eta_{e,LHV}$ for gaseous fuel is 26.0 percent and all measurements meet the accuracy specifications, the relative error is ± 3.0 percent (see generic protocol Table 7-4). The absolute error is 26.0 times 0.030, or ± 0.78 percent. The report, then, should state $\eta_{e,LHV}$ as "26.0 ± 0.8 percent". This will prevent confusion because, for efficiency, both relative and absolute errors can be reported as percentages.

4.3. CHP THERMAL PERFORMANCE

The thermal performance report for the CHP system in heating service will include:

- actual thermal performance (Q_{out}), Btu/h
- actual thermal efficiency ($\eta_{th,LHV}$)
- actual total system efficiency ($\eta_{tot,LHV}$)
- heat transfer fluid supply and return temperatures, degrees Fahrenheit (^{o}F), and flow rates, gallons per minute (gpm) for each heat transfer fluid loop measured

The report will cite η_{th} and η_{tot} and their achieved accuracies in absolute terms because efficiency and relative accuracies are both percentages. Refer to the previous subsection for a discussion on avoiding potential confusion due to terminology.

4.4. ATMOSPHERIC EMISSIONS

Reported parameters for each test run will include the following:

- emission concentrations for carbon monoxide (CO), nitrogen oxides (NO_X), and total hydrocarbons (THC) evaluated in volume parts per million (ppmv) corrected to 15 percent O_2
- emission concentration for carbon dioxide (CO_2) corrected to 15 percent O_2
  - Note: the correction equation is:

$$c_{corr} = c_i \left[\frac{20.9 - 15}{20.9 - O_2} \right]$$

Where:

c_{corr} = concentration corrected to 15 percent O_2, ppmv or percent
c_i = mean concentration of the constituent i, ppmv or percent
20.9 = atmospheric O_2 content, percent
O_2 = mean exhaust gas O_2 content, percent

- emission rates for CO, CO_2, NO_X, and THC evaluated as lb/hr and lb/kWh electrical generation
- exhaust gas dry standard flow rate, actual flow rate, and temperature
- exhaust gas composition, moisture content, and molecular weight

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5.0 REFERENCES

[1] *Generic Verification Protocol -- Distributed Generation and Combined Heat and Power Field Testing Protocol, Version 1.0*, SRI/USEPA-GHG-GVP-04, Southern Research Institute and US EPA Environmental Technology Verification (ETV) Program, available at: <http://www.epa.gov/etv/pubs/sriusepaghggvp04.pdf>, Washington, DC 2005

[2] *Engine-Testing Procedures*, Title 40 CFR 1065, Environmental Protection Agency, Washington, DC, adopted at 70 FR 40410, 13 July, 2005

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Appendix A
Field Data Forms

Appendix A1: Distributed Generator Installation Data

Project Name: OfficePower Date: ____________________

Compiled by: (Company) __________________________ Signature: ______________________________

Site Information

Address 1: _____________________________ Owner Company: _______________________________

Address 2: _____________________________ Contact Person: _______________________________

City, State, Zip: _________________________ Address (if different): ___________________________

Op'r or Technician: ______________________ Company Phone: _______________ Fax: __________

Site Phone: _____________________________ Utility Name: Consolidated Edison

Modem Phone (if used): __________________ Contact Person: _______________________________

Altitude 247 (feet) Utility Phone: _________________________________

Installation (check one): Indoor__ Outdoor__ Utility Enclosure__ Other (describe)______________________

Sketch of HVAC systems attached (if Indoor) ______ Controls: Continuous ____Thermostatic____Other__

Primary Configuration, Service Mode, and CHP Application
(check all that apply; indicate secondary power and CHP application information with an asterisk, *)

Delta		Wye		Grounded Wye	
Single Phase		Three Phase			
Inverter		Induction		Synchronous	
Grid Parallel		Grid Independent		Peak Shaving	
Demand Management		Prime Power		Load Following	
		Backup Power		VAR Support	
Hot water		Steam		Direct-fired chiller	
Indirect chiller		Other DG or CHP (describe)			

Site Description
(Check one)

Hospital	
University	
Resident'l	
Industrial	
Utility	
Hotel	
Other (desc.)	
Office building	

Fuel
(Check one)

Nat'l Gas	X
Biogas	
Landfill G	
Diesel #2	
Other (desc.)	

