# MEASUREMENT AND VERIFICATION PLAN

### FOR

## CHP SYSTEM AT
## PALACE HOTEL

# February 2014

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# 1. Introduction



The Palace Hotel, located in Midtown New York City at 455 Madison Avenue, offers 813 guest rooms and 86 suites, 22,000 square feet of meeting and event space, and a spa and fitness center. The combined heat and power (CHP) system being installed at the site includes twelve (12) 65-kW Capstone Microturbines to provide up to 780 kW of gross electrical generation capacity, and up to 3.45 MMBtu/h of hot water at 200°F using the ICHP integrated heat recovery heat exchangers. Hot water produced by the microturbine skid is used to either drive a 205-ton single effect hot water absorption chiller (COP 0.71) or to provide supplemental heat to the building hot water loop via a plate frame heat exchanger. The system alternates between the heating and cooling mode using isolation valves to dedicate the heat recovered solely to the chiller or heat exchanger as appropriate. Electrically, the microturbines are divided into two banks of six, with each set of microturbines displacing load on a separate Con Edison utility service.

# 2. Monitoring System

A monitoring system will be installed to measure the performance of the CHP system.  The system will be based around the RSP-VUE main controller, using an Obvius AcquiSuite A8812 datalogger as the data collection platform.  All monitoring hardware and field point sensors are being sourced and installed by RSP. The monitored points to be used to quantify performance are listed in Table 1.

**Table 1. Monitored Data Points**

| No. | Data Point | Description | Sensor | Output | Notes |
|---|---|---|---|---|---|
| 1 | WG1 | Turbine Array 1 Electrical Output | Veris H8035-800-4 | Modbus | Multi-phase power meter , reports energy (kWh) and power (kW) |
| 2 | WG2 | Turbine Array 2 Electrical Output | Veris H8035-800-4 | Modbus | Includes parasitic loads related to chiller Multi-phase power meter , reports energy (kWh) and power (kW) |
| 3 | TLS1 | CHP Hot Water Loop Supply Temperature to HX or Chiller | BTU Meter 1 – Onicon System 10 including Onicon F1100 Flow Meter | Modbus | BTU meter provides extended data stream (temperatures, flow) |
| 4 | TLR1 | CHP Hot Water Loop Return Temperature from HX or Chiller | | | |
| 5 | FL1 | CHP Hot Water Loop Flow | | | |
| 6 | QU | CHP Hot Water Loop Heat Recovery | | | |
| 7 | TLS2 | Chiller Loop Supply Temperature | BTU Meter 2– OniconSystem 10 including Onicon F1100 Flow Meter | Modbus | BTU meter provides extended data stream (temperatures, flow) |
| 8 | TLR2 | Chiller Loop Return Temperature | | | |
| 9 | FL2 | Chiller Loop Flow | | | |
| 10 | QCL | Chiller Loop Chilled Water Produced | | | |
| 11 | WT1 | Utility Service 1 Power Import | Shark 100S | Modbus | Multi-phase power meter , with extended data stream |
| 12 | WT2 | Utility Service 2 Power Import | Shark 100S | Modbus | Multi-phase power meter , with extended data stream |
| 13 | FG | Turbine Gas Consumption | Eldridge 8724MPNH | Modbus | Insertion hot wire anemometer gas meter |

