Monitoring and Analysis Plan for Capstone Microturbine 75 kW CHP System at 441 W 47th Street Manhattan, NY – The Fountain House

This document describes the measurements, sensors, and data logging equipment proposed to quantify the performance of the Capstone microturbine based CHP system installed at The Fountain House in New York, NY. The CHP system consists of a single Capstone C65 microturbine 65-kW engine generator system that produce electricity and hot water for domestic hot water, and space cooling via a hot water absorption chiller/heater.

Description of CHP System

The single 65-kW microturbine generator (**MT-1**) is located on the roof level of the building. Hot water piping from the integrated exhaust to hot water heat exchanger (ICHP heat recovery), is run to a basement mechanical room, where it is directed via a three way diverting valve to either feed a large 1,000 gallon domestic hot water (DHW) storage tank, or to provide heat to operate a 20-ton hot water absorption chiller/heater.

Potable DHW is circulated by two 1.5-HP constant speed pumps through the entire heat recovery system, including the hot water absorption chiller/heater, without the use of isolation heat exchangers. The exhaust bypass damper on the ICHP unit provides the only method of rejecting excess heat to ambient. No water side dump radiator is included in the system.

The CHP system is designed to provide the sole source for DHW for the building. When the DHW storage tank has reached its storage temperature of 140°F[1], the system three way diverting valve (**HWV**) directs hot water from the mircroturbine to the hot water driven absorption chiller/heater (**CH-3**). The hot water absorption chiller/heater operates in the cooling mode or heating mode based on ambient temperature, changing between modes at 65°F[2] ambient.

In addition to the CHP system, the building also uses two 90-ton natural gas direct-fired chiller/heater (**CH-1, CH-2**) to provide space heating and cooling operation. The building distribution system primarily consists of a two pipe change-over system, with the majority of the building using chilled or hot water exclusively. An ambient temperature reading is used to change over the building distribution system from heating to cooling, as well as control the operating mode of the direct fired absorption units.

All three chiller/heater units use a single cooling tower (**CT-1**) for condenser water heat rejection. The cooling tower is outfit with a plate frame heat exchanger (**HX-1**) which provides free cooling where ambient conditions permit.

[1] Estimated, actual value to be determined at system startup.
[2] Estimated, actual value to be determined at system startup.

To ensure the highest level of heat recovery possible, the hot water absorption chiller/heater is given priority over the direct fired units for space conditioning, with DHW production by the microturbine given the highest priority. When the CHP system is operating to provide DHW, the two direct fired absorption units will provide space heating operation.

The overall system piping configuration is shown in Figure 1.

Figure 1. CHP System Piping Diagram

Description of Monitored Data Points

Table 1 lists the monitored points required to characterize the performance of the CHP system. Each point is accompanied by the respective sensor and engineering unit measured.

Table 1. Data Point List

No.	Data Point	Description	Units	Sensor	Output
1	WG	Microturbine Energy Output (less fuel gas booster)	kWh	Veris H8053-100	Sold State Contact
2	SHWP3	Hot Water Circulating Pump Runtime (HWP3)	min	Veris H800	Sold State Contact
3	SHWP4	Hot Water Circulating Pump Runtime (HWP4)	min	Veris H800	Sold State Contact
4	FL	Hot Water Loop Flow	gpm	Onicon F1110 flowmeter	4-20 mA
5	TLS	Hot Water Loop Supply Temperature	F	10k Type II Thermistor	Resistance
6	TLR	Hot Water Loop Return Temperature	F	10k Type II Thermistor	Resistance
7	SHWV	Hot Water Diverting Valve Status (DHW/Chiller)	min	Veris H800	Sold State Contact
8	TLS1	Hot Water Loop Supply Temperature to DHW	F	10k Type II Thermistor	Resistance
9	TLS2	Hot Water Loop Supply Temperature to Chiller	F	10k Type II Thermistor	Resistance
10	TAO	Ambient Temepratur	F	10k Type II Thermistor	Resistance
11	WT	Total Facility Power	kWh	Con Ed Bill	Collected directly from internet
12	FG	Microturbine Gas Input	CF	Con Ed Bill	Collected directly from internet
13	FGT	Total Facility Gas Input	CF	Con Ed Bill	Collected directly from internet

A schematic diagram of each sensor location is shown in Figure 2.

