NYSERDA CHP Assessment Report

ASSESSING THE CHP PLANT AT SEA PARK WEST

October 9, 2013

Sea Park West

NYSERDA New York State Energy Research and Development Authority

DISCLAIMER OF WARRANTY

Information contained on this web site is provided "as is," without warranty of any kind. In particular, the New York State Energy Research and Development Authority ("NYSERDA"), its employees, officers, and members, and the State of New York, make no warranties or representations, expressed or implied, as to the fitness for a particular purpose or merchantability of any product, apparatus, downloaded computer software product, service, or the usefulness, completeness, or accuracy of any processes, methods, downloaded computer software product, or other information contained, described, disclosed, or referred to herein. NYSERDA, its employees, officers and members, and the State of New York, make no representation that the use of any product, apparatus, process, method, downloaded computer software product, or other information will not infringe on privately owned rights.

DISCLAIMER OF LIABILITY

In no event shall NYSERDA, its employees, officers or members, or the State of New York be liable for any direct, indirect, punitive, incidental, special, or consequential damages or any damages whatsoever including, without limitation, damages for loss of use, data, or profits, arising out of or in any way connected with the use or performance of this web site, the provision of or failure to provide services, or for any information, software, products, services, or graphics obtained through this web site, or otherwise arising out of the use of this web site, whether based on contract, tort, strict liability, or otherwise, even if NYSERDA, its employees, officers and members, and the State of New York have been advised of the possibility of damages.

DISCLAIMER OF ENDORSEMENT

Reference to any specific product, service, process, or method by trade name, trademark, service mark, manufacturer or otherwise on this web site does not constitute an implied or expressed recommendation or endorsement, or favoring by NYSERDA, its employees, officers or members, or the State of New York, and shall not be used for advertising or product endorsement purposes.

BACKGROUND

The New York State Research and Development Authority (NYSERDA) web-based DG/CHP data system has been providing performance information on CHP systems for the past ten years. This system includes monitored performance data and operational statistics for NYSERDA's Distributed Generation (DG)/Combined Heat and Power (CHP) demonstration projects including:

- Monitored Hourly Performance Data
- Operational Reliability and Availability Data
- Characteristics of Each Facility and its Equipment

The Monitored Hourly Performance Data portion of the database allows users to view, plot, analyze, and compare performance data from one or several different DG/CHP sites in the NYSERDA portfolio. It allows DG/CHP operators at NYSERDA sites to enter and update information about their system. The database is intended to provide detailed, highly accurate performance data that can be used by potential users, developers, and other stakeholders to understand and gain confidence in this promising technology.

The Operational Reliability Data portion of the database is intended to allow individual facility managers to better understand reliability, availability, and performance of their particular units and also determine how their facilities compare with other units. Information on reliability and availability performance will enable potential onsite power users to make a more informed purchase decision, and will help policy makers quantify reliability benefits of customer-sited generation.

NYSERDA’s web-based DG/CHP data system provides general equipment information and detailed performance data, however, data alone does not provide the complete picture with respect to CHP systems design or performance. This report seeks to explain the performance data presented in the two fundamental output graphs: kW/h versus time and Useful MBtu/h versus time.

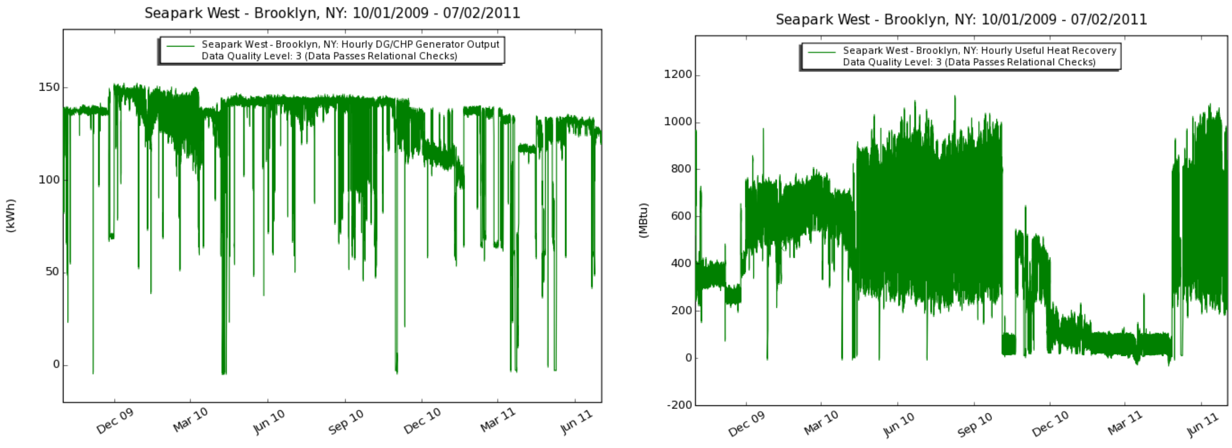


FIGURE 1 NYSERDA CHP WEBSITE PERFORMANCE GRAPHS

This report provides explanation for system performance trends and anomalies by further assessing the data supporting these two graphs and, where necessary, conducts interviews of the developers, owners and operators.

THE SITE

FIGURE 2 SEA PARK WEST IS AN AFFORDABLE HOUSING COMPLEX

Sea Park West is an affordable housing complex consisting of 362 units. Sea Park West is located overlooking the bay at Coney Island, in an Urban Renewal Area of Brooklyn, New York. The development was originally part of the Mitchell-Lama program created in the latter 1950's to provide affordable housing to moderate and middle income families. The owner, The Arker Company, has maintained affordable status by investing nearly $60,000 per unit between 2002 and 2004. HUD continues mortgage interest reduction payments under the Section 236 Rental Housing Assistance Program in order to allow for the much needed rehabilitation of these aging properties.

THE SYSTEM

The CHP system at Sea Park West 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 is used for the domestic water heating and space heating loads. The low temperature heat recovery loop includes a DHW heat exchanger (HX) and a dump radiator to reject unneeded heat (Figure 3). Each Tecogen unit also includes an exhaust-to-hot water HX that adds heat directly to the boiler drum (Figure 4). In the summertime, the jacket water and exhaust HXs are plumbed in series so that both their outputs are directed towards the DHW load.

The generators are located next to the boiler room inside the building and the monitoring equipment is located within the boiler room and maintenance rooms.

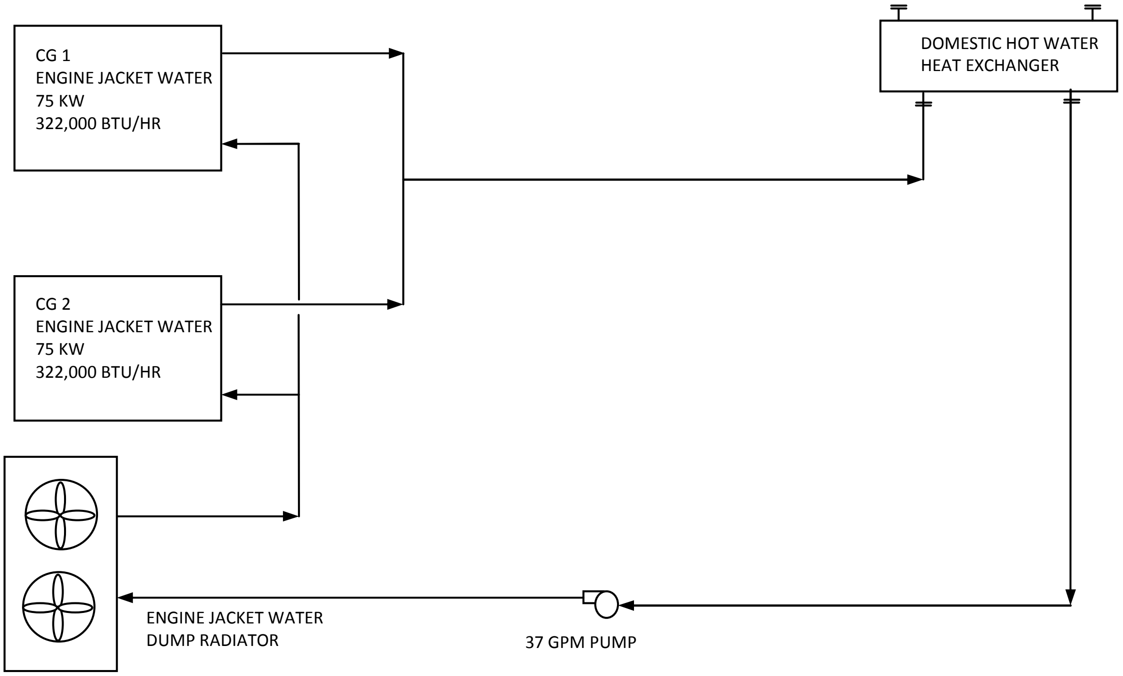


FIGURE 3 SIMPLIFIED SCHEMATIC OF LOW TEMPERATURE HEAT RECOVERY SYSTEM (JACKET WATER / DOMESTIC HOT WATER)

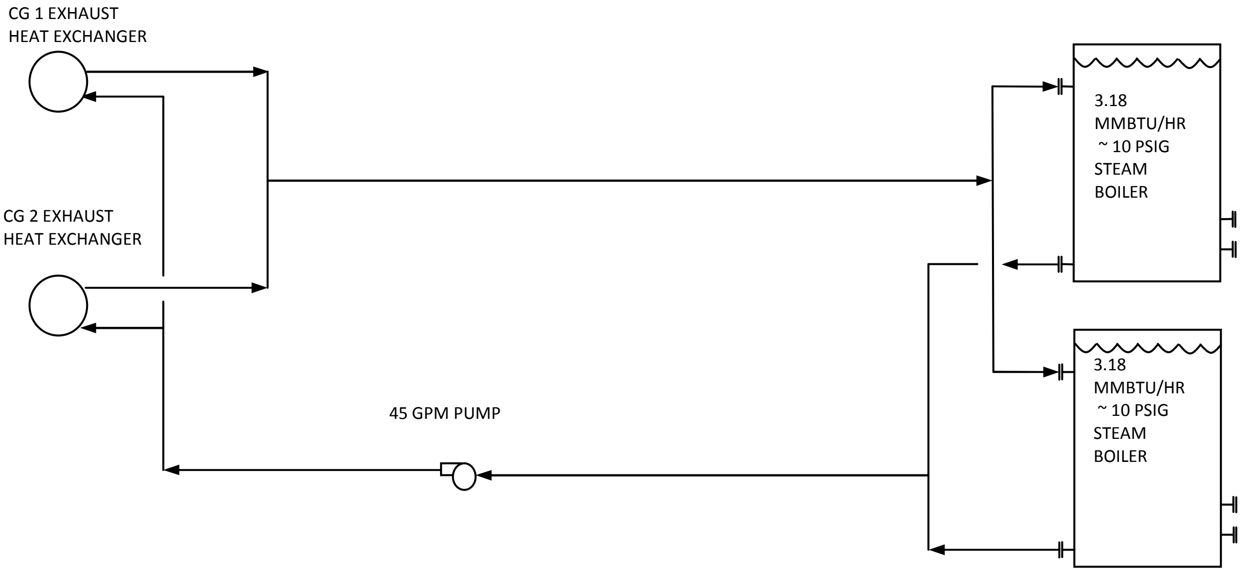


FIGURE 4 SIMPLIFIED SCHEMATIC OF HIGH TEMPERATURE HEAT RECOVERY SYSTEM (EXHAUST / HEATING)

DESIGN PERFORMANCE

The New York State Energy Research and Development Authority (NYSERDA) offers certain incentives to promote the installation of clean, efficient, and commercially available CHP Systems that provide summer on-peak demand reduction. Incentives are performance-based and correspond to the summer-peak demand reduction (kW), energy generation (kWh), and fuel conversion efficiency (FCE) achieved by the CHP system on an annual basis over a two-year measurement and verification (M&V) period. Sea Park West is eligible for the performance-based incentives. The performance period began in May 2010.

All data reported in the web-generated graphs passes range relational checks. This means that data points that do not pass these range checks are discarded from the report. Table 1 provides the results of an energy analysis performed by Steven Winter Associates, Inc.[1]

TABLE 1 ESTIMATED PROJECT PERFORMANCE

Natural Gas Input	12,298,000	MBtu/yr	1,404	MBtu/h
Electric Output	3,163,000	MBtu/yr	361	MBtu/h
DHW Thermal Output	4,039,000	MBtu/yr	461	MBtu/h
Steam Thermal Output	979,000	MBtu/yr	112	MBtu/h
Unrecovered Thermal	4,117,000	MBtu/yr	470	MBtu/h
Electrical Efficiency (HHV)			25.7%	
Overall Efficiency (HHV)			67.2%	

OPERATING SUMMARY

This unit operates to follow the thermal load in two different modes.