The heat recovery loop will operate in one of two modes depending on the season.  During the heating season, the heat recovered from the CHP system will supplement the building hot water loop as seen in Figure 1. During the cooling season, the heat recovered from the CHP system will supply the hot water absorption chiller as seen in Figure 2. The amount of useful heat recovered from the CHP system is measured by a BTU meter located on the heat recovery loop. The BTU meter will internally calculate the useful heat recovery (**QU**) and provide the fundamental measurements (**TLS1**, **TLR1**, **FL1**) used to calculate the useful heat recovery from the CHP system. A second BTU meter located on the chilled water loop will measure chilled water produced (**QCL**) by the absorption chiller, along with the fundamental measurements (**TLS2**, **TLR2**, **FL2**) used to calculate the chilled water produced.  Measuring the delivered chilled water capacity (**QCL**) and simultaneous useful heat recovered (**QU**) allows calculation of the coefficient of performance of the chiller (**COP$_{chiller}$**).
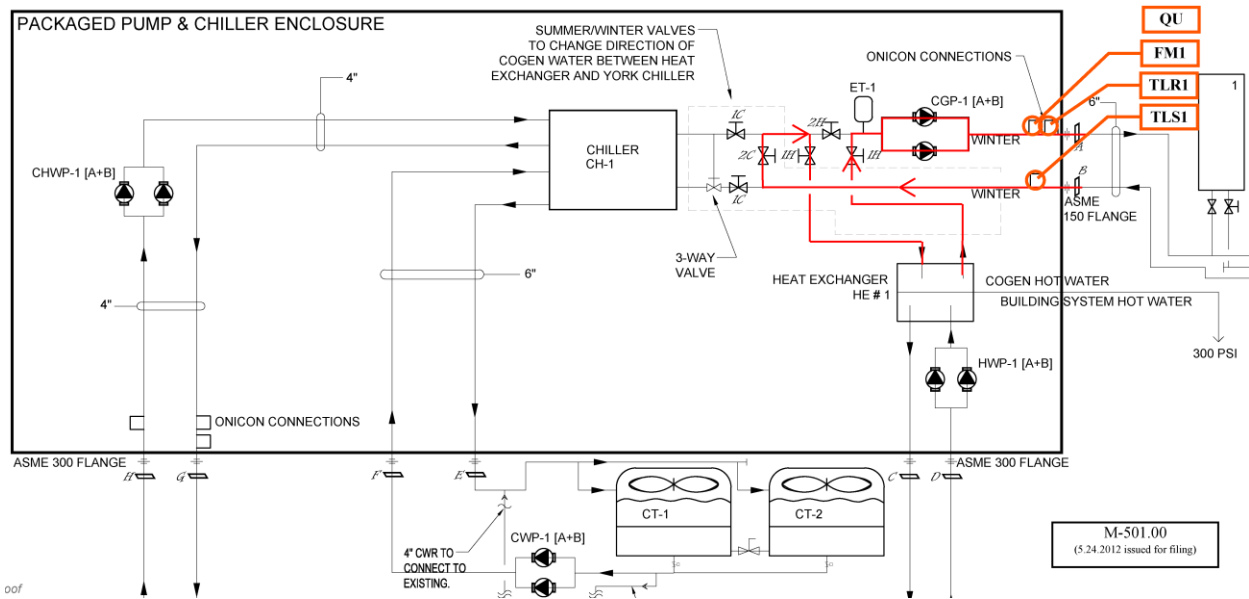
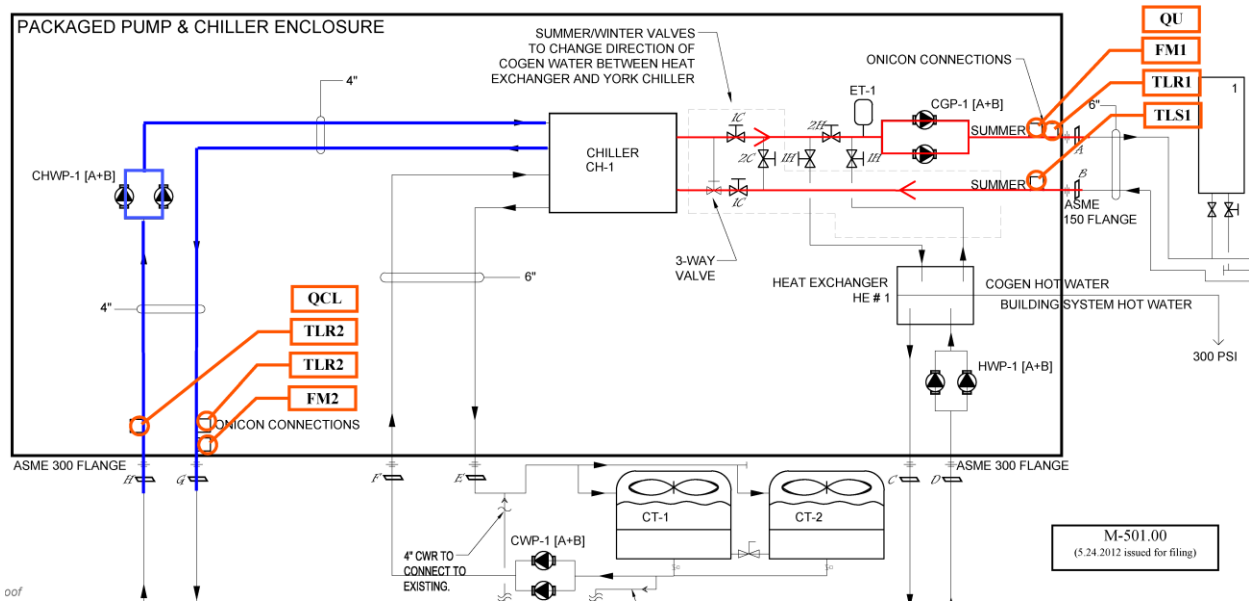**Figure 1. Heating Season CHP System With Monitoring Points**