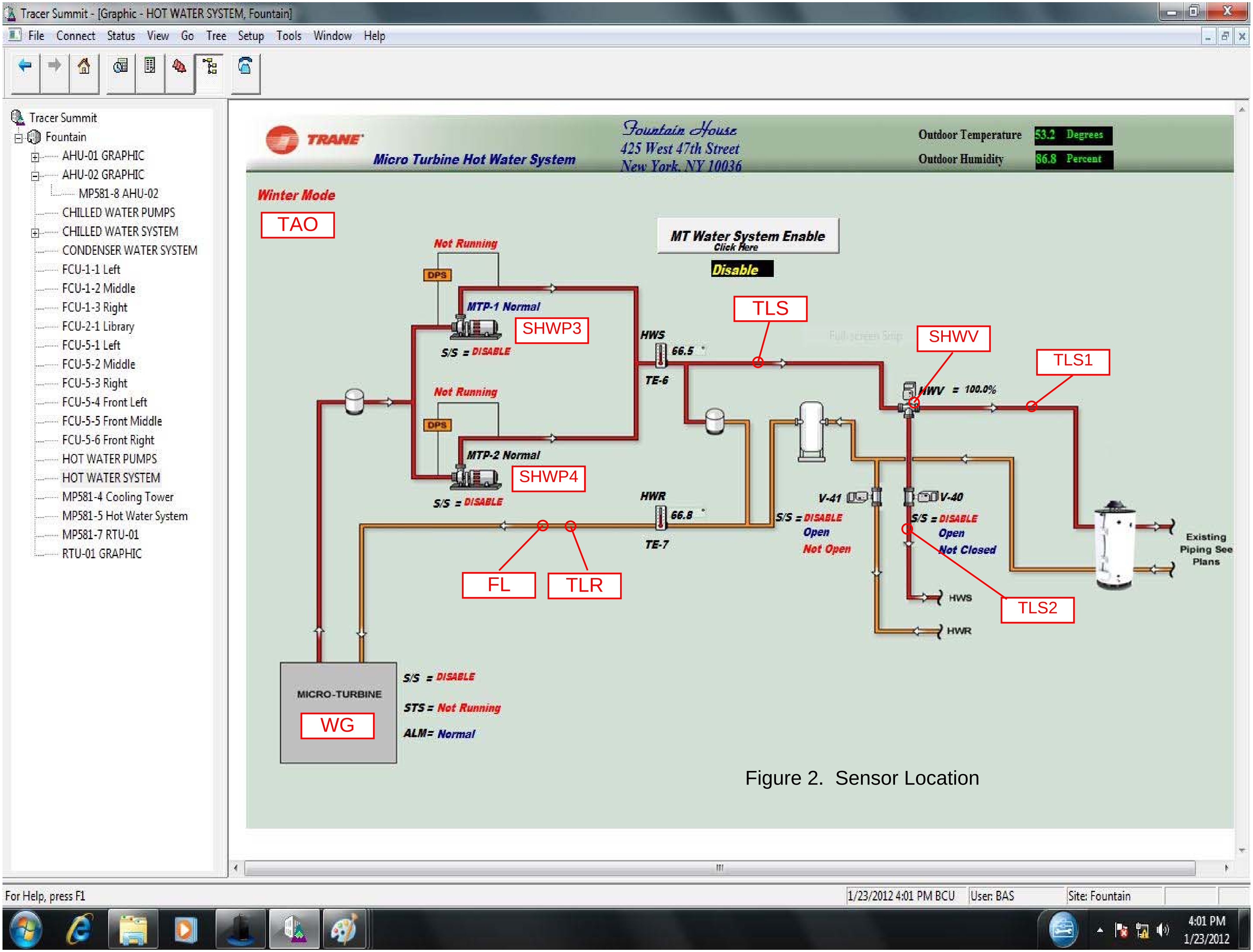
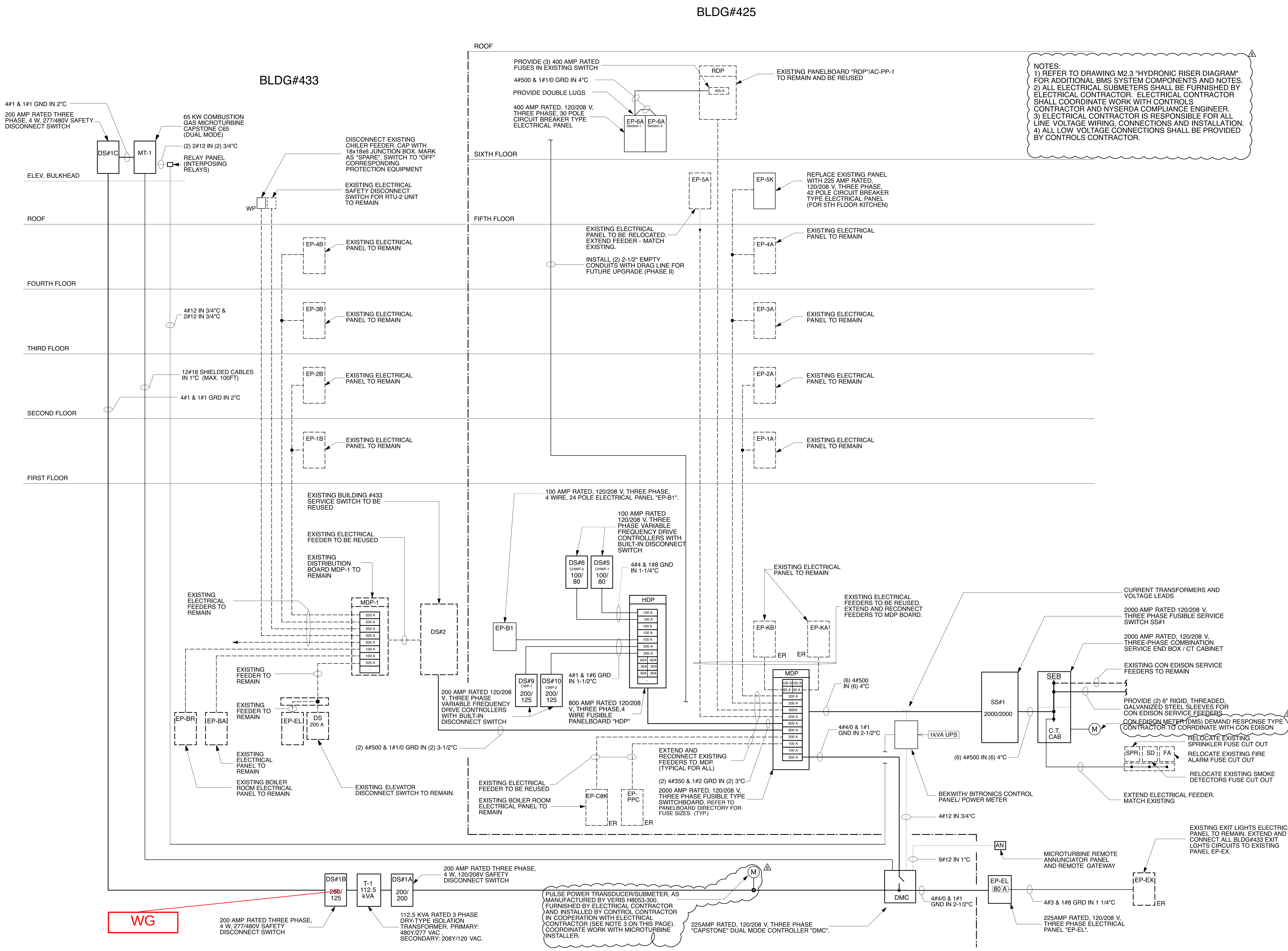


