MEASUREMENT AND VERIFICATION PLAN

FOR

RIVER POINT TOWERS

AS-Built

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Submitted to:

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1. Introduction

American DG has submitted an application to the NYSERDA CIPP program (PON 984) to install a CHP system at River Point Towers at 555 Kappock Avenue in Bronx, New York. The 400+ unit apartment building has significant thermal loads.

The CHP system includes five (5) Tecogen 75 kW units. The total gross power output is 375 kW. Thermal output from the engine-generator units is used to meet various hot water loads in the facility, including space heating, DHW loads, and swimming pool heating. A dump heat exchanger rejects any unused heat from the engines to the cooling tower sump. Four of the five Tecogen units use a Cain exhaust-to-water heat exchanger to provide additional thermal output. As part of the CHP system installation, a 3,000 gallon tank was added outside the building to store preheated water for the DHW system. The DHW heat exchanger (HX) transfers recovered heat to that tank. Figure 4 in the next section schematically shows the system.

The engine-generators are 480 VAC, 3-phase (wye) induction generators. The electrical service for the 5 generators feeds into the main facility bus via two 480-to-208 transformers. A protective relay monitors generator output as well as the utility status to satisfy the Consolidated Edison inter-connection requirements.

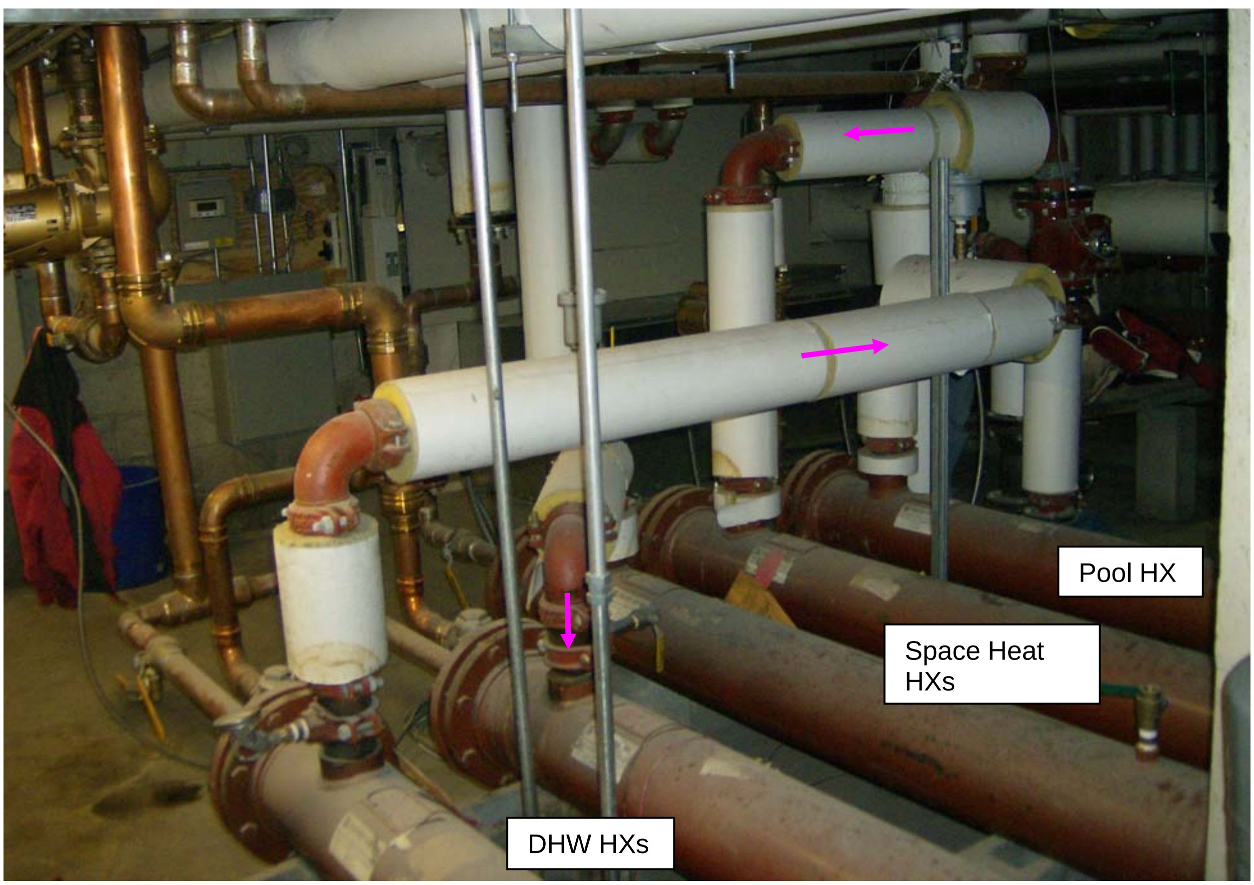

Figure 1. Cogen Loop and Heat Recovery HXs

3,000 gallon DHW Storage tank added at the back of the building

Cain Exhaust Heat Recovery HX

American DG 75 kW Unit (unit #5 w/o Exhaust HX)

Figure 2. Various CHP System Components

2. Instrumentation

American DG supplied the instrumentation listed Table 1 below. American DG installed a single power meter (with 2 sets of CTs) to measure the gross power produced by the 5 generator units. The power output from the generators is consolidated into two feeds. One gas meter measures the natural gas supplied to the five units. American DG provided access to 15-minute facility power use data at the Consolidated Edison web site (or other 3rd party web site). Alternatively, a pulse output from the main Con Ed meter will be provided to measure facility power use.