**Figure 2. Cooling Season CHP System With Monitoring Points**

The facility purchases power from two separate Con Edison utility services.  Power import from each one (**WT1**, **WT2**) will be measured by a Shark 100S meter, which will be located at SSA and SSB on the C-1level respectively, as seen in Figure 3. The power output from each of the two banks of microturbines (**WG1**, **WG2**) will be measured at the main service entrance for panels QMQB-A and QMQB-B respectively with Veris H8035 power meters.  The microturbine power output measurements will be net power (gross power minus the parasitic loads associated with the chiller), so it will not be necessary to also monitor parasitic power use.
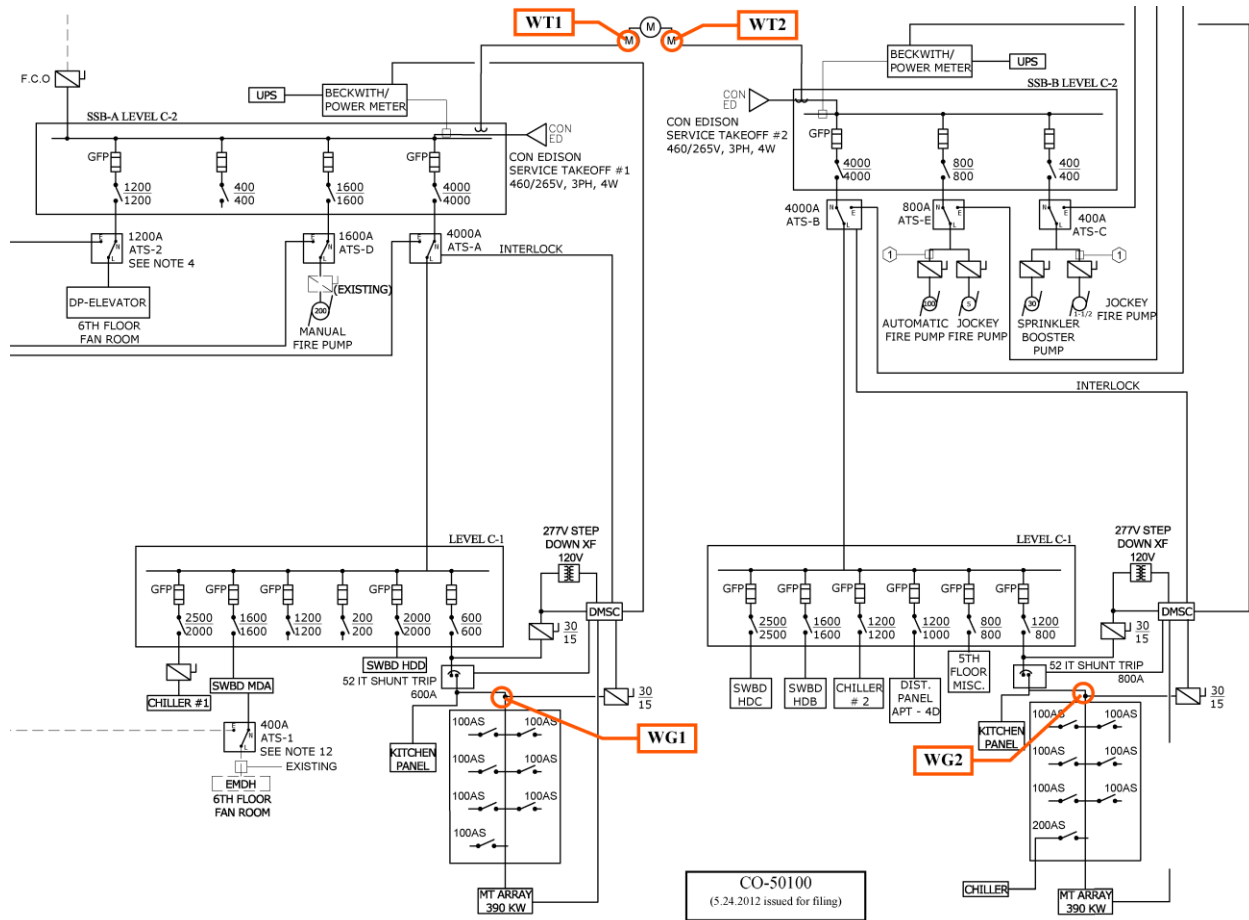
**Figure 3. CHP System Power Meter Locations**