1. A “2-pipe arrangement” where the jacket water and exhaust heat exchanger are in series and serve the domestic hot water heat exchanger (DHW HX) (Figure 3 plus exhaust heat recovery in series with jacket water system).
2. A “4-pipe arrangement” where the exhaust heat recovery HX is piped directly to the boil drum. (Figure 3 plus Figure 4)

Normally the “4 pipe arrangement” is used from October through April. During the period April 2010 to March 2011, the 4 pipe arrangement was started on October 20 but was stopped on January 18, 2011 because the water was flashing in the exhaust heat exchanger. On October 4, 2010, the DHW HX suddenly stopped accepting the heat from the engine loop, because the positions of several manual valves in the system were inadvertently modified. The problem was not fixed until April 26, 2011.

---

[1] http://www.swinter.com/services/mf-govt.php

Through the entire operating period, the engine units frequently limit their power output whenever the supply water temperature from the exhaust heat exchanger or the engine jacket reaches a high limit temperature set point. For the exhaust heat exchanger this temperature is about 220F.

The overall CHP efficiency lags the design because the heat exchange system stopped using the available heat recovery from January through April 2011 and the DHW heat exchanger did not recover heat from October 4, 2010 through April 25, 2011. This problem occurred because a changeover valve was not properly set. The operators were unaware of the problem because their operating protocol was to determine useful heat recovery by monitoring the dump radiator operation which was not a viable method. The situation was resolved through this data analysis effort resulting in improved useful heat recovery in May 2011.

The overall CHP efficiency measured from May 2010 through April 2011 was 49.6%. This is largely due to the thermal system operating problems described above. Efficiency had been much higher than this in earlier months.

TABLE 2 SYSTEM EFFICIENCY,[2]

	Hours of Good (Pwr) Data	**Net Electric Output (kWh)**	**Natural Gas Use (MCF)**	**Useful Heat Output (MMBtu)**	**Electrical Efficiency**	**Useful Thermal Efficiency**	**Fuel Conversion Efficiency**
April-10	701	86,642	825.5	427.5	35.1%	50.8%	85.9%
May-10	733	103,786	1,236.0	518.4	28.1%	41.1%	69.2%
June-10	720	101,848	1,241.4	510.7	27.5%	40.3%	67.8%
July-10	744	104,587	1,236.3	454.4	28.3%	36.0%	64.3%
August-10	744	105,316	1,283.0	486.8	27.5%	37.2%	64.7%
September-10	720	98,789	1,207.5	489.6	27.4%	39.7%	67.1%
October-10	744	95,475	1,174.5	173.5	27.2%	14.5%	41.7%
November-10	720	93,273	1,158.2	221.8	26.9%	18.8%	45.7%
December-10	744	86,341	1,097.4	78.6	26.3%	7.0%	33.4%
January-11	744	87,795	1,093.8	50.1	26.9%	4.5%	31.3%

---

[2] Efficiency data is collected using all data points flagged as high quality data. Generally there is good correlation between the data quality of net electric output, natural gas use and useful heat rejection. Anomalies do occur, particularly with respect to natural gas use which causes distortions in the results. If efficiency results are out of normal range, the most likely cause is poor quality concurrent data which can be corroborated by the Site Data Quality table located in the Lessons Learned section of this report.

February-11	672	76,817	932.6	26.2	27.6%	2.8%	30.3%
March-11	744	75,554	926.8	24.0	27.3%	2.5%	29.8%
April-11	720	80,472	1,015.5	100.5	26.5%	9.7%	36.2%
May-11	744	85,099	1,086.1	471.5	26.2%	42.6%	68.8%
June-11	720	91,280	1,174.5	514.4	26.0%	42.9%	68.9%
July-11	743	93,070	1,178.4	471.6	26.4%	39.2%	65.7%
Total preceding 12 months	**8759**	**1,069,281**	**13,328**	**3,109**	**26.8%**	**22.9%**	**49.7%**

Note: All efficiencies based on higher heating value of the fuel (HHV)

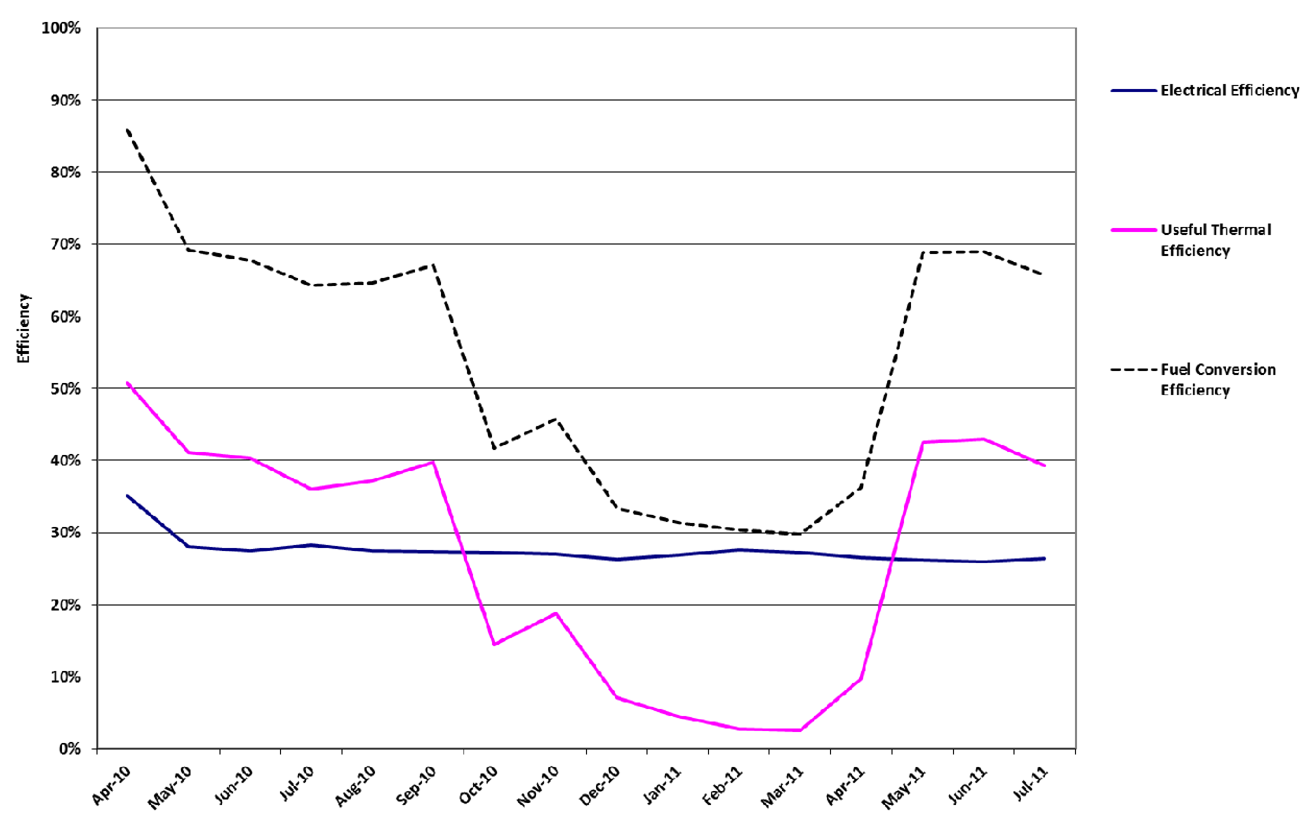


FIGURE 5 POWER, THERMAL AND CHP SYSTEMS EFFICIENCY BY MONTH

Figure 6 and Figure 7 depict the systems operating configuration during the operating period (winter operation) where the low temperature heat recovery system serves only the domestic hot water system and the exhaust heat recovery system (high temperature) serves only the boiler heating system. During the summer months, the system is manually reconfigured (through hand valves) to pipe the jacket water heat exchanger in series with the exhaust heat exchanger, providing heat to the domestic hot water loop, and the heating boilers are shut down.

POWER GENERATION AND USEFUL THERMAL ENERGY

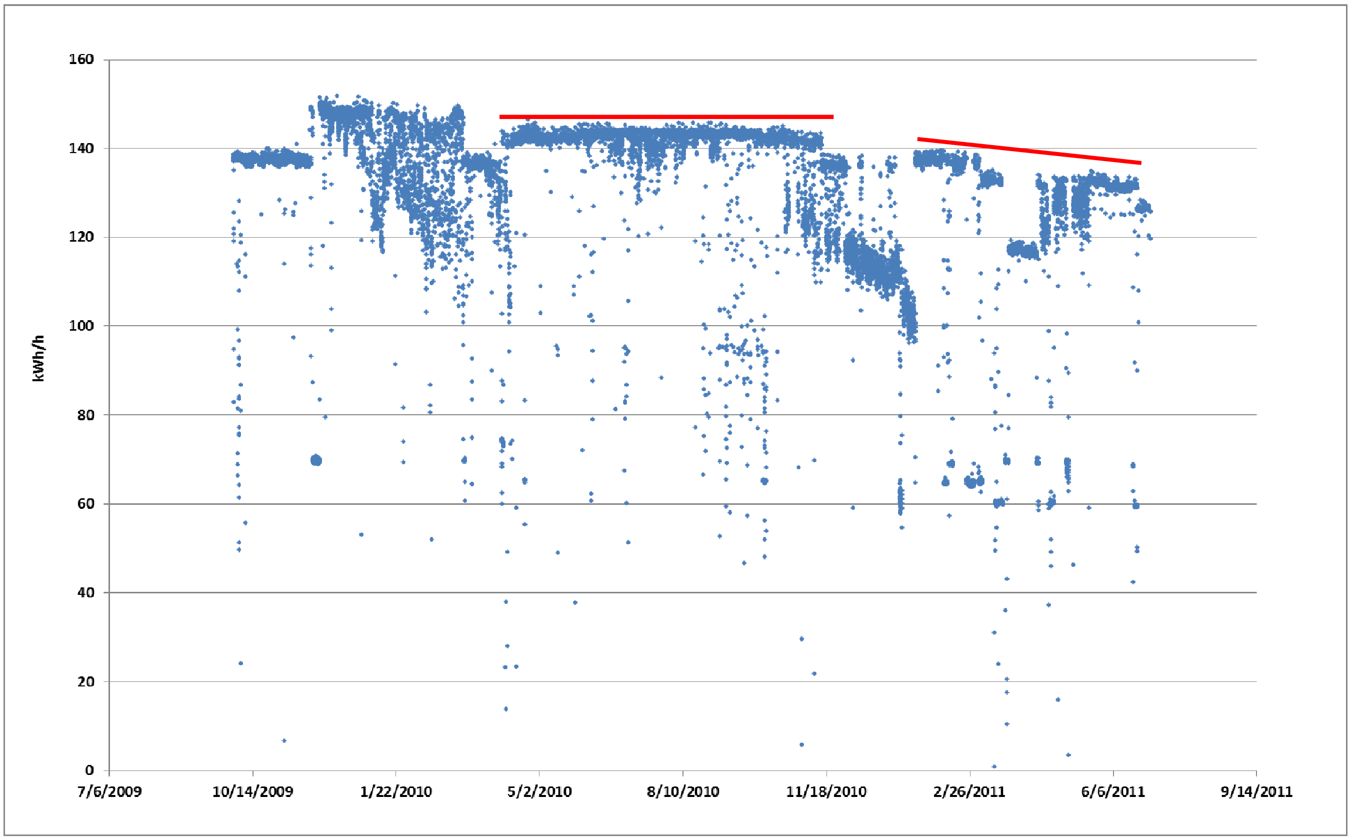


FIGURE 6 CHP POWER OUTPUT VERSUS TIME

No total facility data was available from this site. Figure 6 provides hourly power data (kWh) measured. The red lines indicate potential engine performance degradation.

FIGURE 7 CHP USEFUL THERMAL OUTPUT VERSUS TIME

Figure 7 presents data during the startup period (prior to April 2010) when the system was being commissioned and the full thermal loop was not functioning. Also, questionable thermal energy data was taken as thermistors were used for data acquisition and their accuracy was not sufficient. This was rectified in April of 2010. The “4 pipe arrangement” was started on October 20 but was stopped on January 18, 2011 because the water was flashing in the exhaust heat exchanger. On October 4, 2010, the DHW HX suddenly stopped accepting the heat from the engine loop. The problem was not fixed until April 26, 2011. Both of these problems are clearly evident in Figure 7.

Note that on the following weekly graphs, weekend days are highlighted as dashed lines to quickly distinguish their operating characteristics.

