MEASUREMENT AND VERIFICATION PLAN

FOR

CHP SYSTEM AT
SEA PARK EAST APARTMENT COMPLEX

Submitted to:

New York State Energy Research and Development Authority
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Albany, NY 12203-6399

Submitted by:

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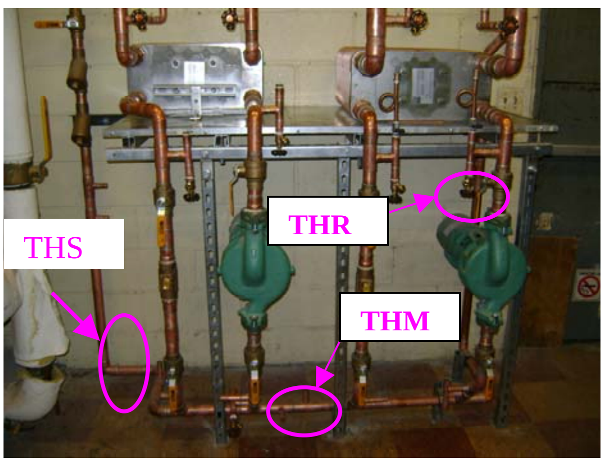
1. Introduction

This monitoring plan presents the measurement and data collection approach for the CHP system at Sea Park East.

The CHP system at Sea Park East includes two Tecogen 75 kW engine generator units. The two units combined provide 150 kW gross electrical output. The thermal energy output from the units will be used for the domestic water heating and space heating loads. The heat recovery loop includes a DHW heat exchanger (HX), a space heating heat exchanger, and a dump radiator to heat reject unneeded heat (see Figure 1 and Figure 2).

The two Tecogen units are located on the second floor of the parking garage adjacent to the building. The dump radiator is located on top of the parking garage near the engines. The gas meter for the generators is also located in garage near the engines. The heat exchangers and pumps are located on the first floor of the main building near the boilers and main electrical panels.



Heat Exchangers with Pumps P2 & P3

Main Engine Loop Pump (FW)

Figure 1. Heat Exchangers and Pumps on Engine Loop (before insulation was added)

2. Instrumentation

The site will supply the instrumentation listed in Table 1. The NYSERDA monitoring contractor will provide the temperature sensors listed in Table 2 and integrate all the sensors into the datalogger.

Table 1. Instrumentation Supplied By Site

Point	Instrument	Output Type	Sensor Location	Notes
Facility Power (**WT**)	Con Ed Utility Meter	Web	NA	Data will be extracted from Con Edison DMS website (account #69-5302-0328-0001-3)
Generator #1 Power Output (**WE1**)	Wattnode WNB-3Y-208P (CTS-1250-400)	Pulse output 10 Wh/pulse	Figure 5	400 amp CT, x 3
Generator #2 Power Output (**WE2**)	Wattnode WNB-3Y-208P (CTS-1250-400)	Pulse output 10 Wh/pulse	Figure 5	400 amp CT, x 3
Parasitic Power (**WP**)	Wattnode WNB-3Y-208P (CTS-0750-50)	Pulse output 1.25 Wh/pulse	Figure 5	50 amp CT
Natural Gas Fuel Input (**FG**)	Roots B3 Series Model: 2M175-ITPWS	Solid State Pulse 100 cf/pulse	On common gas line serving both engines	Temperature Compensated
Fluid Flow (**FW**)	Onicon F-1110 Insertion Flow Meter	4-20 mA output Full Scale: 130gpm	1-1/2” copper piping install with 10x diam before and after	± 1% or better at calibrated velocity

Table 2. Temperature Measurements

Hot Water Supply (**THS**)	Veris 10k type 2 Old(Mamac TE211z 1000 ohm RTD)	Resistance Old(4-20 ma 100 – 250 ºF)	Figure 2	Site provides thermowell, ¼“ probe, ½ “ NPT
Hot Water Return to Radiator (**THR**)	Veris 10k type 2 Old(Mamac TE211z 1000 ohm RTD)	Resistance Old(4-20 ma 100 – 250 ºF)	Figure 2	Site provides thermowell, ¼“ probe, ½ “ NPT
Hot Water Between Exchangers (**THM**)	Veris 10k type 2 Old(Mamac TE211z 1000 ohm RTD)	Resistance Old(4-20 ma 100 – 250 ºF)	Figure 2	Site provides thermowell, ½ “ NPT

