Parker Jewish Institute – Heat Recovery Flow Measurements

The CHP system at Parker Jewish Institute (PJI) recovers engine heat to two separate heat recovery loops, a low temperature loop and a high temperature loop. Each loop has a dedicated set of flow meters and temperature sensors to record the heat recovery independently.

Low Temperature Loop

The low temperature loop recovers heat from the engine block to the domestic hot water system via a plate frame heat exchanger. This low temperature loop also passes through a dump radiator to reject any excess heat to ambient. This loop typically operates between 180°F and 200°F, and uses a constant speed pump to circulate the glycol water mixture through all four engines and the plate frame HX coupling the CHP loop to the DHW system.

Flow for the low temperature loop is recorded using an Onicon F1100 series insertion turbine meter. Several issues have occurred with this meter, and the meter is currently not reading. Figure 1 displays the flow history for this meter, and the table and description below describe the adjustments to the data and the assumptions made where data does not exist.

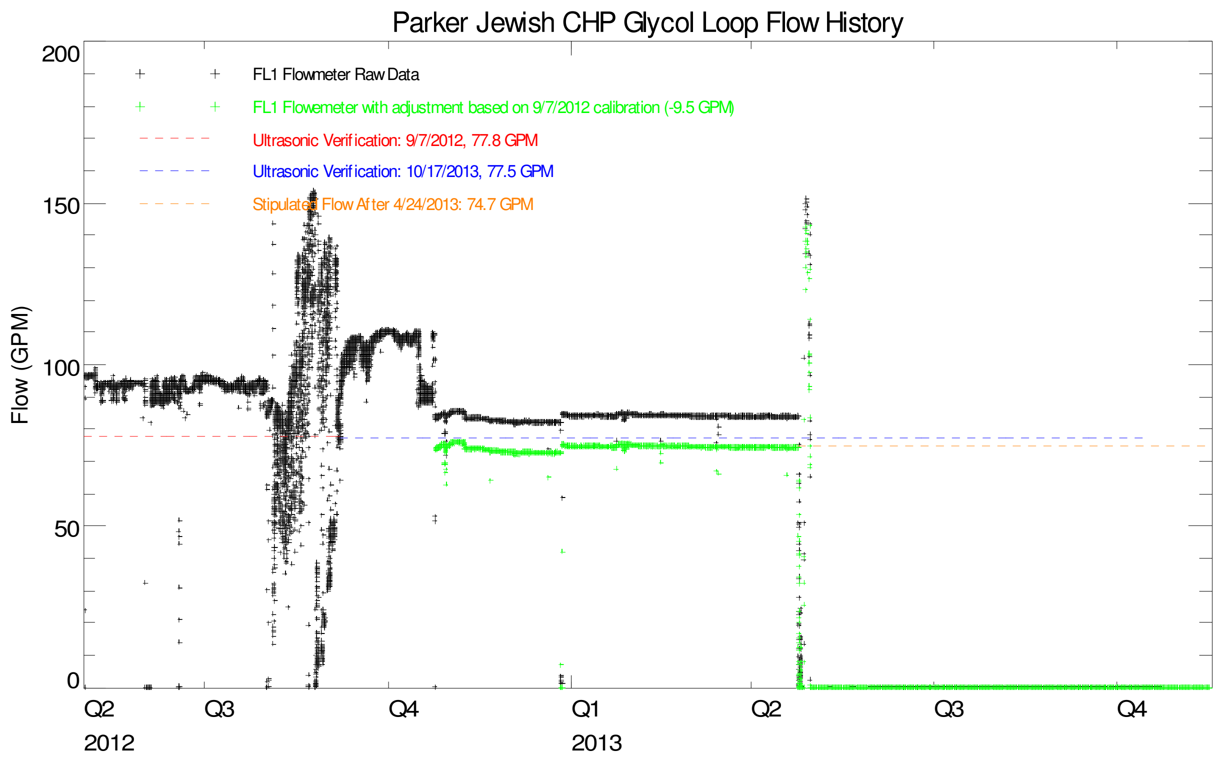

Figure 1. Low Temperature Glycol Loop Flow Readings

At the start of monitoring, the flow meter indicated a flow that was reasonable compared to the nominal flow for the system (25 GPM/engine, 100 GPM total), but was highly variable. This may have been due to unpurged air in the line from system charging. The volatility in the measured flow reached a maximum in Summer 2012, where recorded flows reached as high as 150 GPM.

