Thermal Battery Prototype Operation Manual

Hybrid Thermal/Electrochemical Storage System for OGZEB

<u>Team 23/15 Members:</u>

Nicholas G. Kraft- ME

Tristian Jones- ME

Artur Nascimento- ME

Lucas Dos Santos- ME

Corey Allen- ECE

Kristian Hogue- ECE

Anthony Cappetto- ECE

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I. Background & Function Analysis

The purpose of this project was to design and construct a new thermal energy storage system to work in tandem with the houses current energy storage system. The energy, produced by thirty PV solar panels is currently stored through an array of batteries. These batteries are responsible for providing useful electrical energy to all household appliances such as lights, the refrigerator, and electrical outlets. Once the batteries are fully charged, excess electrical energy will be used to operate the new thermal storage system. Because the space heating and cooling of a house is the primary consumer of power in an average utility bill (60% of energy consumed in Tallahassee), the best method available for thermal storage would be through the house's HVAC system using a well known concept known as Ice Storage. Ice Storage can significantly cut a utility bill due to its very miniscule power consumption as compared to a regular AC system. In this system design, a unique and innovative concept was created by utilizing previously used ice storage concepts and eliminating certain processes within those concepts by adding simpler, more direct methods of heat transfer with airflow. Because a full size system with our concept would be too expensive to build on a student budget, a scaled down prototype (The Thermal Battery) was constructed and is shown below in Figures 1a and 1b. The full size system will be mentioned in certain areas of this manual to create a starting point for future senior design students to construct a full size version of the Thermal Battery. The system consists of a chiller, a finned heat exchange box, and a fan. During the daytime the chiller runs, pumping a super-cooled glycol/water solution through the coils in the heat exchange box. This will remove energy from the water within the highly conductive aluminum storage tanks, lowering the temperature, forming ice and storing energy via the chilling process. At night, a fan will turn on to propel air through the system, operating as an additional air conditioner for the house. Figure 2 shows the fluid flow diagram during both the charging and discharge periods.

Figure 1a: Thermal Battery Prototype (Closed)