Table 1. Instrumentation Supplied By Siemens

Point	Instrument	Output Type	Sensor Location	Notes
Facility Power (**WT**)	Con Ed meter	na	Na	Applicant provided access to 15-minute data on Con Ed DMS web page
Generator Power Output (**WG480**)	Itron/ Sangamo ST-D101 (two sets of CTs)	Pulse output (??? Wh per pulse)	In engine room. At top of 480 volt panels	Measures 480 volt output. (not working as of June 2008)
Generator Power Output (208 Volt) (**WG208**)	OSC/Intellimeter (two sets of three 800:5 amp CTs)	Pulse output (38.4 Wh per pulse)	In main electrical room. Inside Transformers that feed 52IT-1 and 52IT-2	Measures 208 volt output (after Xformer)
Generator Gas Input (**FG**)	American Meter 3.5M G65 serial # 03D001875	Solid State Pulse (SSP) (10 cf per pulse, compensated)	On gas line serving all 5 engines	
fluid loop flow rate (**FHW**)	ISTEC Model #18135 Range 5.3 - 789.5 gpm 32-250°F Continuous: 263.2 gpm	Pulse output: 10 gal/pulse (pulse output from flow meter shared with BTU meter)	In fluid loop as shown Figure 4. With 2-3 feet of straight pipe before meter.	4” diam pipe, nom. flow: ~110 gpm (approx 11 pulses per minute)

The temperature sensors in Table 2 were supplied by CDH. American DG will provide 6-in deep, ¼ inch thermo-wells for the four temperature sensors shown in Figure 4. Table 3 lists the status sensors that are installed to measure equipment runtime. This data will be combined with one time measurements (Table 4) to estimate the parasitic energy use for constantly-loaded equipment, such as the pumps.

Table 2. Summary of Temperature Measurements

Point	Instrument	Output Type	Sensor Location
Hot Water Supply (**T1**)	Mamac RTD with 4-20 ma output, 100-250°F range	4-20 ma	In fluid loop as shown Figure 4 and Figure 6.
Hot Water After Heating HX (**T2**)	Mamac RTD with 4-20 ma output, 100-250°F range	4-20 ma	In fluid loop as shown Figure 4 and Figure 6.
Hot Water After DHW HX (**T3**)	Mamac RTD with 4-20 ma output, 100-250°F range	4-20 ma	In fluid loop as shown Figure 4 and Figure 6.
Hot Water After	Mamac RTD with 4-20 ma	4-20 ma	In fluid loop as shown Figure 4 and

Pool HX (**T4**)	output, 100-250°F range		Figure 6.
Hot Water Return – to engine (**T5**)	Mamac RTD with 4-20 ma output, 100-250°F range	4-20 ma	In fluid loop as shown Figure 4 and Figure 6. (strap-on sensor)