Generator Nameplate Data

Date: _____________Local Time (24-hour): ____________ Hour meter: ___________

Commissioning Date: ___________

Manufacturer: ____________________ Model: __________________ Serial #: __________________

Prime mover (check one): IC generator_____ MTG _____

Range: ____ to ____ (kW; kVA) Adjustable? (y/n) ____Power Factor Range: ___ to ___ Adjustable? (y/n) ____

Nameplate Voltage (phase/phase): ______ Amperes: _____Frequency: _______ Hz

Controller (check one): factory integrated _____ 3rd-party installed _____ custom (describe)_________________

Appendix A1: Distributed Generator Installation Data (cont.)

CHP Nameplate Data

BoP Heat Transfer Fluid Loop

Describe: ____

Nominal Capacity: ________ (Btu/h) Supply Temp. ______ (°F) Return Temp. ______ (°F)

Low Grade Heat loop

Describe: ____

Nominal Capacity: ________ (Btu/h) Supply Temp. ______ (°F) Return Temp. ______ (°F)

Chilling loop

Describe: ____

Nominal Capacity: ________ (Btu/h) Supply Temp. ______ (°F) Return Temp. ______ (°F)

Other loop(s): Describe: ____

Nominal Capacity: ________ (Btu/h) Supply Temp. ______ (°F) Return Temp. ______ (°F)

Parasitic Loads

Enter nameplate horsepower and estimated power consumption. Check whether internal or external. Internal parasitic loads are on the DG-side of the power meter. External parasitic loads are connected outside the system such that the power meter does not measure their effects on net DG power generation.

Description	Name-plate Hp	Est. kVA or kW	Internal (✓)	External (✓)	Function[a]
Fuel Gas Compressor					
CHP Heat Transfer Fluid Pump – Hot Fluid					
CHP Heat Transfer Fluid Pump - Low Grade					
CHP Heat Transfer Fluid Pump - Chilling					
Fans (describe)					
Other: Transformers, etc. (describe)					

[a]Describe the equipment function. Also note whether the equipment serves multiple units or is dedicated to the test DG.

Appendix A2. Power Meter Commissioning Procedure

1. Obtain and read the power meter installation and setup manual. It is the source of the items outlined below and is the reference for detailed information.
2. Verify that the power meter calibration certificate, CT manufacturer's accuracy certification, supplementary instrument calibration certificates, and supporting data are on hand.
3. Mount the power meter in a well-ventilated location free of moisture, oil, dust, corrosive vapors, and excessive temperatures.
4. Mount the ambient temperature sensor near to but outside the direct air flow to the DG combustion air inlet plenum but in a location that is representative of the inlet air. Shield it from solar and ambient radiation.
5. Mount the ambient pressure sensor near the DG but outside any forced air flows. Note: This test will use the Horiba OBS-2200 ambient pressure sensor.
6. Ensure that the fuel consumption metering scheme is in place and functioning properly.
7. Verify that the power meter supply source is appropriate for the meter (usually 110 VAC) with the DVM and is protected by a switch or circuit breaker.
8. Connect the ground terminal (usually the "Vref" terminal) directly to the switchgear earth ground with a dedicated AWG 12 gauge wire or larger. Refer to the manual for specific instructions.
9. Choose the proper CTs for the application. Install them on the phase conductors and connect them to the power meter through a shorting switch to the proper meter terminals. Be sure to properly tighten the phase conductor or busbar fittings after installing solid-core CTs.
10. Install the voltage sensing leads to each phase in turn. Connect them to the power meter terminals through individual fuses.
11. Trace or color code each CT and voltage circuit to ensure that they go to the proper meter terminals. Each CT must match its corresponding voltage lead. For example, connect the CT for phase A to meter terminals I_{A1} and I_{A2} and connect the voltage lead for phase A to meter terminal V_A.
12. Energize the power meter and the DG power circuits in turn. Observe the power meter display (if present), datalogger output, and personal computer (PC) display while energizing the DG power circuits.
13. Perform the power meter sensor function checks. Use the DVM to measure each phase voltage and current. Acquire at least five separate voltage and current readings for each phase. Enter the data on the Power Meter Sensor Function Checks form and compare with the power meter output as displayed on the datalogger output (or PC display), power meter display (if present), and logged data files. All power meter voltage readings must be within 2% of the corresponding digital volt meter (DVM) reading. All power meter current readings must be within 3% of the corresponding DVM reading.
14. Verify that the power meter is properly logging and storing data by downloading data to the PC and reviewing it.

