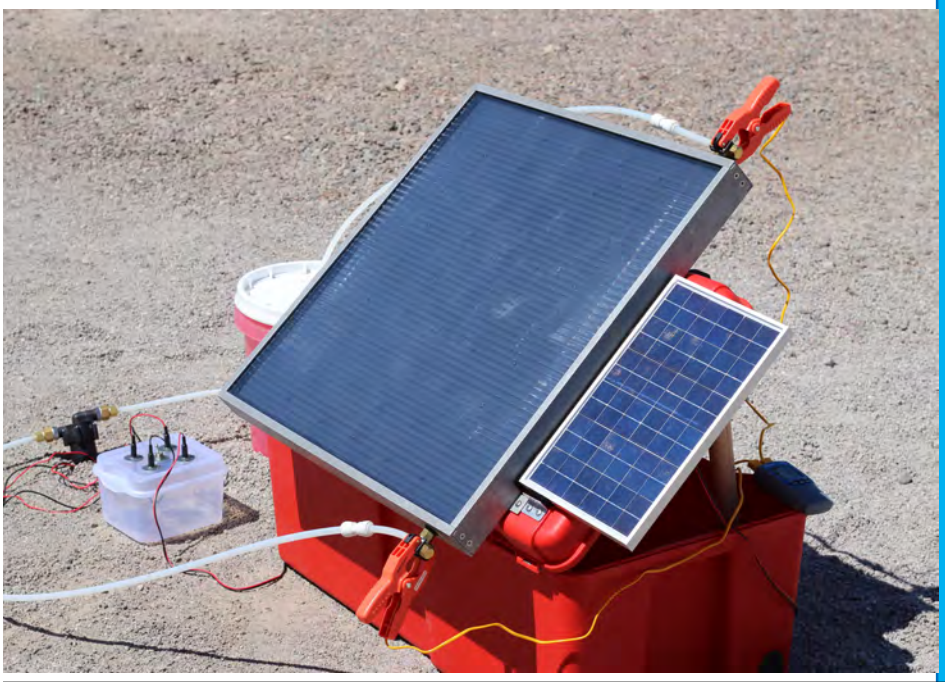

Solar Thermal Water Heater Manual

Laboratory Experience

Solar Energy | Water | Environment
Nexus IN NEVADA

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Objectives

This kit is designed for high school students to learn about solar energy. The set-up and tasks are moderately difficult, but should be attempted by the students directly. Adult supervision is recommended to avoid potential injuries (e.g. touching hot parts) and to prevent materials from being damaged by not following directions (e.g. pump).

Key concepts covered in the activities include:

- conversion of energy forms
- conservation of energy
- unit conversions
- graphing and graph interpretation

Safety Precautions

Handle Items with care. The edges of the panels are sharp and could scratch your skin.

Keep the plastic container with the electrical components closed, especially when water is nearby.