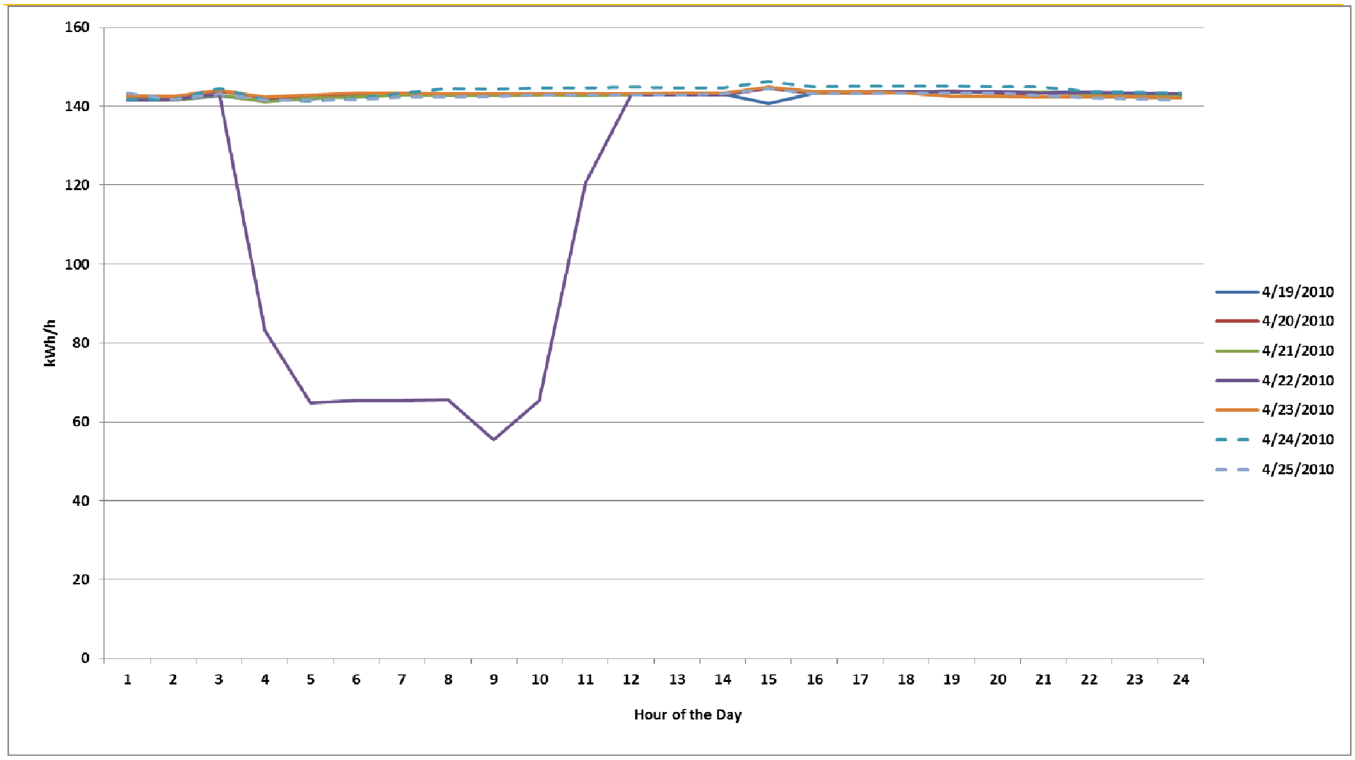


FIGURE 8 CHP POWER OUTPUT VERSUS TIME

Figure 8 covers the time period from April 19-24, 2010, providing CHP system power output by hour of the day pattern for the time period. April 19 is a Monday and April 24 and 25 are Saturday and Sunday, respectively. Figure 8 shows that all days except Thursday, April 22, show similar usage patterns which indicate that one of the two engines was offline in the morning hours. Examining the delivered electric power pattern, the system is being controlled to produce maximum electric power 24x7 during this time.

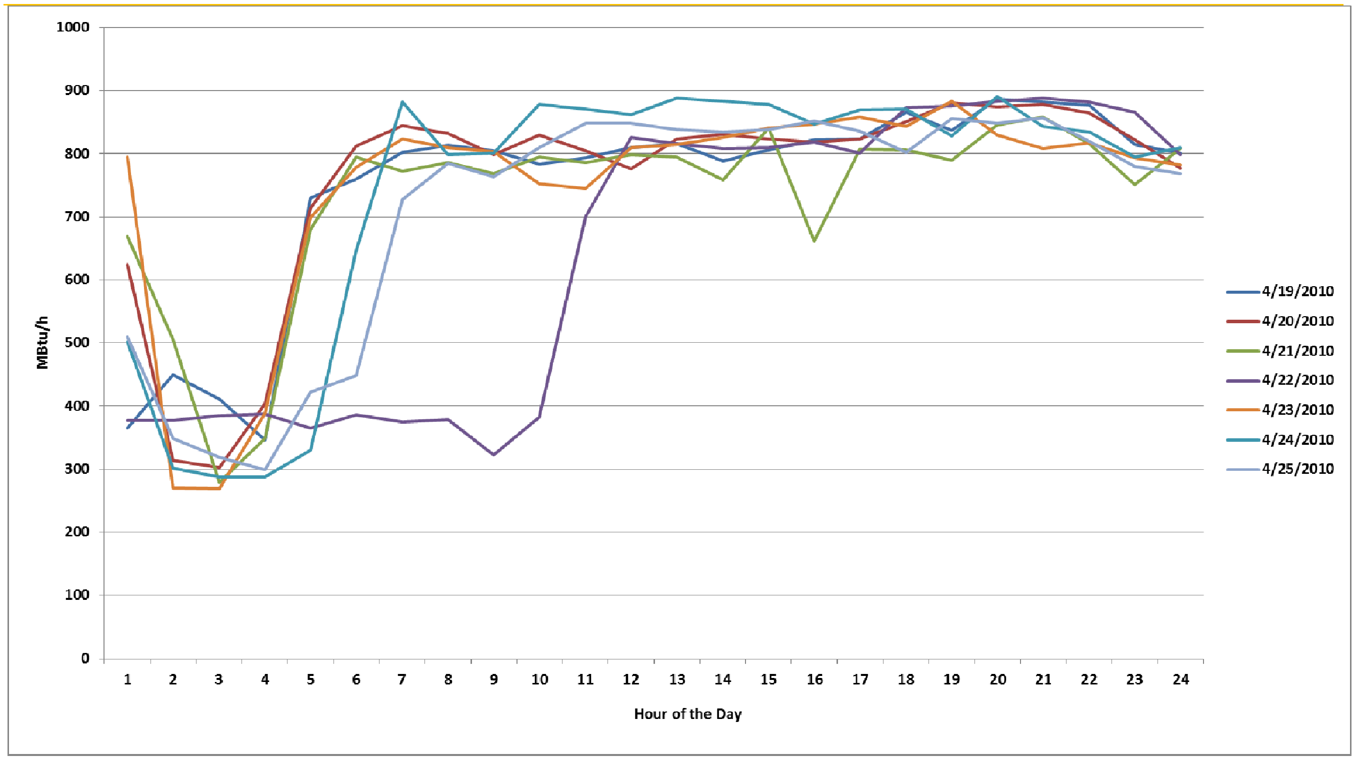


FIGURE 9 CHP USEFUL THERMAL OUTPUT VERSUS TIME

Figure 9 shows the useful thermal energy provided to the building for the same week (April 19-24, 2010) as Figure 8 delivered power. Figure 9 presents a classic hot water thermal energy use for an apartment complex in that weekdays present a nighttime drop-off on load, picking up in the early morning hours. Note that Thursday, April 22, is an outlier in that one engine was offline for a time in the morning. The weekend hot water load shifts to later in the morning indicating a typical later start.

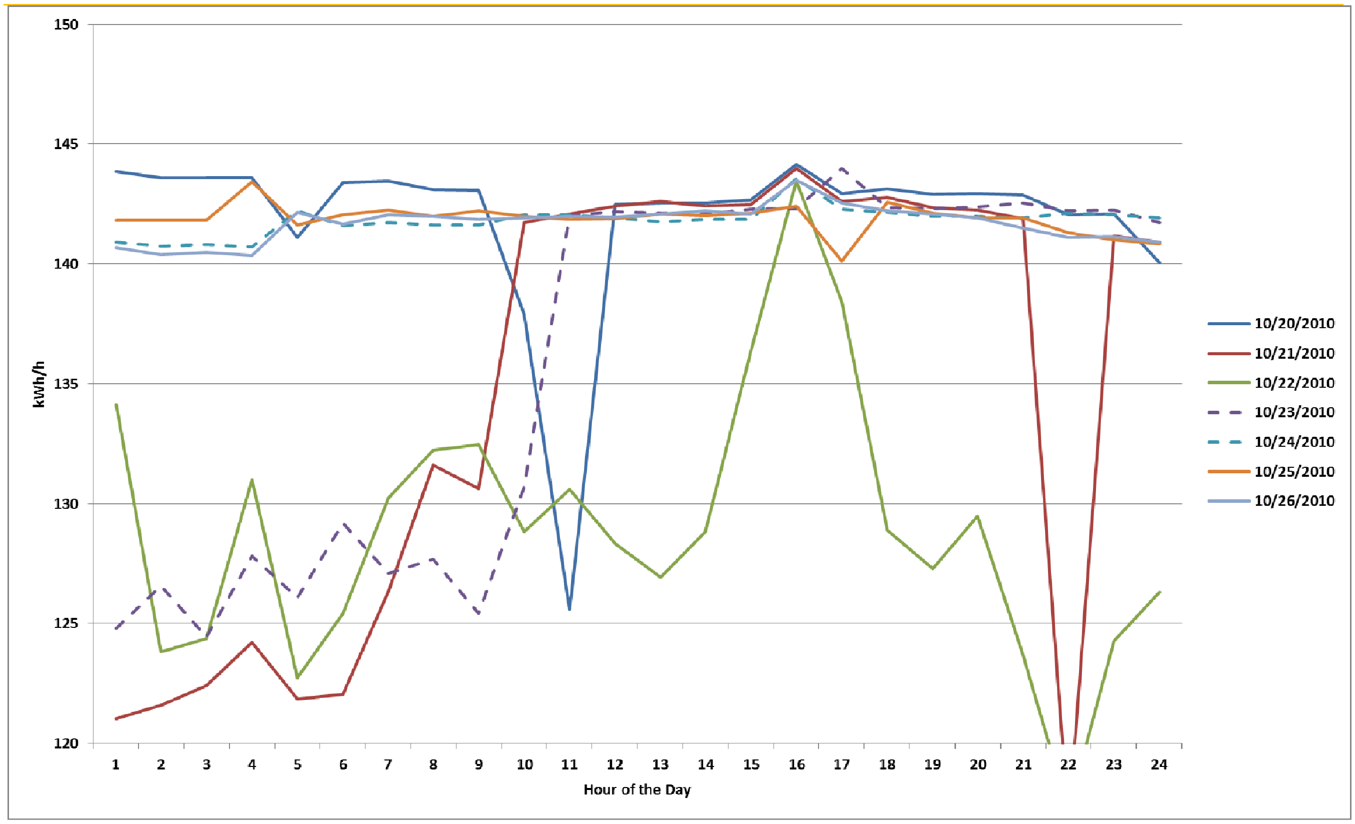


FIGURE 10 CHP POWER OUTPUT VERSUS TIME

Figure 10 covers the time period from October 20-26, 2010, providing CHP system power output by hour of the day pattern for the time period. October 20-26, Friday – Sunday, shows reduced power consumption in the early morning hours while the remaining days exhibit full capacity performance 24x7. Examining the useful thermal pattern for the same week shows no linkage with thermal load profiles (see Figure 11).