Notes: American DG will provide 6 inch thermowells for ¼ inch probes for T1 to T4. T5 will be a strap-on sensor

Table 3. Summary of Equipment Runtime Measurements

Point	Instrument	Output Type	Sensor Location
Unit #1 Pump (**SP1**)	Veris H300 current switch	Status	Locate in panel shown in Figure 3
Unit #2 Pump (**SP2**)	Veris H300 current switch	Status	Locate in panel shown in Figure 3
Unit #3 Pump (**SP3**)	Veris H300 current switch	Status	Locate in panel shown in Figure 3
Unit #4 Pump (**SP4**)	Veris H300 current switch	Status	Locate in panel shown in Figure 3
Unit #5 Pump (**SP5**)	Veris H300 current switch	Status	Locate in panel shown in Figure 3
HW Pump (**SHP**)	Veris H300 current switch	Status	Locate in 120V panel
Pool Pump (**SPP**)	Veris H300 current switch	Status	Locate in 120V panel

Note: as of June 5, the **SP5** current switch was removed since this engine never runs.

Table 4. Summary of Periodic (or One-time) Power Measurements

Point	Sensor Location
Unit Pumps (**WCP1,…,WCP5**)	In 480V panel shown in Figure 3
Loop Pump (**WLP**)	In 480V panel shown in Figure 3
Hot Water Pump #1 (**WP1**)	In 120V panel
Hot Water Pump #2 (**WP2**)	In 120V panel
DHW Water Pump (**WDP**)	In 120V panel
Pool Water Pump (**WPP**)	In 120V panel

Note: power measurements made with hand-held power meter (e.g., Fluke 39). See Appendix A.

Gas Meter

480 V Electrical Panel
(parasitic loads)

Itron/
Sangamo Power Peter (generator output)