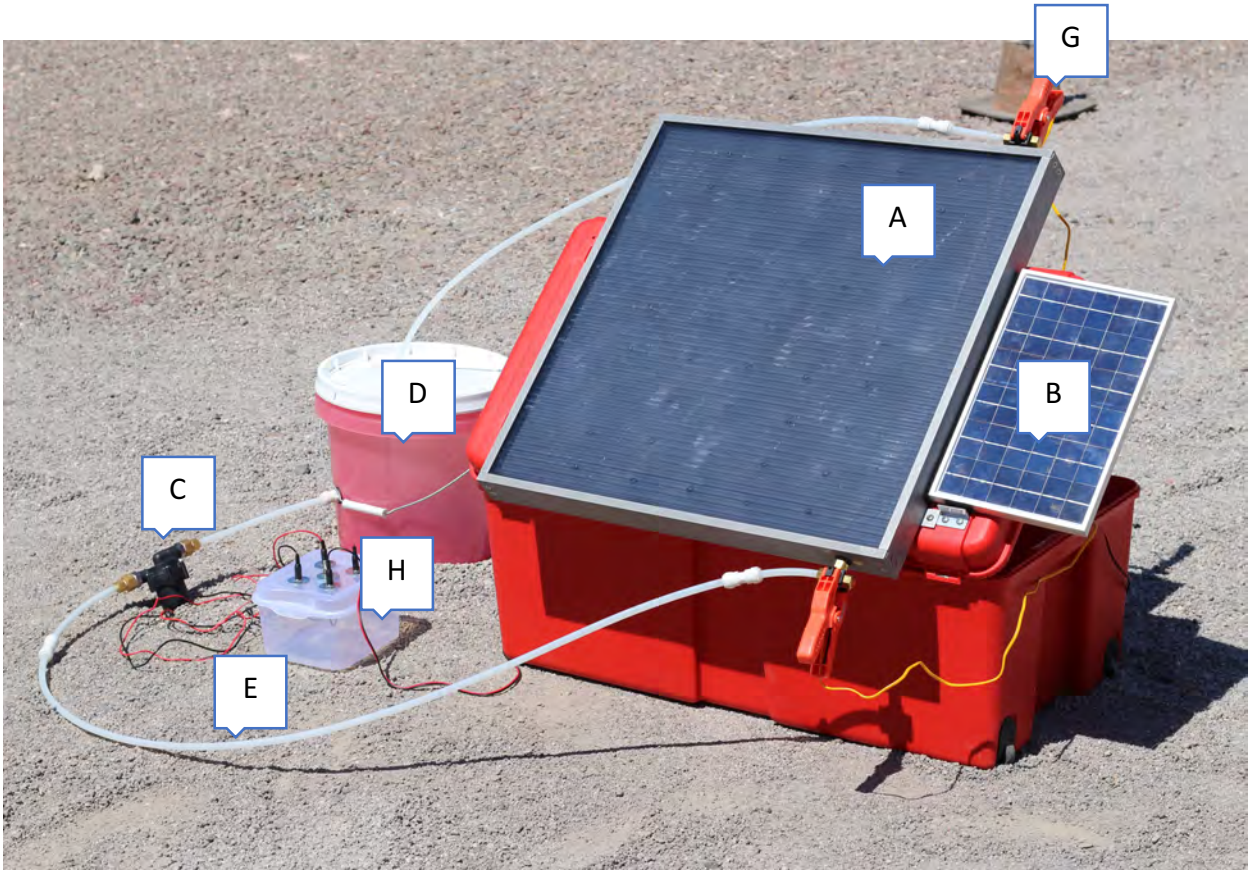
The Solar Thermal Collector and the 10-Watt Solar Panel surfaces do become very hot when placed in the sun for extended periods of time.

Water may also turn into steam on a very hot day.

Use caution when propping the container open with the wood rod and when closing the case. The mounted thermal panel can cause the container lid to close quickly.

The pump must be primed with water before operation. Also, the water should only flow in one direction through the pump (as shown by the arrows). Failure to operate the pump correctly will result in the pump being damaged.

Solar Thermal Water Heater Diagram



A) Solar Thermal Collector

B) 1 – 10 Watt Solar Panel

C) 1 – DC Pump

D) 1 – 3.5 Gallon Bucket

E) 2 – Hoses (Tubing)

F) 1 – Dual Temperature Meter (Not Shown)

G) 2 – Clamp Style, Type K Thermocouples

H) 1 – Switched Electrical Circuit

I) 1 – Volumetric Container (Not Shown)

J) 1 - Hose Removal Tool (Not Shown)

Additional Item Needed:

K) Stop Watch

Solar Thermal Water Heating System Assembly

1) Prop up the lid of the container using the wooden dowel inside. One side is cut at an angle. This should be on the back of the lid and the flat side should be at the bottom of the container. Remove the switch box out of the container.
2) Mount the PV Panel with the Velcro onto the side of the thermal collector. (Figure 1)
3) Find and examine the Pump (Part C). On the pump, there are arrows indicating the direction of flow. Attach the pump, on the **IN ARROW SIDE**, to the bucket (part D) by pushing the hose into the white quick connect attached to the side of the bucket. Push with much force. To ensure the hose is secure, pull back on the hose with a slight tug, it should not detach.

Figure 1

<u>It is very important to make sure no debris enters into the hose, bucket, or the pump itself.</u>

4) Taking care not to allow debris in either end of the hose, connect one of the hoses (tubing) to the pump on the **OUT ARROW SIDE**. Again, push with enough force to ensure the hose is completely within the housing assembly. *(Figure 2)*

Figure 2

5) Hold the hose attached to the pump above the bucket, fill the bucket with water. (Purified water is preferred, but not required). Place the lid on the bucket.
6) Set the bucket next to the wheeled container. Allow the hose to become parallel to the ground until water comes out of the hose. Be careful not to spill water on the electrical parts. Once water is seen, plug hose into the bottom port (inlet) of the Solar Collector (part A). You have now primed and connected the pump. (Figure 3).