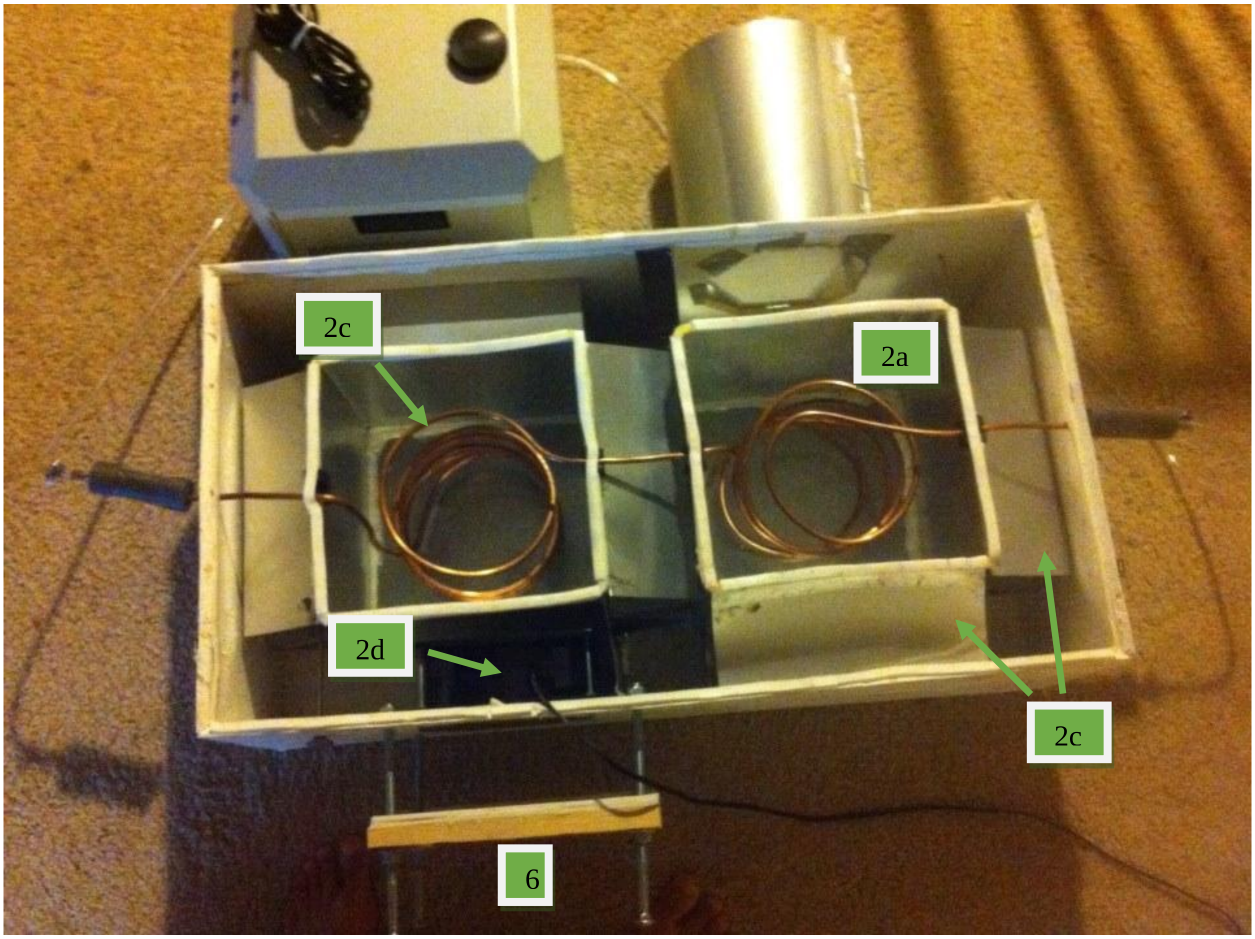

Figure 1b: Thermal Battery Prototype (Open)