Figure 3. Sensors, Meters and Panel Locations

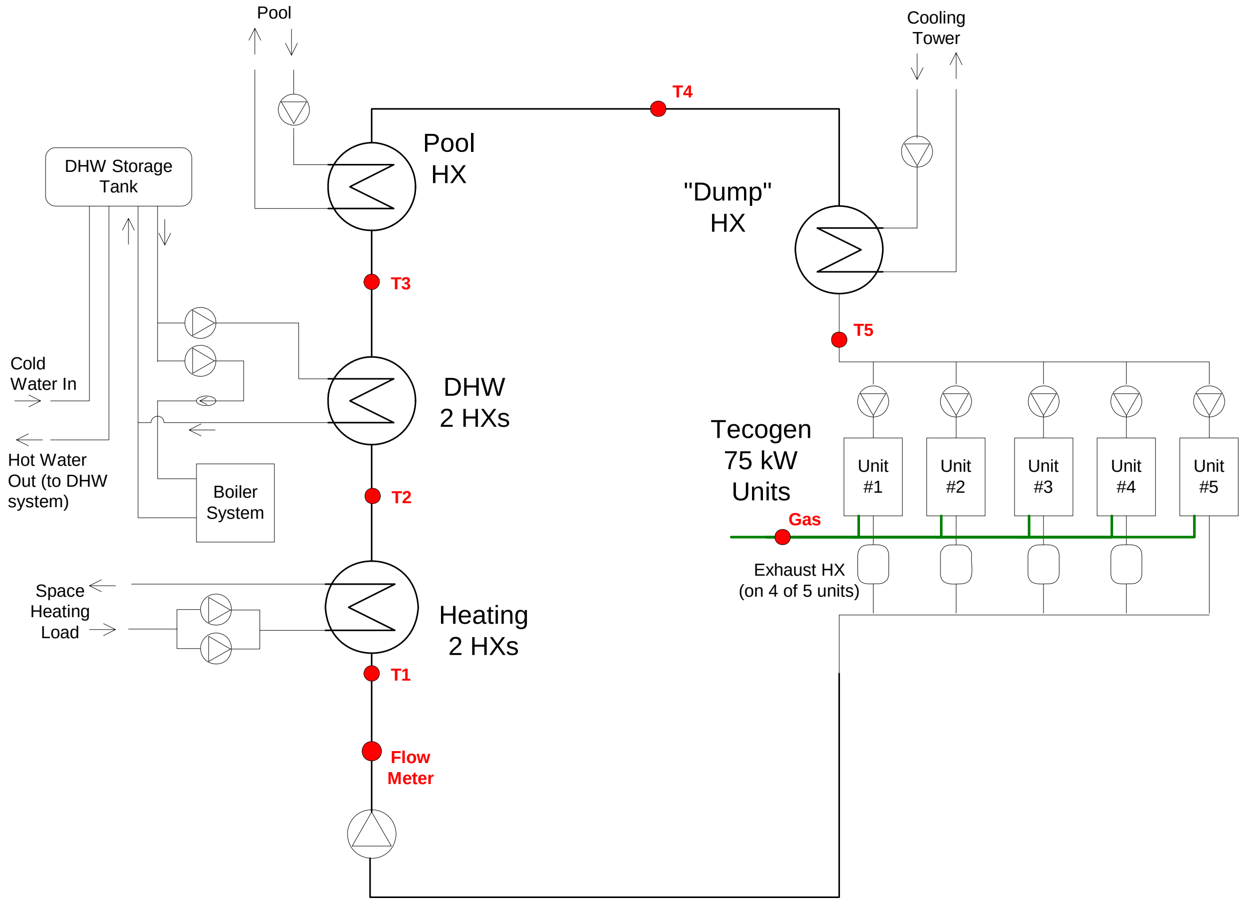

Figure 4. Schematic of CHP System Showing the Location of Temperature Sensors and Flow Meters