Figure 3

7) Taking care not allow debris to enter either end of the hose connect the second hose (part E) to the **TOP** port of the Solar Collector. The top port is the outlet of the Solar Collector. Again, use some force to fully connect the hose to the housing. The other end of the hose is placed inside the hole on the top side of the bucket lid or just placed into the bucket if there is no lid.

Connecting the Switched Electrical Circuit

1) Looking at the Switched Electrical Circuit (Figure 4), ensure that the switch is in the OFF (down) position.

2) At the switched electrical circuit (part H), notice that there are two sets of female connectors: one to the right and one to the left of the switch (Figure 5). Of these, each set has a top connector indicated by red (positive), and a bottom connector indicated by black (negative).

3) The PV panel has two male connectors. Notice that one wire is indicated by black (negative) and one is indicated by red (positive).

   The pump also hosts a wire with two male connectors, the positive is indicated by red, negative indicated by black.

4) Looking again at the Switched Electrical Circuit, the set of connectors to the left of the switch is the DC power side, meaning the LEFT SIDE is designed for the connection of the PV PANEL. Looking at this set of connectors to the left of the switch, one is indicated with red, and one is indicated with silver. Connect the RED wire from the PV Panel to the RED connector on the LEFT side of the switch. Connect the BLACK wire from the Solar Panel to the SILVER connector on the LEFT side of the switch.

Figure 3

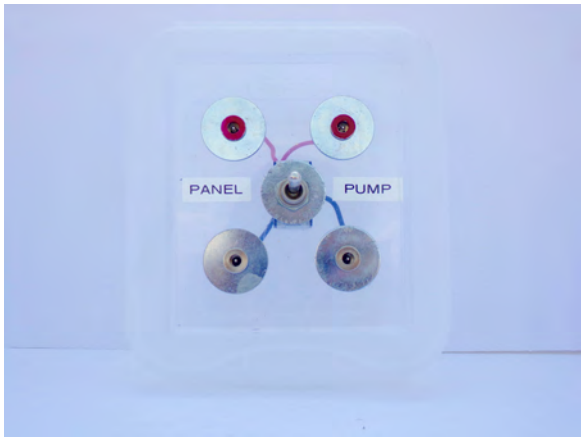


Figure 4

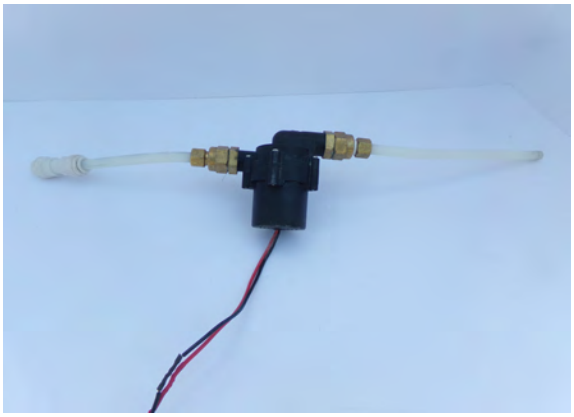


Figure 5

5) Continuing to look at the Switched Electrical Circuit, the set of connectors to the right of the switch is the Accessory side, meaning that the RIGHT SIDE is designed for the connection of the load. The load, in this case, is the PUMP (Figure 7). Looking at this set of connectors to the right of the switch, one is indicated with red, and one is indicated with silver. Connect the RED wire from the pump to the RED connector on the RIGHT side of the switch. Connect the BLACK wire from the pump to the SILVER connector on the RIGHT side of the switch.