Appendix A2a. Power Meter Sensor Function Checks

Project Name: Office Power Location (city, state): New York City, NY

Date:__________ Signature:__________

DUT Description: Elliott microturbine, Unit #6; Power output

Nameplate kW: 100 Expected max. kW: 100

Type (delta, wye): Wye Voltage, Line/Line: 480 Line/Neutral: 277

Power Meter Mfr:__________ Model:__________ Serial No.: __________

Last NIST Cal. Date: __________

Current (at expected max. kW): 121 Conductor type & size:__________

Current Transformer (CT) Mfg: FlexCore Model: 606-401

CT Accuracy: (0.3 %, other): __________ Ratio (100:5, 200:5, other): 400:5

Sensor Function Checks

Note: Acquire at least five separate readings for each phase. All power meter voltage readings must be within 2% of the corresponding digital volt meter (DVM) reading. $\%Diff = ([PowerMeter/DVM] - 1) * 100$

Voltage											
Date	Time (24 hr)	Phase A			Phase B			Phase C			
		Power Meter	DVM	%Diff	Power Meter	DVM	%Diff	Power Meter	DVM	%Diff	

Note: Acquire at least five separate readings for each phase. All power meter current readings must be within 3% of the corresponding DVM reading.

Current										
Date	Time (24 hr)	Phase A			Phase B			Phase C		
		Power Meter	DVM	%Diff	Power Meter	DVM	%Diff	Power Meter	DVM	%Diff

Appendix A2b. Power Meter Sensor Function Checks

Project Name: Office Power Location (city, state): New York City, NY

Date:__________ Signature:__________

DUT Description: Elliott microturbine, Unit #6; Parasitic loads

Nameplate kW:__________ Expected max. kW:__________

Type (delta, wye): Wye Voltage, Line/Line: 480 Line/Neutral: 277

Power Meter Mfr:__________ Model:__________ Serial No.: __________

Last NIST Cal. Date: __________

Current (at expected max. kW): 40 Conductor type & size:__________

Current Transformer (CT) Mfg: FlexCore Model: 606-201

CT Accuracy: (0.3 %, other): 0.2 % Ratio (100:5, 200:5, other): 200:5

Sensor Function Checks

Note: Acquire at least five separate readings for each phase. All power meter voltage readings must be within 2% of the corresponding digital volt meter (DVM) reading. $\%Diff = ([PowerMeter/DVM] - 1) * 100$

Voltage										
Date	Time (24 hr)	Phase A			Phase B			Phase C		
		Power Meter	DVM	%Diff	Power Meter	DVM	%Diff	Power Meter	DVM	%Diff

Note: Acquire at least five separate readings for each phase. All power meter current readings must be within 3% of the corresponding DVM reading.