A verification visit in September 7, 2012 indicated that the flow measured by the flow meter and data logger was 9.5 GPM higher than the flow measured simultaneously by a portable ultrasonic flow meter. A correction for this deviation was applied to the flow data after this date, and data before that date, a constant flow of 77.8 GPM based on the ultrasonic measurement was applied.

Variation in measured flow then settled out during an extended period from November 1, 2012 to April 24, 2013, and the flow measured matched the ultrasonic readings within a reasonable tolerance. After April 24, 2013, the flow meter experienced another flow incident (either from loosened debris or air in the system), and ceased reading. A stipulated flow of 74.7 GPM was applied after this date based on the average flow during the steady flow period. A subsequent ultrasonic measurement on October 17, 2013 indicated that the flow was 77.5 GPM.

With the consistent measurements of flow by the ultrasonic meter, and lack of any control valves or VSD pump control to cause any variation in flow, the stipulate flow of ±77 GPM for the system is a reasonable assumption. It is recommended that a replacement flow meter be purchased. Due to the damage to the existing flow meter, an insertion shedding vortex meter is recommended (Nice Instruments Titan).

Table 1. Low Temperature Glycol Loop Flow Issue History

Period	Issue	Resolution
5/2/2012 – 11/1/2012	Flow variable due to debris/air in line.	Apply fixed flow rate of 77.8 GPM based on ultrasonic verification on 9/7/2012
11/1/2012–4/24/2013	Flow meter calibrated to ultrasonic readings	Apply fixed flow rate adjustment of -9.5 GPM based on ultrasonic verification readings. Flow meter: 87 GPM Ultrasonic: 77.5 GPM
4/24/2013 - present	Flow meter no longer functioning	Apply fixed flow rate of 74.7 GPM based on average of steady-state measured flow for 6-months
10/17/2013	Ultrasonic flow verification	Ultrasonic: 77.5 GPM

High Temperature Loop

The high temperature loop recovers heat from the engine exhaust to heat provide heat to water pulled directly from the facilities boiler jacket. The engines add heat to the loop and re-inject the water back into the boiler jacket. This loop typically operates between 225°F and 240°F, and uses a variable speed pump to circulate the water, based on the pump pressure needed to overcome the static pressure at the boiler (typically 15-psig).

Flow for the low temperature loop is recorded using a Nice Instruments Titan shedding vortex meter. The meter was initially installed in the wrong direction, but was reversed on September 7, 2012. Comparison to the ultrasonic meter has indicated excellent agreement with the flow meter reading.

Figure 2 displays the flow history for this meter, and the table and description below describe the adjustments to the data and the assumptions made.