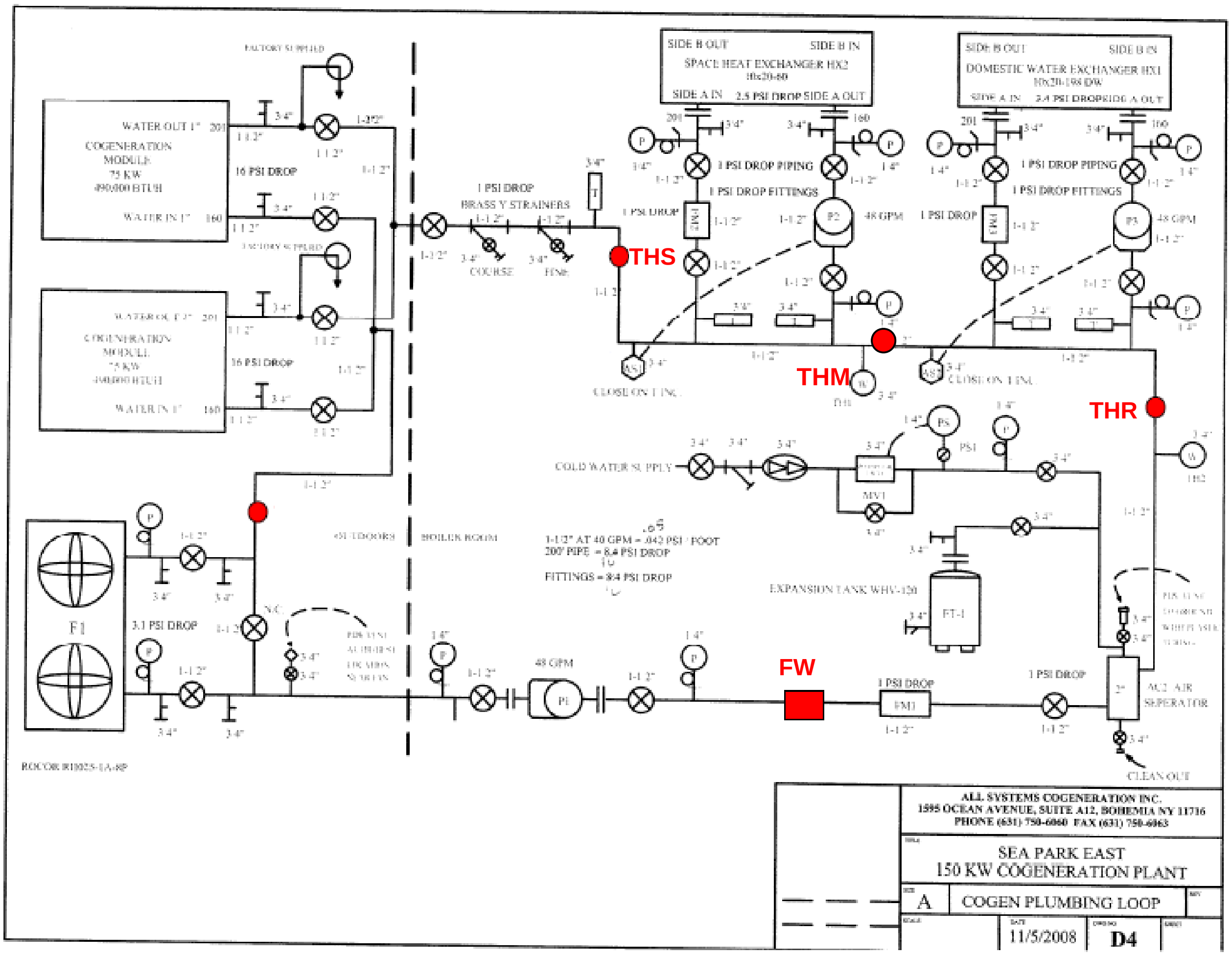


Figure 2. Schematic Drawing (D4) Showing the Location of Temperature Sensors and Flow Meters

