# Adjustments To Aegis CHP Thermal Data at The Schwab House

On January 28, 2010 the temperature sensors measuring CHP system glycol loop temperatures were replaced. The existing sensors (Mamac Systems TE-211Z 1000 Ohm RTD with 4-20 mA transmitters) were replaced with a Veris Industries Type II 10k Ohm thermistor. The existing RTD sensors indicated a temperature offset that was overstating the heat rejection to the dump radiator, and understating the useful heat output from the CHP system.

The heat flows in the CHP system are measured using a two temperature difference measurements (from three temperature sensors) and a common flow meter (Figure 1). The system uses a constant flow heat transfer loop, and therefore any errors in the measured temperature difference result in a proportional difference in the heat transfer calculation.

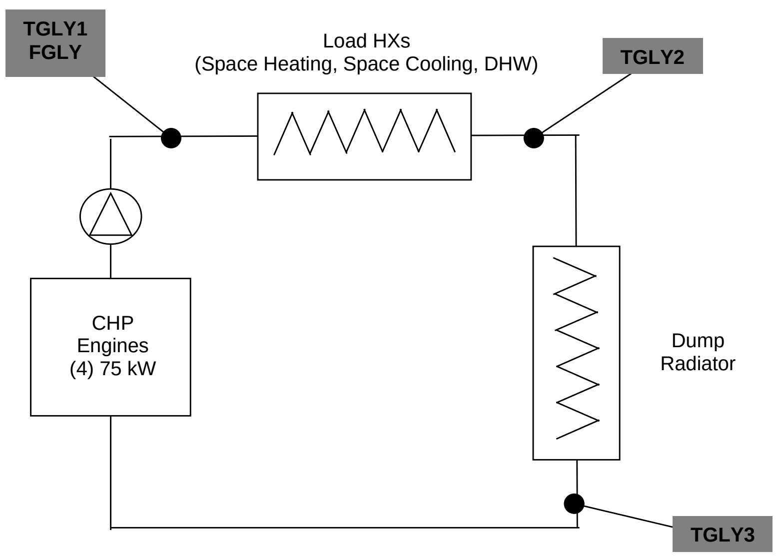


**Figure 1. Schwab House CHP System Thermal Monitoring**

An analysis of the temperature difference data with the RTDs installed was performed during periods in the data set where the engine was shutdown. The temperature difference across the dump radiator (TGLY2 – TGLY3) indicated an offset of 3.5°F between the sensors (when no heat rejection was occurring). The temperature difference data from the CHP engine glycol supply temperature and the temperature leaving the load HX (TGLY1 – TGLY2) indicated a 1.6°F offset in the temperatures.