Current										
Date	Time (24 hr)	Phase A			Phase B			Phase C		
		Power Meter	DVM	%Diff	Power Meter	DVM	%Diff	Power Meter	DVM	%Diff

Appendix A3. Method 2 Exhaust Gas Flow Rate Data Form

Proj_ID: OfficePower Test_ID: CntrlTest Equip_ID: _Unit_6_Description: Elliott 100 kW MTG

Name (printed): ________________________________ Signature: ________________________________

Date: __________ Time: ______________ Run_ID: ____________ Notch: ___________

Elevation_247ft_ Ambient P_{bar} (psia)______ Stack Static P_g (psia) ________ Stack Abs. P_s (psia) ______

Duct dimensions: Round ID: __10"_____

Rectangular; L:______ W: _______

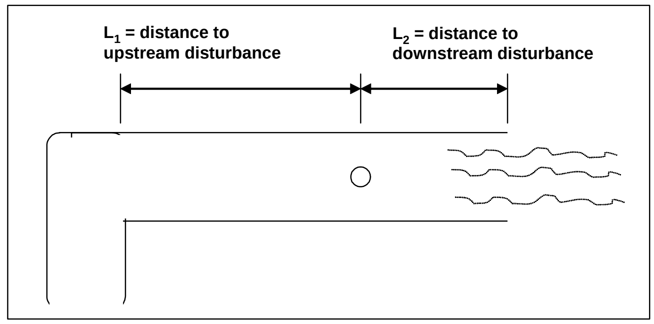
$D_{equivalent}$: ___0.833 ft_ Note: $D_{eq} = \frac{2LW}{L+W}$

L_1: ____15 ft__; diameters: ___18

L_2: ____5'___; diameters: __6____

Pitot ID#: ________ Coefficient (C_p): ______

Last calibration (date): ___________________



Conduct a total of three complete traverses at each notch and one idle setting during the baseline and candidate tests. Fax completed data sheets to Southern for data entry at 919.806.2306.

Index	ΔP, "H_2O	Sqrt(ΔP)	Cyclonic Angle, °	Temperature °F / °C	T_s (Temp. + 460)
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					
11					
12					
	Mean			Mean	

Notes:

____

____

Appendix A4. Horiba OBS-2200 Test Run Record

Project Name: OfficePower Test_ID: CntrlTest Date: ____________

Site_ID: 110 E. 59th Street Equip_ID: __Unit_6__________ Run_ID: ________

Name (printed): ______________________________ Signature: ______________________________

PEMS S/N:__________ Last 11-point Calibration Date: __________ Filename: ____________________

Test Run Host facility operator name: ____________________________________

Start time (hh:mm:ss; use 24-hour clock): ______________ End time: _______________

Describe ambient conditions: ____

Wind speed (estimate): ____________ Direction: ______________ ☐ Fair ☐ Overcast ☐ Precipitation

IMPORTANT: Refer to the OBS-2200 "..._b.csv" worksheets after each test run for the following entries. Cell references are provided.
Enter "✓" if a parameter is acceptable, "Fail" if it is unacceptable. Discuss all "Fail" entries and indicate whether the run is invalid because of them in the Notes below.

PEMS Zero and Span Drift Checks					
Analyte	**Cal. Gas Value and Span (ppmv or %)**	**2 % of Span**	**✓ if Zero drift OK (≤ ± 2 % of span Cells I3 : I6)**	**4 % of Span**	**✓ if Span drift OK (≤ ± 4 % of span Cells J3 : J6)**
CO					
CO_2					
THC					
NO_X					

Parameter	**Criteria**		**✓ if OK**
Allowable ambient temperature range (see _b.csv worksheet Cells M16 : EOF)	within ± 10 °F (6 °C) for T_{amb} ≤ 80 °F (27 °C)		
	within ± 5 °F (3 °C) for T_{amb} > 80 °F (27 °C)		
Allowable barometric pressure range (see _b.csv worksheet Cells N16 : EOF)	within ± 1" Hg (3.4 kPa)		
Allowable "Hangup" (NMHC contamination) (see _b.csv worksheet Cell Z5)	Enter expected THC concentration, ppmv as C		
	Enter 2 % of expected concentration		
	"Hangup must be < 2 % of expected concentration		

NMHC contamination and background check ≤ 2ppmv or ≤ 2 % of conc. ΔP line leak check must be stable for 15 seconds at 3" H_2O. Mean P_{bar} within ± 1.0" Hg of mean for all test runs. Mean T_{amb} within ± 10 °F of mean for all test runs if T_{amb} is < 80 °F. Mean T_{amb} within ± 5 °F of mean for all test runs if T_{amb} is ≥ 80 °F. Drift = (Post-test span minus Pre-test span); must be ≤ 4.0 %.