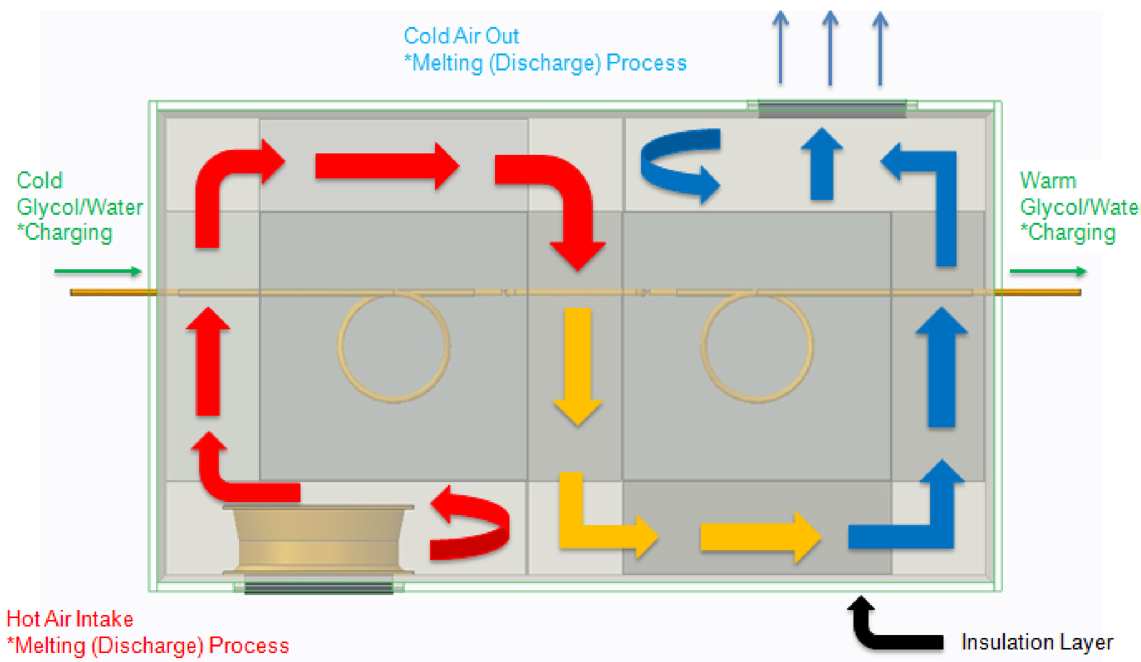

Figure 2: Fluid Flow Diagram

II. Thermal Battery Components and Specifications

Component number, description, and quantity (Refer to Figure 1a and 1b for location and visualization of major components):

1. Chiller and power cable (1)
2. Heat exchange box (1)
    i. 2a. Aluminum tanks (2)
    ii. 2b. Aluminum fin stack (5)
    iii. 2c. Copper Coils (2)
    iv. 2d. Fan and power cable (1)
3. Connecting tubes (2)
4. Air duct
5. Thermometers- one in each water tank, at the inlet, and at the exit (4)
6. Inlet axial sliding door
7. Paint
8. Insulation

Theoretically, if the Thermal Battery was to be purchased as a whole, the following steps would need to be taken to make the system operational.

1. A mixture of propylene glycol and water (70/30) would need to be added to the chiller tank. The best way to do this is to unscrew the lid and pour into the tank until full. At this point the chiller should be plugged in and turned on. The chiller will start to pump the glycol mixture through the system. Pour more of the glycol mixture into the tank, while the chiller is running, until the tank is full. NOTE: While propylene glycol is fairly innocuous, avoid contact with skin and eyes and also avoid inhalation and ingestion.
2. The aluminum tanks inside of the heat exchange box must be filled with water. Water from a simple garden hose is fine.
3. For the theoretical full size system, the processing unit would need to be plugged in. This controls the opening and closing of all the doors and the turning on and off of the fan. For the Thermal Battery this must be done by hand and the fan is turned on by simply plugging it in. Doors should be closed during the "charging phase" while the chiller is running and the fan is off. Doors should be opened at night during the "discharge phase" when the chiller is off and the fan is on. NOTE: Be wary of the fan!

For construction of a full size installable prototype for future senior design groups/anyone else wishing to use this system, we provide the following safety and construction recommendations:.

1. *Weld tanks and fins together for increased thermal conductivity*
2. *Be careful of the fan. Watch your fingers.*
3. *Cut holes for air ducts before assembling the heat exchange box.*
4. *Heat exchange box should be constructed of metal to avoid damage from mold*

III. Battery Specifications

The currently installed energy storage system contains a newly selected array of Fullriver DC400-6 (6 Volt 415 Amp Hour AGM) batteries. Figure 3 contains an image of one of these batteries while Figures 4-8 give details on its specifications.

