The QLIC Heat Recovery Measurements – September 2, 2016

Heat recovery on the QLIC CHP system are recorded by four measurements from two sensors. A Badger 380 BTU meter is located across the dump HX skid. The BTU meter consists of a remote temperature probe **[THW2]** measuring the temperature entering the skid and a flowmeter **[FHW]** and temperature probe **[THW3]** (both sensors located at the BTU meter body), measuring the conditions leaving the HX skid. This temperature difference and flow combination is used to calculate the heat rejection **[QR]**.

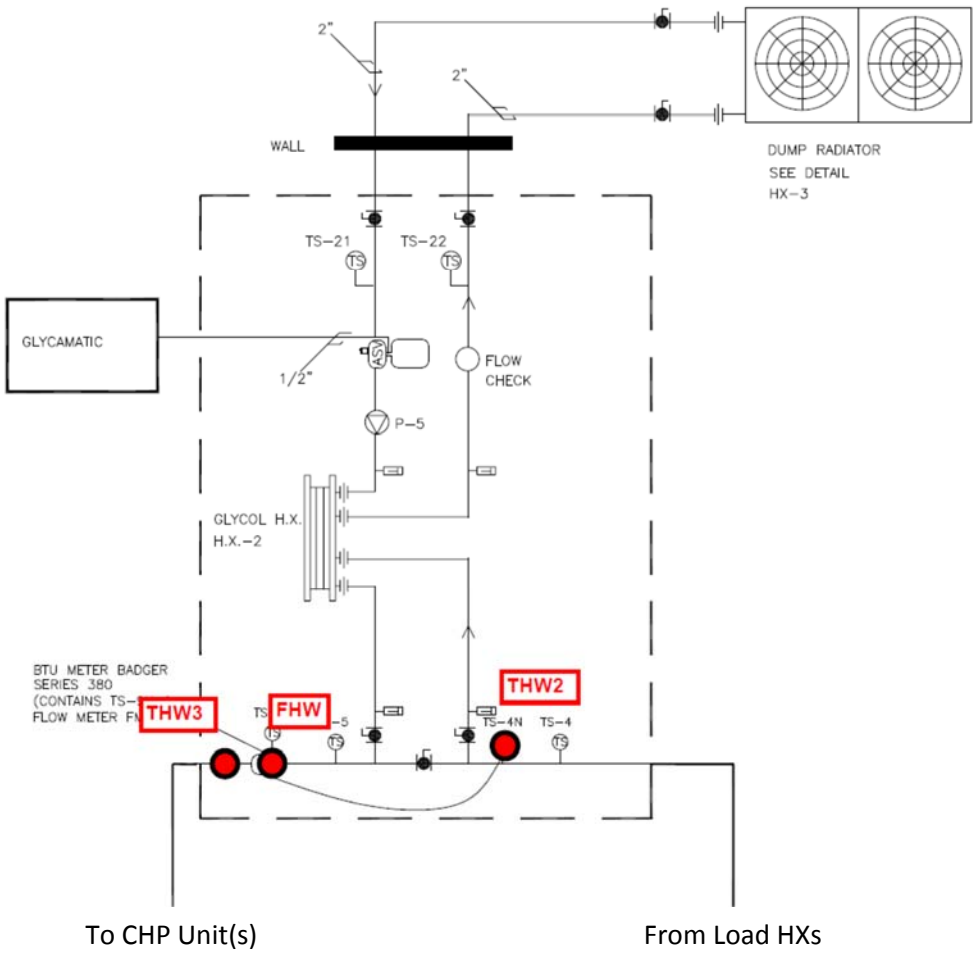

Figure 1. Dump HX Schematic

A separate Veris 10k Type II Thermistor is used to measure the temperature entering the load HXs **[THW1]**. This temperature, combined with the temperature entering the dump HX **[THW2]** and flow **[FHW]** are used to separately calculate the useful heat recovery **[QU]**.