Notes: ____

Appendix A5: Load Test Run Log

Project Name: Office Power ________ Location (city, state): New York City, NY

Date:__________________ Signature:__________________

SUT Description: Elliott 100 kW MTG ________ Run ID:________ Load Setting: %_____ kW_____

Clock synchronization performed (Initials):_________ Run Start Time:_____ End Time:________

Data file names/locations (incl. path): File:__________________

IMPORTANT: For ambient temperature and pressure, record one set of readings at the beginning and one at the end of each test run. Also record at least two sets of readings at evenly spaced times throughout the test run.

B3-1. Ambient Temperature and Pressure			
Time (24-hr)	**Amb. Temperature, °F**	**Ambient Pressure**	
		" Hg	**PSIA = " Hg * 0.491**
Average			

Permissible Variations

1. Each observation of the variables below should differ from the average of all observations by less than the maximum permissible variation.
2. Acquire kW and Power Factor data from the power meter data file at the end of the test run. Transfer fuel flow data from the Fuel Flow Log form. Obtain ambient temperature and pressure from Table A3-2 below. Obtain gas temperature and pressure from Appendix B4.
3. Choose the maximum or minimum with the largest difference compared to the average for each value.
4. Use the maximum or minimum to calculate the %Diff for kW, Power Factor, Fuel Flow, and Ambient Pressure:

$$\%Diff = \left({}^{(MaxorMin)-Average}\!/_{Average} \right) * 100 \qquad \text{Eqn. B3-1}$$

5. For Ambient Temperature, *Difference = (Max or Min)-Average*

Variable	Average	Maximum	Minimum	%Diff or Difference	Acceptable? (see below)
Ambient air temperature					
Ambient pressure					
Fuel flow					
Power factor					
Power output (kW)					
Gas pressure					
Gas temperature					

Permissible Variations		
Measured Parameter	**MTG Allowed Range**	**IC Generator Allowed Range**
Ambient air temperature	± 4 °F	± 5 °F
Ambient pressure (barometric station pressure)	± 0.5 %	± 1.0 %
Fuel flow	± 2.0 %[a]	n/a
Power factor	± 2.0 %	n/a
Power output (kW)	± 2.0 %	± 5.0 %
Gas pressure	n/a	± 2.0 %[b]
Gas temperature	n/a	± 5 °F[b]
[a]Not applicable for liquid-fueled applications < 30 kW. [b]Gas-fired units only		

Appendix A6: Fuel Consumption Determination

Project Name:	Office Power		Location (city, state):	New York, NY	
Date:			Signature:		
Test Description:	Elliott MTG	Run_ID:		Load, % or kW:	
Meter A Mfg:		Model:		S/N:	
Meter B Mfg:		Model:		S/N:	

This procedure assumes that each of the two gas meters (Meter A and Meter B) run at approximately the same rate, or about 10 standard cubic feet per minute (scfm). Collection of readings every 50 scf will allow about 5 minutes between readings at each meter. This will allow the observer to alternate between the two meters with reasonable confidence.