The gas meter will be an Eldridge 8724MPNH insertion hot wire anemometer gas meter, which will be located on the roof, as seen in Figure 4.
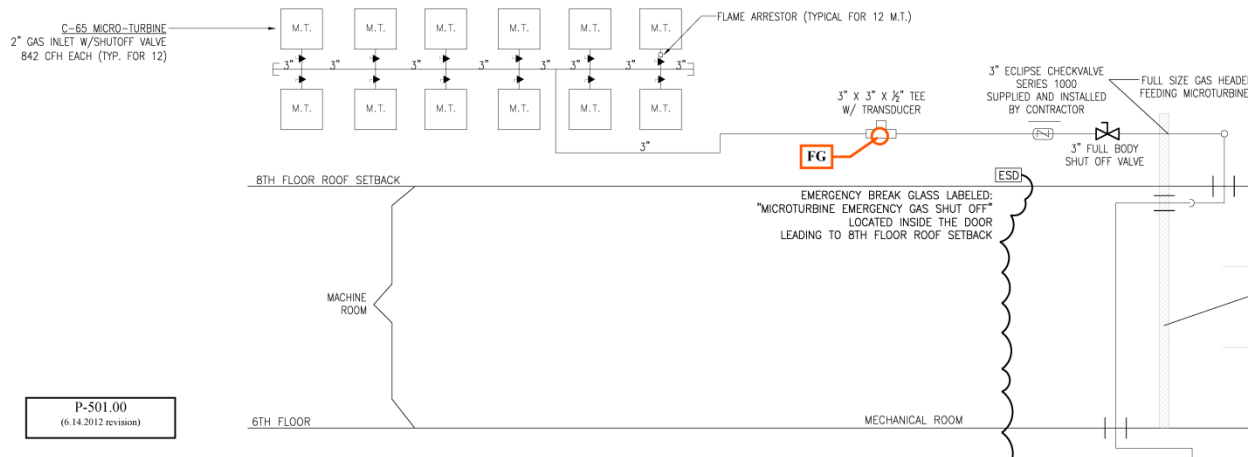


**Figure 4. Gas Meter Location**

### Sensor Details

- *Heat Recovery*.  The BTU meters are Onicon System 10 BTU meters, which consist of two compatible Onicon temperature sensors and an Onicon F1100 flow meter integrated into one instrument that integrates the heat transfer measurement and provides a Modbusinterface to transfer data to the data logger.