Figure 3: Fullriver 6V battery

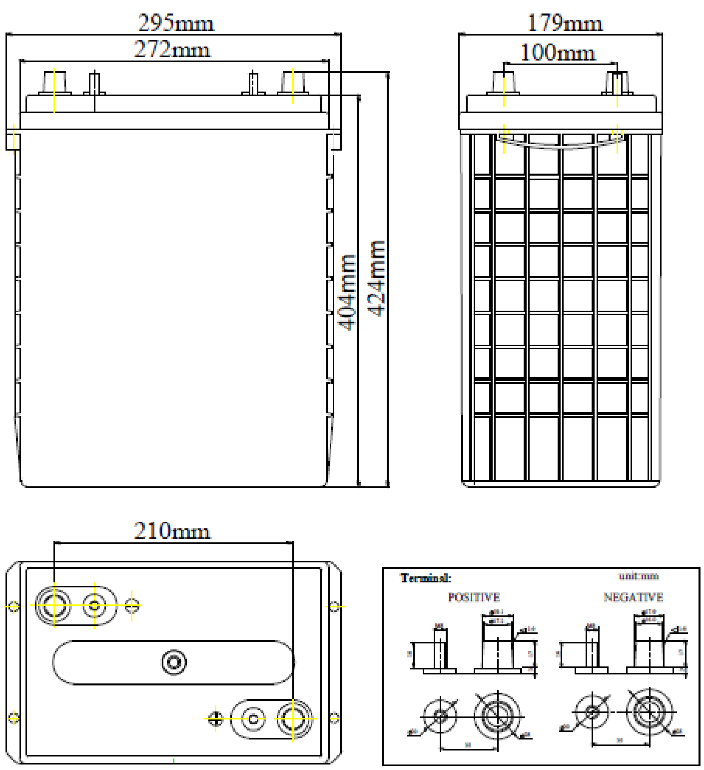

Figure 4: Battery Dimensions

Specifications

Nominal Voltage		6V
Rated Capacity (20 hour rate)		415AH
Dimension	Total Height (with terminals)	424mm(16.69inches)
	Height	404mm(15.90inches)
	Length	295mm(11.61inches)
	Width	179mm(7.05inches)
Weight		Approx. 56.0 kg (123.2 Ibs)

Figure 5: Detailed Specifications

Discharge characteristics 77℉ (25℃)