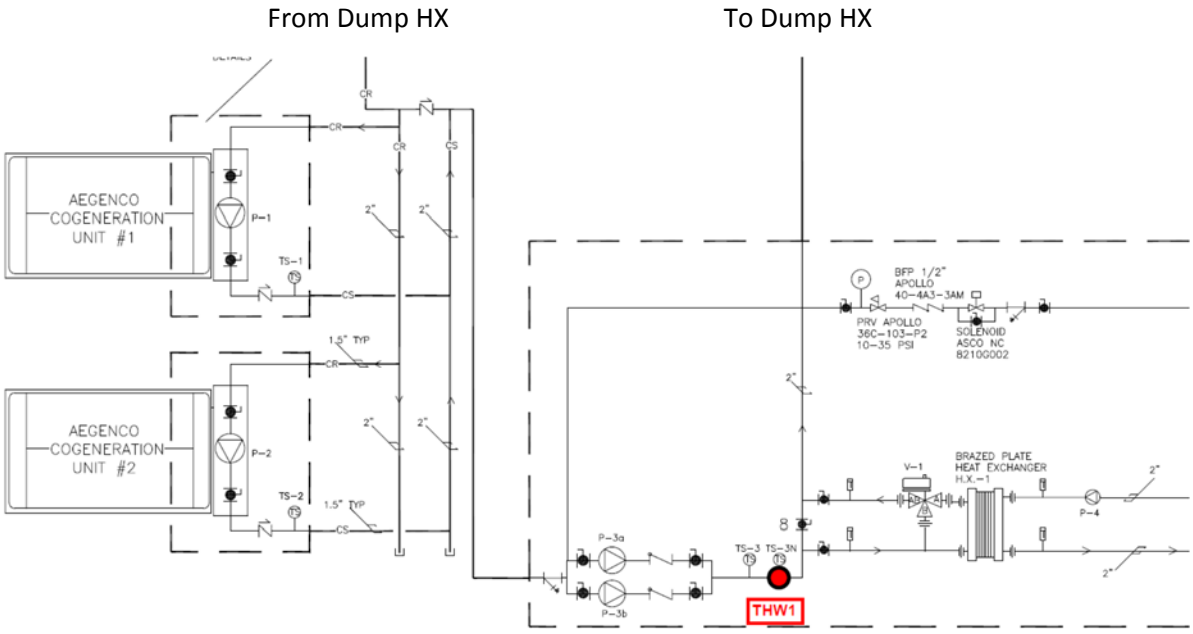

Figure 2. Load HX Schematic

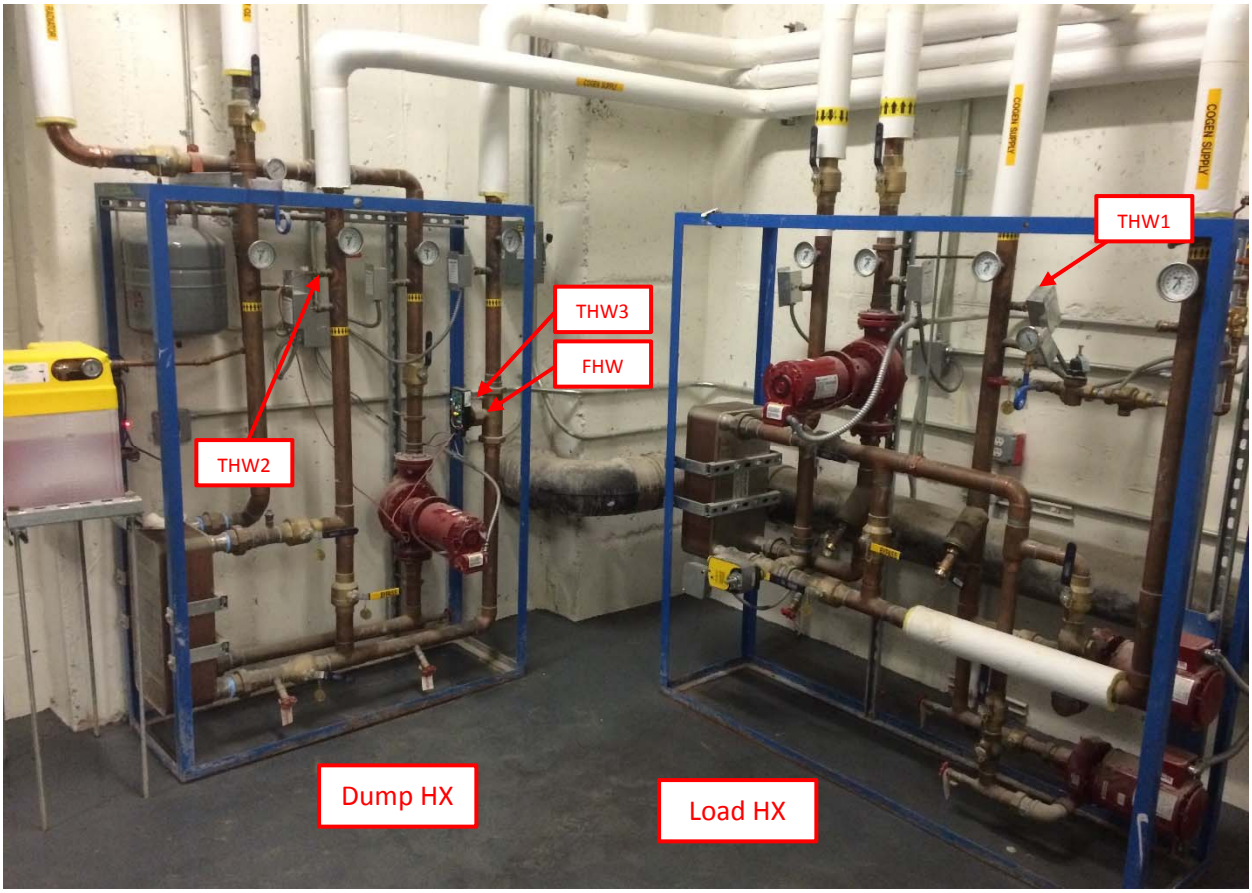

Figure 3. Dump HX And Load HX

Useful and rejected heat are calculated by the following equations:

Useful Heat (MBtu/h): $QU = 0.488 \times FHW \times (THW1 - THW2)$

Rejected Heat (MBtu/h): $QR = 0.488 \times FHW \times (THW2 - THW3)$

Figure 4 displays the temperature and flow history for the system, along with the CHP power to indicate operation.