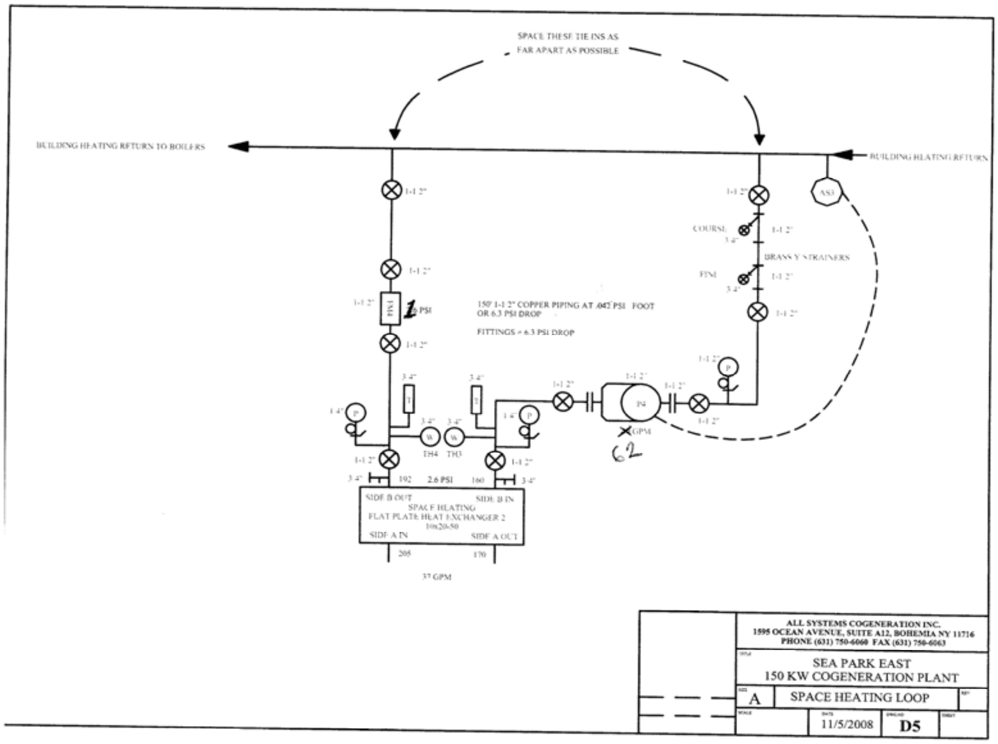


Figure 3. Connection of Space Heating HX into Building (Drawing D5)

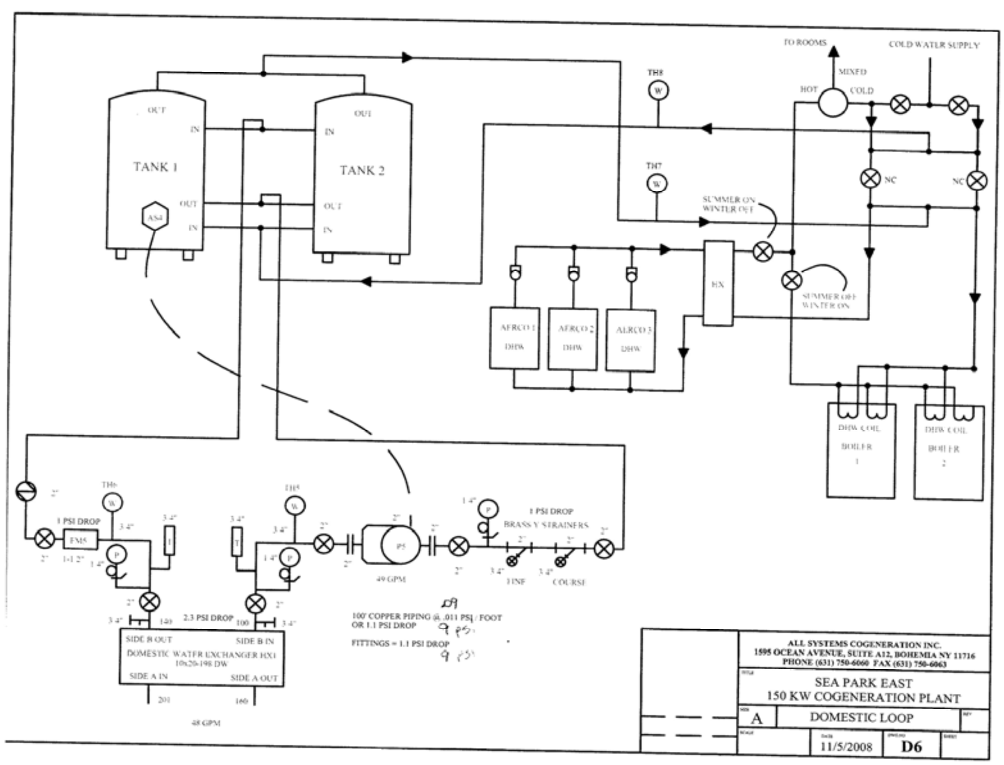


Figure 4. Connection of DHW HX into Building Systems (Drawing D6)