1. Start the test run by logging an initial gas meter reading and the exact time of day to 0.1 seconds. Start with Meter A. The initial reading consists of the last 3 or 4 odometer digits. The last digit to the right on the meter reads as "0.1" Ccf, or 1/10 of 100 scf. This means that each integer reading amounts to 10 scf. The odometer wheel to the right of the last digit has a hash mark which, when it pass by the scale arrow, indicates the exact instant of the integer reading. Log that time of day by holding a timepiece next to the odometer and watching for the hash mark. Try to be as consistent as possible in determining where the hash mark crosses the scale arrow.
2. Add 0.5 (or 50 scf) to the initial Meter A odometer reading. This will be the reading at which to collect the second time of day. Fill in the rest of the Meter A odometer columns (at least 9 entries) in 0.5 increments.
3. About 2 minutes after collecting the initial Meter A readings, collect the same data from Meter B. Fill in the Meter B odometer columns similar to Meter A.
4. About 5 minutes after collecting the initial Meter A readings, watch its odometer for the odometer reading you entered at step 2. Record the exact time of day.
5. About 5 minutes after collecting the initial Meter B readings, watch its odometer for the odometer reading you entered at step 2. Record the exact time of day.
6. Continue until at least 9 complete readings have been collected from each meter.
9. Perform the calculations as indicated. Calculate the total elapsed time as the difference between the final and initial times or as the sum of the elapsed times. Calculate and enter the total rate in standard cubic feet per minute (scfm) for each of the 3 test runs onto Appendix AXX. Maximum permissible variation for all three runs is ± 2.0 %.

	Meter A			**Meter B**		
Ref. (n)	**Odometer** (scf)	**Time**	**Elapsed** ($Time_n$ - $Time_{n-1}$)	**Odometer** (scf)	**Time**	**Elapsed** ($Time_n$ - $Time_{n-1}$)
1						
2						
3						
4						
5						
6						
7						
8						
9						
	Tot.Used (Final-Initial)	**Total elapsed, mm:ss**		**Tot.Used (Final-Initial)**	**Total elapsed, mm:ss**	
		Total elapsed, decimal minutes			**Total elapsed, decimal minutes**	
	Rate A, scfm (Tot.used/dec.min.)		**Rate B, scfm** (Tot.used/dec.min.)		**Rate Tot, scfm** (RateA + RateB)	

Appendix A7: Fuel Sampling Log

IMPORTANT: Use separate sampling log and Chain of Custody forms for each sample type (gas fuel, liquid fuel, heat transfer fluid).

Project Name:___OfficePower___________________ Location (city, state):_____New York City, NY

Date:____ Signature:_____________________________________

SUT Description:________MTG array_____________ Run ID:_________ Load Setting: %_____ kW_____

Fuel Source (pipeline, digester):___pipeline_________________

Sample Type (gas fuel, liquid fuel, heat transfer fluid): ___________gas fuel________________________

Fuel Type (natural gas, biogas, diesel, etc.):___________________natural gas__________________________

Note: Obtain fuel gas sample pressure and temperature from gas meter pressure and temperature sensors or sampling equipment.

Gas Fuel Samples						
Date	**24-hr Time**	**Run ID**	**Canister ID**	**Initial Vacuum, "Hg**	**Sample Pressure (from gas meter pressure sensor or sampling train pressure gage)**	**Sample Temperature (from gas meter temperature sensor or estimated)**

Appendix A8: Sample Chain-of-Custody Record

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

Project Name: Office Power Location (city, state): New York City, NY

Test Manager/Contractor Southern Research Institute Phone: 919.282.1050 Fax: 919.282.1060

Address: 5201 International Drive City,State / Zip: Durham, NC 27712

Originator's signature:________________ Unit description: MTG array

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

Laboratory: Empact Analytical Phone: 303.637.0150 Fax: 303.637.7512

Address: 365 S. Main City: Brighton State: CO Zip: 80601

Sample ID	Bottle/Canister ID	Sample Pressure	Sample Temp. or T_{Avg}, (°F)	Analyses Req'd
				ASTM D1945, D3588

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 B
Elliott Microturbine Specifications

ELLIOTT MICROTURBINES

100 kW CHP Microturbine

Elliott Energy Systems, Inc. has been designing and supplying microturbines since 1997. Our experience has made us a leader in microturbine technology. Located in Stuart, Florida, USA,

The TA100 CHP is packaged as an efficient combined heat and power (CHP) genset. Our Microturbine CHP system is capable of producing 100kW of electrical energy and 172kW of thermal power per hour. Cogeneration usage can consist of hot water, absorption chiller or drying system applications. Depending upon the user application, overall total thermal efficiency could be greater than 75%.