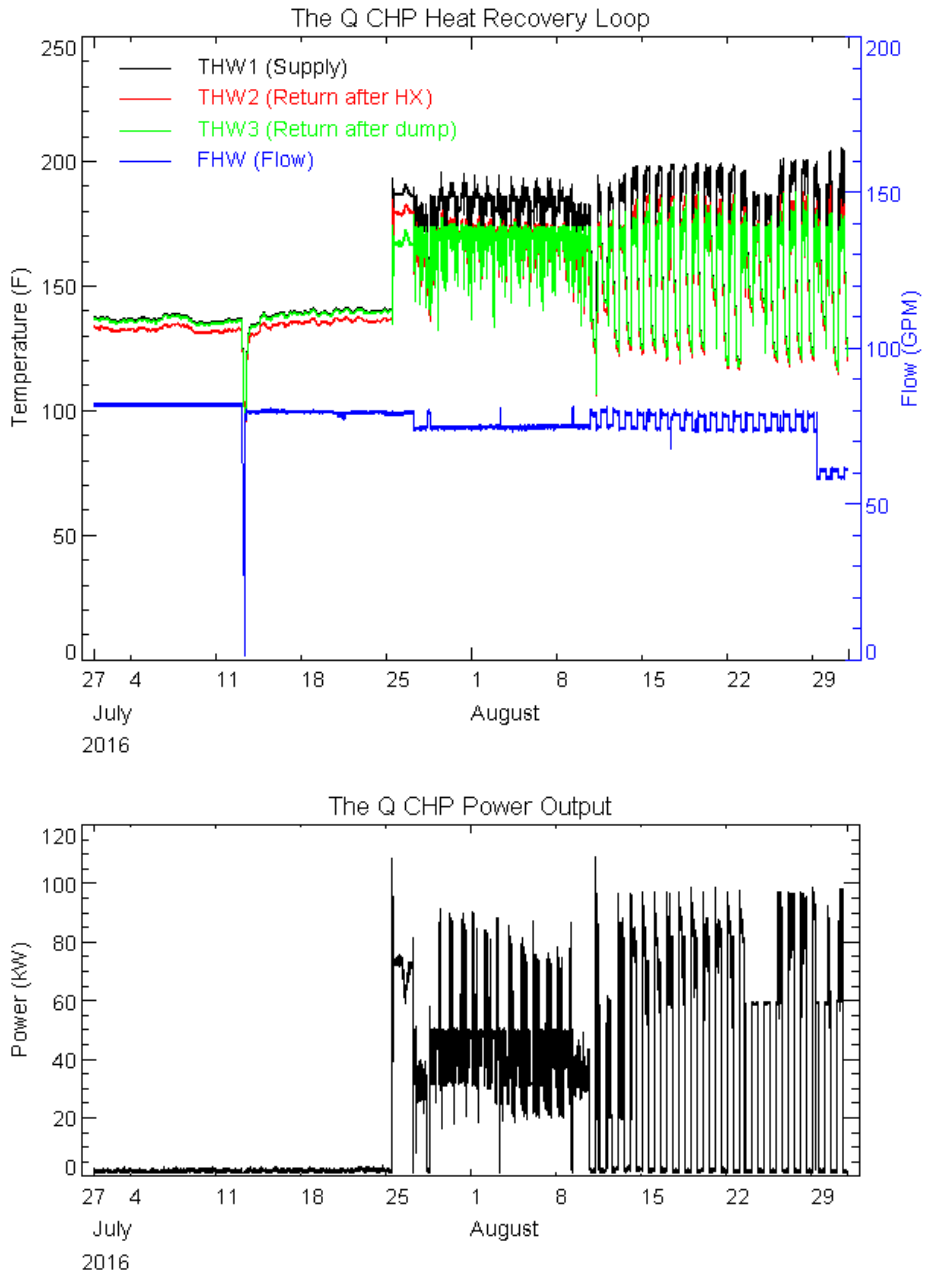

Figure 4. System Heat Recovery Temperatures and Flows

System temperatures follow a logical progression from hottest [THW1] to coldest [THW3]. The CHP loop pump operated for several weeks in July with no CHP system operation, and then operated at a slightly lower flowrate when the CHP system was started up in late July. CHP loop flow is slightly impacted by valve operation as the system cycles on and off.

Figure 5 and Figure 6 displays the relation of the temperature sensors against each other while the heat recovery pump is operating. During periods of no CHP system operation, the temperature sensors should converge along the unity line (dashed black line) if there is no systemic calibration or measurement error. A trend line was plotted along the data where no active heat recovery (THW1 vs THW2) or heat rejection (THW2 vs THW3). Both plots indicate a systemic error on the order of 5-7°F under typical operating temperatures, where the THW2 temperature reported is lower than the actual temperature. This level of error is consistent with the spot measurements observed by ERS during the site inspection on August 17, 2016.