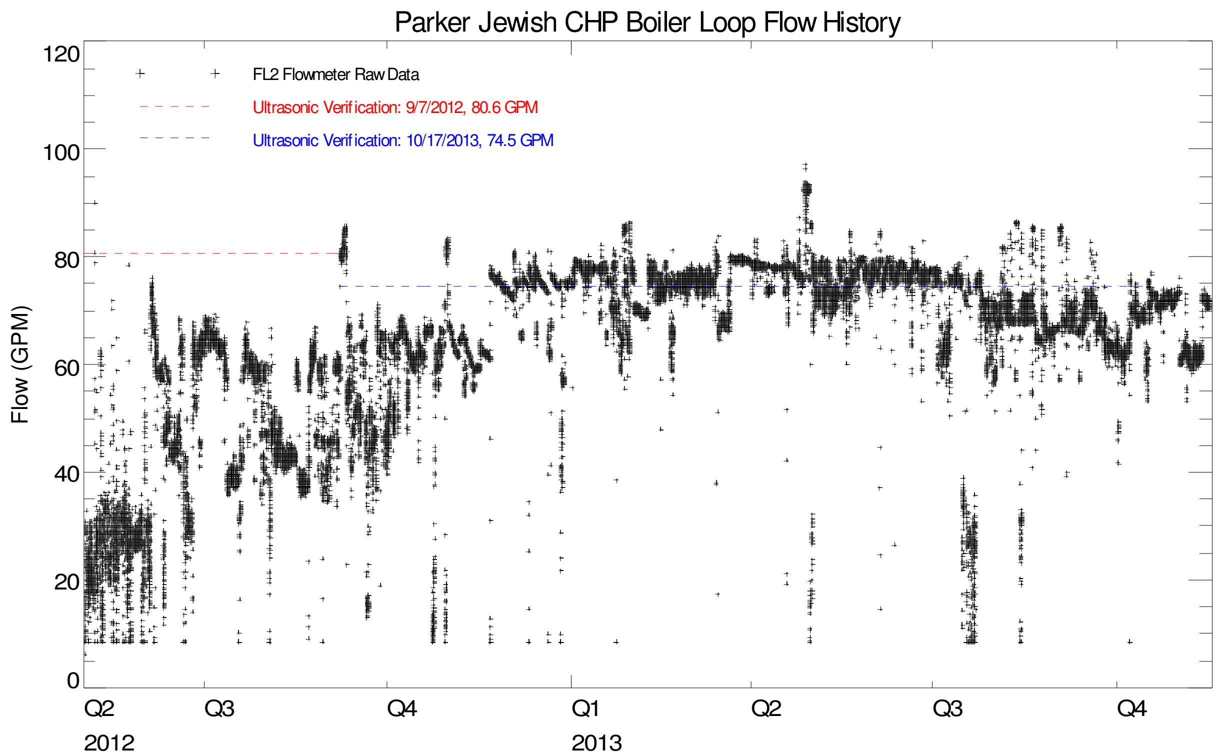

Figure 2. High Temperature Boiler Loop Flow Readings

When the meter was oriented in the direction of flow on September 7, 2012, a comparison was performed to the ultrasonic flow meter reading, and both readings were very similar, near 80 GPM. As there was a significant difference between the spot reading flow with the meter in the correct orientation and the historic flow recorded before that date, it was assumed that the meter had been under-reporting the flow. The data was adjusted to use a stipulated flow of 80 GPM prior to that date, and no adjustment thereafter.

Subsequent inspection of the data indicated that this lower flow range of 60-70 GPM occurred even after the orientation of the flow meter was changed. This implies that the meter was most likely reading accurately even while installed in the reverse direction, and the flow stipulation should be removed.

Verification of the meter reading on October 17, 2013 indicated that the meter continues to record flow accurately, and no change is required in the metered data.

Table 2. High Temperature Boiler Loop Flow Issue History

Period	Issue	Resolution
5/2/2012 – 9/7/2012	Meter installed backwards – low flow readings presumed to be due to meter orientation. Review of subsequent data indicates this adjustment is erroneous, and has been removed.	Apply fixed flow rate of 80 GPM to data prior to this date based on ultrasonic meter reading Flow meter: 80.3 GPM Ultrasonic: 80.6 GPM
10/17/2013	Ultrasonic flow verification	Flow meter: 73.3 GPM Ultrasonic: 75.8 GPM

Parker Jewish Institute – Natural Gas Consumption Measurements

The four engines at PJI are served by a common gas meter on a dedicated natural gas account. Prior to November 15, 2013, the natural gas consumption for the system was measured using the utility billing data collected from Con Edison's Transportation Customer Information System (TCIS). This reading provides the total gas use in CF between the two billing periods, typically 30 days apart.

