UCR | College of Engineering- Center for Environmental Research & Technology

Improving Certification Test Methods for Low Emissions Distributed Generators

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Discussion Topics

- Background & motivation
- Goals of Energy Commission project
- Technical approach & test matrix
- Results to date
- Open Discussion

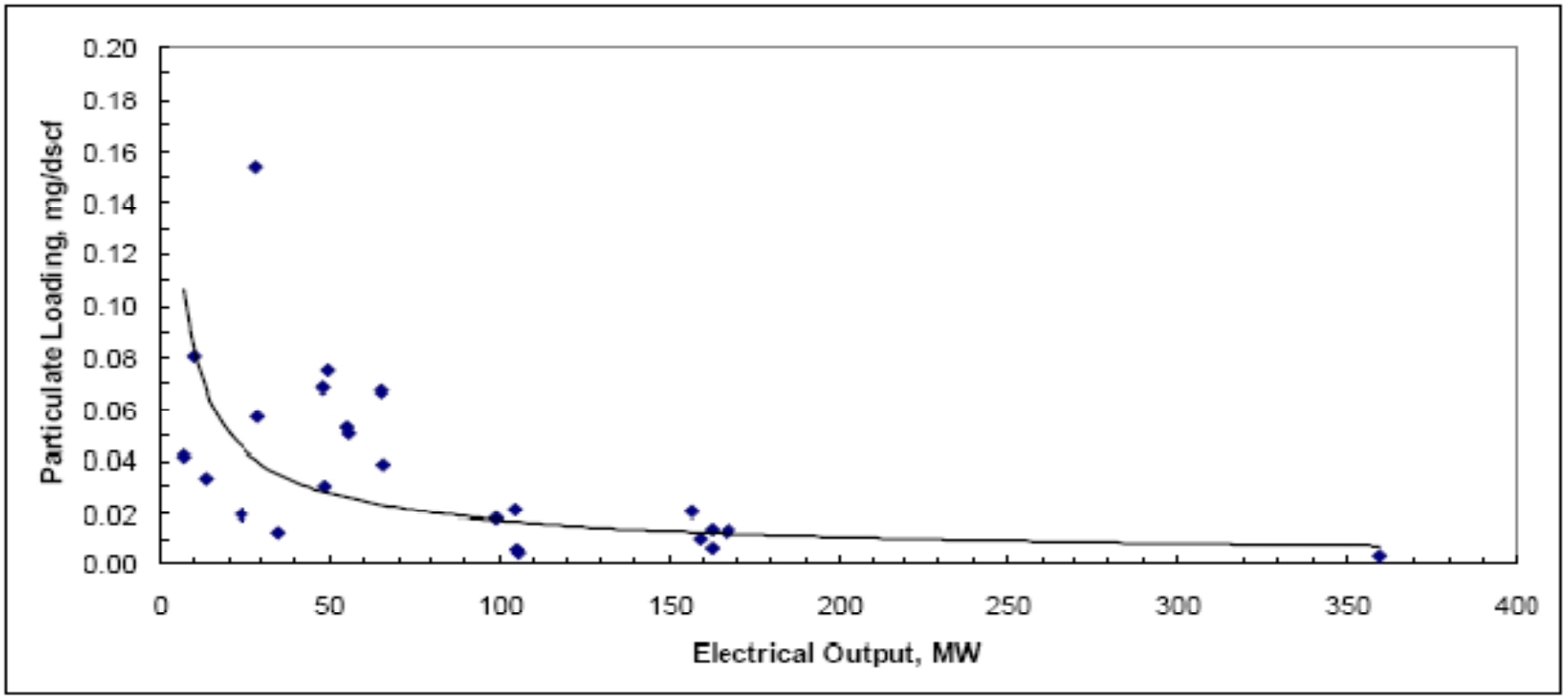
Background

- For non-permitted units, ARB requires manufacturers to certify their technologies to specific emission standards
  - Includes DG units, such as micro-turbines and fuel cells.
- Modern DG units have low emissions
  - New combustion sources have low NO_x and CO emissions. Some new permits are <10 ppm for NO_x & CO.
  - The new combustion sources requires NO_x and CO analyzers to be more accurate and precise.
  - Analysis is complicated by interference of combustion gases.

Background: AQMD PM Project

- Goal: "Control Strategies and Technologies for $PM_{2.5}$ and Ultrafine PM Emissions from Natural Gas-Fired Turbine Power Plants"
- Fossil Energy Research Corporation (FERCO) is the prime contractor. Project budget: $3.6M
  - Delta Air Quality Services to assist with field measurements
  - UCR and Environ are monitoring the physical and chemical nature of the PM, including impinger solutions.
  - Several control strategies to be demonstrated.
- Benefits: AQMD demonstrates add-on $PM_{2.5}$ control technologies for natural gas-fired power plants.

Background: PM Emissions Low for Large Plants



Source: AQMD

Approach: Use Five Tasks

1.0	**Administration**
	Project Technical Activities
2.0	Literature Review and Development of the Work Plan
3.0	Field Testing
4.0	Data Analysis & Recommendations
5.0	Initiate Method Improvements

Energy Commission Project

- Objectives
  - Phase 1: Evaluate current ARB distributed generation (DG) **gaseous** test methods to determine if new instrumentation and/or test methods need to be developed.
  - Phase 2: Address the development of new methodologies and/or instrumentation.
  - Overall; try to meld with AQMD's **PM** project.