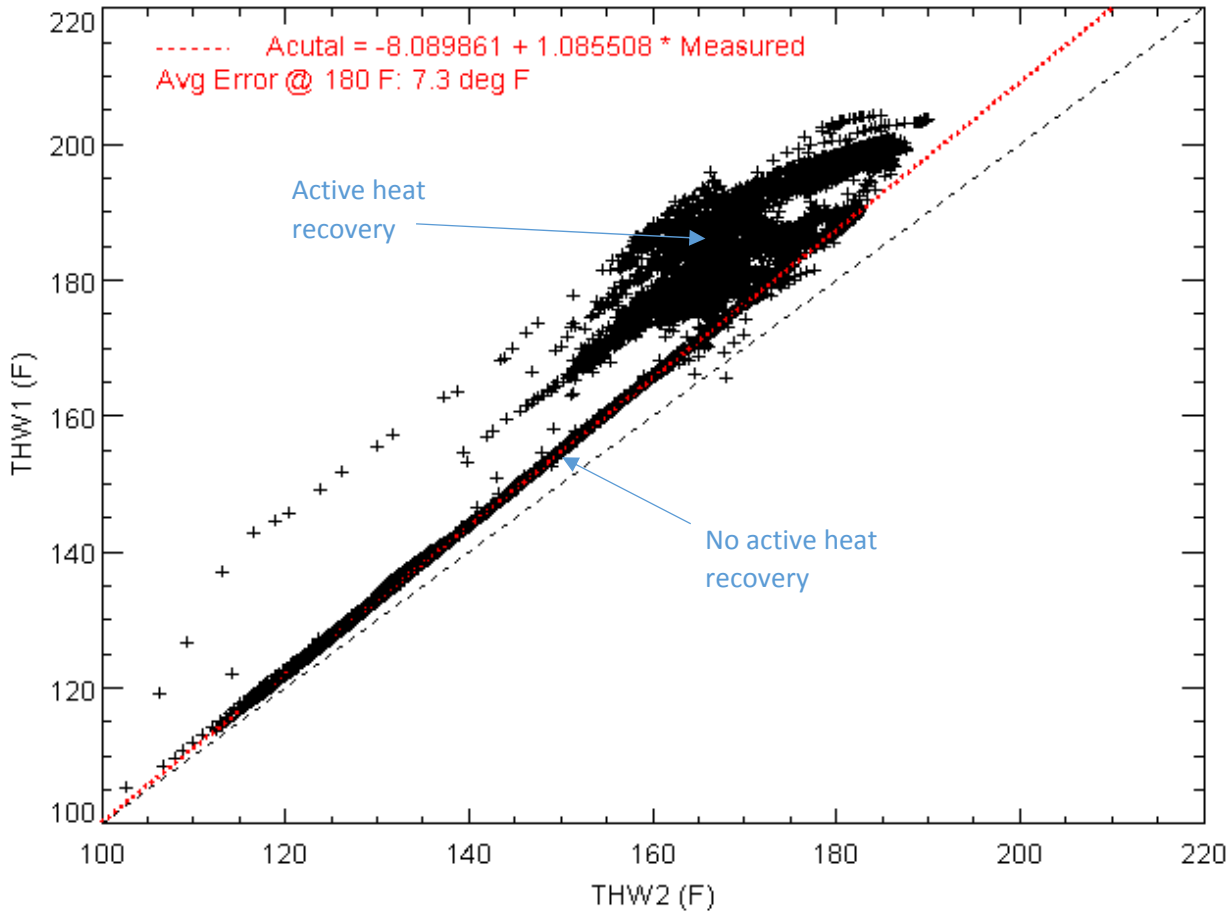

Figure 5. Comparing THW2 vs THW1

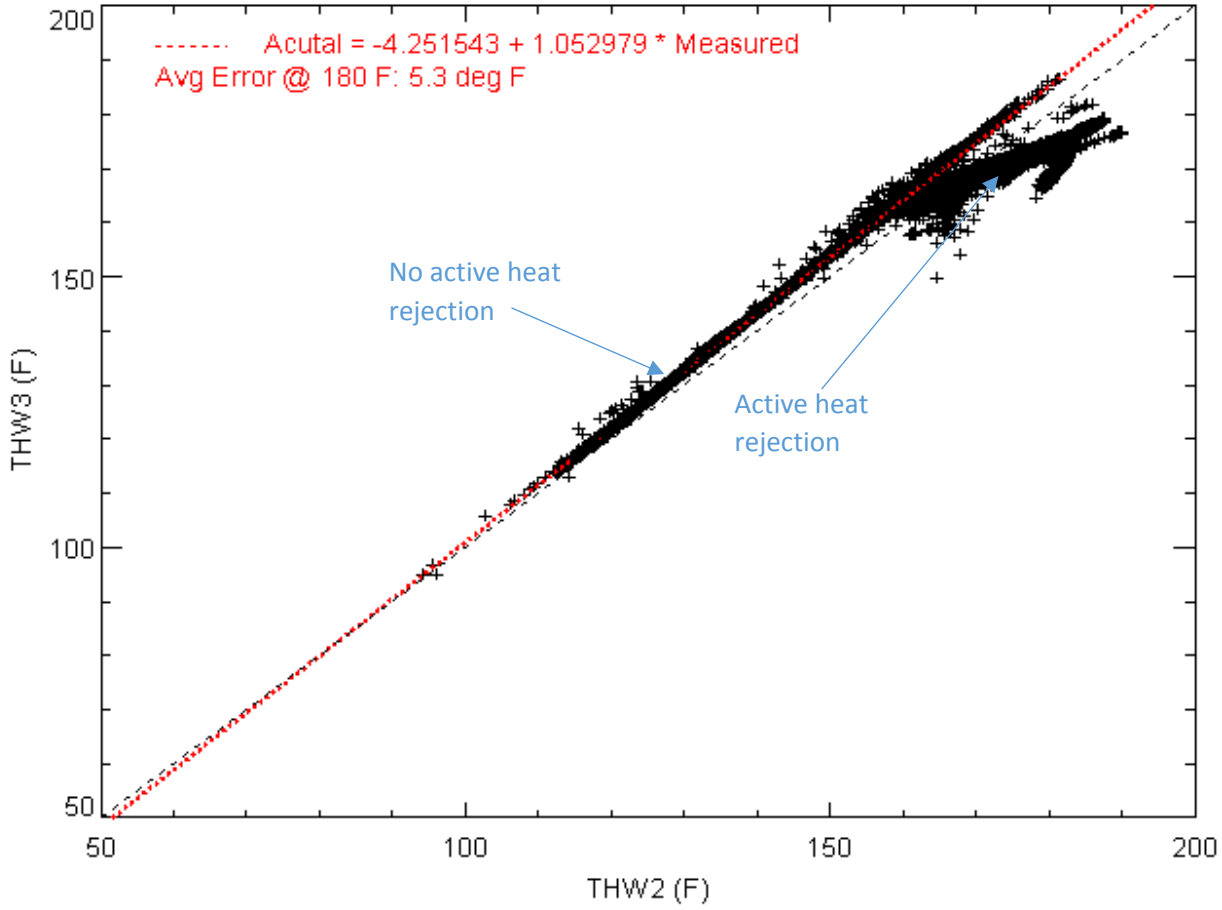

Figure 6. Comparing THW2 vs THW3

The trend line in Figure 6 is the most reliable indication of the error, as both sensors are part of the BTU meter. THW2 will be adjusted by this relation, and QU and QR recalculated. This will reduce the useful heat recovery, since THW2 will be increased, but the total heat production will remain unchanged (Figure 7 and Figure 8).

