Post Installation Analysis of Combined Heat and Power Projects

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ABSTRACT

Like many energy projects, the potential energy savings from the installation of a combined heat and power (CHP) system is based on the system's specifications and the building's previous energy consumption patterns. Although this is a generally accepted way to analyze the feasibility of the system, actual energy savings will often depend on the way the system is ultimately engineered, installed and operated. This article will show the importance for budgeting nominal resources to conduct independent post installation commissioning, metering and data logging (especially on smaller projects). It will show how using independent metering and monitoring can help optimize CHP operations, identify operational problems and limit unwanted thermal dumping.

This article will show how actual data and utility metering data collected after the installation of a 150-kW CHP in a New York City (NYC) multi-family building were used to optimize system performance of radiator fans, circulating pumps and existing domestic hot water (DHW) equipment. The article will also show how logger data were used to identify problems with system components that may limit the potential savings to the client. Finally, it will show how post installation monitoring helped establish the optimal seasonal operating hours for the system that maximized thermal energy consumption and minimized unwanted heat dumping.

BUILDING DESCRIPTION

The CHP project was installed in a multi-family building on the west side of Manhattan. This 921 unit, high end rental building features a gym, parking garage, tennis and basketball courts and an indoor, heated lap pool.

Each apartment has its own electrical meter. Natural gas and steam for heating is provided by the base building. Cooling is provided through packaged terminal air conditioner (PTAC) units in the apartment. Common area cooling is provided by a series of air-cooled self-contained air conditioners.

The building is heated using two Cleaver Brooks steam boilers that fire on natural gas or #2 diesel oil. The domestic hot water system is split into three systems; low rise, mid rise and high rise. Each system has two natural gas water heaters, distribution pumps and hot water storage tanks. The low-rise and mid-rise domestic hot water systems are located in the ground floor boiler room. Both the domestic hot water boilers and the steam boilers vent into a common stack that runs the length of the building. The boiler room is less than 100 feet from the building's electrical room and the building's gas meter room.

The electrical room contains all of the building's electrical services. This includes the base building electrical service and main bus. The apartment electrical services also come through this room. The electrical room sits along an exterior wall of the building. Summer electrical demand is around 550 kW and winter electrical demand is approximately 340 kW.

ORIGINAL PROJECT SCOPE

Several CHP options were investigated for the building including a 250-kW unit, a 150-kW unit or two 70-kW units. After analyzing the building's energy consumption, thermal loads and constructability issues, a 150-kW prepackaged CHP was recommended. This recommendation was based on several key reasons:

- Access to the high-rise DHW system was not economically feasible or justifiable.
- Multi-family residential buildings have thermal loads that are extremely volatile with peaks that are short lived.
- There was limited room in the building for two CHP units.
- A 250-kW machine would have led to significant thermal dumping.

The original analysis concluded that to optimize the operation of the CHP plant, 1600 gallons of additional hot water storage capacity would be required. (More was desired, but space was limited.) In addition, it was recommended that the unit only operate 16 hours a day during the summer months to avoid thermal dumping in the overnight period.

The plan for the systems was to have the CHP thermal output go to the boiler room and store it in the new hot water tanks. The water would be drawn through the water heaters and sent to the original storage tanks. Once the water in the new tanks reached the required temperature of 170°F, the water heaters would not fire and a thermostat turns off the circulating pump from the boiler room heat exchanger to the tanks.

The electrical output of the CHP would be tied directly to the building's common area electrical bus. This electrical bus serves common area A/C units, lobby and corridor lights, pumps and motors.

The unit was projected to generate over 800,000 kWh/yr of electricity (or $120,000), and approximately 48,000 therms/yr of heat (or $60,000). Net annual savings after CHP gas cost and maintenance was projected to be around $72,000/year.

POST INSTALLATION MEASUREMENT AND VERIFICATION STRATEGY

A schematic of the CHP is shown in Figure 1. Arrows show the areas being monitored.

CHP Supply and Return Temperatures

The CHP supply and return temperatures were monitored by installing temperature sensors on the supply and return lines at the heat exchanger bank in the boiler room (see Figure 2). The temperature sensors were connected to the exterior of the lines and wrapped in insulation. Data were collected using HOBO data loggers. For the most part, readings were taken every 15 minutes.