Main Features:

Rated Power Output

Electrical	100 kW @ 0.8PF at 59ºF/ 15ºC, Sea Level
Thermal	172 kW/ 587,000 BTU/ hr
Noise	Outdoor <62 dBA @ 10 m Indoor <75 dBA @ 1 m

Electrical Data

Parallel Ready

Voltage Output	400/ 480 VAC
Amps	200 Max
Frequency	50/ 60 Hz
Output Circuit	4-Wire Wye
Operating Mode	Island & Grid Connect)

Standard Equipment:

- Integral Gas Compressor
- Integral Heat Recovery Unit (Stainless Tube & Copper Fin)
- Remote Interface RS485/ Modbus
- Automatic Voltage Regulation
- Battery Charger
- Single Stage Dry Type Air Filter
- Corrosion Resistant Hardware
- Digital LCD Touch Panel
- System Protection Including:
  - Under and Over Voltage
  - Under and Over Frequency
  - Over Current, Over Temperature
- Optional Outdoor Kit (NEMA 3R, IP 44)
- Battery Start
- CE Certified

* Photo is shown with exhaust flange.

Compressor
The compressor is a rugged stainless steel radial flow design. The approximate pressure ratio is 4 to 1.

Combustor
Combustor is designed with the aid of advanced computational fluid dynamics capabilities and precision tested with high accuracy flow systems to provide reliable starting, robust operation during onload/ offload, extended life, and low NOx and CO over the entire operating range.

High Speed Alternator
The electric power is generated through a 4 pole, permanent magnet alternator rotating within an oil cooled stator assembly. The stator assembly is energized as a motor during initial start-up reducing the need for auxiliary starting hardware.

Turbine
The radial super-alloy turbine provides design margin and long life capability to provide energy to drive both the compressor alternator.

Heat Exchanger
The heat exchanger is an air to liquid tube and fin counter current flow design, fired by the exhaust gas. The tube and fin materials have been selected to provide long life, maximum thermal energy recovery and allows for potable water applications. The outlet liquid temperature is dependent upon inlet liquid temperature and liquid flow.

Power Electronics
The output from the alternator is converted into 480 or 400 VAC, 60 or 50 Hz, depending upon the needs of the end-user.

Control System
The control system provides automatic control of the CHP System, Turbine and Engine protection features as well as complete control of engine, starting, speed, safety systems , and outside communications.

Conforms to:

- UL Standard 2200
- UL Standard 1741
- EU Directive 90/396/EEC

CE 0063 /07

INTERTEK ETL LISTED US

 EESI #51 Rev. 3

Appendix B, Continued
Elliott Microturbine Specifications

TA100 CHP Specifications

Performance:
Electrical Output
Output (@ ISO) 100 kW net
105 kW gross
Maximum Block Loading 100%
Minimum Load 0kW
Efficiency* 29% (+/- 1) LHV
THD < 3%
Voltage Regulation +/- 2%

Fuel Consumption (ISO Rated Power)
Natural Gas: 22 SCFM/
0.62 m^3/min
(940 BTU/ SCF)
362 kW (@ 1,235,000 Btu/ hr.) LHV
Heat Rate 12,355 BTU/ kWh

Thermal Output (Hot water)
172 kW / 587,000 Btu/ hr.
Water Inlet Temp 120ºF / 49ºC
Water Outlet Temp 140ºF / 60ºC
Flow 60 GPM/ 3.8 L/s
Total System Efficiency* >75%
* Not Including Gas Compressor

Engine
Manufacturer Elliott Energy Systems
Model TA-100 CHP
Type Recuperated Gas Turbine
Pressure Ratio 4 to 1