Specific Project Goals and Scope

- Evaluate ARB Test Method 100 and SCAQMD Test Method 25.3
  - Desired: VOC, NOx, and CO concentrations down to 0.10 ppm, acceptable at 0.1 ppm
- Evaluate ARB Test Methods 1-4 for accuracy of measuring velocity and flow rate
  - Desired: test methods that can accurately measure exhaust gas velocity and flow rate within +/-5%
- Evaluate other test methods for distributed generation sources.
- Determine if new instrumentation and/or test methods need to be developed

Plan: Other Test Methods

- Measure flow rates with current ARB protocols. Test alternative methods:
  - Use carbon balance based on ISO 8178
  - Review additive approach
- Characterize PM with electronic, real-time methods
  - Reportedly, PM is same level for ambient and exhaust on a 'clean' machine (Delta)

Advisory Board Members for Plan

- California Energy Commission & GER
  - Ms Marla Mueller; Ms Nicole Davis
- California Air Resources Board
  - Messrs. David Mehl; David Todd; Jonathan Foster
- Academic; UC, Irvine Combustion Lab
  - Dr. Vince McDonald
- Technical experts
  - Dr. Glenn England, Mr. Robert Finken
- South Coast Air Quality Management District
  - Ms. Joan Niertit
- Manufacturers
  - Fuel cell (Jeff Cox); micro-turbines (Rene Flores)

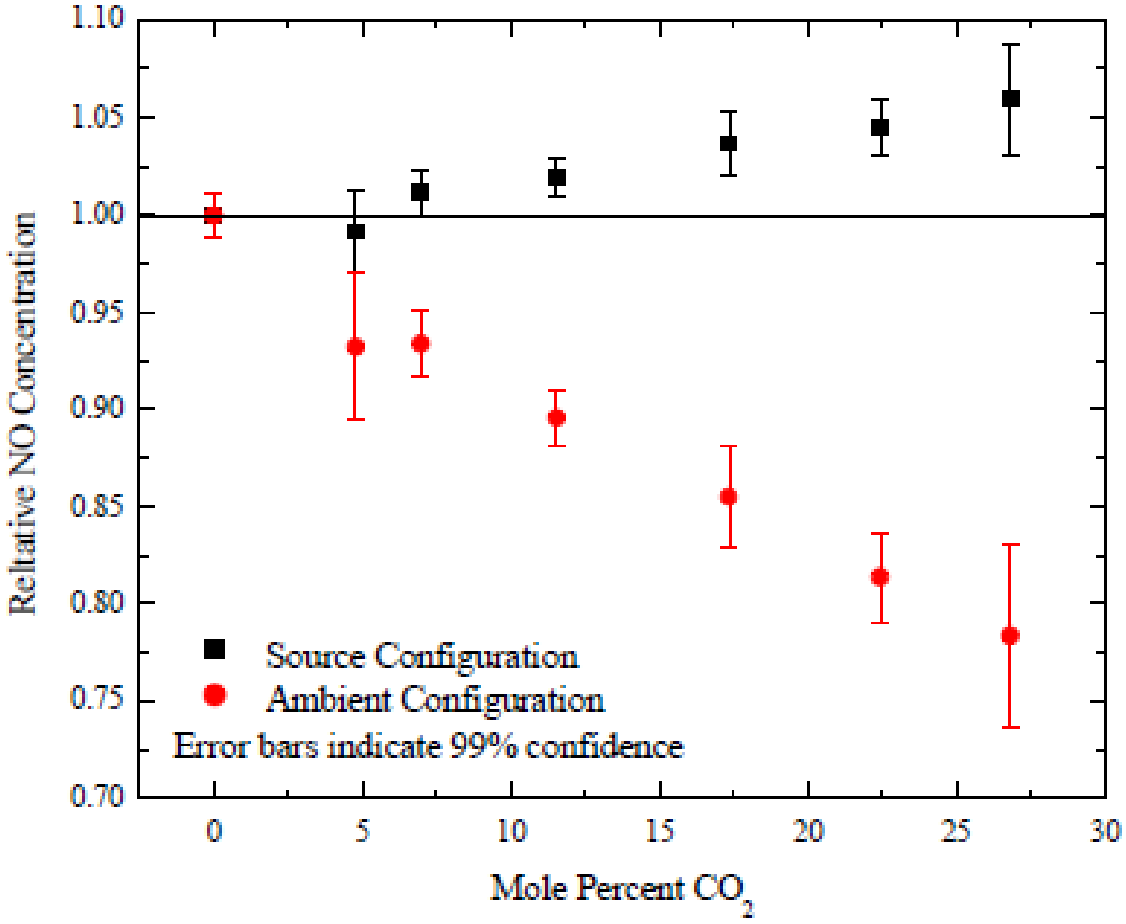
Plan: Test Sources & Fuels

- Test modern low emission sources; up to 5 units.
- Test a range of distributed sources
  - Micro-turbines: 30-200kW
  - Micro-turbine: 14MW
  - Fuel cell; high temperature, direct reforming type
- Test sources with controls:
  - UC, San Diego co-gen plant (~25MW) with control technology; NOx from 0.1 to 2.1 ppmv.
  - EMx control technology ~400 ppb NOx (Redding, CA)
- Test turbines fueled with natural gas

Plan: Focus on Gaseous Test Methods

- Measure gases (CO, CO_2, NOx, HCs) with current ARB protocols
  - Explore use of ambient instruments
  - Measure NOx with new methods (EPA 7E)
  - Measure HC with AQMD Method 25.3
  - Measure HC with EPA TO-12
  - Measure gases for trace carbonyl and hydrocarbon species content using sorption media
- Characterize ambient levels