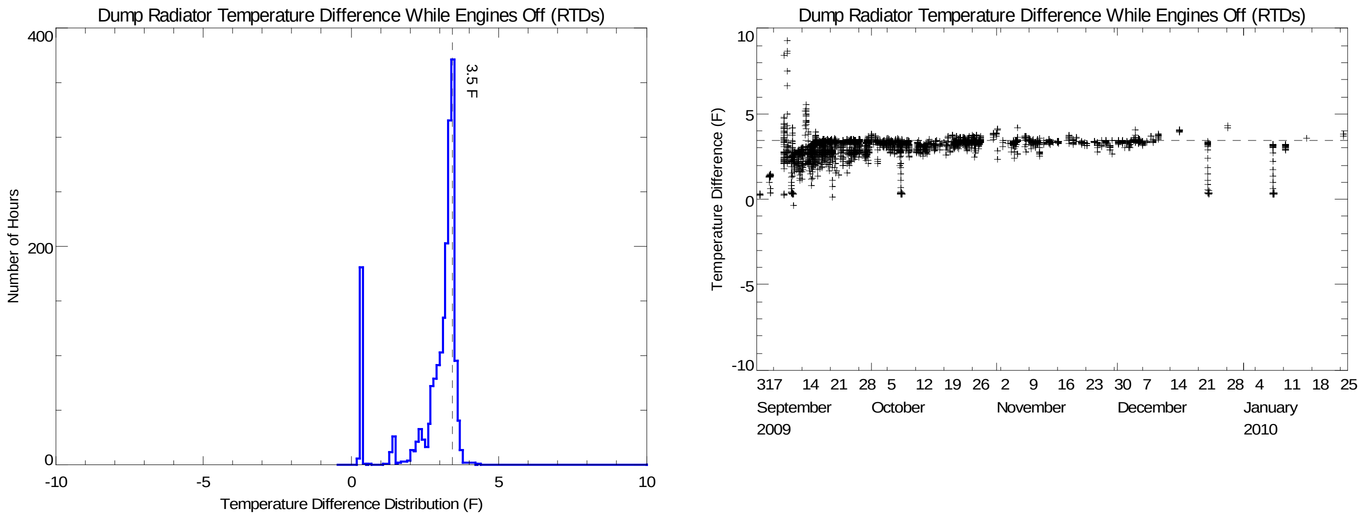


**Figure 2. Dump Radiator Temperature Difference Trend**

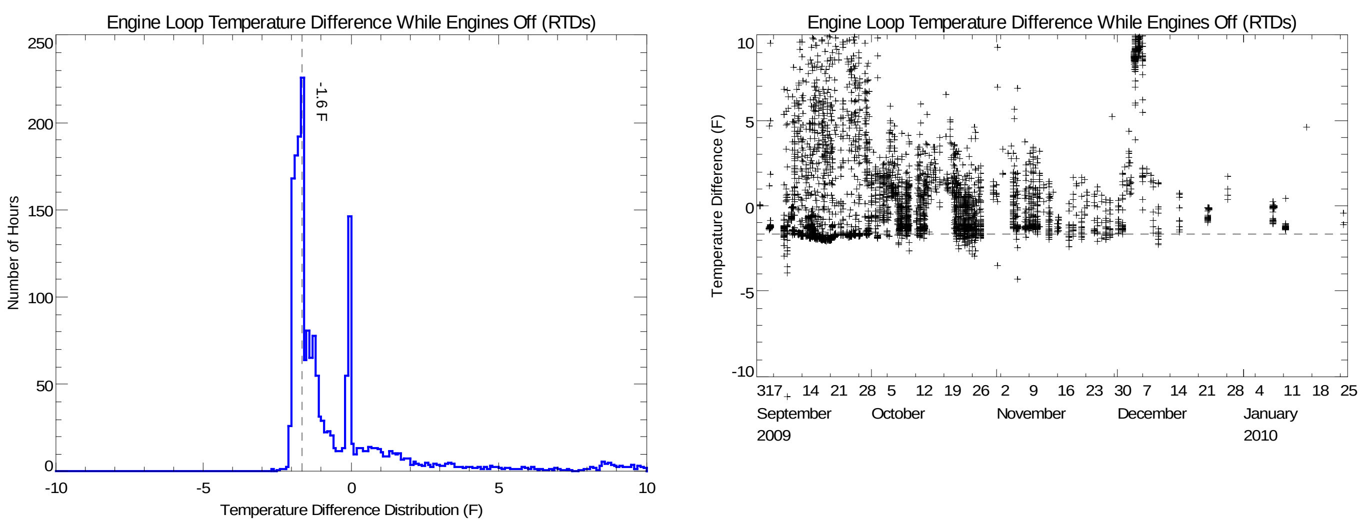


**Figure 3. CHP Load HX Temperature Difference Trend**

These temperature offsets were verified using a handheld Fluke thermocouple probe to measure pipe and thermowell temperatures adjacent to each RTD temperature sensors. Handheld temperature readings and simultaneous readings from the data logger were compared to determine the offset.