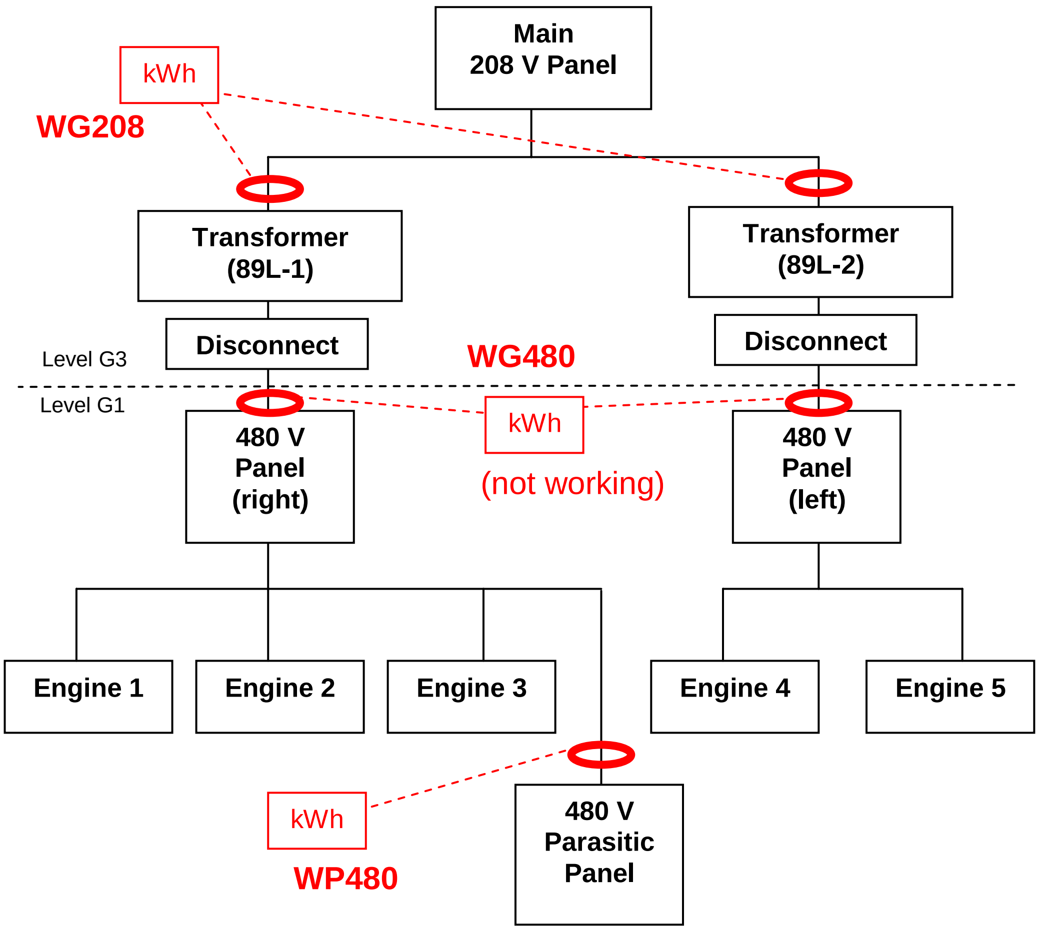

Figure 5. One-Line Schematic of Electrical System

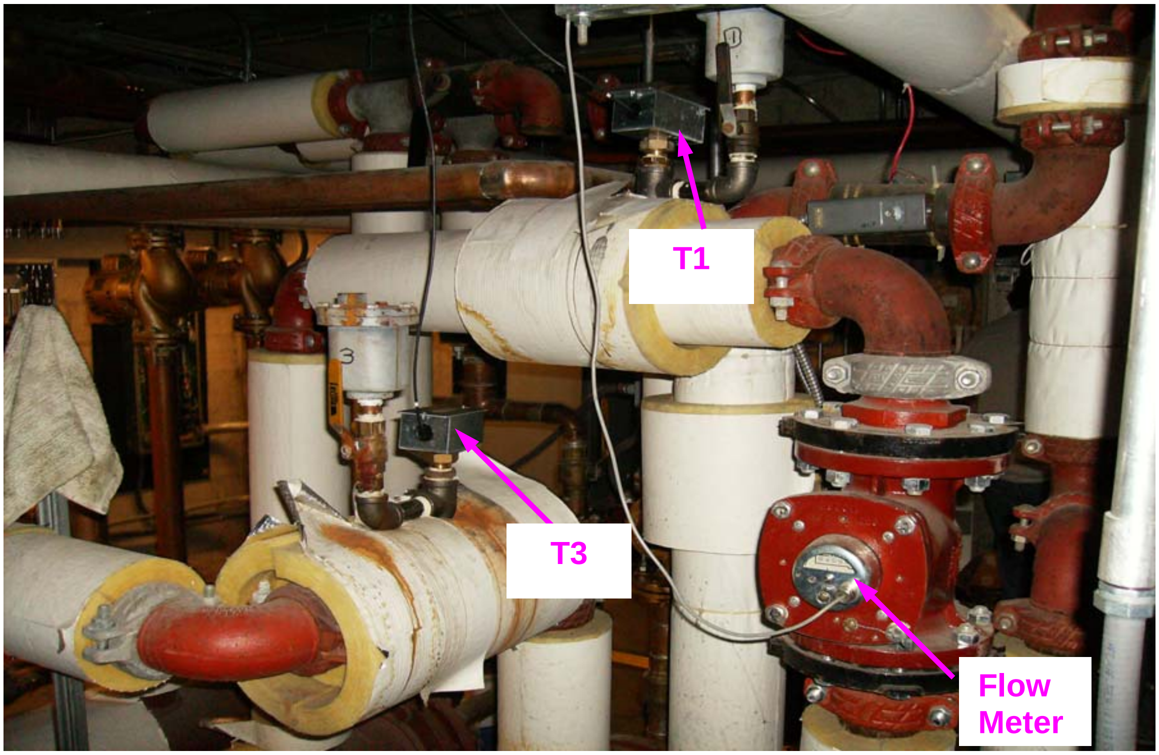

Figure 6. Piping with Temperature Sensors and Flow Meter Shown

Datalogger

A CR10X Campbell Scientific datalogger was installed to record the required data. The sensors are sampled or scanned at 3-second intervals. All readings and calculated quantities are averaged, summed or integrated for each 15-minute interval. The datalogger is 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 are downloaded from the datalogger once or twice a day by a phone-modem connection and loaded into a database. The data are checked for validity and posted on the NYSERDA web site.