- *Gas Flow*.  The gas will be metered by an insertion hot wire anemometer style sub-meter, with either a Modbus interface.  The gas consumption measured by the meter will be compared to the natural gas utility bill data on a periodic basis to ensure accuracy.

- *Power*. The utility import power meters will be Shark 100S multi-phase power meters, located on C-1 Level.  The microturbine output power meters will be Veris H8035 multi-phase power meters, located at the QMQB panels of the microturbine distribution on the roof.

### Data Logging System

The data logging device will be an Obvius AcquiSuite A8812 data logger.  The data logger meets the following general criteria, and therefore is acceptable to NYSERDA:

- Sample and integrate heat transfer measurements at least once every 15seconds, provide 15-minute totals and averages of heat transfer measurements.
- Record energy and demand on a 15-minute basis
- Store up to 30-days of data on site in the event of a communication disruption
- Record data in a column oriented, comma delimited file (CSV) for data transfer
- Provide automated data transfer via FTP, HTTP, or email to NYSERDA integrated data system on a basis no less than once per day

The Obvius data logger will use an Ethernet connection to transfer data to CDH Energy once per day.  The logger can use either a dynamic (DHCP) or static IP connection.  Note that if the logger is on a dynamic IP connection, no remote access to the logger for configuration purposes is possible.

CDH Energy will then load the raw data into a database, where it will be checked for internal consistency using range and relation checks to validate the data.  The data will then be automatically converted into a format compatible with the NYSERDA integrated data system website, and uploaded each night.

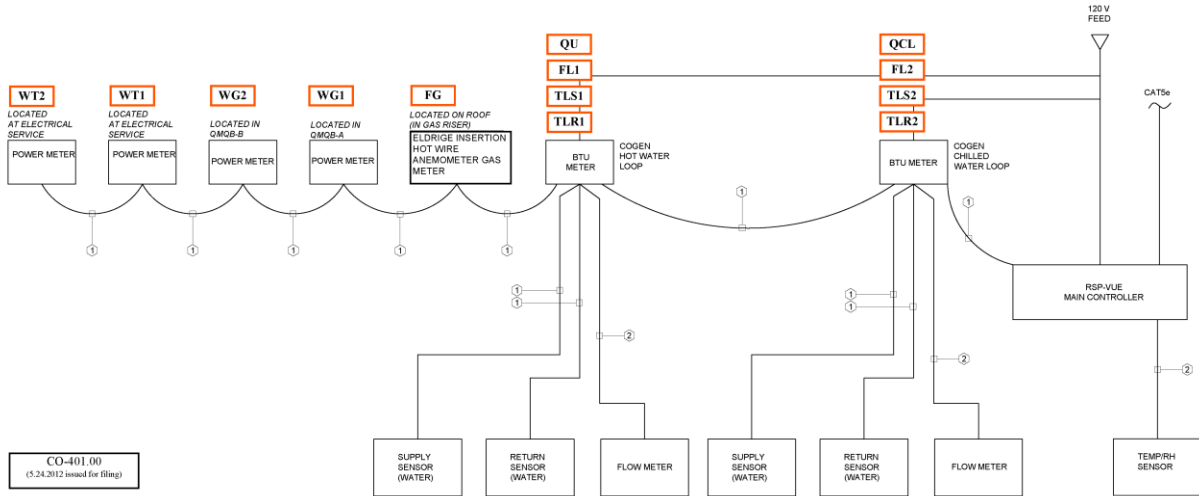Figure 5 displays a general connection diagram for the data logger and field point sensors installed.