Domestic Hot Water Storage Tanks

The new hot water storage tanks have built-in water temperature sensors. However, these are analog sensors, and logging the data was not

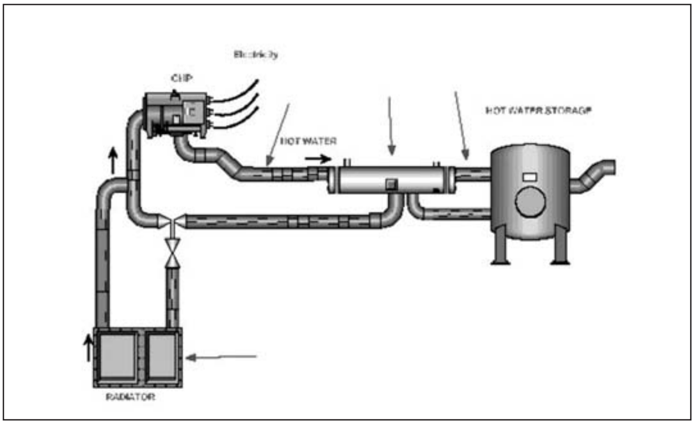

Figure 1. CHP Schematic with Monitoring Points

Figure 2. Heat Exchangers

possible. Temperature sensors were attached to the supply and return lines into and out of the tanks. The sensors were covered with insulation, and the readings were calibrated against the internal temperatures. Data loggers were used to record the temperatures as above. One set of storage tanks is shown in Figure 3.

Hot Water Circulating Pumps

The operation of the hot water circulating pumps was measured using current transformers (CTs) attached to the conduits in the shut-off switch. In this case, the amperage values were less important than establishing when the pumps were operational. Data logging intervals were established to coordinate with the other loggers to compare the readings against other parameters such as CHP supply temperatures or storage tank return water temperatures. The hot water pumps are shown in Figure 4.

CHP Room Temperature

Because of limited construction space, the CHP was installed in an open area inside the existing electrical room. A concrete block room was constructed around the installation and supply and exhaust ducts installed to bring air into and remove air out of the room. The CHP developer was concerned that the enclosure might over heat during CHP operation, especially during the summer period. The room temperature was measured and recorded using a data logger with a built-in temperature sensor. The sensor was located in the middle of the room away from the supply air duct. Another data logger with a built-in

Figure 3. DHW Tanks

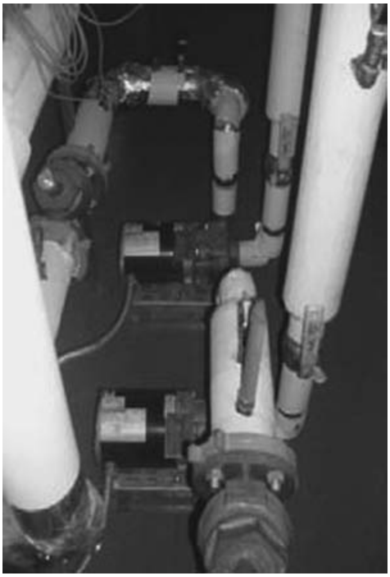

Figure 4. Circulating Pumps

temperature sensor was installed in the electrical room, just outside the CHP room, to measure the impact the operation had on the room.

Thermal Exhaust Radiator

To establish if and when heat was being "dumped" by the system, a CT and data logger were connected to the disconnect switch of the radiator fan motor. True power readings were taken to establish the maximum operating amps of the system and resulting kW demand. A temperature sensor was set on the supply line to the radiator to establish when the by-pass valve was opening. The sensor was covered with insulation and taped. This sensor was able to establish when a significant temperature rise occurred in the line, suggesting the valve was opening or open.

KEY FINDINGS

Room Temperatures

The CHP room temperature was found to be, on average, 115°F and fairly stable. This appears to be in the acceptable operating range for the CHP. The electrical room temperature was found to be in the mid to high 90s. This temperature was not much higher than the typical room temperature prior to the start of the CHP. The data are shown graphically below in Figure 5. Because the readings represented a worst case scenario, no further action was required.

DHW Supply and Return

A representative graph of the data collected on the DHW storage tanks, the CHP supply temperature and the circulating pumps is shown below in Figure 6.