CO_2 Effects on Reported NO Concentration



Ref: Thermo Environmental

Plan: Hydrocarbon Test Matrix

Focus: THC Accuracy, Precision & Speciation

	Description	M25.3	TO12	Sorption tubes	Carbonyls
Unit 1	Typical of low	5	5	5	5
Unit 2	Typical of low	4	4	4	4
Unit 3	Typical of low	4	4	4	4
Unit 4	Controlled unit	4	4	4	4
Unit 5	Controlled unit	4	4	4	4

Pilot Studies

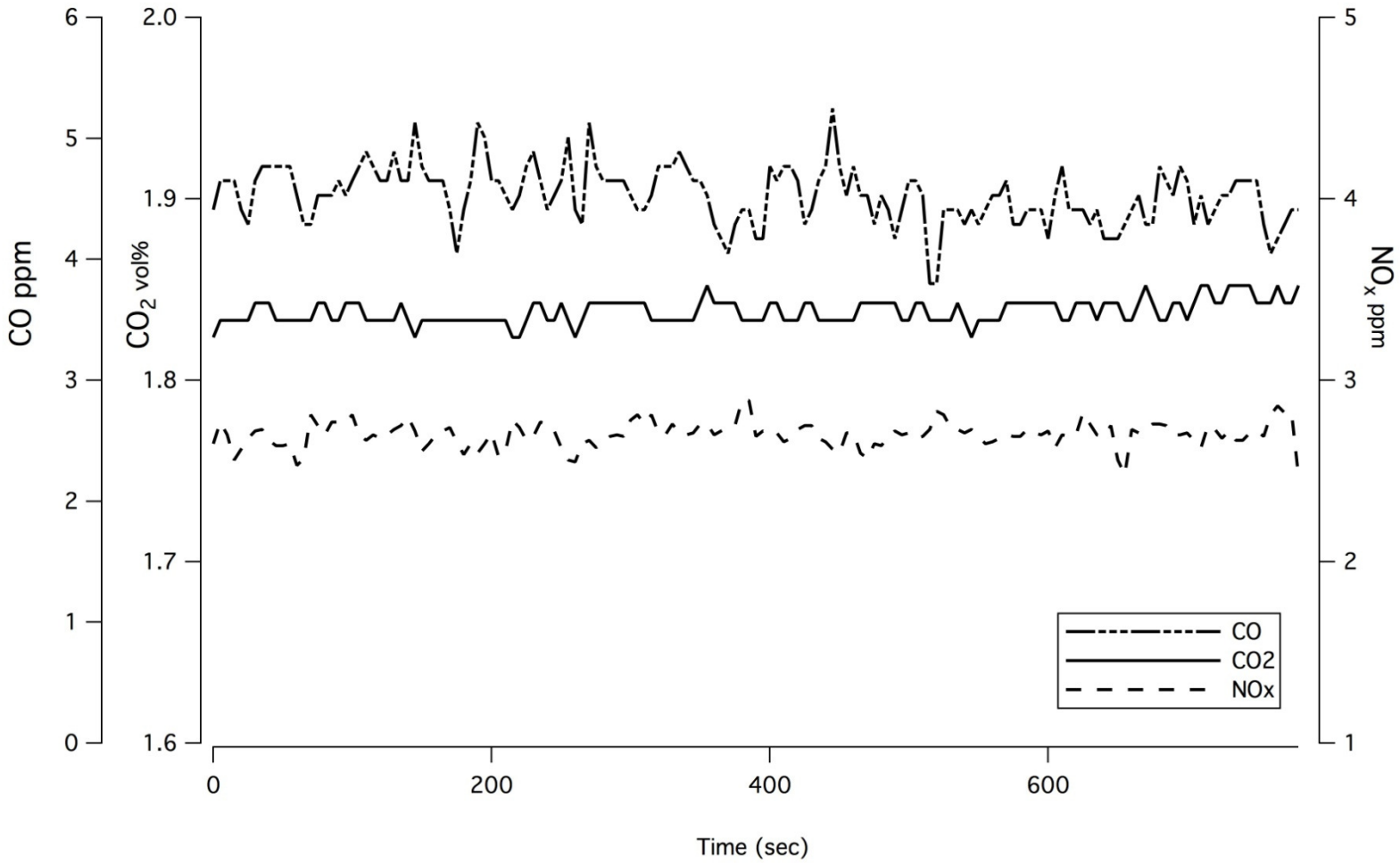
Capstone C-65

1) Gaseous instruments
2) PM methods

Emissions from Micro-Turbine

- Test of micro-turbine (~60kW) UC, Irvine
- Monitored gas concentration with existing methods (Horiba PG-250)
  - NOx: Heated Chemiluminescence Detector (HCLD); 0-25 ppm
  - CO: Non dispersive Infrared Absorption (NDIR); 0-200ppm
- Measured PM mass on Teflon filters with dilution tunnel per ISO 8178-1

Emissions from Micro-Turbine



Emissions from Micro-Turbine

✓**Data Corrections are significant**

	Raw Data		Calibrated Data		
	ppm-NOx	ppm-CO	ppm-NOx	ppm-CO	ppm-CO2
Average:	0.36	2.52	1.20	2.86	4410.41
STDEV:	0.05	0.18	0.05	0.21	121.33
COV	14%	7%	4%	7%	3%

✓**Measured values less than AP-42**

Measurement with Dilution	PM (g)/CO2 (kg)	NOx (g)/CO2 (kg)	CO (g)/CO_2 (kg)
Test 1-Ave	0.02	0.31	0.45
Test 2-Ave	0.01	0.29	0.39
Test 3-Ave	0.01	0.29	0.35