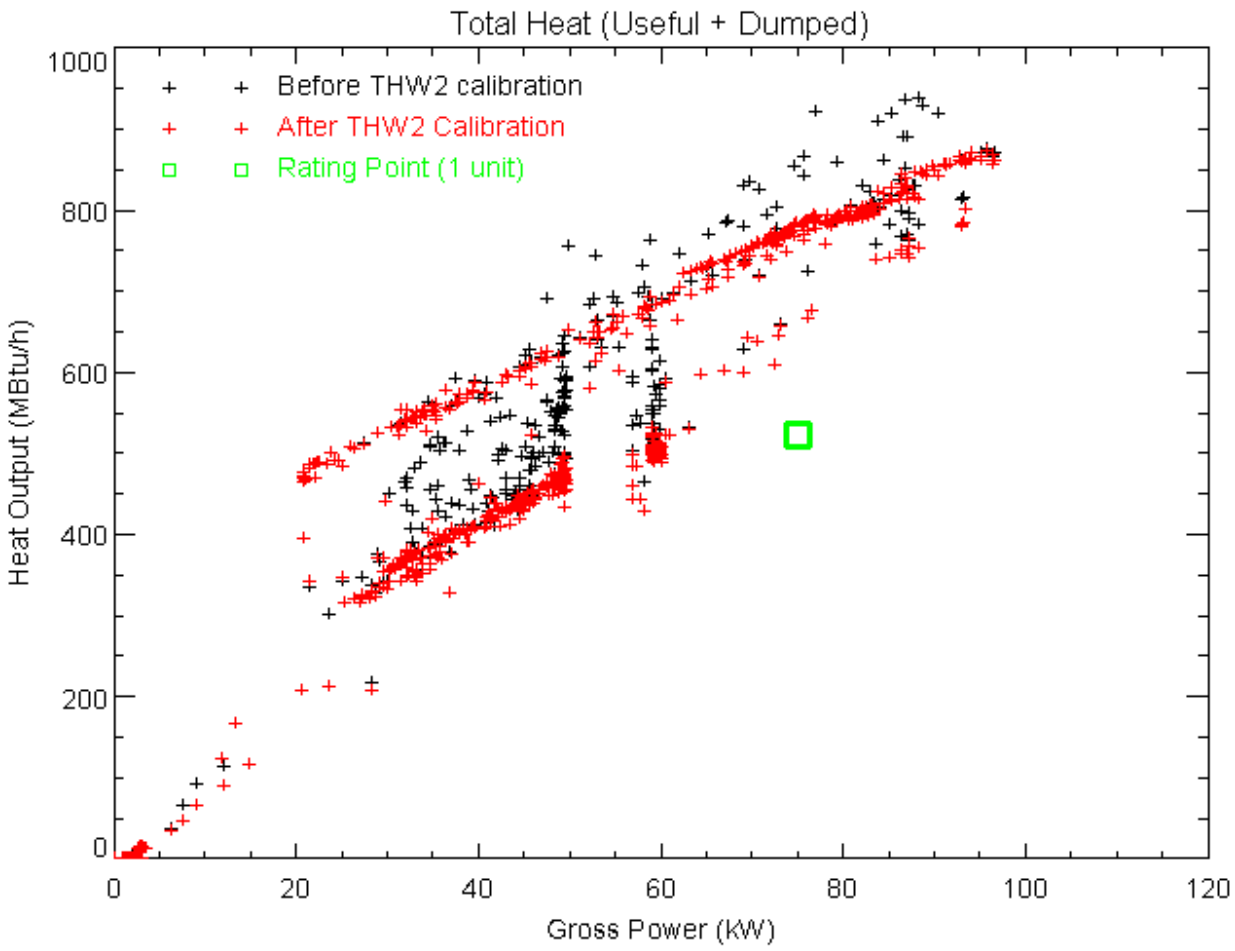

Figure 7. Total Heat Output vs Gross Power Before and After THW2 Correction

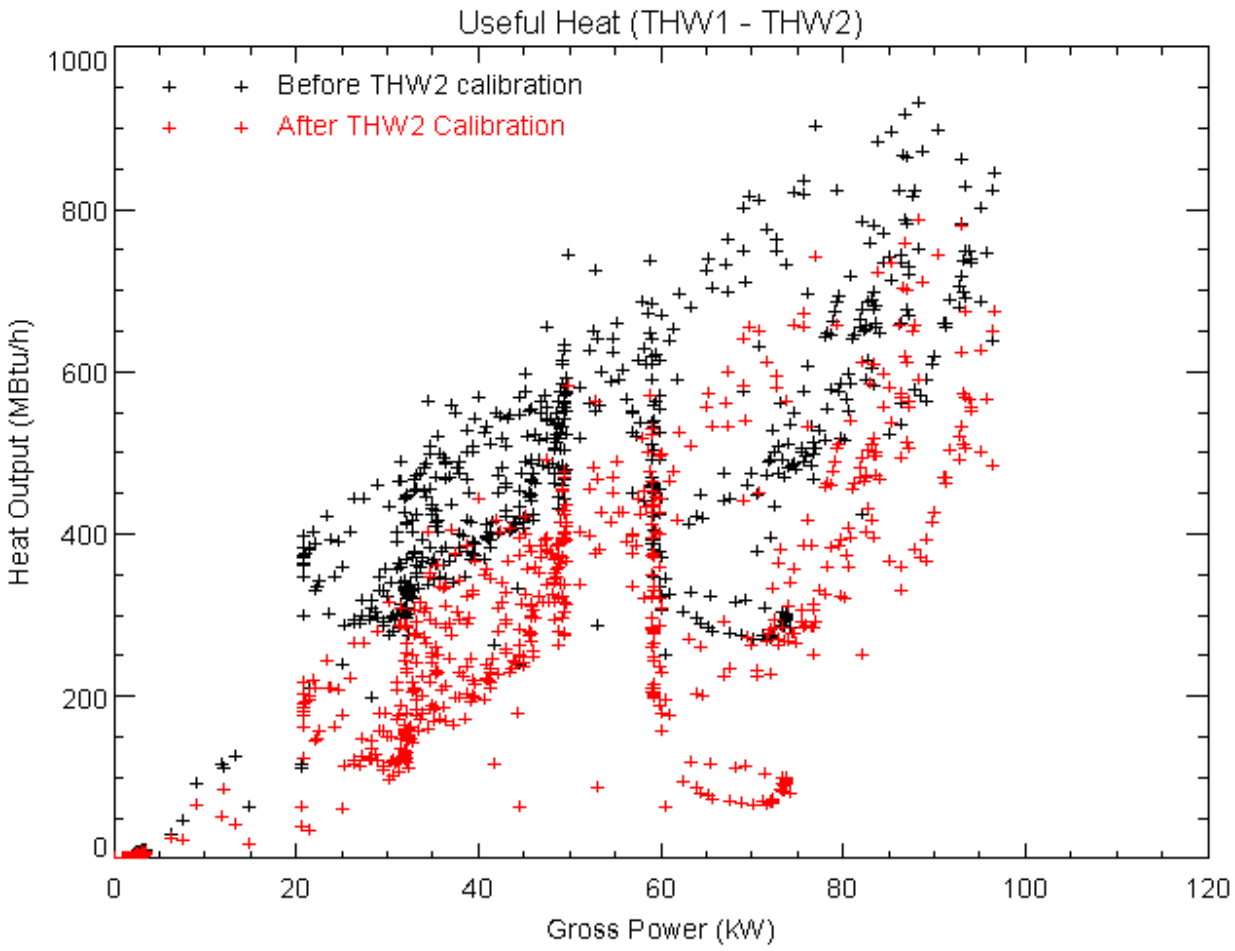

Figure 8. Useful Heat Output vs Gross Power Before and After THW2 Correction

The correction to THW2 reduces the FCE_{chp} substantially, as useful heat recovery drops by nearly 35% after the correction. Little change occurs in the overall system energy balance.

Table 1. Impact of THW2 correction on Efficiency Calculation

	W/O THW2 Correction	W/ THW2 Correction
Energy (kWh)	32,941	32,941
Recovered Heat (Mbtu)	296,686	192,270
Rejected Heat (Mbtu)	60,656	150,351
Gas Consumption (CF)	502,920	502,920
FCEelec (% HVV)	21.7%	21.7%
FCEchp (% HVV)	78.8%	58.7%
Energy Balance (% HVV)	90.5%	87.7%

This correction will be applied to back data until a thorough field calibration of the system temperature sensors can be performed.