Analysis of the data collected along with the CHP supply and return readings suggested the following:

- The data showed that there are two (2) points of "peak" hot water usage; once in the morning and another (smaller) peak at night.

- The storage tanks "equalize" twice a day. This is when the temperature of the water into the tank is the same as the temperature coming out of the tank. The first time is in the early afternoon and the second time is in the early morning hours (12 a.m. to 5 a.m.).

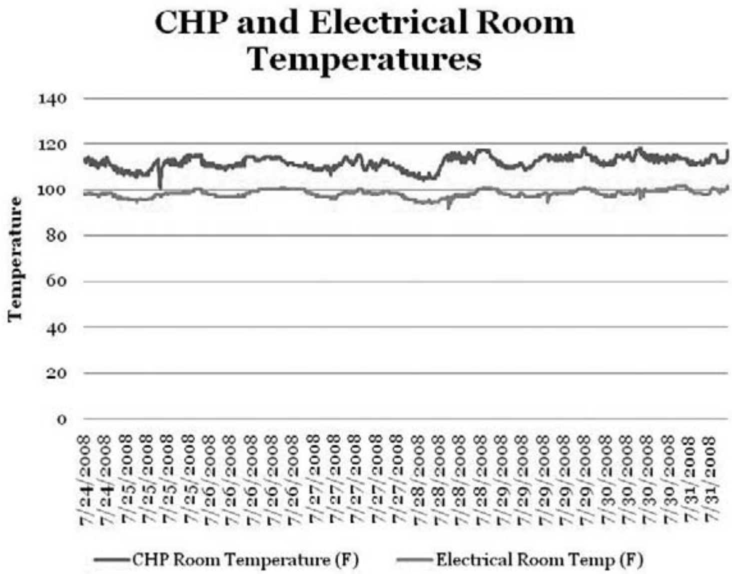

Figure 5. CHP and Electrical Room Temperatures.

- The CHP supply water temperature never reached the 190°F temperature as specified by the CHP provider. This can be seen on the graph when the temperatures into and out of the tanks were at their highest point and did not exceed 180°F.

- One of the thermostats on the circulating pumps was either not working or was not configured correctly. This would be a problem if the supply temperature exceeds 180°F, which represents the maximum allowable temperature in the tank.

Heat Dumping

The data collected from the loggers installed on the radiator fan motor disconnect and radiator inlet temperature (as well as the other data collected throughout the system) suggested that dumping was happening more frequently than expected. Some of the data are shown graphically below in Figure 7.

The data showed a clear correlation between the point of equalization in the domestic hot water tanks and thermal dumping in the radiator, as expected. However, the amount of dumping, as seen by the level of fan operation appeared to be much higher than expected, espe-

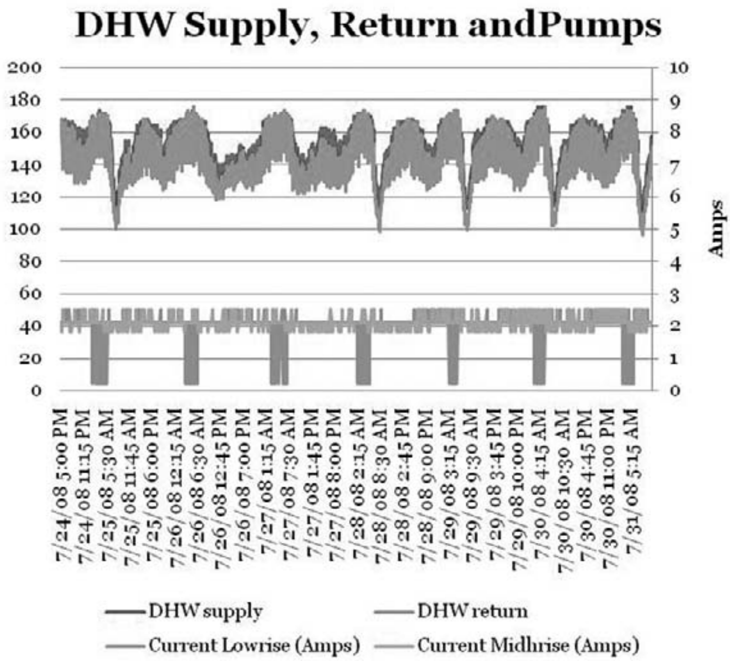

Figure 6. DHW Storage and Circulating Pumps.