AP-42 Natural Gas Turbine Emission Ratios	
PM/CO2	0.06 g/kg CO2
NOx	0.831-2.689 g/kg CO2

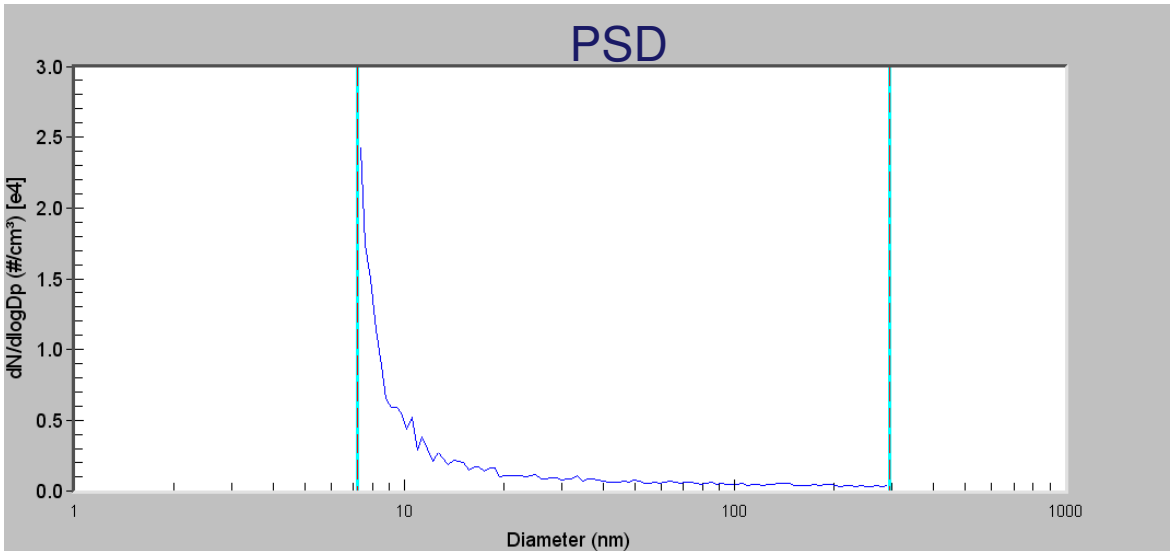
Real Time Particulate Matter (PM) Measurement Methods…

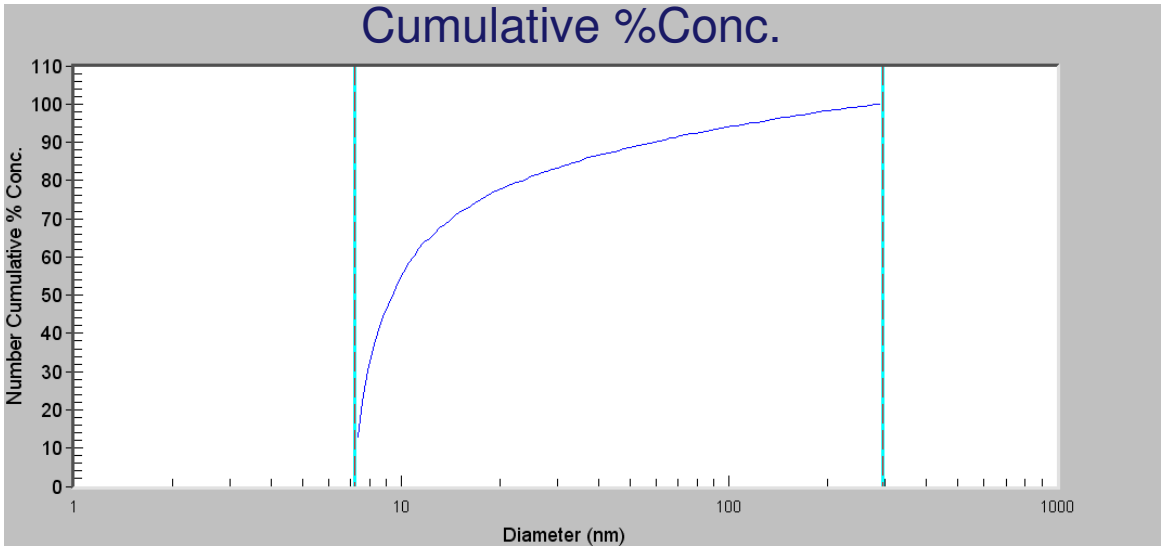
- Filter based methods for mass
- Real time methods; some being considered for SAE AIR6037