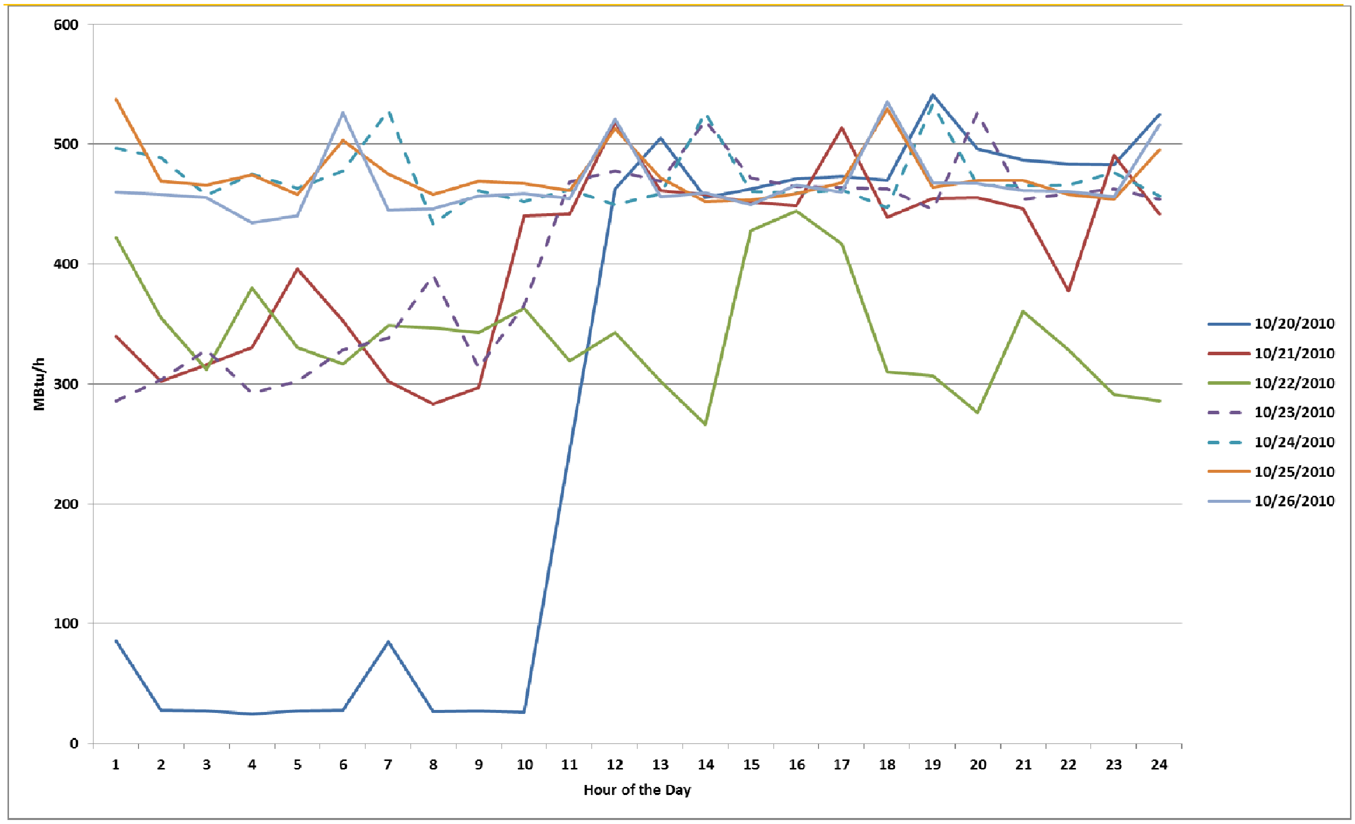


FIGURE 11 SELECTED DAY CHP USEFUL THERMAL OUTPUT VERSUS TIME

Comparing 24 hour useful CHP recovered heat thermal load profiles from October 20-26, 2010 (Figure 11) with October 20-26, 2010 (Figure 11), it is apparent that the useful thermal energy is distinctly different. On October 20, prior to 10 am, virtually no useful thermal energy was recovered (On October 4, 2010, the DHW HX suddenly stopped accepting the heat from the engine loop). After 10 am, the “4 pipe arrangement” was started and heat was flowing to the boilers for heating purposes which continued for the remainder of the week.

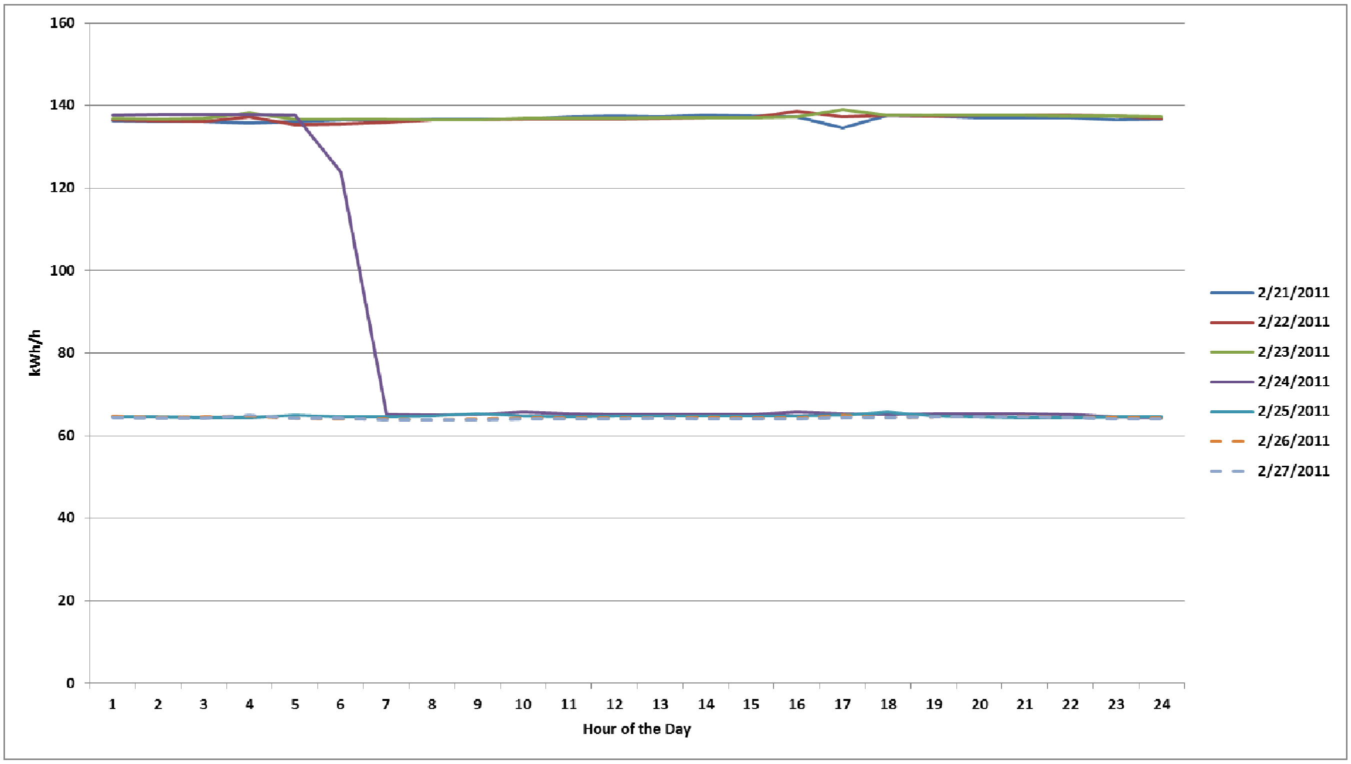


FIGURE 12 CHP POWER OUTPUT VERSUS TIME (AVG KW) FEBRUARY

Figure 12 covers the time period from February 21-27, 2011, providing CHP system power output by hour of the day pattern for the time period. February 21 through the morning of February 24, both engine generators are at full capacity performance 24x7. On the morning of February 24, one engine went offline showing reduced power delivery in the early morning hours through the end of the week. Examining the useful thermal pattern for the same week shows no linkage with thermal load profiles (see Figure 13).

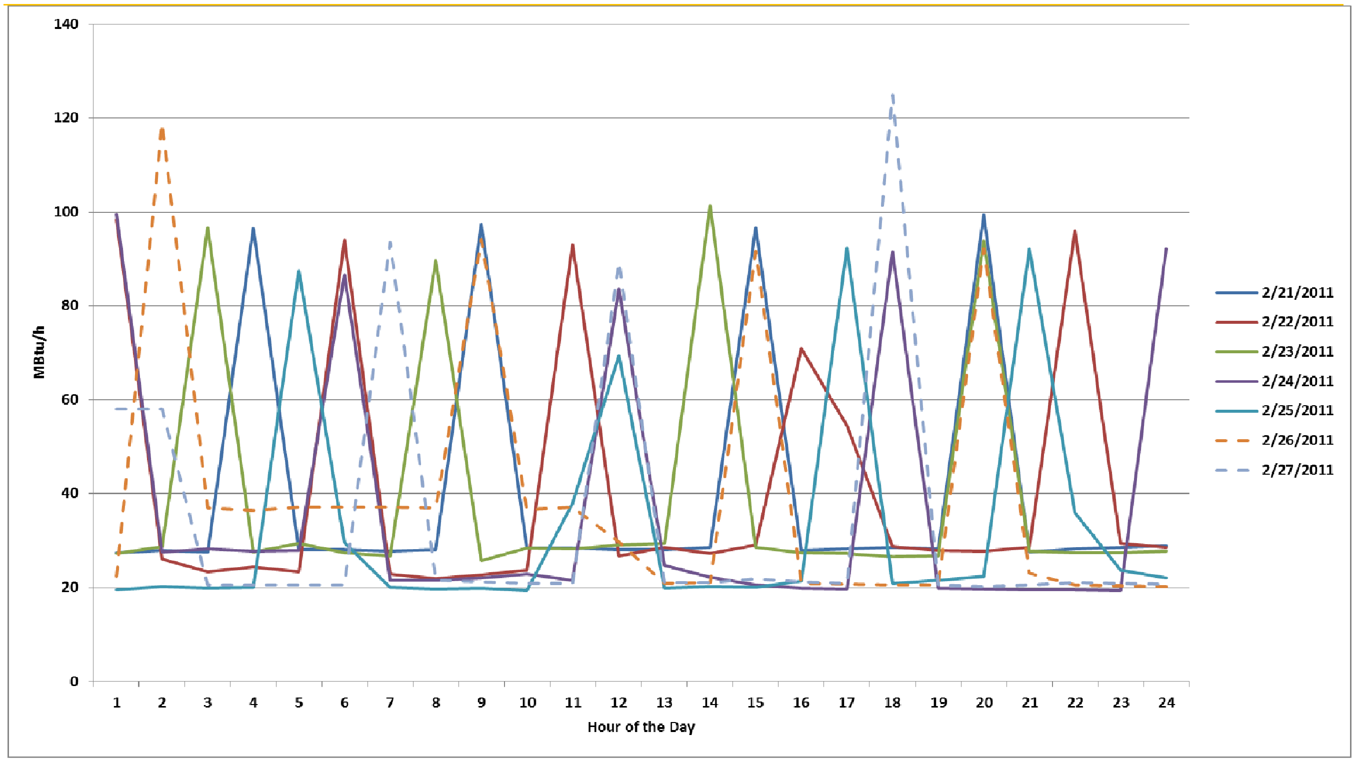


FIGURE 13 SELECTED DAY CHP USEFUL THERMAL OUTPUT VERSUS TIME

Figure 13 shows a week of useful thermal energy where the DHW HX was still not accepting the heat from the engine loop and the “2 pipe arrangement” was in use.   This essentially indicates little or no useful energy was recovered during this period.