**Table 1. Glycol RTD Sensor Readings Compared to Handheld – January 28, 2010 3:41 – 3:54 PM**

| | Sensor Reading | | | Absolute Error | | |
|---|---|---|---|---|---|---|
| Fluke TC Temperature (F) | TGLY1 4-20 mA RTD # 1 (F) | TGLY2 4-20 mA RTD # 2 (F) | TGLY3 4-20 mA RTD # 3 (F) | TGLY1 4-20 mA RTD # 1 (F) | TGLY2 4-20 mA RTD # 2 (F) | TGLY3 4-20 mA RTD # 3 (F) |
| 196.27 | 196.1 | | | (0.2) | | |
| 159.20 | | 161.9 | | | 2.7 | |
| 160.33 | | | 158.6 | | | (1.7) |

The handheld Fluke thermocouple readings were similar to the difference in temperatures observed in the data set. As the data set trends indicated a more consistent and repeatable error when compared to the one time handheld reading, the offset determined in Figure 4 and Figure 5 were used to adjust the data. The adjustment to TGLY1 was applied as measured in the field, then the remaining adjustments performed to minimize the temperature difference based on the monitored data. The final offsets determined are shown in the table below.

**Table 2. Temperature Channel Offsets**

| Data Channel | Final Offset Adjustment |
|---|---|
| TGLY1 | -0.2°F |
| TGLY2 | -1.4°F |
| TGLY3 | 2.1°F |

By offsetting each temperature channel by the error in Table 2, the overall temperature difference error was minimized.