Test 2

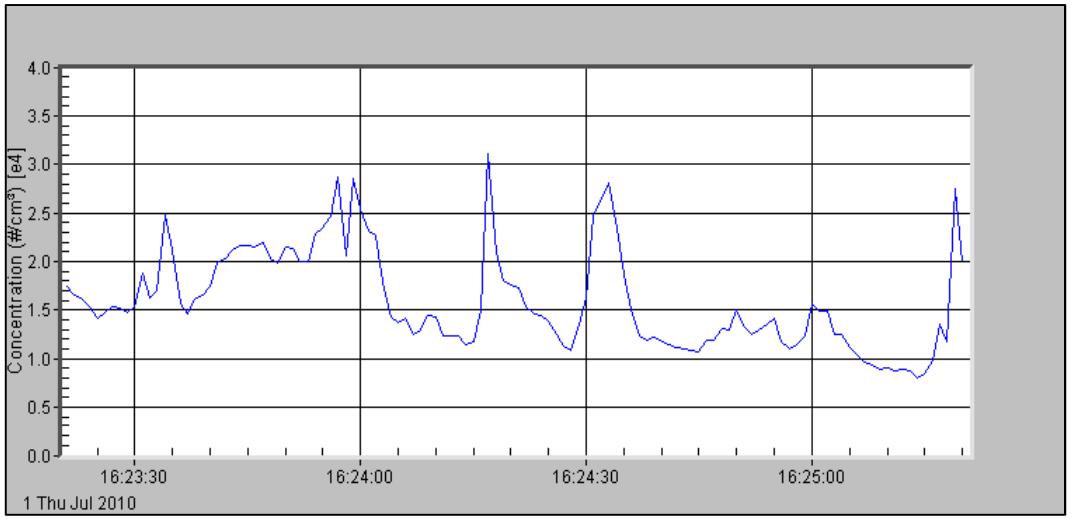
Instrument	Description
CPC Model: TSI 3781	Water based Condensation Particle Counter (CPC) capable of measuring particles larger than 6nm
CPC Model: TSI 3776	Butanol based ultra-fine CPC designed to detect particles as small as 2.5nm
SMPS Model: TSI 3081	Size Mobility Particle Sizer (SMPS), Range altered to measure from 7-260 nm, composed of a Differential Mobility Analyzer (DMA) and a CPC
Aethalometer, Magee Scientific AE-42, Portable	Measures optical absorption by suspended aerosol particles at two wavelengths: 880 nm (IR), quantitative for the mass of 'Black' Carbon; and 370 nm (UV), indicating aromatic organic compounds.

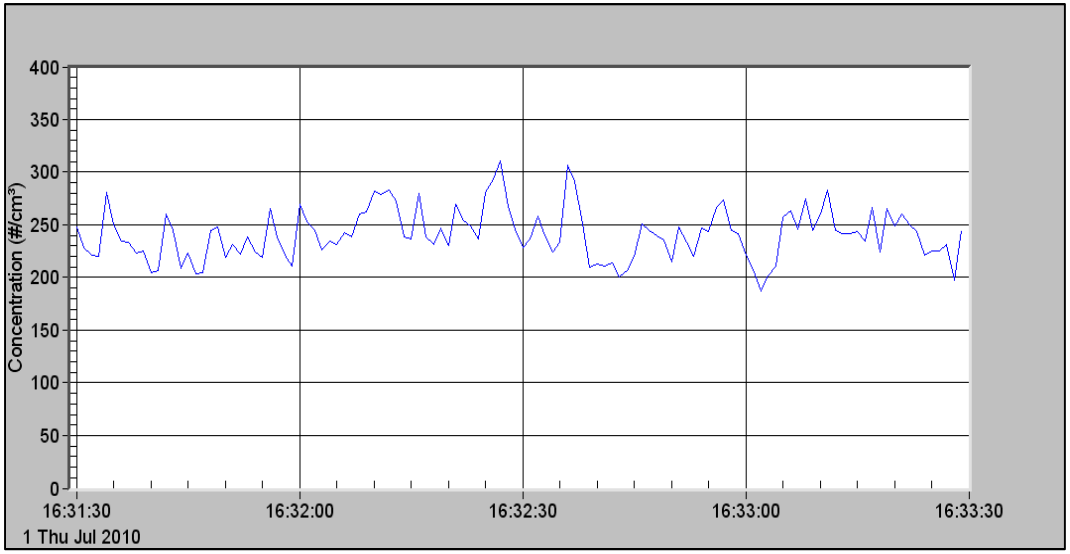
Particle Size Distribution (PSD)