Figure 2. Sensor Location

Power Meters (WG)

A power transducer is installed in a fused disconnect on the 480 VAC side of the interconnection transformer. The power transducer provides a pulse output for each 100-Wh of electricity produced by the microturbine. The power transducer measures the net output of the microturbine (gross output minus power needed for the integrated natural gas booster), but does not include the power of the hot water circulating pumps.

Figure 3. Microturbine Power Transducer Installed in 480 VAC disconnect



NOTES:
1) REFER TO DRAWING M2.3 "HYDRONIC RISER DIAGRAM" FOR ADDITIONAL BMS SYSTEM COMPONENTS AND NOTES.
2) ALL ELECTRICAL SUBMETERS SHALL BE FURNISHED BY ELECTRICAL CONTRACTOR. ELECTRICAL CONTRACTOR SHALL COORDINATE WORK WITH CONTROLS CONTRACTOR AND NYSERDA COMPLIANCE ENGINEER.
3) ELECTRICAL CONTRACTOR IS RESPONSIBLE FOR ALL LINE VOLTAGE WIRING, CONNECTIONS AND INSTALLATION.
4) ALL LOW VOLTAGE CONNECTIONS SHALL BE PROVIDED BY CONTROLS CONTRACTOR.

ELSKOP • SCHOLZ
350 5TH AVENUE SUITE 7518
NYC 10018
T 212.244.1307 f 212.244.1315

IP GROUP
CONSULTING ENGINEERS
648 Broadway No. 400
NEW YORK, NY 10012
212 982 3877 T
212 614 0752 F

REVISION NO	DATE
BULLETIN 4	07/14/2010

REVISION NO	DATE
BULLETIN 8	01/07/2011

PROJECT
FOUNTAIN HOUSE
421-433 West 47th Street
New York City 10036

DRAWING TITLE
ELECTRICAL DISTRIBUTION RISER DIAGRAM

SEAL & SIGNATURE

DATE:	01/22/2010
PROJECT NO.:	281810
DRAWING BY:	SB
CHK BY:	IS
DWG No.:	
	E0.1
CAD FILE No:	1 of >

Natural Gas Flow (FG)

No direct natural gas metering will be performed by the monitoring system. Interval gas use for the microturbine will be calculated based on a performance map that relates gas consumption to delivered power. The microturbine will be commanded to produce various power levels (typically 20 kW, 40 kW, 60 kW and full power), for a fixed interval of 30-minutes each. Readings on the natural gas billing meter will be recorded at the start and end of each 30-minute period, and the corresponding gas use will be determined for each operating power level.