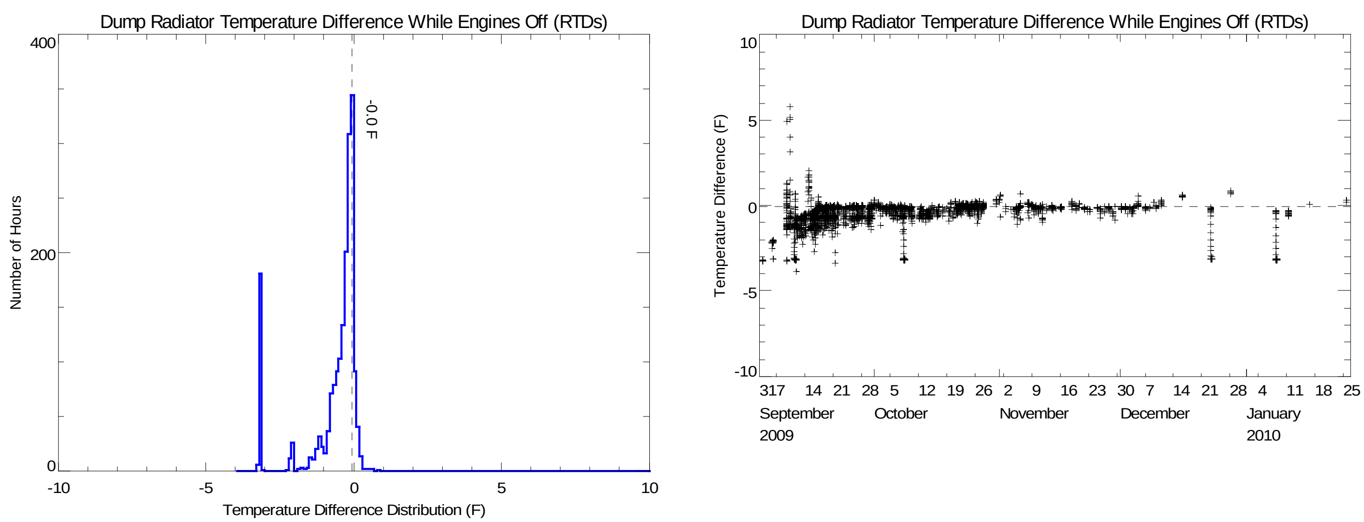


**Figure 4. Dump Radiator Temperature Difference Trend – After Offsets Applied**

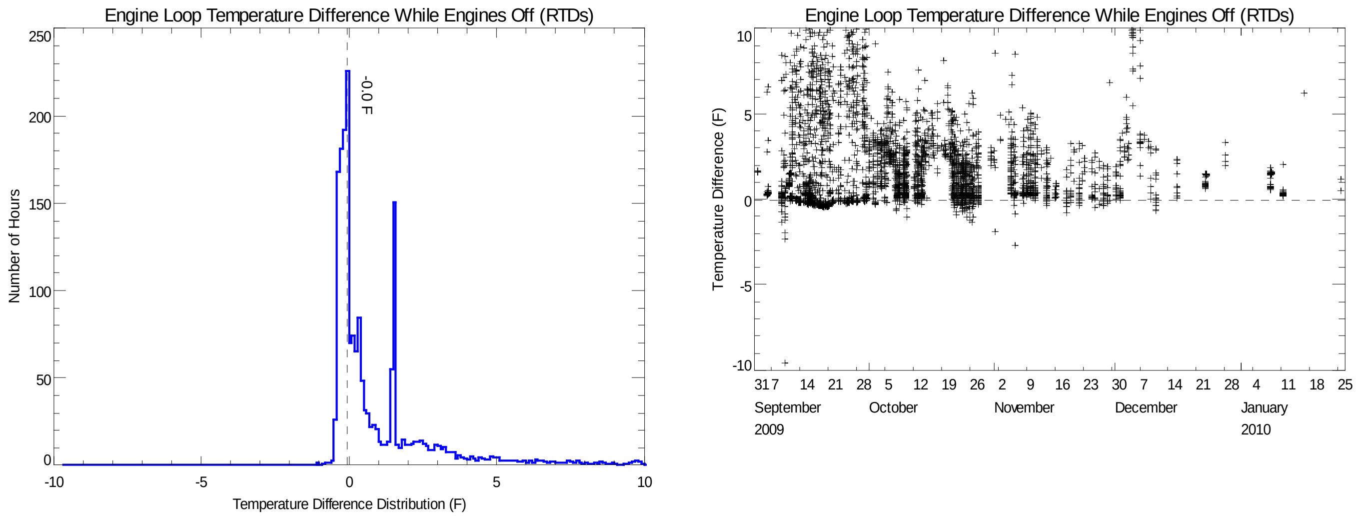


**Figure 5. CHP Load HX Temperature Difference Trend – After Offsets Applied**

The new 10k Type II thermistors were calibrated in a stirred bath before installation on January 28, 2010. A curve fit calibration was applied to each curve, and when compared to the first sensor indicate an error no more than 0.4°F between any of the sensors.

**Table 3. 10k Type II Thermistor Calibration Table**

| | Sensor Reading | | | Absolute Error | | | Relative Error to TGLY1 | | |
|---|---|---|---|---|---|---|---|---|---|
| Stirred Bath Temperature (F) | TGLY1 - 10 K Type II Thermistor # 18 (F) | TGLY2 - 10 K Type II Thermistor # 19 (F) | TGLY3 - 10 K Type II Thermistor # 21 (F) | TGLY1 - 10 K Type II Thermistor # 18 (F) | TGLY2 - 10 K Type II Thermistor # 19 (F) | TGLY3 - 10 K Type II Thermistor # 21 (F) | TGLY1 - 10 K Type II Thermistor # 18 (F) | TGLY2 - 10 K Type II Thermistor # 19 (F) | TGLY3 - 10 K Type II Thermistor # 21 (F) |
| 154 | 155.5 | 155.7 | | 1.5 | 1.7 | | - | (0.5) | |
| 157 | | | 158.9 | | | 1.9 | | | (0.6) |
| 169 | | | 171.8 | | | 2.8 | | | (0.3) |
| 171 | | 173.5 | | | 2.4 | | | 0.0 | |
| 172 | 174.0 | | | 2.0 | | | - | | |
| 186 | | | 188.9 | | | 2.9 | | | 0.1 |
| 186.8 | 190.2 | 189.4 | | 3.4 | 2.6 | | - | 0.4 | |

| | | | |
|---|---|---|---|
| Slope | 0.945090057 | 0.972679738 | 0.96964448 |
| Offset | 7.20278151 | 2.488518696 | 2.750099843 |