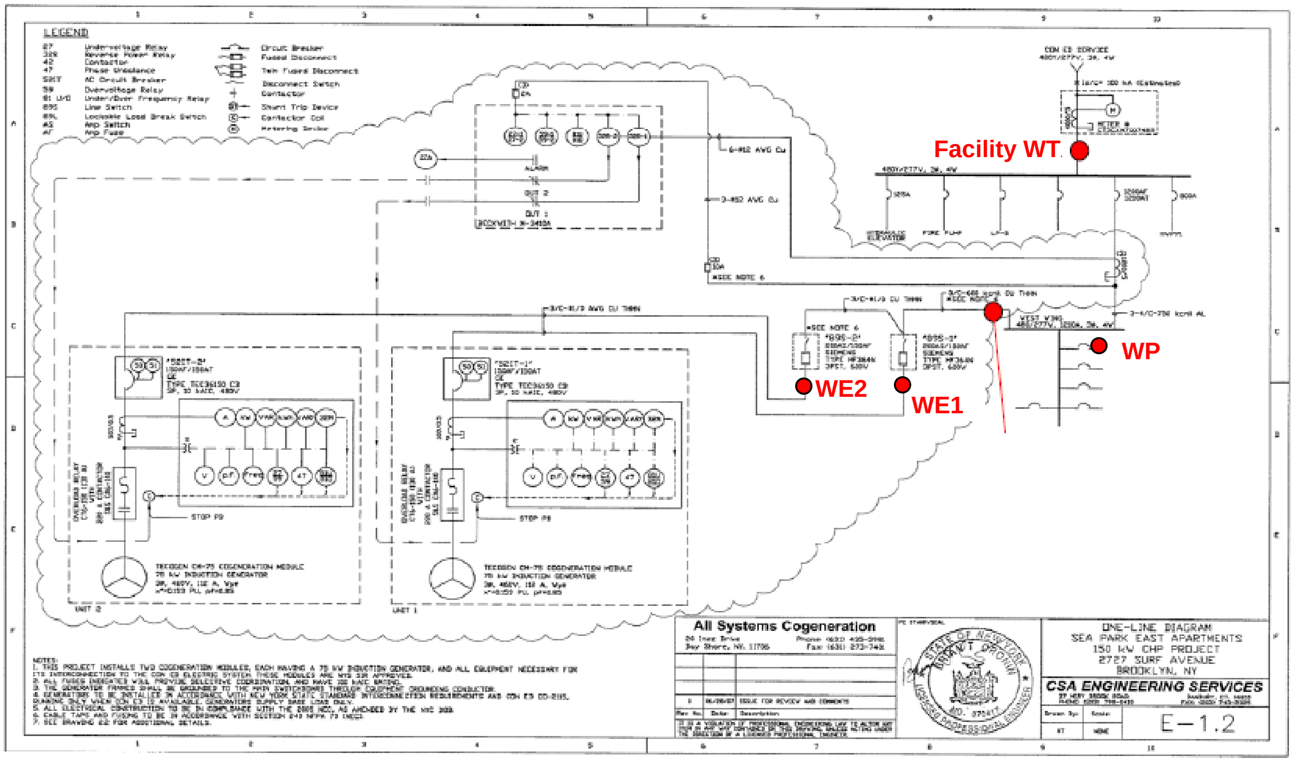


Figure 5. One Line Electrical Drawing (E-1.2) Showing locations of Power Measurement

<u>Datalogger</u>

An Obvius Acquisuite 8812 datalogger will be installed to record the required data. The system will have a UPS power supply. The logger will be located in the pump room near the boiler. The power transducers will be located in the nearby electrical room, which is located near the pump room.

The sensors will be sampled or scanned at one-second intervals. All readings will be averaged, summed or calculated for each 1-minute interval. The datalogger will be able to hold more than 100 days of recorded data if communications are lost. The datalogger will continue to log data for a few hours in the event of a power outage at the site. The data will be downloaded from the datalogger at least once a day by a phone-modem connection and loaded into a database. The data will be checked for validity and posted on the NYSERDA web site.

Figure 6. Datalogger and Power Supply

Onsite Installation

CDH Energy will install a datalogger panel at a location in the boiler room agreeable to the site and developer. The monitoring system panel will be approximately 1.5 ft x 1.5 ft x 1 ft. The panel will be wired into the nearby electrical panel.

Communications

The site will provide a dedicated phone line (a POTS outside line; not through a phone system) for the datalogger in the pump room. Alternately a phone mux can be installed to save a phone line.