Onsite Installation and Communications

The NYSERDA monitoring agent installed a datalogger panel at a location shown in the figure below. The monitoring system panel is approximately 2 ft x 2 ft x 1 ft. The site provided a dedicated phone line from nearby phone block.

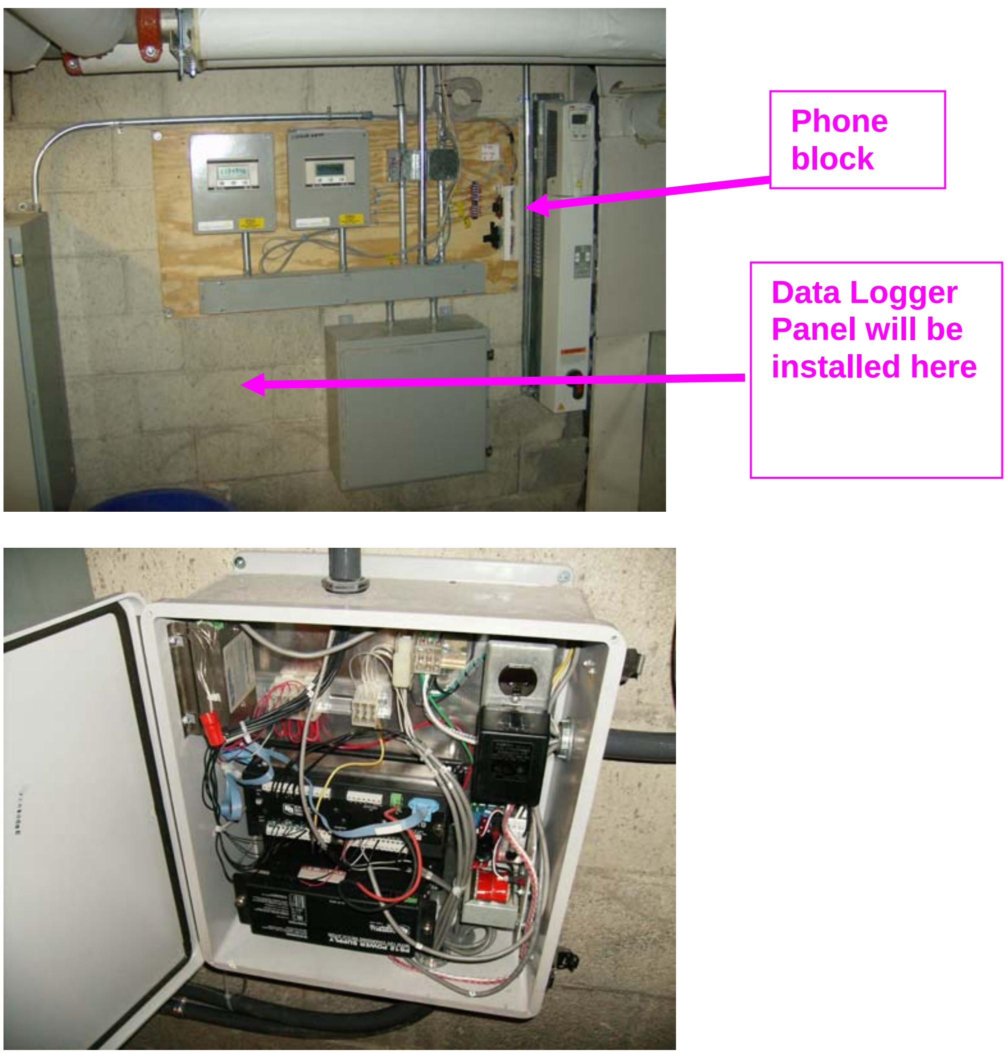

Figure 7. Location of Datalogger Panel and Phone Line

BTU Meter Compatibility

American DG has installed a CONTREC 212 BTU meter to measure the total heat recovery from the system. This meter also uses the same ISTEC flow meter (as shown above) but uses its own temperature sensors. This meter will be used by AmericanDG to bill the facility owner for recovered heat. In order to provide consistency with the heat transfer calculations based on data collected by the monitoring system (and presented NYSERDA CHP web site), CDH will recommend a calibration factor (or pulse multiplier) for the CONTEC meter that will make its output more closely match the data posted on the 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 5. Summary of Monitored Data Points