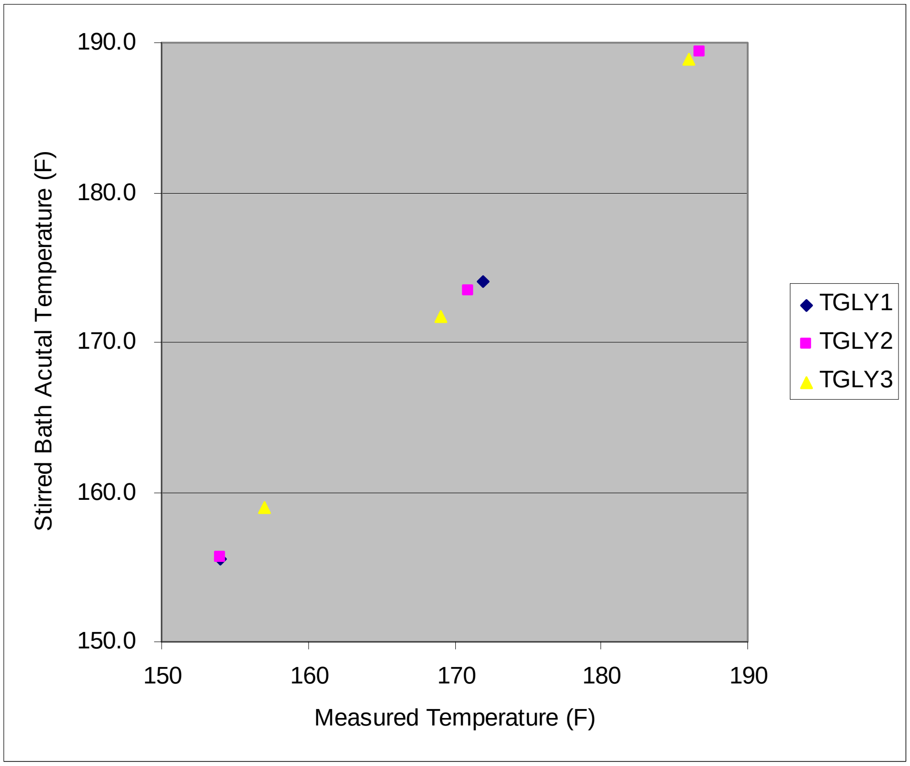


**Figure 6. Calibration Temperatures Versus Stirred Bath Temperature**

With the stirred bath calibration applied, the thermistors display almost no temperature difference across the loop when the engines are off.