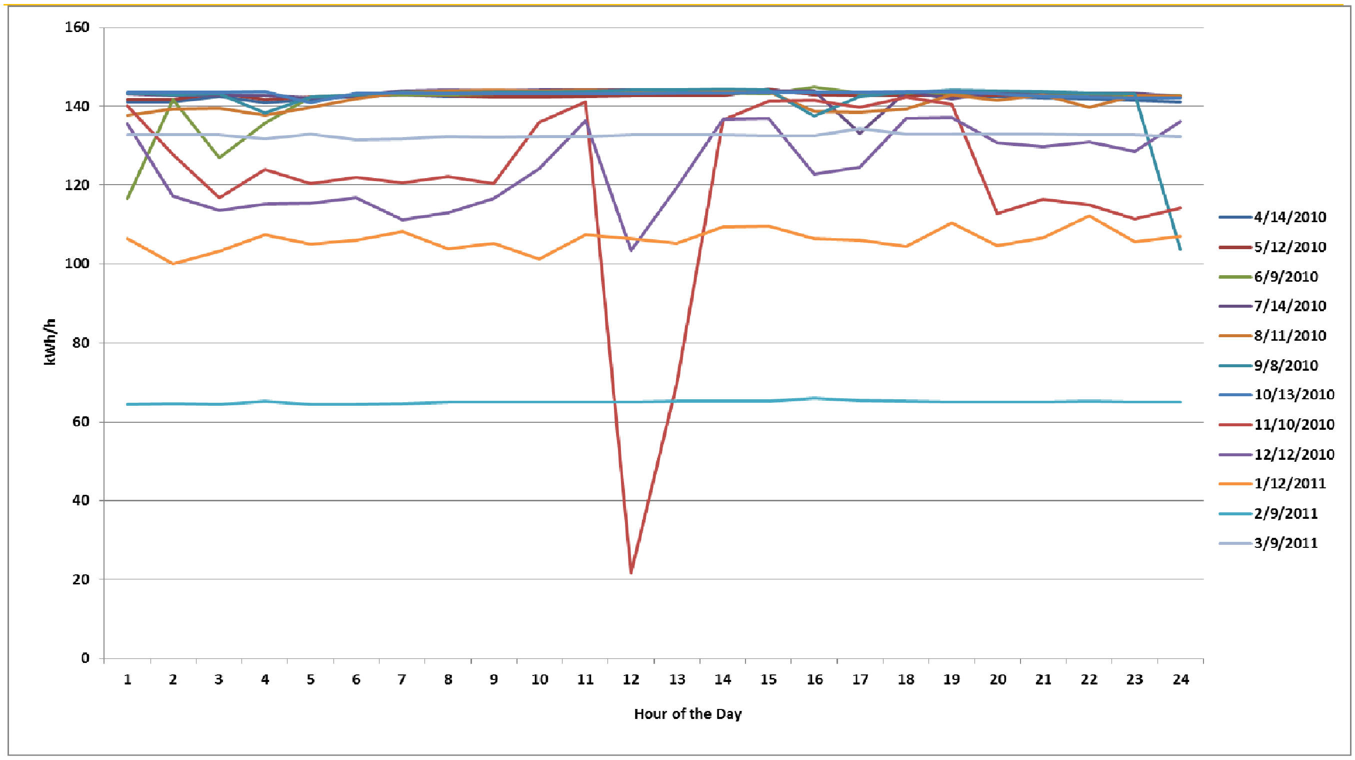


FIGURE 14 SELECTED WEDNESDAY PERFORMANCE CHP POWER OUTPUT BY TIME OF DAY

Figure 14 shows relative same day of the month performance (second Wednesday of every month) over six months of operation. In general, the CHP system delivers about 140 kWh of electricity all hours of the day.

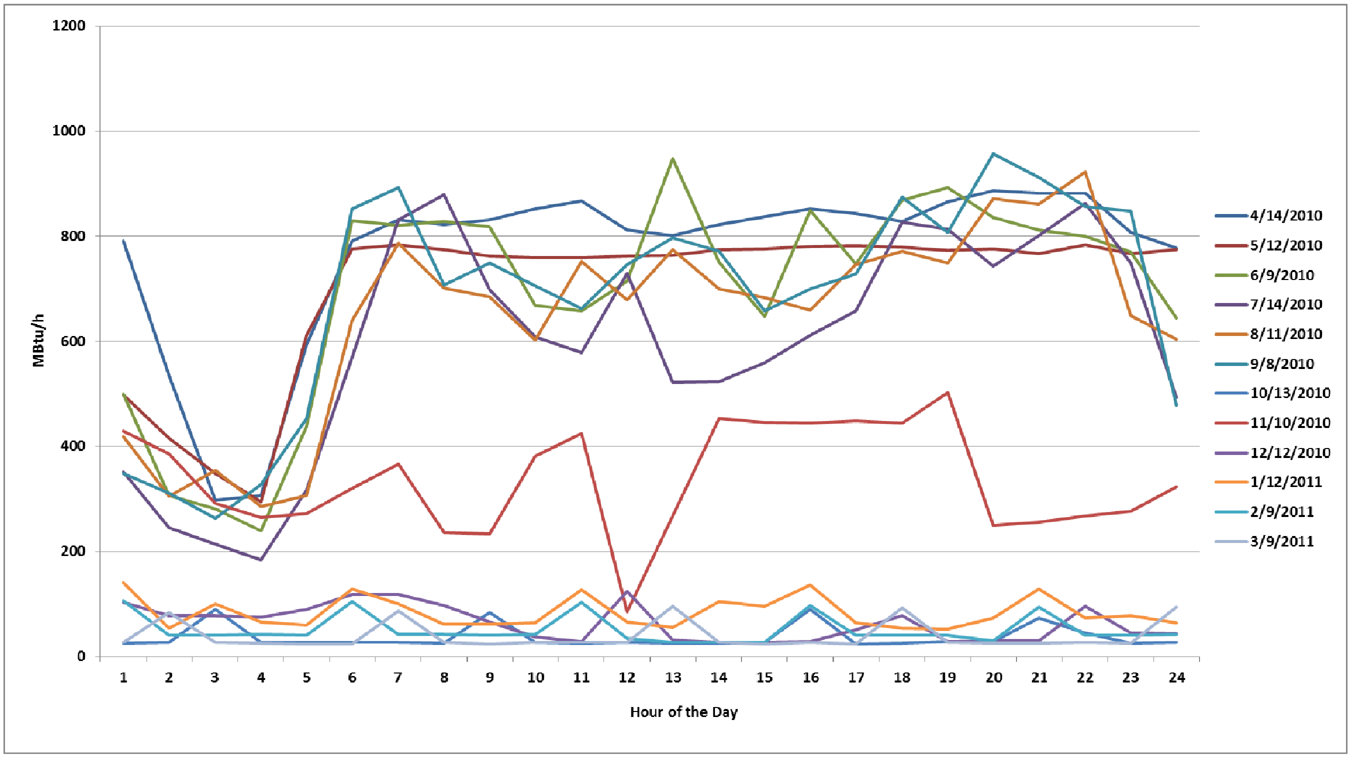


FIGURE 15 SELECTED WEDNESDAY CHP USEFUL THERMAL OUTPUT BY TIME OF DAY

Figure 15 shows relative same day of the month performance (second Wednesday) over operating a 15 month operation. This graph confirms a rather consistent DHW pattern while the DHW HX system is functioning. The outlier curves were during the period when the DHW system was not functioning. April through October 2010 useful thermal heat curves in Figure 15 are consistent. November 2010 through March 2011 curves reflect the crossover valve problem.

PERFORMANCE SUMMARY

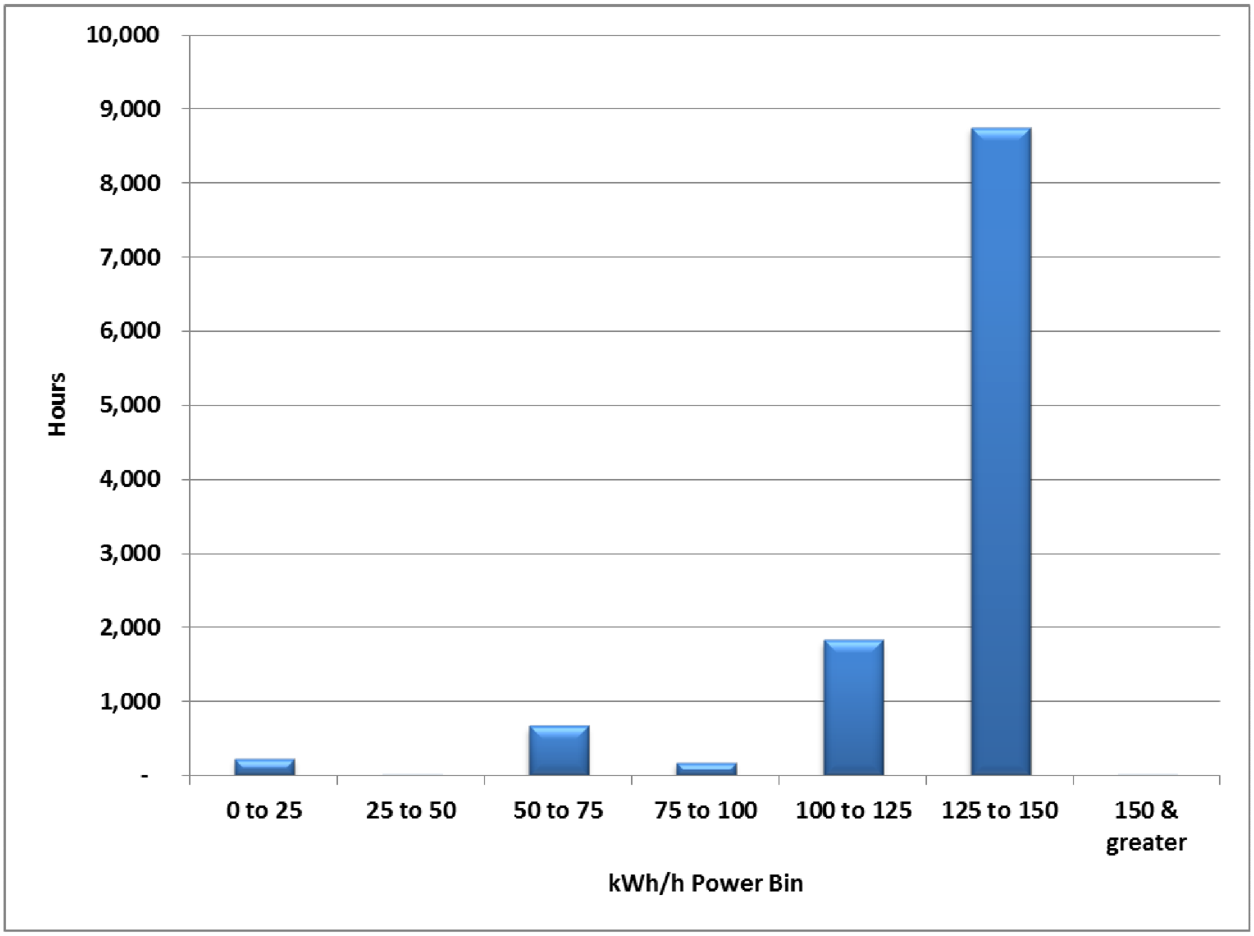


FIGURE 16 PERFORMANCE BY POWER BINS

During the 11,657 hours that met the range and relational checks 90.7% of this time, the CHP system delivered 100 kW and greater (Figure 16).

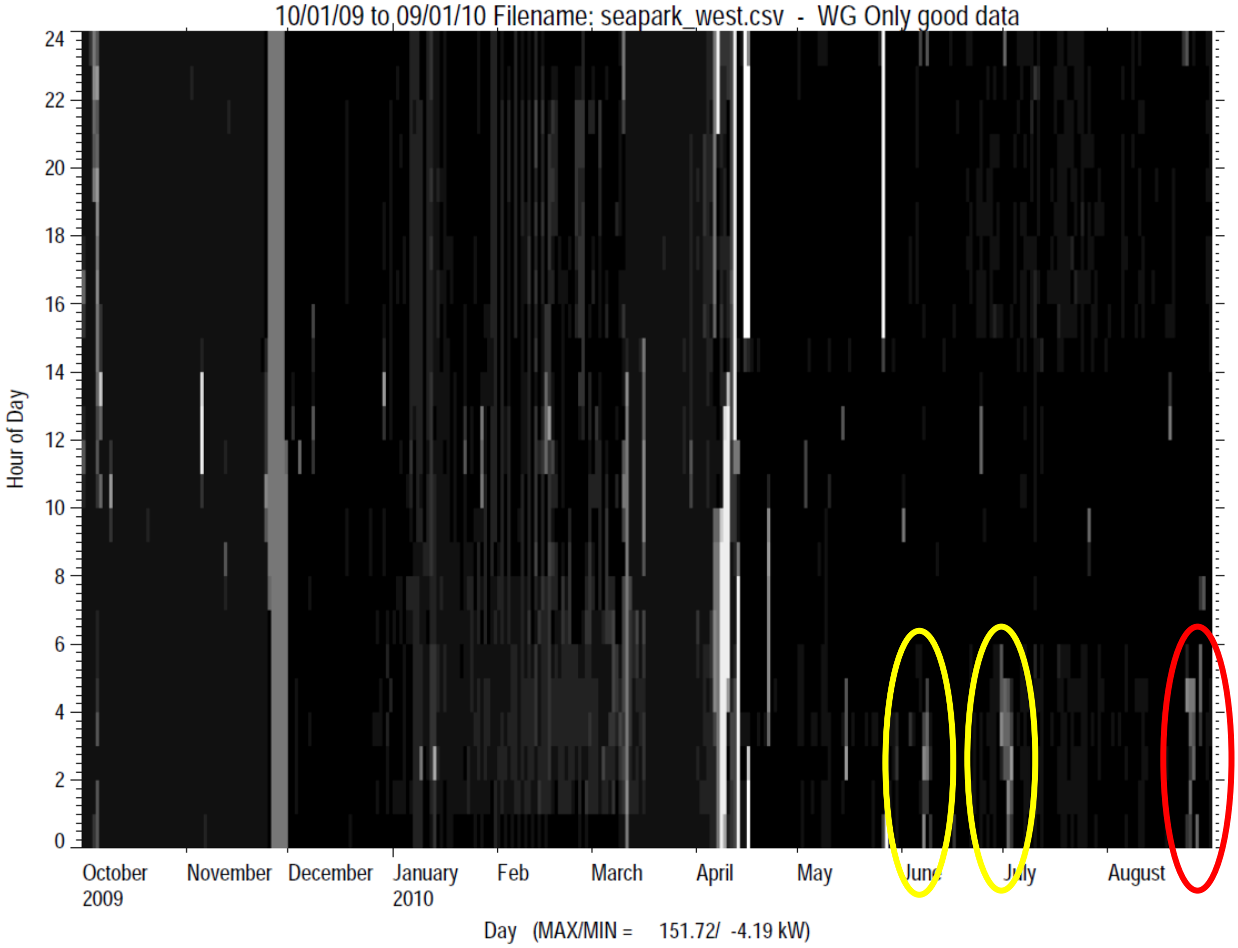


FIGURE 17 SHADE PLOT OF ONE GENERATOR PERFORMANCE

The Shade Plot in Figure 17 shows that during the last week in August 2010, this engine generator reduced performance. This electric power reduction was due to operational testing of the site's standby generator.