Since microturbine gas use is influenced by ambient temperature, the performance mapping effort will be performed at low ambient temperatures (below 60°F ambient), and high ambient temperatures (above 80°F). A multiple linear regression model incorporating microturbine power and ambient temperature to gas consumption will be developed. This regression analysis, based on the results of this on-site performance mapping, will be used to calculate the gas consumption for every data interval where the microturbine is producing power.

Each month the microturbine natural gas billing data will compared to the results of the regression calculation. An adjustment factor for each month will be developed to correct the regression results to the actual metered gas consumption.

Heat Recovery Calculations (TLS, TLR, FL)

The total recovered heat from the CHP system is measured using two thermistors (**TLS, TLR**) and an insertion turbine flow meter (**FL**). The heat recovery measurement includes heat transfer to both the DHW storage tank, and hot water absorption chiller/heater operation. Dis-aggregation of the total heat transfer to the two end uses (DHW or space conditioning) is performed using the diagnostic temperatures sensors (**TLS1, TLS2**), valve position sensor (**SHWV**), and ambient temperature (**TAO**).

The three way diverting hot water valve position (**SHWV**) is measured using a current status switch on the valve control wiring. Additional temperature sensors located on the supply piping to the DHW storage tank (**TLS1**), and absorption chiller (**TLS2**), will also be used to validate the position of the diverting valve. The diverting valve operates as a two-position valve (normally closed/normally open), not modulating. This results in flow (and therefore heat recovery) to be fully directed to either end use.

Hot water absorption chiller operation will be allocated to cooling/heating operation based on ambient temperature (**TAO**), and the observed setting on the building EMS system.

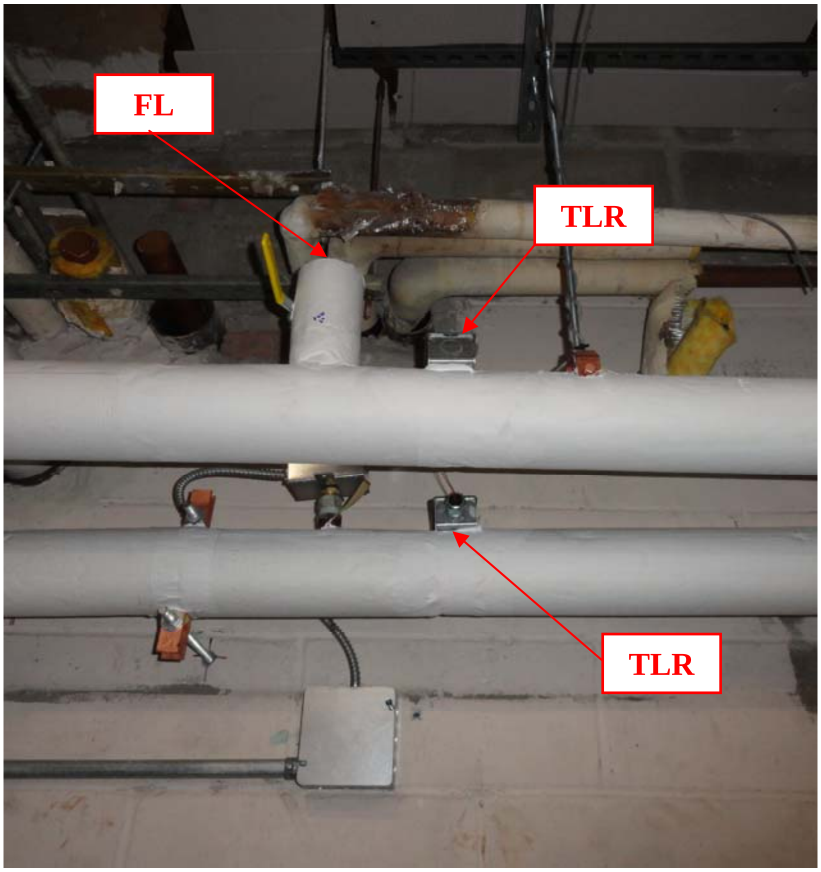
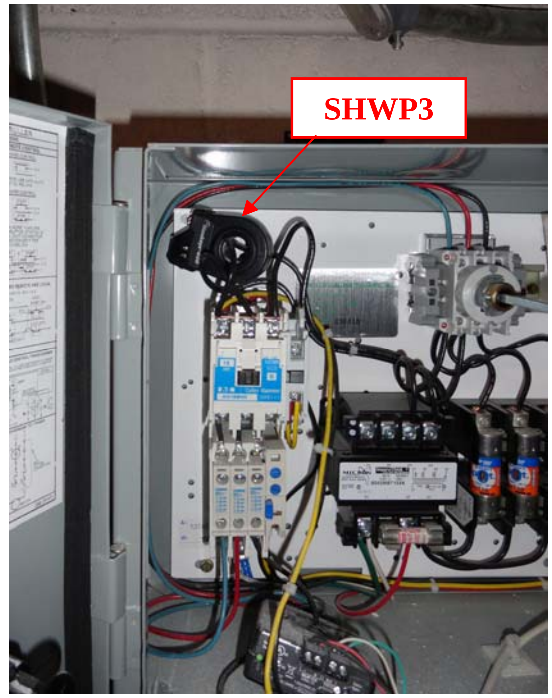