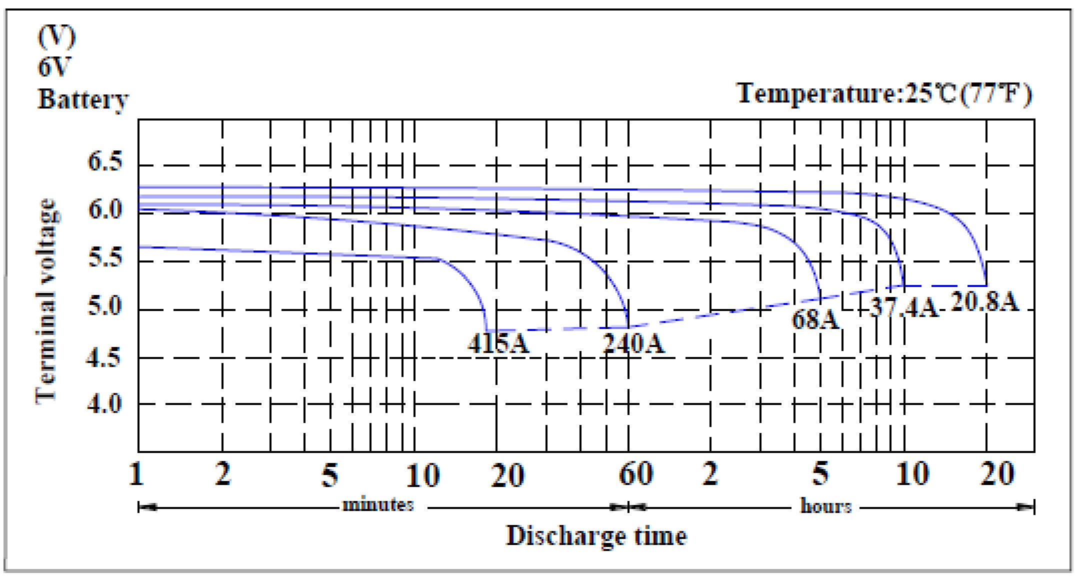

Figure 6: Battery Discharge Characteristics

Duration of discharge vs. Discharge current

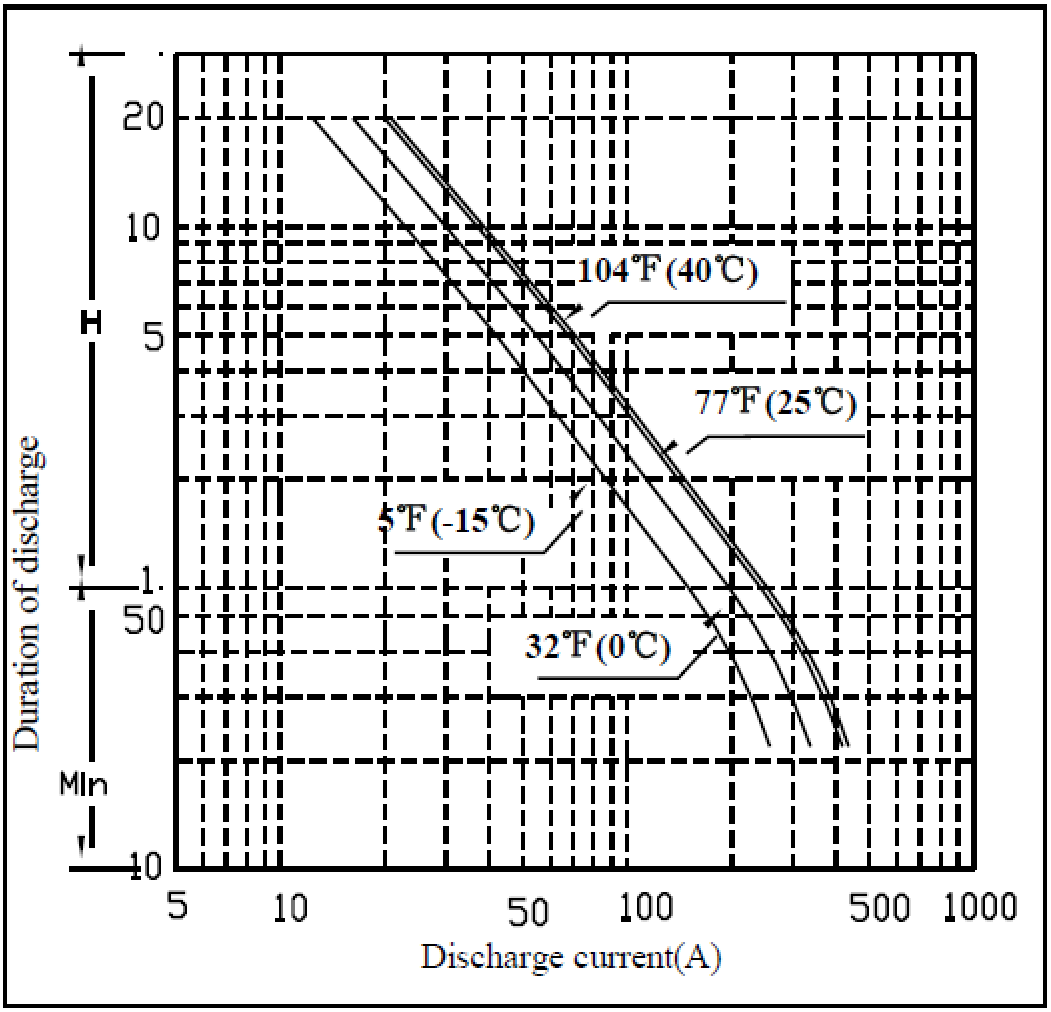

Figure 7: Discharge time vs. Discharge Current

Characteristics

<table>
<tr><td colspan="2" rowspan="3">Capacity
77℉(25℃)</td><td>20 hour rate (20.8A to 5.25Volts)</td><td>415AH</td></tr>
<tr><td>10 hour rate (37.4A to 5.25Volts)</td><td>374AH</td></tr>
<tr><td>5 hour rate (68A to 5.1Volts)</td><td>340AH</td></tr>
<tr><td colspan="2">Internal Resistance</td><td>Full charged 77℉(25℃)</td><td>1.6mΩ</td></tr>
<tr><td colspan="2" rowspan="4">Capacity affected
by Temperature
(20 hour rate)</td><td>104℉(40℃)</td><td>102%</td></tr>
<tr><td>77℉(25℃)</td><td>100%</td></tr>
<tr><td>32℉(0℃)</td><td>85%</td></tr>
<tr><td>5℉(-15℃)</td><td>65%</td></tr>
<tr><td colspan="2" rowspan="3">Self-Discharge
77℉(25℃)</td><td>Capacity after 3 month storage</td><td>91%</td></tr>
<tr><td>Capacity after 6 month storage</td><td>82%</td></tr>
<tr><td>Capacity after 12 month storage</td><td>64%</td></tr>
<tr><td colspan="2">Standard Terminal</td><td colspan="2">DT</td></tr>
<tr><td colspan="2">Max. Discharge
Current 77℉(25℃)</td><td colspan="2">2000A (5s)</td></tr>
<tr><td colspan="2" rowspan="2">Reserve Capacity
(Minutes to 5.25V at 80℉(27℃)</td><td>@ 25Amps</td><td>885Min</td></tr>
<tr><td>@ 75Amps</td><td>229Min</td></tr>
<tr><td rowspan="2">Charging
(Constant
Voltage)</td><td>Cycle</td><td colspan="2">Initial Charging Current 80A Or Small
7.25V～7.45V/77℉(25℃)</td></tr>
<tr><td>Float</td><td colspan="2">6.8V～6.9V/77℉(25℃)</td></tr>
</table>