On Site Support

Our role as the MA will be to maintain the data logger over the two-year monitoring period. We will periodically check the CHP web site to ensure the system is operating properly and also respond to issues identified by the Data Intergrator or others. In the event of a data logger issue, we will be on-site within 48 hours. If the problem is with the instrumentation supplied by the site, we will work with them to help correct the problem in a timely manner.

Around the 12th and 24th month of the monitoring period, we will come on site to verify and check the instrumentation and sensors. Temperature sensors will be compared to readings with handheld instruments, power transducer readings will also be compared to handheld power readings. Where feasible, we will check flow readings with ultrasonic flow meters. Based on these measurements we will prepare a verification summary report documenting the findings from each visit. The verification/calibration reports will also be posted on the CHP web site.

3. Data Analysis

The collected data will be used to determine the net power output of the system as well as the fuel conversion efficiency (FCE).

Table 3. Summary of Monitored Data Points

No.	Data Point	Description	Engineering Unit
1	WT	Facility Power Consumption (imported)	kWh/int
2	WE1	Generator #1 Power Output	kWh/int
2	WE2	Generator #2 Power Output	kWh/int
3	WP	Parasitic Power Consumption	kWh/int
4	FG	Engine Fuel Consumption (both engines)	CF/int
5	FW	Engine Loop Flowrate	gpm
6	THS	Supply Hot Water Temperature	ºF
7	THR	Return Hot Water Temperature (into dump radiator)	ºF
8	THM	Temperature between Exchangers	ºF

Peak Demand or Peak kW

The peak electric output or demand for each power reading will be taken as the average kW in a 5-minute interval, or

$$kW = \frac{kWh}{\Delta t} = \frac{\text{kWh per interval}}{(1/60)\ h}$$

Heat Recovery Rates

The heat recovery rates will be calculated in the datalogger at each 1-minute interval.

Useful heat recovery (**QU**) = K·FW·(THS-THR)

The loop fluid is expected to be water. The factor K is based on the properties of the loop fluid. (K ~ 500 Btu/h-gpm-°F for pure water; ~480 for 30% glycol). CDH will use a Hygrometer to estimate the glycol concentration if required.

<u>Calculated Quantities</u>

The total power usage of the facility will be defined as the gross power imported from Con Ed and from the CHP system. For this site, the <u>net</u> power output from the engine generators is:

WG = WE1 + WE2 – WP

The fuel conversion efficiency of the CHP system, based on the lower heating value of the fuel, will be defined as:

$$FCE = \frac{QU \cdot \Delta t + 3{,}412 \cdot (WG)}{LHV_{gas} \cdot FG}$$

where:	QU	-	Useful heat recovery (Btu/h)
	WG	-	Generator output (kWh)
	FG	-	Generator gas consumption (Std CF)
	Δt	-	1/60 hour for 1-minute data
	LHV_{gas}	-	Lower heating value for natural gas (~905 Btu per CF)

The FCE can be calculated for any time interval. When converting to daily, monthly, or annual values, each value is summed and then the formula is applied:

$$FCE = \frac{\sum^{N} QU \cdot \Delta t + 3412 \cdot \sum^{N} (WG)}{LHV_{gas} \cdot \sum^{N} FG}$$

Where N is equal to the number of intervals in the period of interest.

4. Environmental Monitoring

CDH Energy will also complete the emissions testing required for the NYSERDA CHP Program. We will use a Testo XL350 to measure NOx and CO from each unit. The program calls for engine generator units have emissions less than:

NOx: 1.6 lb per MWh
CO: 6.3 lb per MWh

These limits translate to the following concentrations assuming a 275°F exhaust and the rated engine efficiency:

NOx: 100 ppmv in exhaust
CO: 600 ppmv in exhaust)

To measure these values we will rent a Testo XL350 with the option to measure NO and NO_2. Figure 7 shows the instrument and measurement ranges. This instrument corresponds to the EPA Conditional Test Method (CTM-030). We will rent a unit from Clean Air Engineering (www.cleanair.com) with standard measurement ranges. The instrument automatically calculates the NOx from the measured NO and NO_2 concentrations.