Particle Count Lower with Water

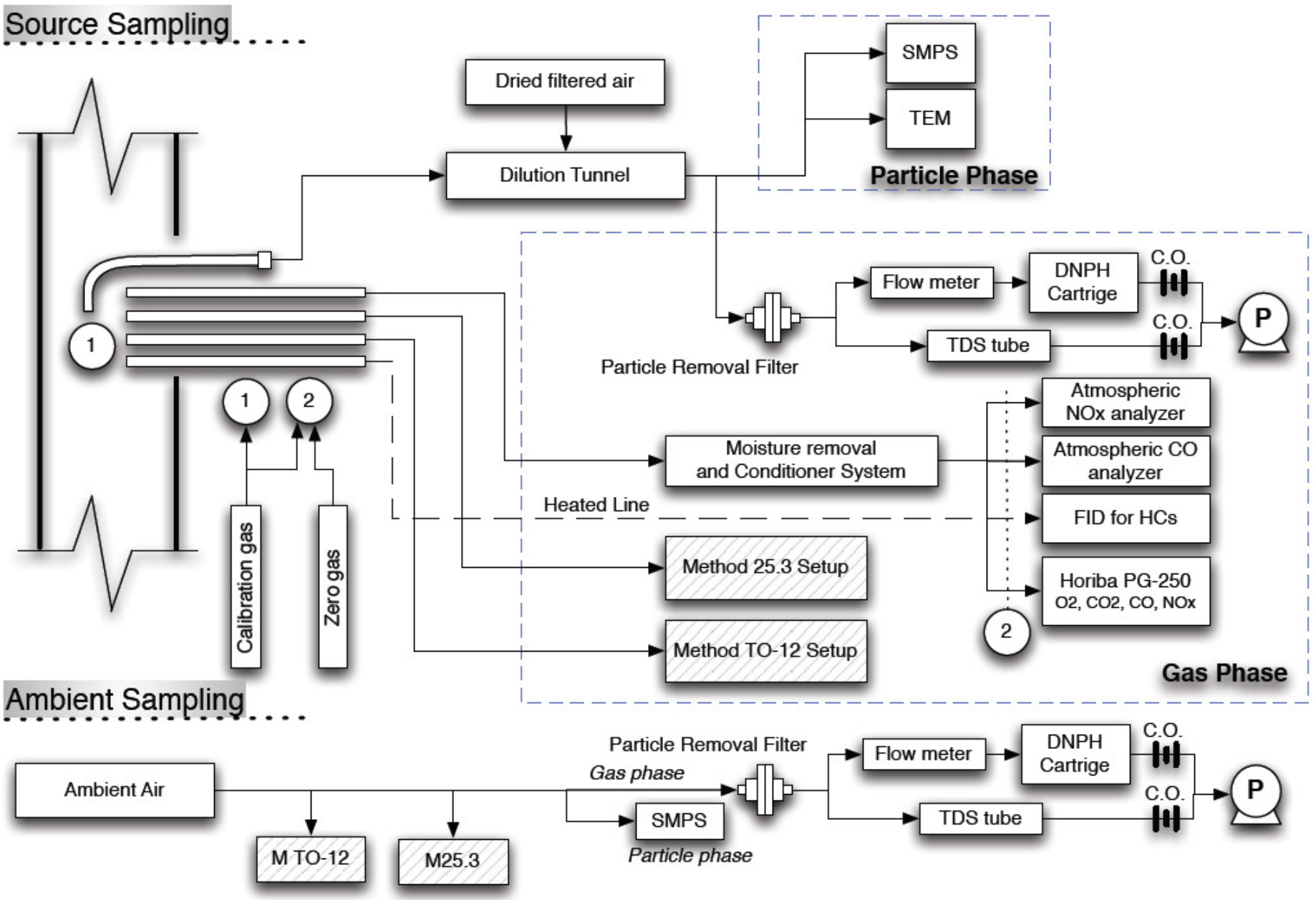




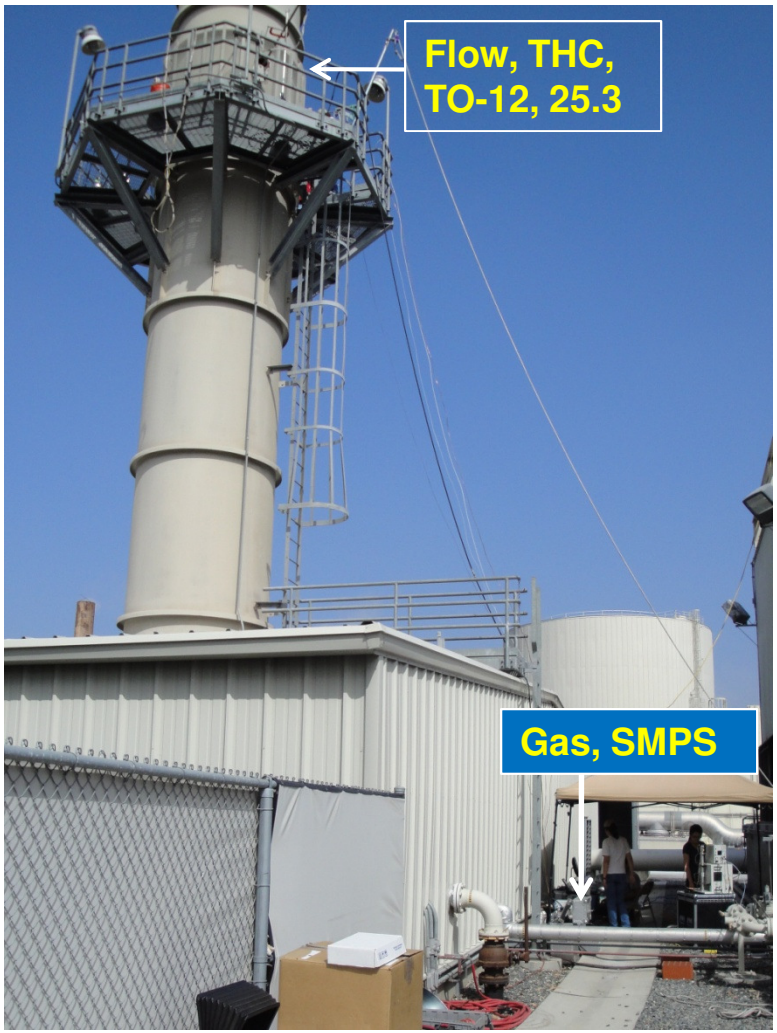
Initial Test Results

- Capstone turbine C-65 kW system
- Co-Gen System 13 MW Solar Titan turbine

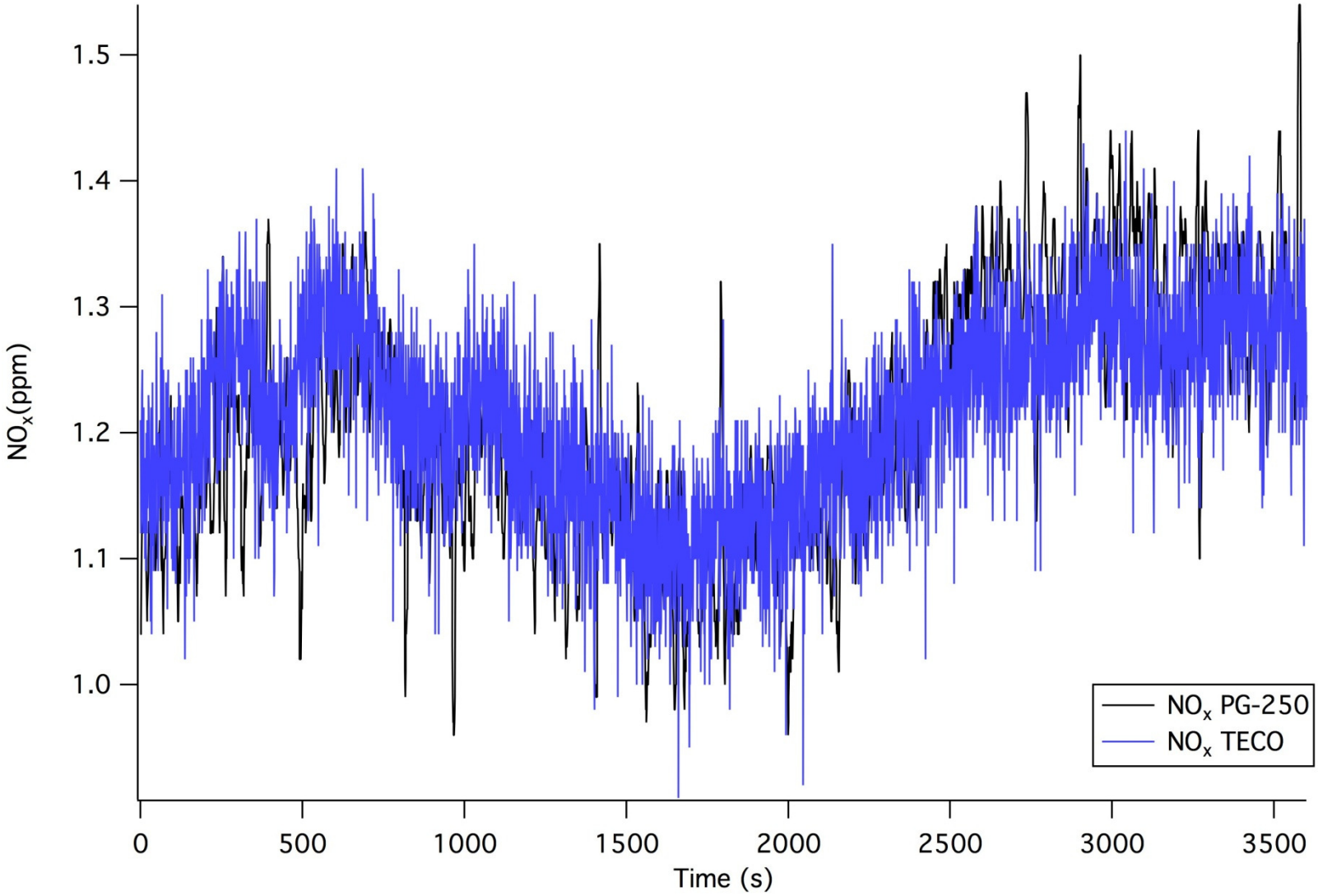
Test 1: Setup for C-65


Source Sampling
Dried filtered air
Dilution Tunnel
SMPS
TEM
Particle Phase
Flow meter
DNPH Cartrige
C.O.
C.O.
P
TDS tube
Particle Removal Filter
1
1
2
Calibration gas
Zero gas
Moisture removal and Conditioner System
Heated Line
Atmospheric NOx analyzer
Atmospheric CO analyzer
FID for HCs
Horiba PG-250
O2, CO2, CO, NOx
2
Method 25.3 Setup
Method TO-12 Setup
Gas Phase
Ambient Sampling
Ambient Air
M TO-12
M25.3
Particle Removal Filter
Gas phase
SMPS
Particle phase
Flow meter
DNPH Cartrige
C.O.
C.O.
P
TDS tube