Figure 8: Battery Characteristics

IV. Procedure for Thermal Battery Operation

1. Prototype Startup & Operation

a. First and foremost, make sure all fluid process connections are secure to avoid leaking of the process solution.
b. Check the temperature readings on all thermometers and recalibrate if necessary.
c. Check the water levels and process solution capacity in both the water tanks and chiller respectively.
d. Check the fan for defects as well as make sure its power cable is securely connected.

e. Plug in chiller and flip power switch to begin the chilling process. Be sure to check every few hours to make sure the temperature readings are decreasing in both the water tanks and chiller (once the chiller setpoint temperature of -2°C is at steady state).

f. Once the water within the tanks has reached its pinnacle in ice formation, turn the chiller off and run the fan.

2. Full Size System Modes of Operation

a. Charging: While the system is charging, the chiller runs to freeze the water and all other components stay off. At this time, the regular air conditioner is responsible to regulate the house's temperature.

b. Discharge: During the system discharge, the chiller will be turned off while the fan turns on to cycle the house air through the system. While the storage system is discharging the main AC system is turned off, and the only power being consumed is the fan power requirement.

3. Full Size System Operation Summary

The system will freeze the water during the day via the chiller, and at night the air will be recycled from the house through the floor vent and propelled through the system, chilling the air and sending it back out through the smaller dispersing vents located around the house. The regular AC system runs in parallel with the Ice Storage System and it is activated in two situations. The first is during the daytime, while the chiller freezes the water. The second situation occurs if, for some extreme case, the water melts completely during nighttime.

V. Trouble Shooting Diagnosis & Repair

Potential Problem	Possible Cause	Recommended Solution
Fan not ventilating/high vibration	Broken Blade/Blades	Replace fan
Chiller uncalibrated	Absence of inspection	Calibration of the equipment and perform regular inspections
Low Chiller Performance	Dirty tubes	Inspect and clean the cooler tubes at the end of the first operating season
Low Chiller Performance	Water flow rates may be incorrect	Change the size of the tubes
Low Chiller Performance	Misuse of the refrigerant	Look for the indication of the manufacturer`s procedure
Compressor failure	Failure to maintain lubrication	Change the lubrification system regularly
Refrigerant leak	Incorrect intallation	Remake the installation of the tubes

Figure 9: Trouble Shooting Guidelines

VI. Regular/Routine Maintenance

The main piece of equipment that will need regular maintenance, especially on the full size system, will be the chiller while other aspects such as mold and condensation control, although secondary, remain important as well. Because the Thermal Battery utilizes a thermoelectric chiller instead of a refrigeration based chiller, maintenance will be needed less often as there are fewer components to maintain. In the case of a full size system a high chiller performance is obtained by regular inspections and maintenance in certain components such as the tubes, oil, compressor, condenser, and refrigerant.