Figure 5. Heat Recovery Sensors (FL to be installed in valve assembly)

Parasitic Power Loads (SHWP3, SHWP4)

Operation of the constant speed heat recovery circulating pumps (**SHWP3, SHWP4**) will be recorded as pump runtime using current status switches. The energy for this pump operation will be calculated based on the recorded runtime, and a one-time measurement of each pump's power using a hand held watt-transducer (Fluke 39).

Heat Recovery Loop Pumps



Heat Recovery Loop Pumps Status Sensor (1 of 2 typ)

Figure 6. Parasitic Loads – Hot Water Pumps

Utility Account Information (WT, FG, FGT)

Monthly utility electricity data for the building (**WT**), natural gas consumption for the microturbine (**FG**), and natural gas consumption for the direct fired absorbtion chiller/heaters and other building loads (**FGT**) will be collected using utility billing information.

Data Logger Location and Communication

The data logger is installed adjacent to the microturbine disconnect and transformer in the boiler room located in the cellar level. The data logger utilizes a DHCP internet connection provided by the Fountain House, and uploads data nightly to the CDH Energy data servers. A dedicated 15-amp circuit for the data logger panel has been provided by the facility.

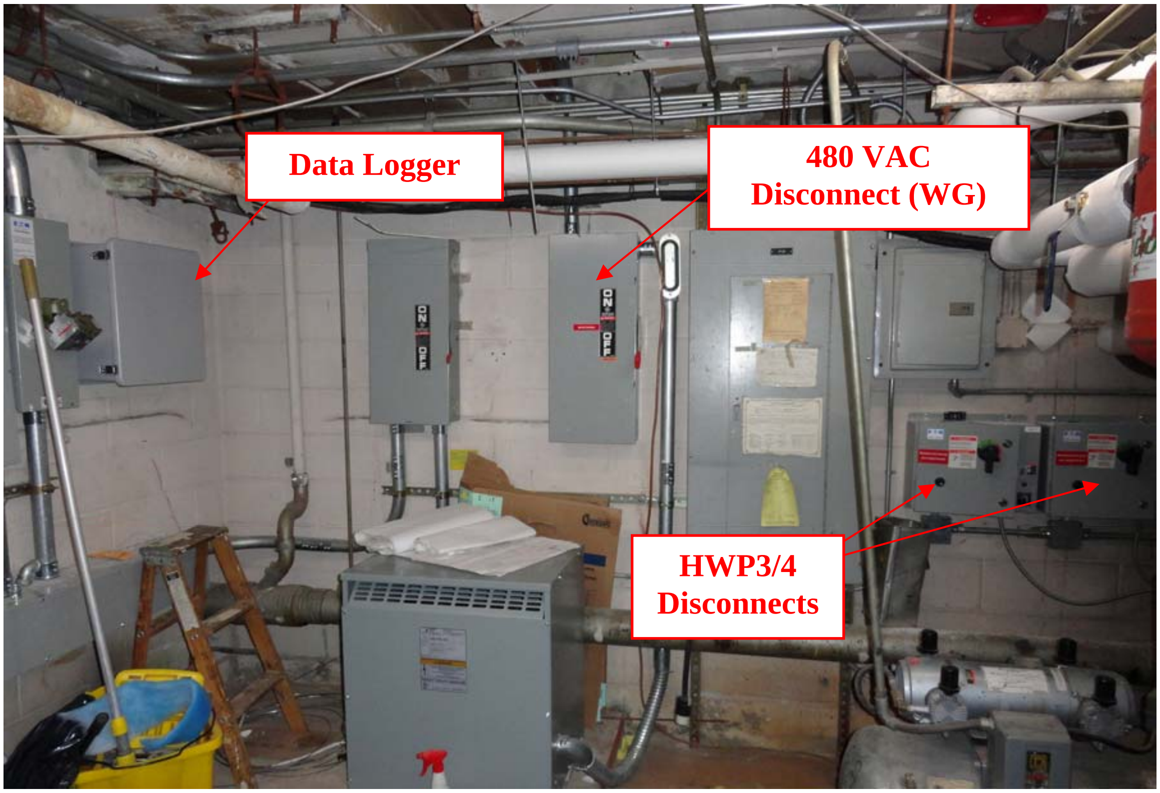


Figure 7. Mechanical Room Panel Locations

Figure 8. Obvius Data Logger

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).