LESSONS LEARNED

TABLE 3 SYSTEM EFFICIENCY[3]

	Hours of Good (Pwr) Data	Net Electric Output (kWh)	Natural Gas Use (MCF)	Useful Heat Output (MMBtu)	Electrical Efficiency	Useful Thermal Efficiency	Fuel Conversion Efficiency
April-10	701	86,642	825.5	427.5	35.1%	50.8%	85.9%
May-10	733	103,786	1,236.0	518.4	28.1%	41.1%	69.2%
June-10	720	101,848	1,241.4	510.7	27.5%	40.3%	67.8%
July-10	744	104,587	1,236.3	454.4	28.3%	36.0%	64.3%
August-10	744	105,316	1,283.0	486.8	27.5%	37.2%	64.7%
September-10	720	98,789	1,207.5	489.6	27.4%	39.7%	67.1%
October-10	744	95,475	1,174.5	173.5	27.2%	14.5%	41.7%
November-10	720	93,273	1,158.2	221.8	26.9%	18.8%	45.7%
December-10	744	86,341	1,097.4	78.6	26.3%	7.0%	33.4%
January-11	744	87,795	1,093.8	50.1	26.9%	4.5%	31.3%
February-11	672	76,817	932.6	26.2	27.6%	2.8%	30.3%
March-11	744	75,554	926.8	24.0	27.3%	2.5%	29.8%
April-11	720	80,472	1,015.5	100.5	26.5%	9.7%	36.2%
May-11	744	85,099	1,086.1	471.5	26.2%	42.6%	68.8%
June-11	720	91,280	1,174.5	514.4	26.0%	42.9%	68.9%
July-11	743	93,070	1,178.4	471.6	26.4%	39.2%	65.7%
Total preceding 12 months	**8759**	**1,069,281**	**13,328**	**3,109**	**26.8%**	**22.9%**	**49.7%**

Note: All efficiencies based on higher heating value of the fuel (HHV)

The CHP system at Sea Park West 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 is used for the domestic water heating and space heating loads. Engine jacket water is used to heat domestic hot water. Engine exhaust heat is used to make low pressure steam.

---

[3] Efficiency data is collected using all data points flagged as high quality data. Generally there is good correlation between the data quality of net electric output, natural gas use and useful heat rejection. Anomalies do occur, particularly with respect to natural gas use which causes distortions in the results. If efficiency results are out of normal range, the most likely cause is poor quality concurrent data which can be corroborated by the Site Data Quality table located in the Lessons Learned section of this report.

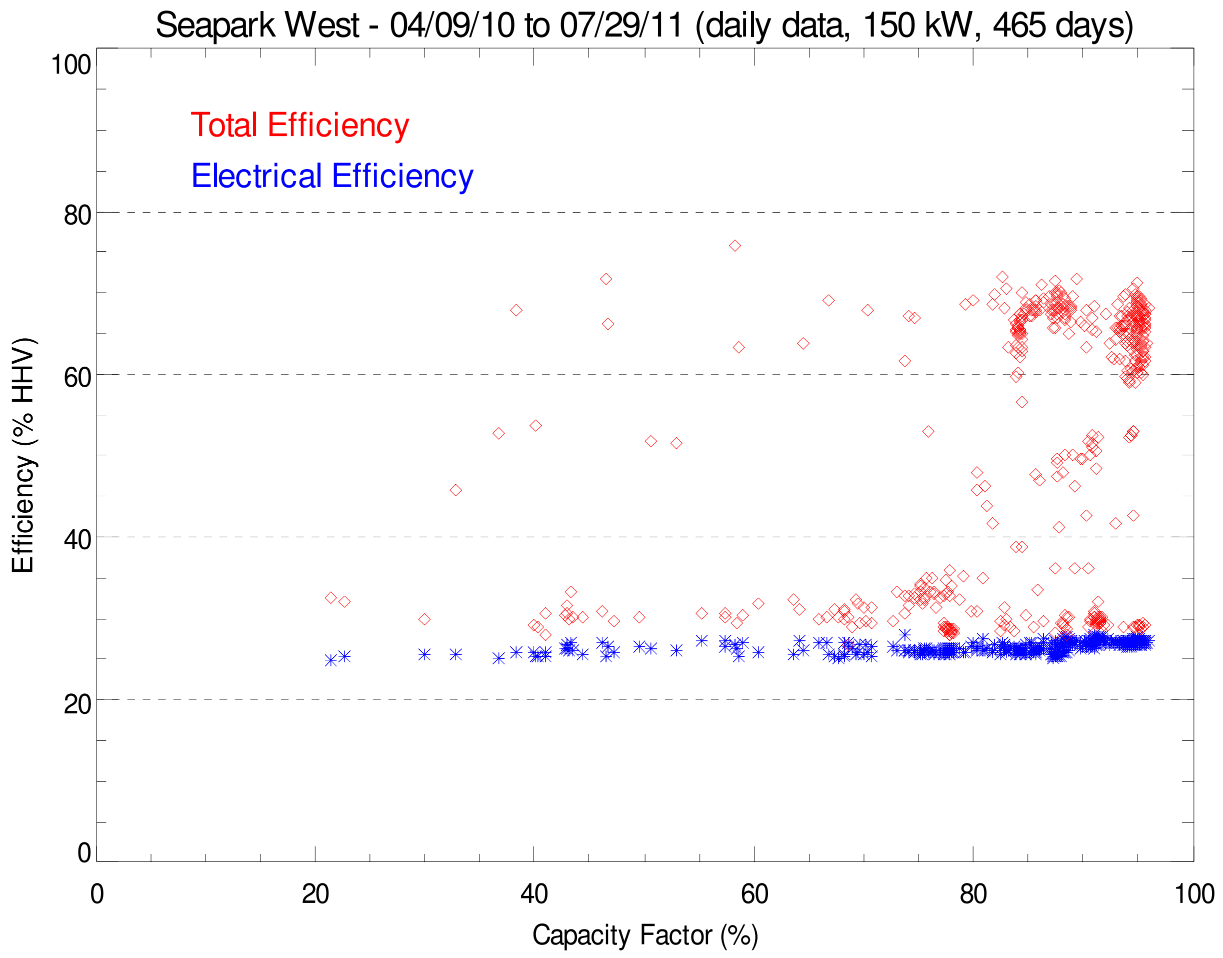


FIGURE 18 CAPACITY FACTOR[4]

Capacity Factor (FIGURE 188) presents the CHP generated power efficiency over the time period (465 days). This Figure provides a very good overview of the CHP power capacity versus site power requirements and a good understanding of the useful thermal energy recovered. The Figure shows the system generally operated between 20% and 95% of the generating capacity at about 26.8% power efficiency (HHV) during the last 12 months of Table 2. The electric capacity supports the electric load following operation pattern observed in the previous graphs. The useful thermal energy (heating and DHW) operating efficiency during the entire period averaged 22.9% thermal efficiency (HHV). The thermal profile shows high capacity generally associated with high electric capacity. Examining the useful thermal data over time shows slightly higher useful thermal energy performance in the summer than in the winter.

The idea to use the exhaust heat exchanger to directly heat water in the low pressure boiler drum was an innovative and promising idea. However, several issues were identified that hurt system efficiency and performance: 1) Bubbles formed in the exhaust heat exchanger, which confounded the flow measurement,

---

[4] The data shown in the Capacity Factor graph passes all data quality checks and therefore, in some cases where data quality is poor, leaves out a significant amount of data points.

and 2) high water temperatures from the boiler drum caused the safety limits on the Tecogen units to reduce generator power output.

CHP system operators need better low cost metrics to track system operation. In this case the operations tracked the runtime of the dump radiator fans to confirm proper operation. However, this metric did not detect the loss of heat transfer when system valves were inadvertently changed in the winter of 2011. Complicated systems with various operating modes and requirements for manual changeover with each season can be hard to understand and track. Simpler systems are easier to track, debug and keep on target for expected seasonal operation.

APPENDIX A: KEY DATA MEASURES AND QUALITY

The three key parameters contributing to system energy efficiency were DG/CHP Generator Output, DG/CHP Generator Gas Use and Useful Heat Recovery (total MBtu). These parameters were measured at this site as follows:

1. **DG/CHP Generator Output (total kWh)** Power transducers are installed on-site to measure the net generator power. One transducer measures the gross power output of the eight engines and the other two measure parasitic loads associated with the power generation. The difference between the gross power and the parasitic power is calculated on a 15-minute interval. This 15-minute data is then summed into hourly data for the online database. For this site, the net power output from the engines is determined as: WG = WE1 + WE2 – Parasitic Power Consumption
2. **DG/CHP Generator Gas Use (total cubic feet)** Data for this point comes from a utility gas pulse output installed on the meter serving the engines. The 15-minute data is summed into hourly data for the online database. The meter has a resolution of 1000 cu. ft. making the data coarse on an hourly basis. The data for this channel is best viewed on a daily basis.
3. **Useful Heat Recovery (total MBtu)** The Useful Heat Recovery is calculated at 1-minute recording intervals. The piping arrangement at this site allows for multiple heat rates to be determined with five temperature sensors and two flow readings using the following equations:
    a. Useful heat recovery (QU) = K· [FW·(THS-THR1) + FB·(TBS-TBR)]
    b. Rejected (unused) heat recovery (QR) = K· FW·(THR1-THR2)]
    c. The loop fluid is expected to be water. The factor K is based on the properties of the loop fluid.
    d. (K ~ 500 Btu/h-gpm-°F for pure water; ~480 for 30% glycol).

The operators of this system developed simple metrics to track its performance. They looked at total power output and runtime of the dump radiator fan. However, metrics, which considered separately, did not let the operators understand the loss of heat recovery over the 2010-2011 winter season. Direct measurement of heat recovery and power output are necessary to understand performance.

Many CHP systems have built in controls that limit power output when jacket water supply temperatures (or in this case water temperatures from the exhaust heat exchanger) get too hot. In contrast, the dump radiator controls usually focus on the return water temperature to the engine. Therefore, systems with fluctuating thermal loads can exhibit surprisingly complicated operating patterns as thermal loads vary across the day and season. Care should be taken to understand when power output is fluctuating based on these temperatures and set points may need to be adjusted for different seasons.

The general design and performance of this system, from a fuel utilization efficiency perspective, is good when the system is operating correctly.