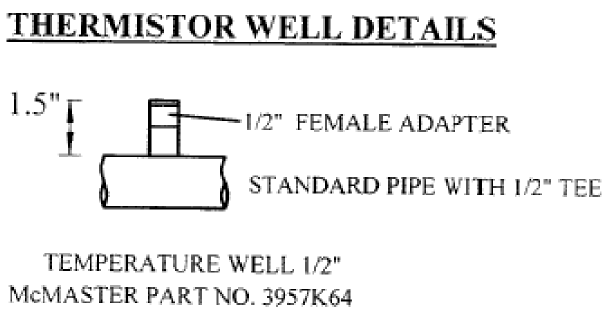
	O_2	CO	~~CO-low~~	NO	~~NO-low~~	NO_2	SO_2	H_2S	C_XH_Y
Range	0-25%vol	0-10,000 H2 comp	~~0-500ppm H2 comp~~	0-3000 ppm	~~0-300ppm~~	0-500 ppm	0-5000 ppm	0-300 ppm	0-4%
Accuracy	<0.8% of f.v	<5ppm 0-99 ppm <5% of m.v. 100-2000 ppm <10% of m.v. 2001-10000 ppm	~~<2 ppm 0-39.9 ppm <5% of m.v. 40-500 ppm~~	<5 ppm 0-99 ppm <5% of m.v. 100-2000 ppm <10% of m.v. 2001-3000 ppm	~~<2 ppm 0-39.9ppm <5% of m.v. [illegible]00 ppm~~	<5 ppm 0-99 ppm <5% of m.v. 500 ppm	<5 ppm 0-99 ppm <5% of m.v. 100-2000 ppm <10% of m.v. 2001-5000 ppm	<2 ppm 0-39.9 ppm <5% of m.v. 40-300 ppm	<0.04% vol. 0-0.4% vol. <10% of m.v. 0.41 - 4% vol.
Resolution	0.1% vol	1 ppm	~~0.1 ppm~~	1 ppm	~~0.1 ppm~~	0.1 ppm	1 ppm	0.1 ppm	0.01 vol%
Resp. Time	20s (t95)	40s (t90)	~~40s (t90)~~	30s (t90)	~~[illegible]0s (t90)~~	40s (t90)	30s (t90)	35s (t90)	40s (t90)

Figure 7. Testo XL350 Handheld Emissions Tester with Specs (Std Measurement Ranges)

Measurements will be taken in the exhaust stack above each Tecogen Unit (we will drill a ¼ inch port if not available). Emissions will be measured for 30 minutes. The average for the 30-minute period must be below the upper limits given above.

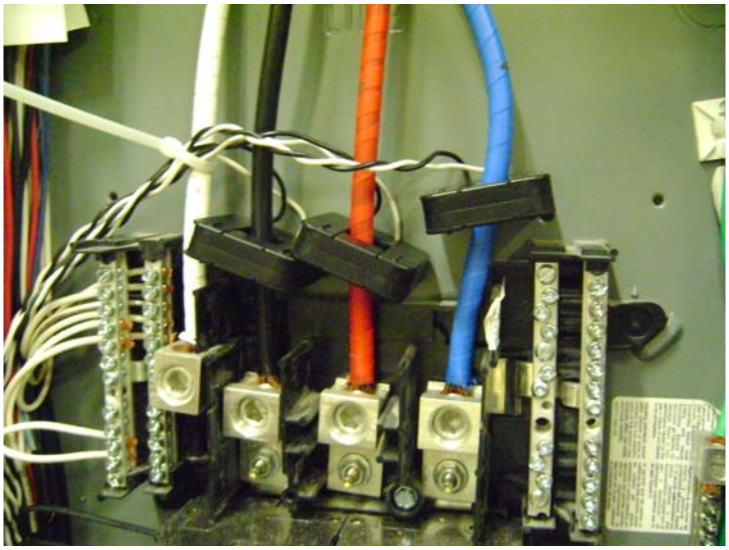
Once the applicant has confirmed the engine-generator units will meet the requirements, CDH will come onsite to complete the testing. In the event that units do not pass, CDH will remain on site for up to 8 hours while units are adjusted or tuned. In the event that the units do not pass, CDH will reschedule and return to site for only one additional day for retesting.

Appendix A



Temperature Sensor (THM)

Flow Meter (FW)



CTs for Power Transducers for Parasitic Panel (WP)

Power Transducer Enclosures near Generator Disconnects (WG1 & WG2)

Appendix B – Installation Notes

Seapark East

Generator Power

	Generator #1		Generator #2		Parasitic	
	Manual (kW)	Obvius (kW)	Manual (kW)	Obvius (kW)	Manual (kW)	Obvius (kW)
Trial 1	67	66.2	63	63.5	5.68	5.625
Trial 2	67	66.24	63.5	63.48	5.66	5.625
Trial 3			64.5			

Volts:	482 V, 484 V	482 V, 484 V	207 V, 207 V, 207 V
Amps:	100 A, 98 A, 99 A	98 A, 95 A, 95 A	15.6 A, 26 A, 25.4 A

Here the Watt Node was giving negative power outputs similar to the West, but since there was more room where the CT's were installed, they were flipped to face the line instead of the load, changing the power output to positive.