Using the interval monitored data, the total measured gross energy in the same period is calculated, and the normalized fuel consumption per gross kWh of generation is computed (CF/kWh). This normalized fuel consumption rate is then applied to each interval of generation data to compute the fuel consumption for each record. Using a CF/kWh value rather than an actual heat rate (BTU/kWh) reduces the confusion when evaluating performance at either HHV or LHV. The result of the calculation is CF/interval, to which the appropriate heating value can be applied.

Table 3 displays the natural gas data, gross electrical generation, and resulting normalized fuel consumption rate for each billing period.

Table 3. Parker Jewish Natural Gas Utility Billing Data and Coincident Generation

		[1]	[2]	[3]	[4] = [2+3]	[5] = [1/4]	[6] = [4]*3.413 / [1] * 1.03 * .9
Start Date	**End Date**	**Gas Consumption (CF)**	**Net Generation (WG) (kWh)**	**Parasitic Consumption (WPAR) (kWh)**	**Gross Generation (kWh)**	**Normalized Fuel Consumption (CF/kWh)**	**Gross Electrical FCE (% LHV)**
5/7/2012	8/8/2012	3,143,000	234,174	14,156	248,330	12.66	29.1%
8/8/2012	9/7/2012	1,458,000	111,620	6,188	117,808	12.38	29.7%
9/7/2012	10/9/2012	1,555,000	158,165	6,161	164,326	9.46	38.9%
8/8/2012	10/9/2012	3,013,000	269,785	12,348	282,133	10.68	34.5%
10/9/2012	10/31/2012	1,069,000	94,408	3,873	98,280	10.88	33.8%
10/31/2012	12/10/2012	3,444,000	215,413	7,532	222,945	15.45	23.8%
12/10/2012	1/9/2013	2,062,000	158,886	6,351	165,237	12.48	29.5%
1/9/2013	2/8/2013	1,851,000	142,722	6,221	148,943	12.43	29.6%
2/8/2013	3/12/2013	2,302,000	177,150	6,902	184,052	12.51	29.4%
3/12/2013	4/10/2013	1,981,000	152,077	6,174	158,252	12.52	29.4%
4/10/2013	5/9/2013	1,889,000	144,608	6,136	150,744	12.53	29.4%
5/9/2013	6/10/2013	2,143,000	164,146	6,877	171,023	12.53	29.4%
6/10/2013	7/10/2013	2,009,000	158,543	6,477	165,020	12.17	30.2%
7/10/2013	8/8/2013	1,563,000	112,293	5,441	117,733	13.28	27.7%
8/8/2013	9/9/2013	1,767,000	131,297	6,669	137,966	12.81	28.7%
9/9/2013	10/8/2013	1,601,000	141,926	6,115	148,041	10.81	34.0%
10/8/2013	11/6/2013	2,131,000	135,161	6,013	141,174	15.09	24.4%
	Totals	**34,981,000**	**2,702,373**	**119,634**	**2,822,006**	**12.40**	**29.7%**

Note: Red indicates monthly readings that appear either high or low for monthly electrical FCE

The normalized fuel consumption and electrical FCE displayed a significant amount of variation between billing periods, with significant variations highlighted in red. This may occur to billing issues and/or adjustments such as estimated billing. These local variations are dampened out by computing the cumulative electrical FCE. Since the onset of monitoring, the cumulative electrical FCE for the CHP system has been 28.4% LHV, or 12.4 CF/kWh. This normalized fuel consumption ratio has been applied to all data through November 6, 2013.

After November 15, 2013 natural gas data are collected via a pulse output from the utility gas meter. The pulse constant is 1,000 CF/pulse, making the frequency of the pulse is marginally adequate for use as hourly interval data. Gas use is totalized on a daily basis and distributed across the daily generation, on a similar CF/kWh basis to the utility data. The CF/kWh value is evaluated each day.