TABLE 4 SITE DATA QUALITY

	Percentage of Good Data		
	Power	Gas Use	Useful Heat
April-10	97.4%	74.9%	98.3%
May-10	98.5%	97.0%	98.5%
June-10	100.0%	100.0%	100.0%
July-10	100.0%	96.9%	100.0%
August-10	100.0%	100.0%	100.0%

September-10	100.0%	100.0%	100.0%
October-10	100.0%	100.0%	100.0%
November-10	100.0%	100.0%	100.0%
December-10	100.0%	100.0%	100.0%
January-11	100.0%	100.0%	100.0%
February-11	100.0%	100.0%	100.0%
March-11	100.0%	100.0%	100.0%
April-11	100.0%	100.0%	100.0%
May-11	100.0%	100.0%	100.0%
June-11	100.0%	100.0%	100.0%
July-11	100.0%	100.0%	100.0%

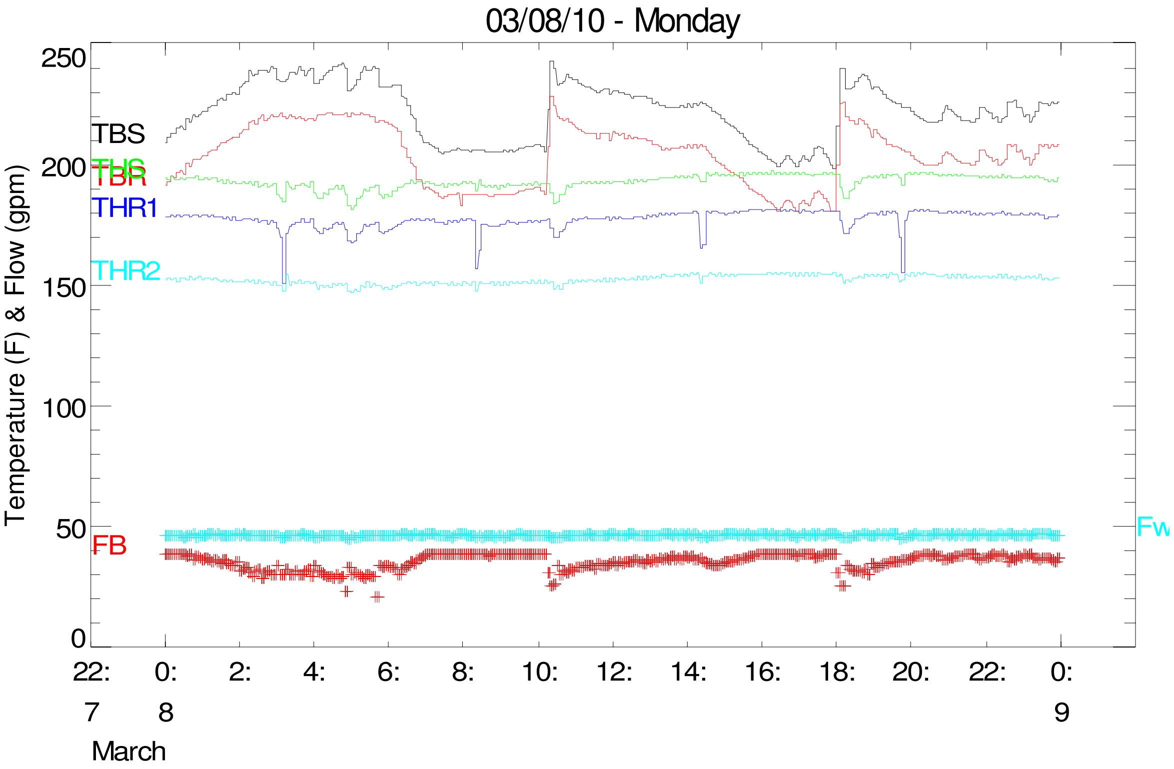
APPENDIX: IMPACT OF BOILER CYCLING ON ENGINE OPERATION

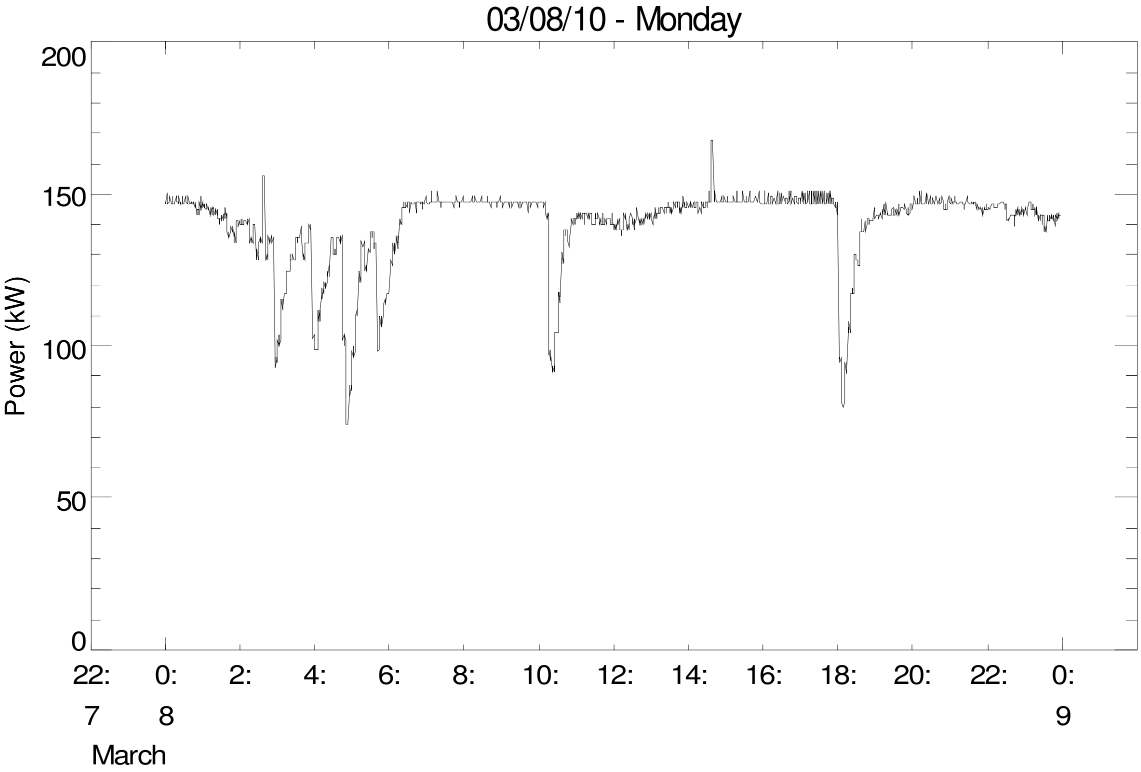
The engine exhaust heat exchanger for the Tecogen 75 units adds heat into the water drum of the 10 psig boilers (Figure 2). The temperature of supply and return water to the boiler drum (TBS and TBR) is plotted on the following Figures for 4 different days. The temperature of the water in the boiler drum periodically increases from 205°F Supply (185°F Return), to 240°F Supply (220°F Return), presumably when the boiler fires. Whenever this happens, the Tecogen units appear to decrease their power output by 10-50 kW. This implies the units throttle back power output in response to a temperature (or pressure) sensor in the exhaust heat exchanger loop. The flow through the boiler (FB) decreases when the temperature goes up which implies the hot water may be flashing.

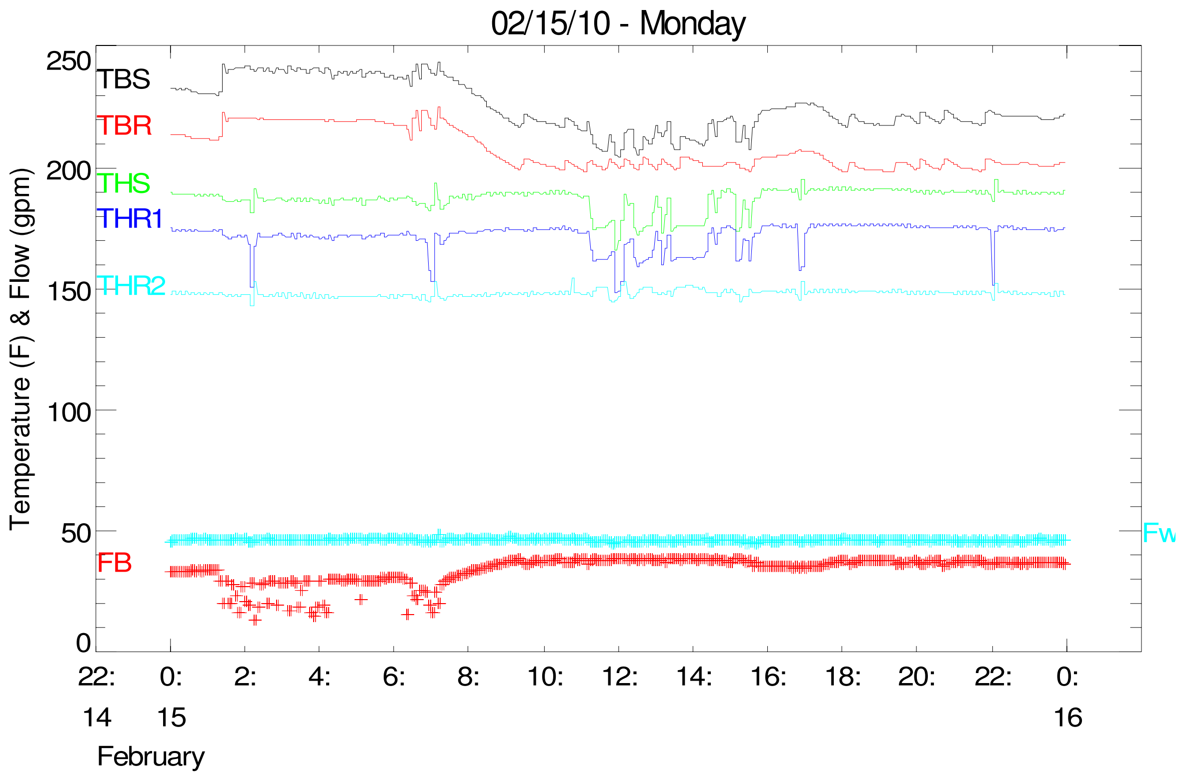
The temperature of the jacket water loop back to the engine (THR2) remains constant throughout this period. This behavior is only observed when the heat recovery piping is in the “4-pipe arrangement” with flow to the boiler. It does not occur in the “2-pipe arrangement” with the exhaust heat exchanger in series with the jacket water loop.