Temperature Sensors

	HWS / Sensor #6		HWM / Sensor #7		HWR / Sensor #8	
	Guage (F)	Obvius (F)	Guage (F)	Obvius (F)	Guage (F)	Obvius (F)
1:15	234	225.94	222	222.24	218	213.775
2:00	232	230.5	225	226.9	220	218.8

The gauges weren't directly next to the sensors, so the readings don't match exactly, but in relation to the other temperatures, the gauge readings and Obvius readings match. As in sensor #8 is supposed to be the coolest of the three, and #6 the hottest.

Flowmeter

The flowmeter read 44 gpm, and expected flow is 48 gpm.

Seapark East Addendum

Site Events

Date	Event
9/25/2009	Data Collection Begins
11/10/2009	Pwr mults increased by 1000 (from Wh to kWh)
11/24/2009	Added 24VDC supply, added a 249 ohm resistor to FW to and changed to 0-10VDC input
4/5/2010	Switched to collecting 1 minute data
4/7/2010	Pulse counts from the fuel meter were not being counted properly, changed the closed resistance threshold for pulse inputs on the data logger from 1000 to 2500. Switched the RTD sensors to thermistors.
6/14/2010	Changed the output of for the temperature sensors to ohms for debugging purposes.
6/16/2010	Installed new veris 10k type 2 Curve on the obvius datalogger. Output has been returned to degrees F.

Data Logger Setup

Logger Chan	Chan Type	Data Point	Wire	Logger Mult	Notes
250-In1	Pulse	WE1	0 – Red/Blk	0.023 kWh/p	Mult by: 23.083/23.000
250-In2	Pulse	WE2	0 – Grn/Wht	0.023 kWh/p	Mult by: 23.083/23.000
250-In3	Pulse	WP	3 – 12g Rd/Blu	0.001 kWh/p	Mult by: 1.25/1.00
250-In4	4-20ma	FG	Green wire	100 cf/p	
250-In5	0-10VDC	FW	Red/Blk/Grn	-32.5 to 293.8 gpm	Was 4-20ma 11/24/09
250-In6	Resistance	THS	6	100-250F	Was 4-20ma 4/7/10
250-In7	Resistance	THM	7	100-250F	Was 4-20ma 4/7/10
250-In8	Resistance	THR	8	100-250F	Was 4-20ma 4/7/10

Notes: 250 = main board, 001 = expansion board

Database Setup

```
Chan Name Device    column
WE1_ACC,  mb-250,  0
WE2_ACC,  mb-250,  5
WP_ACC,   mb-250,  10
FG_ACC,   mb-250,  15
FW,       mb-250,  20
THS,      mb-250,  26
THM,      mb-250,  31
THR,      mb-250,  36
```

Temperature Sensor Calibration Before 4/7/10 3 pm

Data Point	**Sensor ID**	**Multiplier**	**Offset**
THS	#6	0.9876	-1.2105
THM	#7	0.9818	+0.3614
THR	#8	0.9923	-0.9044

Temperature Sensor Calibration After 4/7/10 3 pm

Data Point	**Sensor ID**	**Multiplier**	**Offset**
THS	#22	1	-2.2
THM	#28	1	-2.2
THR	#29	1	-2.9