Cooling System
Alternator Oil Cooled
Power Electronics Air Cooled
Enclosure 2,400 CFM/ 1.13 m^3/s

Exhaust System
Outlet Size 10" Diameter
Max. Back Pressure 5" water column
1.2 kPa
Exhaust Gas Flow 1,500 SCFM
0.71 Nm^3/s

Fuel
Fuel Type Natural Gas
Pressure Required 0.5 - 5 PSIG
3.4 - 34.5 kPa

Oil System
Oil Type Mobil SHC 824
Capacity 5 US gal. (19 L)
Oil Filter Spin On Type, 3 Micron

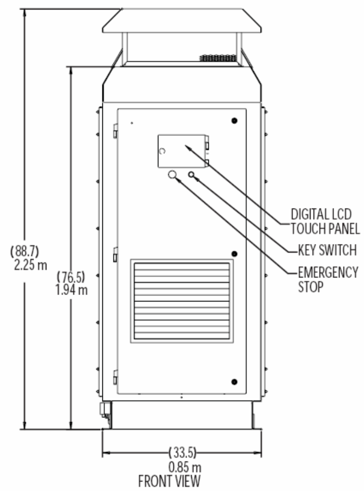
* All figures at ISO 59ºF/ 15ºC unless otherwise noted.

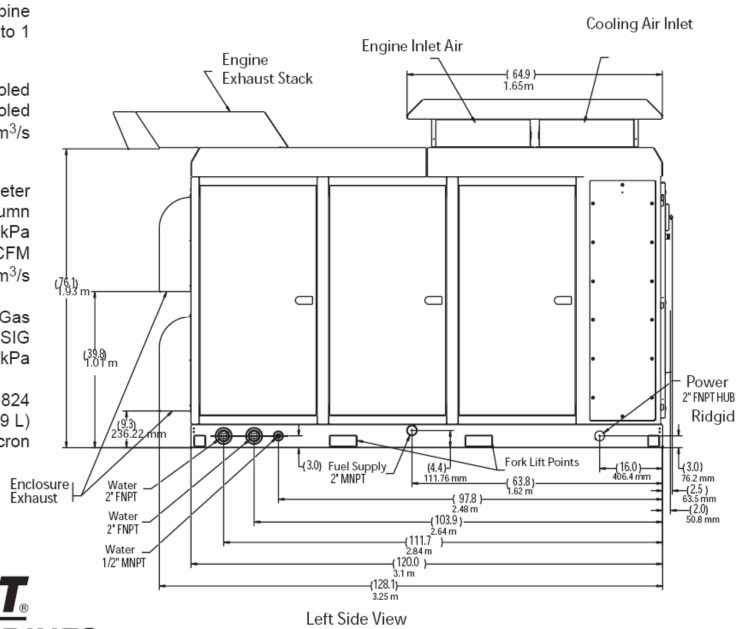
Emissions, Natural Gas (Typical)
CO: 20 PPM @ 15% O_2
25.4 mg/MJ
25.0 mg/m^3@ 15% O_2
0.77 lbs/ MWhr
0.243 grams /bhp hr
0.059 lbs /MMBTU
NOx: 22 PPM @ 15% O_2
48.7 mg/MJ
45 mg/m^3@ 15% O_2
1.48 lbs/ MWhr
0.467 grams /bhp hr
0.113 lbs /MMBTU

Exhaust Gas Temperature
Heat Recovery Mode 180ºF/ 82ºC
Full HRU Bypass 560ºF/ 293ºC

Batteries 24VDC min.
Two 12 volt, Group 27, lead acid, maintenance free - 105Ah nominal

Total Weight with Enclosure:
Indoor: 4,100 lb./ 1,860 kg
Outdoor: 4,500 lb./ 2,040 kg





ELLIOTT MICROTURBINES

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The specifications in this catalogue are subject to change without prior notice.

 EESI #51 Rev. 3