Point	Description	Engineering Units
WT	Facility Power / Purchased Utility Power	kWh per interval
WG	Generator Power Output (calculated, see below)	kWh per interval
FG	Generator Gas Consumption	Standard CF per interval
WPARA	Parasitic Power (calculated; see below)	kWh per interval
FL	Fluid Loop Flow Rate	gpm
T1	Loop Supply Temperature	°F
T2	Loop Supply Temperature – to DHW HX	°F
T3	Loop Supply Temperature – to Pool HX	°F
T4	Loop Return Temperature – to Dump HX	°F
T5	Loop Return Temperature	°F
SP1	Cogen Pump #1 Runtime	Minutes per interval
SP2	Cogen Pump #2 Runtime	Minutes per interval
SP3	Cogen Pump #3 Runtime	Minutes per interval
SP4	Cogen Pump #4 Runtime	Minutes per interval
SP5	Cogen Pump #5 Runtime	Minutes per interval
SHP	Hot Water Pump Runtime	Minutes per interval
SPP	Pool Pump Runtime	Minutes per interval

Peak Demand or Peak kW

The peak electric output or demand for each power reading will be taken as the average kW in a 15-minute interval, or

$$kW = \frac{kWh}{\Delta t} = \frac{kWh\ per\ interval}{0.25\ h}$$

Heat Recovery Rates

The heat recovery rates will be calculated in the datalogger at each scan interval and averaged for each 15-minute recording interval. The piping arrangement at this site allows for multiple heat rates to be determined with 5 temperature sensors and one flow reading:

Total Useful heat recovery (**QU**)	=	K·Σ [FL·(T1-T4)] / n
Space Heating heat recovery (**QSH**)	=	K·Σ [FL·(T1-T2)] / n
DHW heat recovery (**QDH**)	=	K·Σ [FL·(T2-T3)] / n
Pool heat recovery (**QPH**)	=	K·Σ [FL·(T3-T4)] / n
Rejected (unused) heat recovery (**QR**)	=	K ·Σ [FL·(T4-T5)] / n
Total heat recovery (**QT**)	=	K ·Σ [FL·(T1-T5)] / n

The loop fluid is expected to be water. The factor K is 487 Btu/h-gpm-°F for pure water at 180ºF (the nominal temperature expected in the heat recovery loop). 'n' is the number of scan intervals included in each recording interval (e.g., with 3 sec scans and 15-minute data, n=300)

Calculated Quantities

The gross power output from the generators is calculated from two power transducers, which are shown in Figure 5.

WG = WG208 + WP480

The net power output from the CHP system will be defined as the gross power from the engine generators (WG) minus the parasitic power (WPARA). The parasitic power will be determined using the one-time measurements and pump runtime data:

$$WPARA = \sum_{i=1}^{5} \frac{SPi}{60} \cdot WCPi + (WP1 + WP2) \cdot \frac{SHP}{60} + WPP \cdot \frac{SPP}{60}$$

The loop pump and the DHW pump are assumed to operate all the time. The other pumps are multiplied by their runtime fraction.

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

$$FCE = \frac{QU \cdot \Delta t + 3.412 \cdot (WG - WPARA)}{0.9 \cdot HHV_{gas} \cdot FG}$$

where:

where:	QU	-	Useful heat recovery (Btu/h)
	WG	-	generator gross output (kWh)
	WPARA	-	Parasitic power use (kWh)

FG	-	Generator gas consumption (Std CF)
Δt	-	0.25 for 15-minute data
HHV_{gas}	-	Lower heating value for natural gas (~1030 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, the each value is summed and then the formula is applied:

$$FCE = \frac{\sum^{N} QU \cdot \Delta t + 3.412 \cdot \sum^{N} (WG - WPARA)}{0.9 \cdot HHV_{gas} \cdot \sum^{N} FG}$$

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

Appendix

Cut Sheets for Key Sensors and Instruments

Itron Power Transducer
American Meter Gas Meter
ISTEC Flow meter
Mamac Temperature Sensors
CONTREC BTU Meter