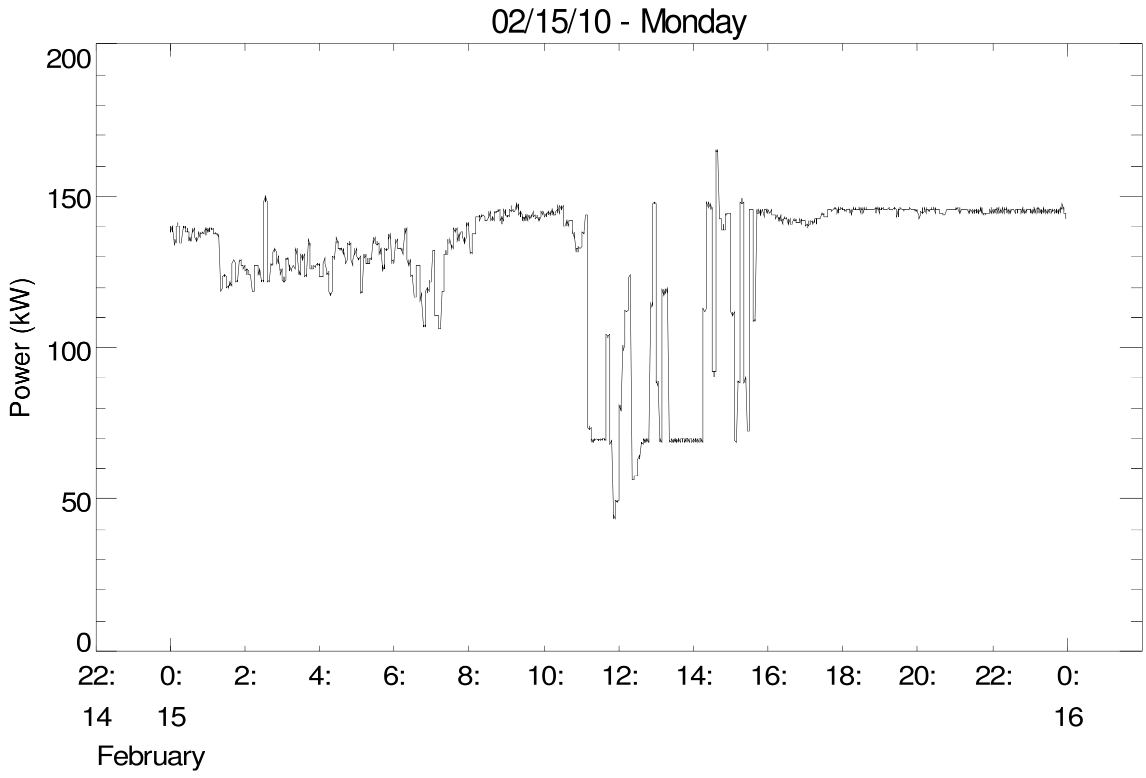
Key

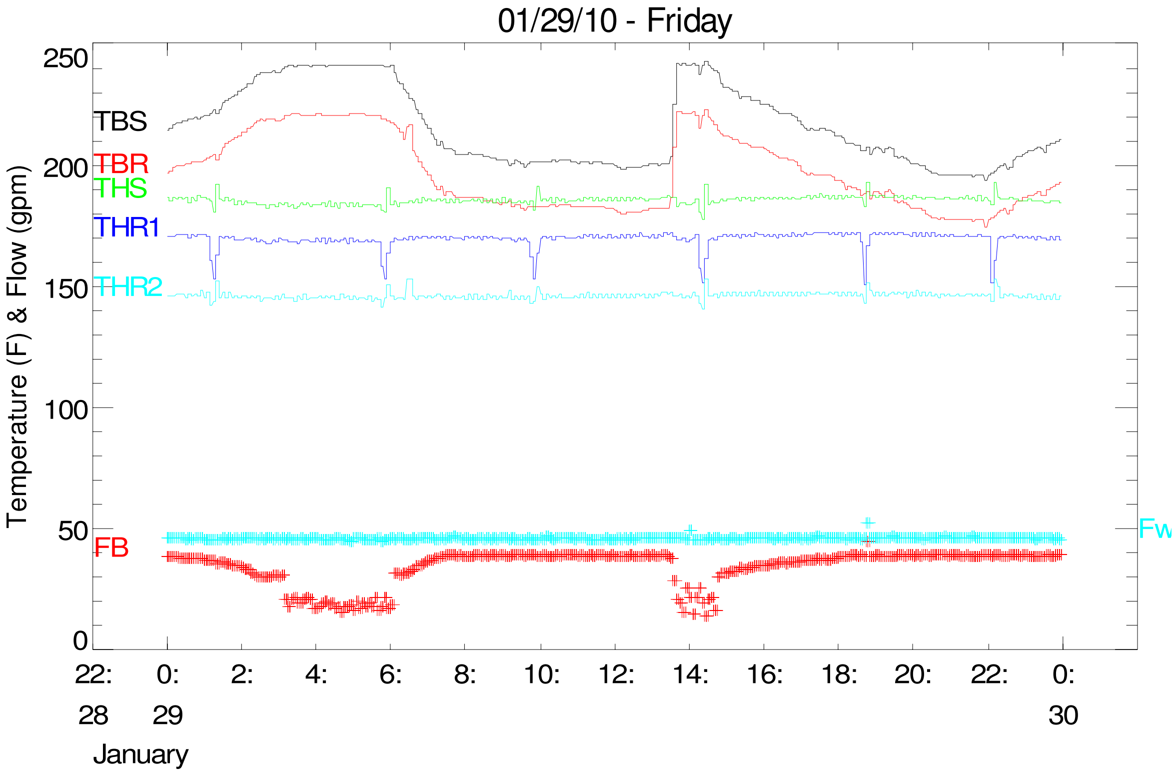
TBS - Supply Temperature to Boiler
TBR - Return Temperature back from Boiler
THS - Supply Temperature from Engine Jacket (also includes oil cooler and manifold cooler)
THR1 - Return Temperature After DHW HX
THR2 - Return Temperature After Dump Radiator (back to engine)
FB - Flow to Boiler
FW - Return Jacket Water Flow

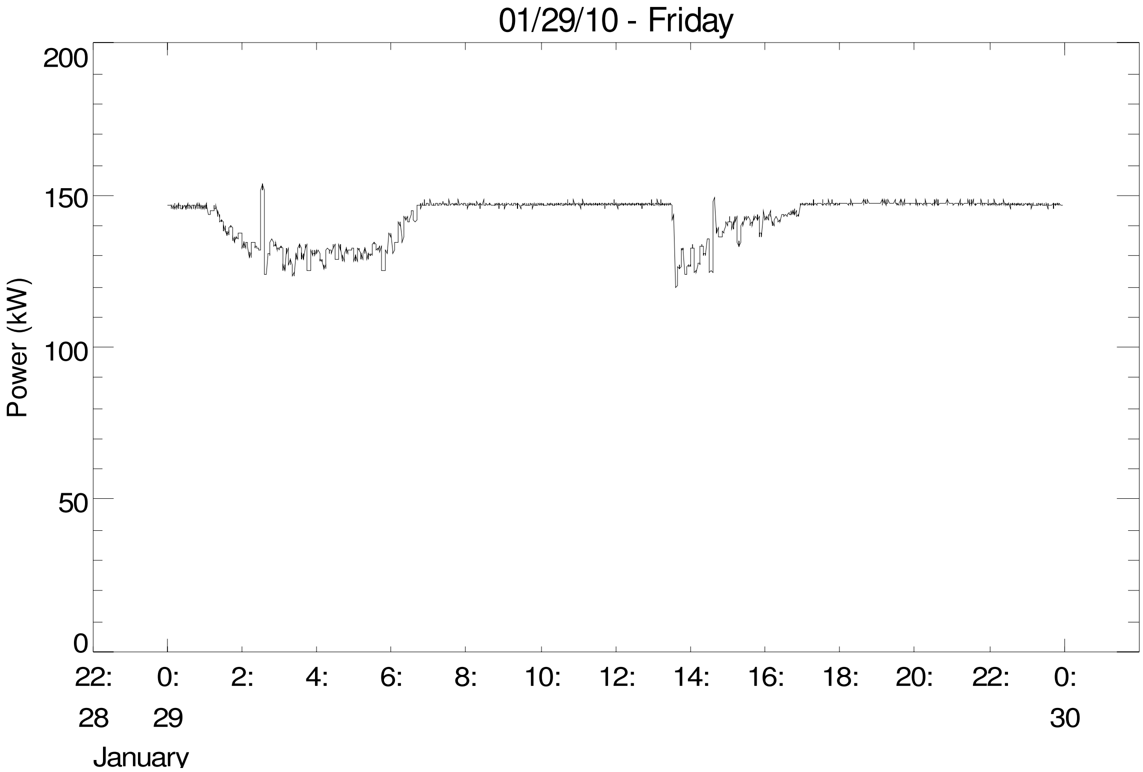

03/08/10 - Monday
Temperature (F) & Flow (gpm)
250
200
150
100
50
0
TBS
THS
TBR
THR1
THR2
FB
Fw
22:
7
0:
8
2:
4:
6:
8:
10:
12:
14:
16:
18:
20:
22:
0:
9
March


03/08/10 - Monday
Power (kW)
200
150
100
50
0
22:
7
0:
8
2:
4:
6:
8:
10:
12:
14:
16:
18:
20:
22:
0:
9
March

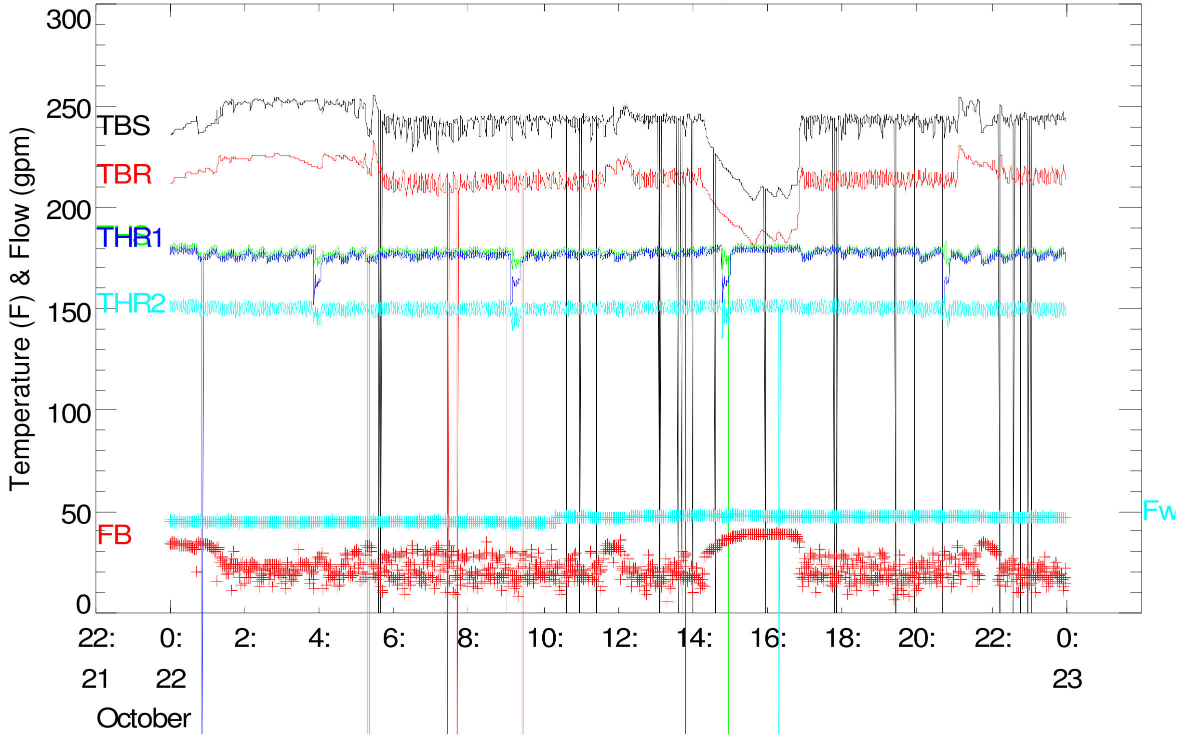

02/15/10 - Monday
Temperature (F) & Flow (gpm)
250
200
150
100
50
0
TBS
TBR
THS
THR1
THR2
FB
Fw
22:
0:
2:
4:
6:
8:
10:
12:
14:
16:
18:
20:
22:
0:
14
15
16
February


02/15/10 - Monday
Power (kW)
200
150
100
50
0
22:
0:
2:
4:
6:
8:
10:
12:
14:
16:
18:
20:
22:
0:
14
15
16
February

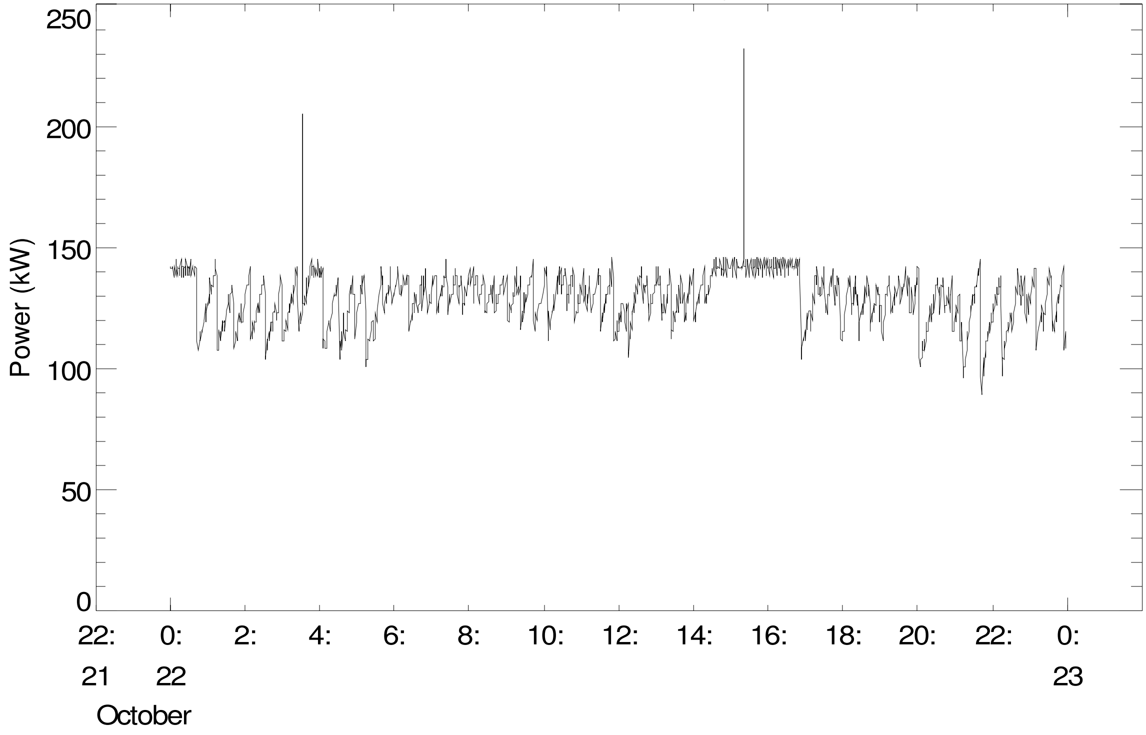

01/29/10 - Friday
Temperature (F) & Flow (gpm)
250
200
150
100
50
0
TBS
TBR
THS
THR1
THR2
FB
Fw
22:
0:
2:
4:
6:
8:
10:
12:
14:
16:
18:
20:
22:
0:
28
29
30
January


01/29/10 - Friday
Power (kW)
200
150
100
50
0
22:
0:
2:
4:
6:
8:
10:
12:
14:
16:
18:
20:
22:
0:
28
29
30
January

10/22/10 - Friday



10/22/10 - Friday



This plot implies that the sensor limiting engine power output is on the return side of the heat exchanger. It appears to limit power output at about 220°F.