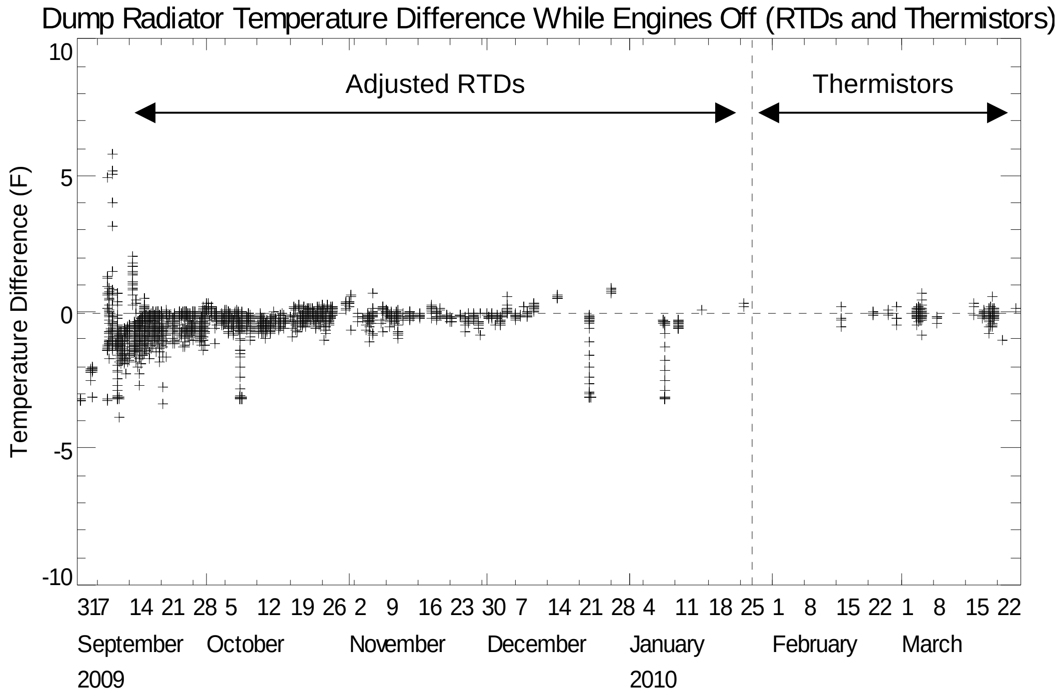


**Figure 7. Dump Radiator Temperature Difference With Engines Off (Adjusted RTDs and Thermistors)**

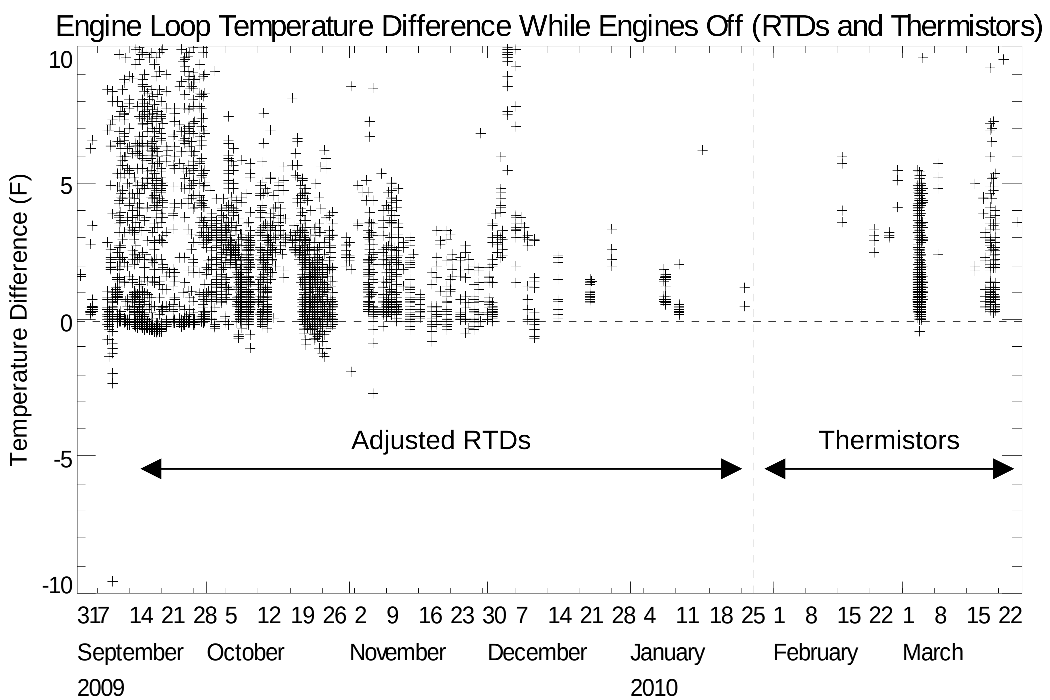


**Figure 8. Engine Loop Temperature Difference With Engines Off (Adjusted RTDs and Thermistors)**

The impact of these calibration changes on the total volume of heat transfer recorded (September 3, 2009 – March 29, 2010), is shown in Table 4. The useful heat transfer measurement (based on TGLY1-TGLY2) increased by 143,633 MBtu or 3%. The dumped heat transfer measurement (based on TGLY2-TGLY3) decreased by 418,499 MBtu or 92%. This decrease in the dumped heat transfer measurement is consistent with the physical state of the system, where the dump radiator circuit is not in operation during the winter, and has heat traps installed on the radiator piping loop to minimize any natural convection.

**Table 4. Impact of Temperature Calibration on Total Volume of Heat Transfer Measured**

| | Without Adjustments (MBtu) | With Adjustments and Thermistor Replacement (MBtu) | Difference (MBtu) | Relative Error (%) |
|---|---|---|---|---|
| Useful Heat Transfer | 5,217,322 | 5,360,955 | 143,633 | 3% |
| Dumped Heat Transfer | 455,773 | 37,274 | (418,499) | -92% |