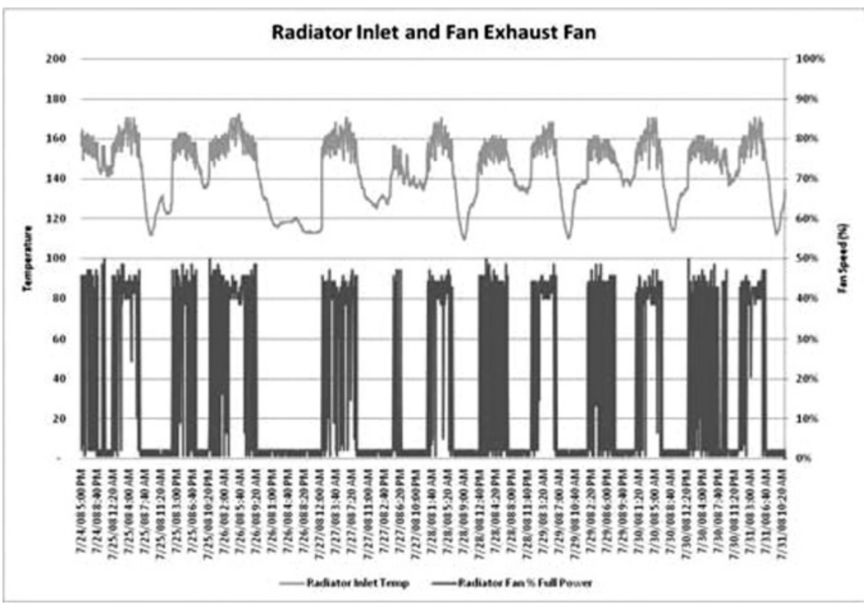

Figure 7. Radiator Logger Data.

cially during the afternoon. Finally, the data showed that dumping was occurring even though the CHP supply temperature did not reach the 190°F specified in the literature. A 24-hour sample of the data is shown graphically in Figure 8.

The thermal dumping at night was much steadier than that during the day. The data confirmed our initial study conclusion that the machine should not run at night.

SYSTEM RECOMMENDATIONS

The following are recommendations made to adjust the system based on the information collected from the data loggers.

- To minimize the thermal dumping, the bandwidth on the variable frequency drive (VFD) was expanded to allow for greater variability in fan operation. In addition, the trigger temperature was increased to 160°F to limit fan operation during nominal bypass events. These adjustments significantly reduced the incidence of radiator operation, as shown in Figure 9. However, it is evident that there will be dumping even in the winter in spite of using the system to heat the pool during this time.

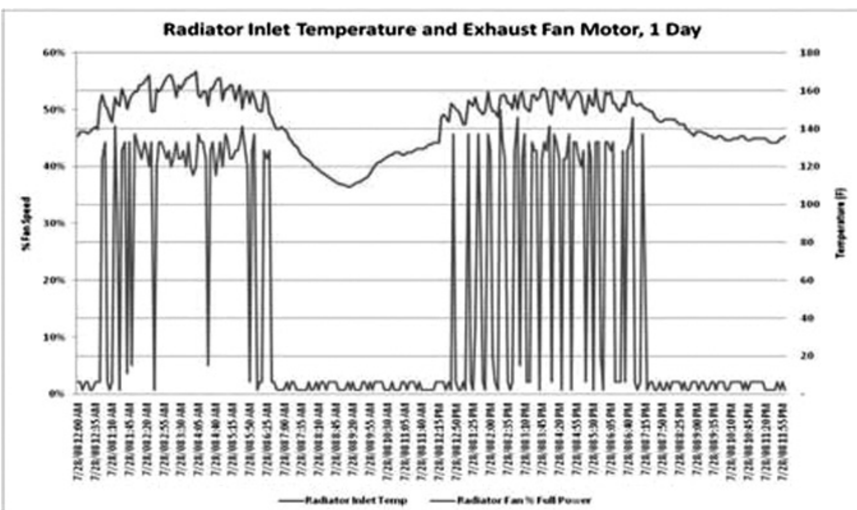

Figure 8. 24-hour Radiator Data.