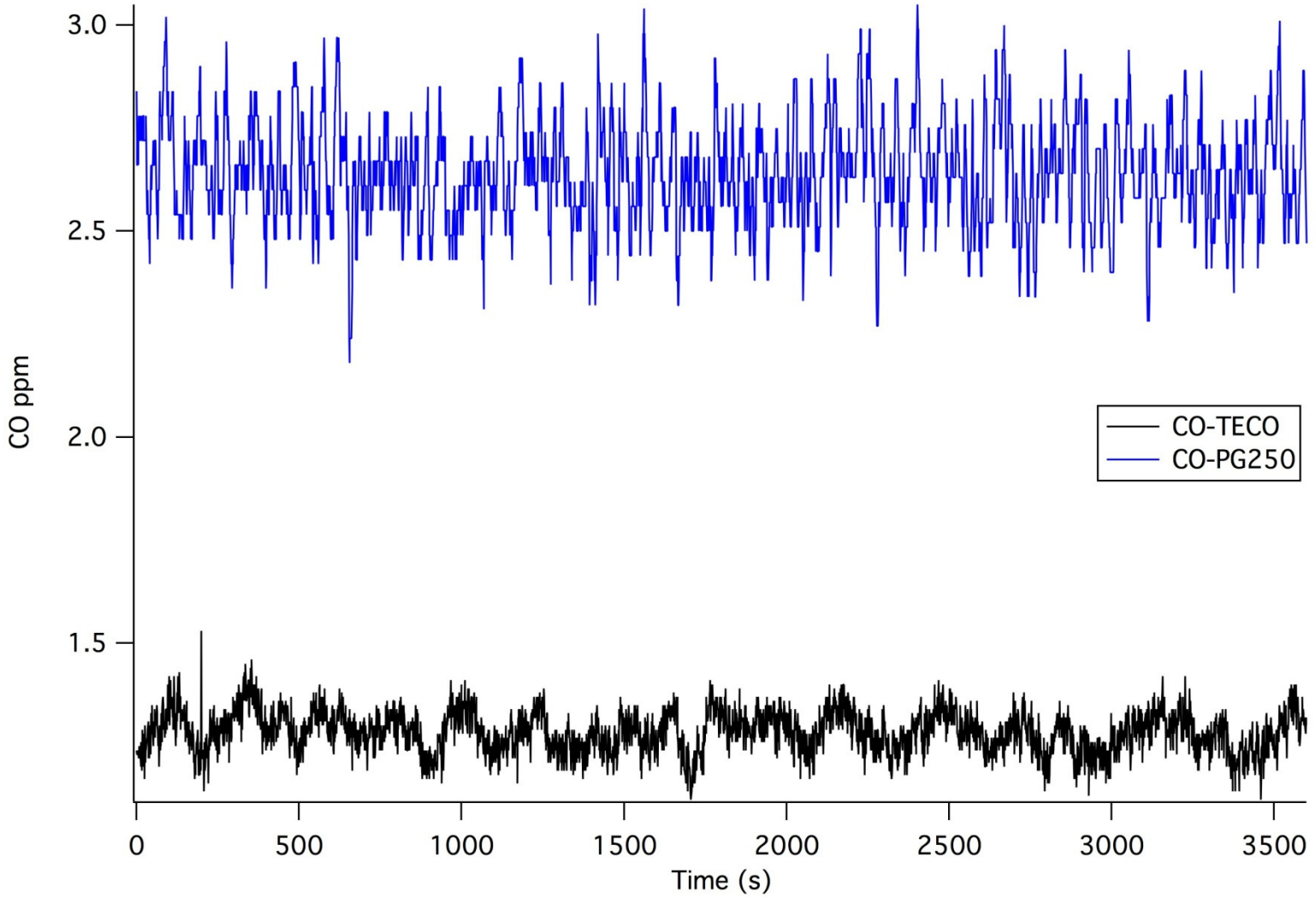
Test 2: Setup for 14MW Turbine



Comparative NOx Data



Comparative CO Data



Comparative Results

Horbia .. PG-250

	NOx ppm	CO ppm	CO_2 %
Range	0-25	0-200	0-5
Ave	1.209	2.642	3.510
STDEV	0.099	0.125	0.007
COV	8.2%	4.7%	0.2%

Ambient instruments- TECO

	NOx ppm	CO ppm
Range	0-5000ppb	0-5
Ave	1.214	1.284
STDEV	0.077	0.051
COV	6.4%	3.9%

Example: Possible Flow Accuracy

Minute	CT Gas Flow klb/hr	CT Heat Input mmBtu/hr	DB Gas Flow klb/hr	DB Heat Input mmBtu/hr	Stack Flow kdscf/hr	Megawatts	N
11:31	6.53	152.8	0.66	15.4	4754	13.1	
11:32	6.52	152.6	0.66	15.4	4748	13.1	
11:33	6.49	151.8	0.66	15.4	4727	13.1	
11:34	6.52	152.5	0.66	15.4	4737	13.1	
11:35	6.51	152.1	0.66	15.4	4728	13.1	
11:36	6.51	152.4	0.66	15.4	4741	13.1	
11:37	6.52	152.5	0.66	15.4	4738	13.0	
11:38	6.51	152.1	0.66	15.4	4728	13.1	
11:39	6.52	152.4	0.66	15.4	4741	13.1	
11:40	6.52	152.6	0.66	15.4	4740	13.1	
11:41	6.50	151.9	0.66	15.4	4716	13.1	
11:42	6.50	152.0	0.66	15.4	4725	13.1	
11:43	6.51	152.1	0.66	15.4	4720	13.0	
11:44	6.50	152.0	0.66	15.4	4718	13.1	
11:45	6.51	152.4	0.66	15.4	4733	13.0	
11:46	6.52	152.4	0.66	15.4	4734	13.1	
11:47	6.51	152.3	0.66	15.4	4724	13.1	
11:48	6.50	151.9	0.66	15.4	4722	13.0	
11:49	6.49	151.8	0.66	15.4	4712	13.0	
11:50	6.51	152.4	0.66	15.4	4726	13.1	
11:51	6.48	151.6	0.66	15.4	4698	13.1	
11:52	6.49	151.7	0.66	15.4	4708	13.1	
11:53	6.50	151.9	0.66	15.4	4715	13.1	
11:54	6.51	152.1	0.66	15.4	4720	13.0	
11:55	6.48	151.6	0.66	15.4	4705	13.1	
11:56	6.48	151.6	0.66	15.4	4713	13.0	
11:57	6.49	151.7	0.66	15.4	4715	13.0	
11:58	6.48	151.5	0.66	15.4	4703	13.0	
11:59	6.49	151.8	0.66	15.4	4719	13.0	
Average Total	6.51	152.3	0.35	8.2	4709	13.1	

Summary

- CEC-funded project is aimed at evaluating and improving existing methods for measuring gas emissions from modern, low emission DG sources.
- CEC project has completed the testing of two turbines fueled with natural gas; analysis of the data is underway.
- Project will mesh with AQMD PM project to advance knowledge on emissions from DG sources.