[Actual T] = [measured T] x mult + offset

WattNode Multiplier Table

CT Size (amps)	Pulses Per kilowatt-hour (PpKWH)				Watt-hours per pulse (WHpP)			
	3Y-208 3D-240	3Y-400 3D-400	3Y-480 3D-480	3Y-600	3Y-208 3D-240	3Y-400 3D-400	3Y-480 3D-480	3Y-600
5	8000.00	4173.91	3465.70	2766.57	0.125	0.2396	0.2885	0.3615
15	2666.67	1391.30	1155.24	922.190	0.375	0.7188	0.8656	1.0844
30	1333.33	695.652	577.617	461.095	0.750	1.4375	1.7313	2.1688
50	800.000	417.391	346.570	276.657	$\boxed{1.250}$	2.3958	2.8854	3.6146
60	666.667	347.826	288.809	230.548	1.500	2.8750	3.4625	4.3375
70	571.429	298.137	247.550	197.612	1.750	3.3542	4.0396	5.0604
100	400.000	208.696	173.285	138.329	2.500	4.7917	5.7708	7.2292
150	266.667	139.130	115.523	92.219	3.750	7.1875	8.6563	10.844
200	200.000	104.348	86.643	69.164	5.000	9.5833	11.542	14.458
250	160.000	83.478	69.314	55.331	6.250	11.979	14.427	18.073
300	133.333	69.565	57.762	46.110	7.500	14.375	17.313	21.688
400	100.000	52.174	43.321	34.582	10.000	19.167	$\boxed{23.083}$	28.917
600	66.667	34.783	28.881	23.055	15.000	28.750	34.625	43.375
800	50.000	26.087	21.661	17.291	20.000	38.333	46.167	57.833
1000	40.000	20.870	17.329	13.833	25.000	47.917	57.708	72.292
1200	33.333	17.391	14.440	11.527	30.000	57.500	69.250	86.750
1500	26.667	13.913	11.552	9.2219	37.500	71.875	86.563	108.44
2000	20.000	10.435	8.6643	6.9164	50.000	95.833	115.42	144.58
3000	13.333	6.9565	5.7762	4.6110	75.000	143.75	173.13	216.88
any	$\frac{40.000}{CTsize}$	$\frac{20.870}{CTsize}$	$\frac{17.329}{CTsize}$	$\frac{13.833}{CTsize}$	$\frac{CTsize}{40}$	$\frac{CTsize}{20.87}$	$\frac{CTsize}{17.329}$	$\frac{CTsize}{13.833}$

Table 5: Scale Factors - Bidirectional Outputs

Sensor Verification

Power Meters

There was no power output from Generators #1 and #2 initially due to the neutral wire not being connected. This was corrected by connecting neutral to ground in the meter enclosure.

For the parasitic power measurement, the CT's were facing the load instead of the line, which gave a negative power output. The CT was flipped to face the line, changing the power output to positive (so output P1 was used).

	Generator #1		Generator #2		Parasitic	
	Fluke 39 (kW)	Obvius (kW)	Fluke 39 (kW)	Obvius (kW)	Fluke 39 (kW)	Obvius (kW)
Trial 1	67	66.2	63	63.5	5.68	5.625
Trial 2	67	66.24	63.5	63.48	5.66	5.625
Trial 3			64.5			

Volts:	482-484 V	482-484 V	207 V
Amps:	100 A, 98 A, 99 A	98 A, 95 A, 95 A	15.6 A, 26 A, 25.4 A
kVA	82.8	80.3	8.0
Implied PF	0.81	0.79	0.71

Gas Verification 4/7/10

Timestamp	Obvious
3:11	12102800
3:35	12103800
3:37	12103900
3:41	12104000
3:45	12104100
348	12104200
3:51	12104300
40	1500
Cf/hour =	2200

Flowmeter

The water flowmeter (FW) read 44 gpm. The expected flow from the drawings is 48 gpm. All-systems cogen also wrote down flow readings of 44 gpm based on their portable meter.

Photos

WE1 & WE2 – In front maintenance room where facilities phone lines split.

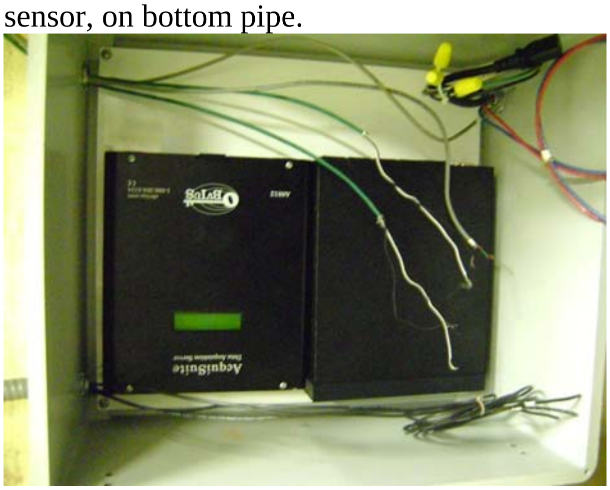
WP – In HX room on left hand wall.

FG – In front left corner of adjacent parking garage.

FW – In HX room on left hand wall, above blue pump.

THS – On HX wall, lower left most temp sensor, on bottom pipe.

THM – On HX wall, on bottom pipe, center of the three temperature sensors.



Obvius Datalogger and UPS

Turbine and generator, on 2nd floor of parking garage.