- The thermostat on the circulating pump was changed and the activation temperature changed. This is a strap-on thermostat, which is subject to a high error bandwidth and calibration errors. If the CHP can be made to reach 190°F, these thermostats will have to be changed to ensure the hot water storage tanks do not exceed 180°F.

- The flow to each set of hot water storage tanks was adjusted to keep them balanced and optimize thermal transfer.

- NCG recommended that the system not operate from 12 midnight to 5 a.m., especially in the summer period. However, because it is not clear how many Btus are being dumped during this period, it is hard to quantify the economic impact to the project. The thermal dumping may be negligible to the value of the electricity offset.

- The domestic water heaters inlet trigger temperature was lowered from 165°F to 155°F to minimize their firing. This adjustment had no impact to resident comfort.

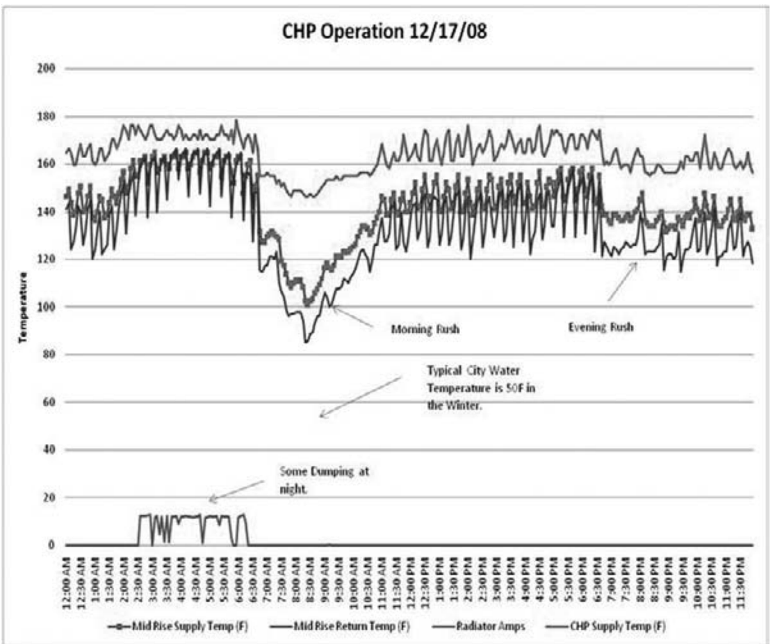

Figure 9. Post-adjustment Radiator Operation.

CONCLUSION AND RESULTS

The following are some of the major findings and conclusions resulting from the post installation measurement and verification (M&V) of the CHP system:

- The data clearly showed that the CHP supply temperature does not reach the level in the product specification. Discussions with the manufacturer revealed that the unit can only increase temperature through the system by 10 to 15°F. Although not critical in this application, if you need 190°F, it should be specified in engineering documentation and guaranteed. CHP analysis should take into account that not all heat will be at this level.

- Although the CHP was sized for less than 30% of the building peak kW load, the hot water storage capacity increased by 1,600 gallons and the system was used to heat an in-ground pool, there is still not enough need for all of the thermal energy from the system.

- The M&V process confirmed an inherent conflict in the system between thermal utilization and CHP operations. The higher the CHP supply water, the higher the risk for a high temperature trip of the CHP unit. Keeping the return water temperature to the CHP low results in lower supply water temperatures and less heat recovery.

- The project should budget for short-term M&V, and owners should plan for an independent, third party consultant or commissioning agent to carry it out. On board CHP sensors and meters should not be relied on to gather this information. These systems are primarily used to ensure proper operation, not optimize performance. This can be done for approximately 1% of the project cost.

ABOUT THE AUTHOR

Rafael M. Negron has worked in the energy industry for 20 years. As Principal of Norgen Consulting Group, Inc., Mr. Negron

is responsible for overseeing energy savings projects for some of the largest commercial and institutional clients in New York City. His responsibilities include conducting energy audits, energy modeling, and rate schedule analysis. Mr. Negron is involved in identifying energy savings measures, project managing installations and securing energy incentives from public and private entities. Mr. Negron also helps clients identify and implement sustainable policies and activities and pursue LEED certification.

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