In the case of the full size system, to maintain steady operation, the tubes will need cleaning which can be done in a multitude of ways. The frequency of tube cleaning can be minimized by using distilled water without any extra additives. Another issue pertains to the lubrication system. This needs to be inspected systematically because, if not maintained, major damage to the chiller will occur. Therefore it is important to verify the oil every 1-5 years depending of the conditions. The oil levels on the other hand must be checked on a weekly basis. In relation to the refrigerant it is important to follow the manufacturer`s instructions, because too much refrigerant can cause the evaporation of the refrigerant within the compressor and insufficient refrigerant can cause the uppermost layers of the cooler tube bundle to not be completely submerged in the liquid refrigerant. One last thing that must to be checked regularly is the appearance of leaks caused by a bad installation of the tubes. One way to analyze the performance of the chiller is to check the system`s vital signs such as the temperature and the pressure frequently.

For condensation and mold control, the inside of the Thermal Battery is easily accessible and can be checked and dried with a towel or cleaned if necessary on a weekly basis. Molding should not occur very frequently because of the outdoor paint on the outside shell of the system. The full size system will have an easily accessible inside as well although will most likely be constructed out of sheet metal to further avoid molding problems and plug drains would be utilized to control excess moisture within the box.

VII. Major Future Repair/Replacement of Key Components

The main components that will eventually require repair or replacement are the fan and the chiller. After repeated use, the fan can sometimes start to vibrate and not perform optimally. In that case, depending on the condition, the fan can either be repaired or replaced.

The chiller has many components that may need repair or replacement and should be examined on a regular, scheduled basis for signs of wear or fatigue. Only a trained service tech should remove and examine these components, thus, an elaborate diagnosis can be done to examine whether or not the equipment can be repaired.

VIII. Extra Pictures of Thermal Battery Components

Figure 10: Fan Electrical Connection

Figure 11: Chiller Process Fluid Tank Access

Figure 12: Chiller Process Tube Connections

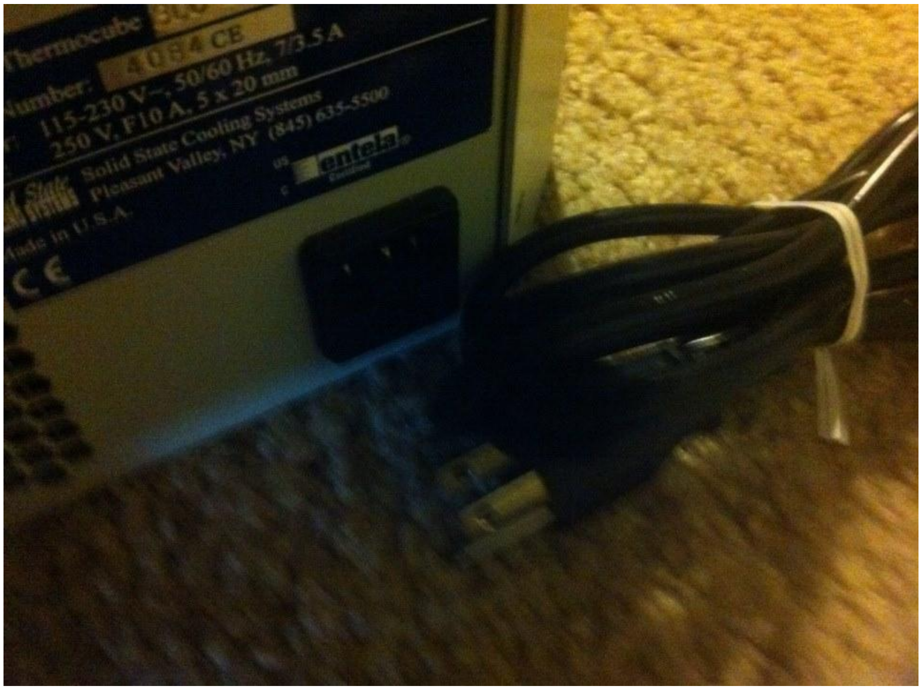

Figure 13: Chiller Power Cord and Connection

Figure 14: Thermal Battery Air Outlet

Figure 15: Thermal Battery Process Tube Connection