**Figure 5. Data Logger Configuration**

# 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 2. Summary of Monitored Data Points**

| No. | Data Point | Description | Engineering Unit |
|---|---|---|---|
| 1 | WG1 | Turbine Array 1 Electrical Output | kW / kWh |
| 2 | WG2 | Turbine Array 2 Electrical Output | kW / kWh |
| 3 | TLS1 | CHP Hot Water Loop Supply Temperature to HX or Chiller | deg F |
| 4 | TLR1 | CHP Hot Water Loop Return Temperature from HX or Chiller | deg F |
| 5 | FL1 | CHP Hot Water Loop Flow | gpm / Gallons |
| 6 | QU | CHP Hot Water Loop Heat Recovery | BTU |
| 7 | TLS2 | Chiller Loop Supply Temperature | deg F |
| 8 | TLR2 | Chiller Loop Return Temperature | deg F |
| 9 | FL2 | Chiller Loop Flow | gpm / Gallons |
| 10 | QCL | Chiller Loop Chilled Water Produced | BTU |
| 11 | WT1 | Utility Service 1 Power Import | kW / kWh |
| 12 | WT2 | Utility Service 2 Power Import | kW / kWh |
| 13 | FG | Turbine Gas Consumption | CF |

**Peak Demand or Peak kW**

The net microturbine output (**WG**) is simply the summation of the output from the two banks of microturbines (**WG1**, **WG2**).

$$WG = WG1 + WG2$$

The peak electric output or demand for each power reading will be taken as the average kW in a fixed 15-minute interval (0:00, 0:15, 0:30, etc.):

$$kW_{Peak} = \sum\nolimits_{15\min} \frac{WG\ (\text{kWh})}{\Delta t} = \sum\nolimits_{15\min} = \frac{WG\ (\text{kWh})}{0.25\ \text{h}}$$

The microturbine power meters will measure the net output of each of the two banks of turbines. A one-time measurement can be used to determine the magnitude of the parasitic loads if it is necessary to calculate gross power. A one-time measurement of the gas booster located in the basement will be performed, to account for this continuous parasitic load that is not measured by any of the power meters.

## Heat Recovery and Chilled Water Production Rates

The heat recovery rates will be calculated offline.

**Total Useful Heat Recovery:**

$$QU_{avg} = k \cdot \frac{1}{N} \sum^{N} FL1 \cdot (TLS1 - TLR1)$$

**Chilled Water Heat Recovery:**

$$QCL_{avg} = k \cdot \frac{1}{N} \sum^{N} FL2 \cdot (TLS2 - TLR2)$$

Where:   $N$   =   The number of intervals in the period of interest

$k$   =   The product of density and specific heat, 487.8 Btu/h·gpm·°F (for water at 180ºF)

## Other Calculated Quantities

**Fuel Conversion Efficiency:**

$$FCE = \frac{\sum^{N} QU + 3.413 \cdot \sum^{N} (WG)}{0.9 \cdot HHV_{gas} \cdot \sum^{N} FG}$$

Where:   $HHV_{gas}$   =   Higher heating value for natural gas (~1030 Btu per CF) and 0.9 is the conversion factor between HHV and LHV

$N$   =   The number of intervals in the period of interest

**Thermal Efficiency:**

$$THE = \frac{QU \cdot \Delta t}{HHV_{gas} \cdot FG}$$

**Electrical Efficiency:**

$$EE = \frac{3412 \cdot (WG)}{HHV_{gas} \cdot FG}$$

**Measured Chiller Coefficient of Performance:**

$$COP_{chiller} = \frac{QCL}{QU}$$

# Appendix A

## Cut Sheets for Key Sensors and Instruments