Peak Demand or Peak kW

The peak electric output or demand for each power reading will be taken as the average kW in a 1-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 based on the 1-minute data recorded by the data logger. The piping arrangement at this site requires for separate heat rates to be determined with four temperature sensors and two flow readings:

Useful heat recovery (**QHU**) = K·Σ [FL·(TLS-TLR)] / n

The loop fluid is expected to be pure water, (K ~ 500 Btu/h-gpm-°F). ‘n’ is the number of scan intervals included in each recording interval (e.g., with 1-minute data, n=60).

Parasitic Loads

The parasitic electric loads on this system consists of two circulation pumps.

Parasitic Energy (**WPAR**) =SHWP3 (min) x kW_{HWP3} / 60 min/h + SHWP3 (min) x kW_{HWP3} / 60 min/h

Calculated Quantities

The net power output from the CHP system will be defined as the power from the engine generators minus the parasitic power.

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

$$FCE = \frac{QHU \cdot \Delta t + 3.412 \cdot (WG - WPAR)}{LHV_{gas} \cdot FG}$$

where:

QHU	-	Useful heat recovery (Btu/h)
WG	-	Engine generator gross output (kWh) (WG1+WG2)
WPAR	-	Parasitic energy (kWh)
FG	-	Generator gas consumption (Std CF)

	Δt -	1/60 for 1-minute data
	LHV_{gas} -	Lower heating value for natural gas (~920 Btu per CF).
Where		
		0.9 is the conversion factor between HHV and LHV

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

$$FCE = \frac{\sum^{N} QHU \cdot \Delta t + 3.412 \cdot \sum^{N} (WG - WPAR)}{LHV_{gas} \cdot \sum^{N} FG}$$

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

Data Logging Equipment

The data logging system will be based around the Obvius AquiSuite A8812 data logger. The logger has eight analog or digital inputs on the main board, and monitoring capabilities can be extended using expansion boards. The primary sensor connection configuration for the logger is a two-wire twisted pair network, that reduces the number of low voltage sensor wire runs. The logger has 32 MB of onboard RAM for data retention. The logger is equipped with both a 10/100 LAN port and an analog phone modem for remote data retrieval.

Obvius AcquiSuite

Figure 9. Obvious AcquiSuite Data Logger

Each night we poll the logger via a network connection, and collect the data recorded across the day. Data are automatically loaded into the database system here at CDH Energy, where a number of automated data verification routines will identify any suspect data. Verification routines will consist of range checks, where the data are compared to a preset range of value, and data exceeding these values will be flagged; and/or relational checks, where the data are compared to the operational state of the unit for validity. Data that fails the verification routines will be checked manually by CDH personnel on a daily basis, and corrupt data will be removed from the database. We will endeavor to address data collection issues such as data logging hardware or sensor failures within 48-hours of the failure being identified.

All data collected will be converted to hourly data in a comma delimited CSV format consistent with the requirements for inclusion into the NYSERDA integrated data system website.

All sensors are scanned on the order of once per second, and these samples will be combined into 1-minute averages (for analog data) and totals (for digital data). The logger has sufficient memory to hold up to 30-days of data without overwriting the logger memory.

All data logging equipment is installed in a fiberglass NEMA Type 1 enclosure to be mounted inside the cellar mechanical room.

Other Monitoring Requirements

The data logger will require a connection to the Internet. A dedicated static IP address is desired, but not required. If a dynamic IP address is used, the logger will upload data every night to the CDH Energy servers, but we will not be able to access the logger for remote configuration purposes.

All low voltage signal wiring will not be installed in conduit. Cable runs will be neat and secured to existing conduit.

Sensor Selection

Cut sheets for the data logging equipment and sensors are attached.

Sensor Verification

To be performed at monitoring system installation.

System Energy Flows

System energy and thermal flows documented in data analysis section.

Data Collection Status

The data logger is currently uploading data to the CDH Energy servers, but CHP system operation has not begun.

APPENDIX A – Data Logger and Sensor Cut Sheets

APPENDIX B – Data Logger Wiring Diagrams

Instrumentation, Wiring Schematic, and Installation Details

Site Visits

January 23, 2012	Initial site visit and rough in Data logger connected to internet

Description of Monitored Data Points and Schematics

Table B-1 lists the monitored points installed at the site.

Table B-1. Monitored Data Point List

No.	Data Point	Description	Units	Sensor	Output
1	WG	Microturbine Energy Output (less fuel gas booster)	kWh	Veris H8053-100	Sold State Contact
2	SHWP3	Hot Water Circulating Pump Runtime (HWP3)	min	Veris H800	Sold State Contact
3	SHWP4	Hot Water Circulating Pump Runtime (HWP4)	min	Veris H800	Sold State Contact
4	FL	Hot Water Loop Flow	gpm	Onicon F1110 flowmeter	4-20 mA
5	TLS	Hot Water Loop Supply Temperature	F	10k Type II Thermistor	Resistance
6	TLR	Hot Water Loop Return Temperature	F	10k Type II Thermistor	Resistance
7	SHWV	Hot Water Diverting Valve Status (DHW/Chiller)	min	Veris H800	Sold State Contact
8	TLS1	Hot Water Loop Supply Temperature to DHW	F	10k Type II Thermistor	Resistance
9	TLS2	Hot Water Loop Supply Temperature to Chiller	F	10k Type II Thermistor	Resistance
10	TAO	Ambient Temeprature	F	10k Type II Thermistor	Resistance
11	WT	Total Facility Power	kWh	Con Ed Bill	Collected directly from internet
12	FG	Microturbine Gas Input	CF	Con Ed Bill	Collected directly from internet
13	FGT	Total Facility Gas Input	CF	Con Ed Bill	Collected directly from internet

Figure B-1 displays the data logger termination diagram.

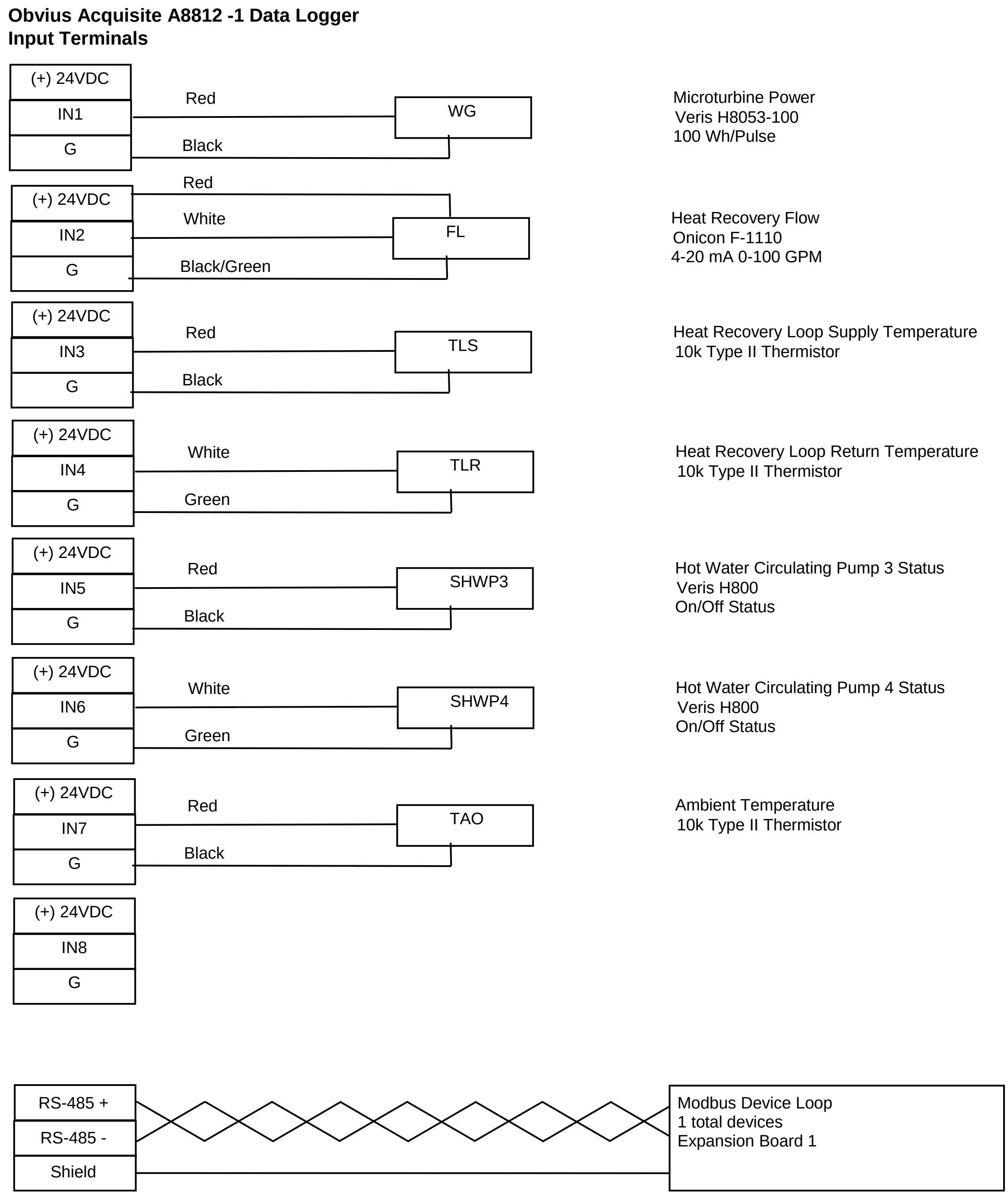


Figure B-1. Obvius Data Logger Wiring Schematic

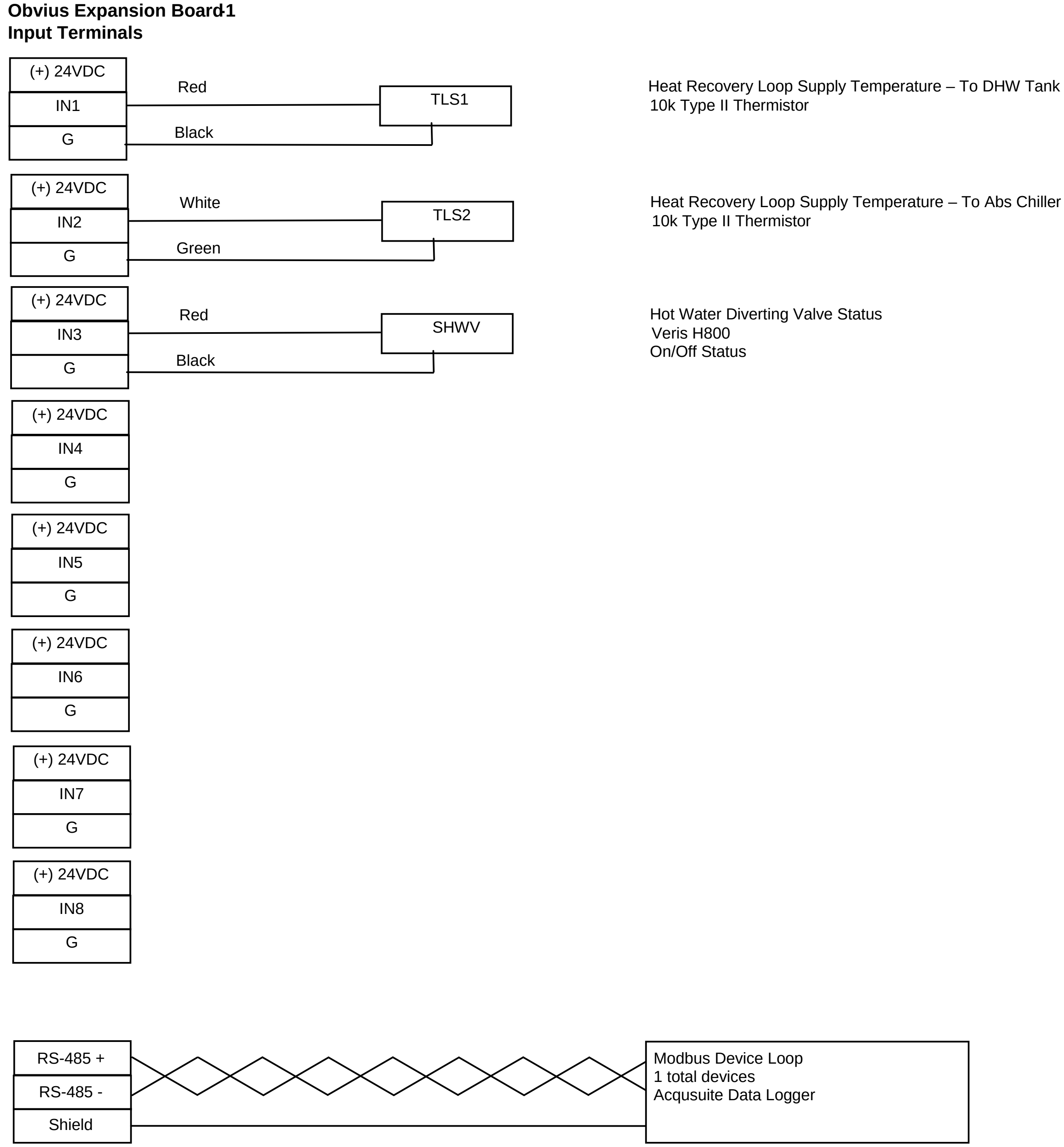


Figure B-2. Obvius Expansion Board Wiring Schematic