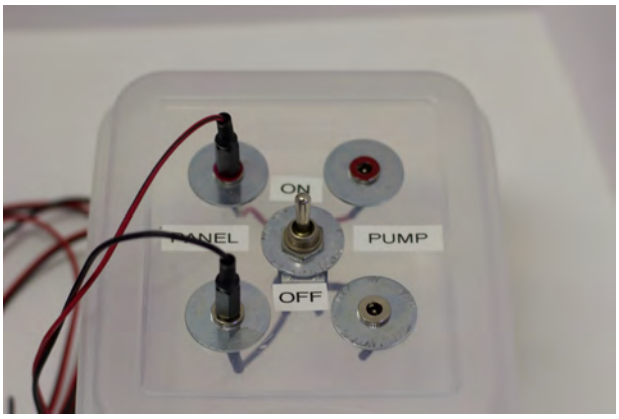


Figure 7

6) Flip the Switch to the ON (up) position. Note that there are two off positions (down and middle), and one on or up position. Ensure that the switch is in the up position for operation.

7) Check to make sure that the pump is on and water is flowing. The outlet tube can be pulled from the bucket to see if there is flow.

   <u>*If water is not flowing, turn off the pump so that it is not damaged.</u>

   If water is not flowing, check to see that the PV panel is receiving direct sunlight and that it is connected to the Switched Electrical Circuit. Test again by turning on the pump.

   If water is not flowing, prime the pump again. See the disassembly instructions on how to remove the hose safely from the housing assembly.

8) Flip the switch back to the OFF position until you are ready to measure the system.

Taking Measurements with Thermocouples

1) Look at the yellow end of the Clamp Style Thermocouples (part G). There is a positive (+) side and a negative (-) side.

2) Look at the top of the Dual Temperature Meter (part G). There are two sets of female connection ports. One set is identified as T1, and the other by T2. Both T1 and T2 host a positive (+) and a negative (-) connection port. Locate them.

Figure 8

3) Take one of the Clamp Style Thermocouples. This thermocouple will measure the inlet temperature at T1. Using the T1 connection ports on the Dual Temperature Meter, connect the positive (+) prong on the yellow end of this thermocouple to the positive (+) connection port, and the negative (-) prong on the thermocouple to the negative (-) connection port. Clamp this thermocouple to the brass adapter at the inlet of the Solar Collector. The inlet is located on the bottom side of the Solar Collector.

Figure 9

4) Take the other Clamp Style Thermocouple. This thermocouple will measure the outlet temperature at T2. Using the T2 connection ports on the Dual Temperature Meter, connect the positive (+) prong on the yellow end of this thermocouple to the positive (+) connection port, and the negative (-) prong on the thermocouple to the negative (-) connection port. Clamp this thermocouple to the brass adapter at the outlet of the Solar Collector. The outlet is located on the top side of the Solar Collector.

Figure 10

5) Turn the Dual Temperature Meter on. T1 and T2 are both shown in the digital screen. When the system is first powered on and water is flowing, the T1 and T2 temperature readings may vary within 0.2 degrees. This is a normal error for this particular temperature meter.

6) Power the system ON by flipping the switch on the Switched Electrical Circuit. Note the time the system is powered on, as well as the temperatures at T1 and T2. These are the initial temperature measurements.

7) As the system runs, record T1 and T2 at periodic time intervals from zero (initial temperature) to 15 minutes. Take at least 5 measurements

Temperature and Flow Measurement Chart			
Initial Water Temperature:			
Interval	Time (min:sec)	T1 (inlet)	T2 (Outlet)
1 (~ 3 min)			
2 (~ 6 min)			
3 (~ 9 min)			
4 (~ 12 min)			
Final Water Temperature:			
Flow Rate: 1 Liter / sec		1 Liter/sec = 0.001 m^3/sec = 15.9 gal/min	

Measuring Flow Rate and Flow Rate Conversions

1) Locate the volumetric container.
2) While the system is running, remove the lid to the water container so that the end of the outlet hose can be manipulated. Keep the water flow into the bucket.
3) Simultaneously, place the hose into the volumetric container and start the timer.
4) Stop the timer as soon as the container becomes full.
5) Note the **volume** of the container, as well as the time, in seconds, it took to fill the container.
6) Flow rate is volume per unit time.
7) Discard the water from the volumetric container back into the bucket.
8) Replace the lid.
9) Record the flow rate in the table on page 9. Then convert the flow rate to gal/min as shown below.
10) Fill in the graph on the next page for Temperature versus Time. Use the data collected for T2. Also add points indicating the initial and final temperatures of the water. Note the unit used for temperature measurement on the y-axis.

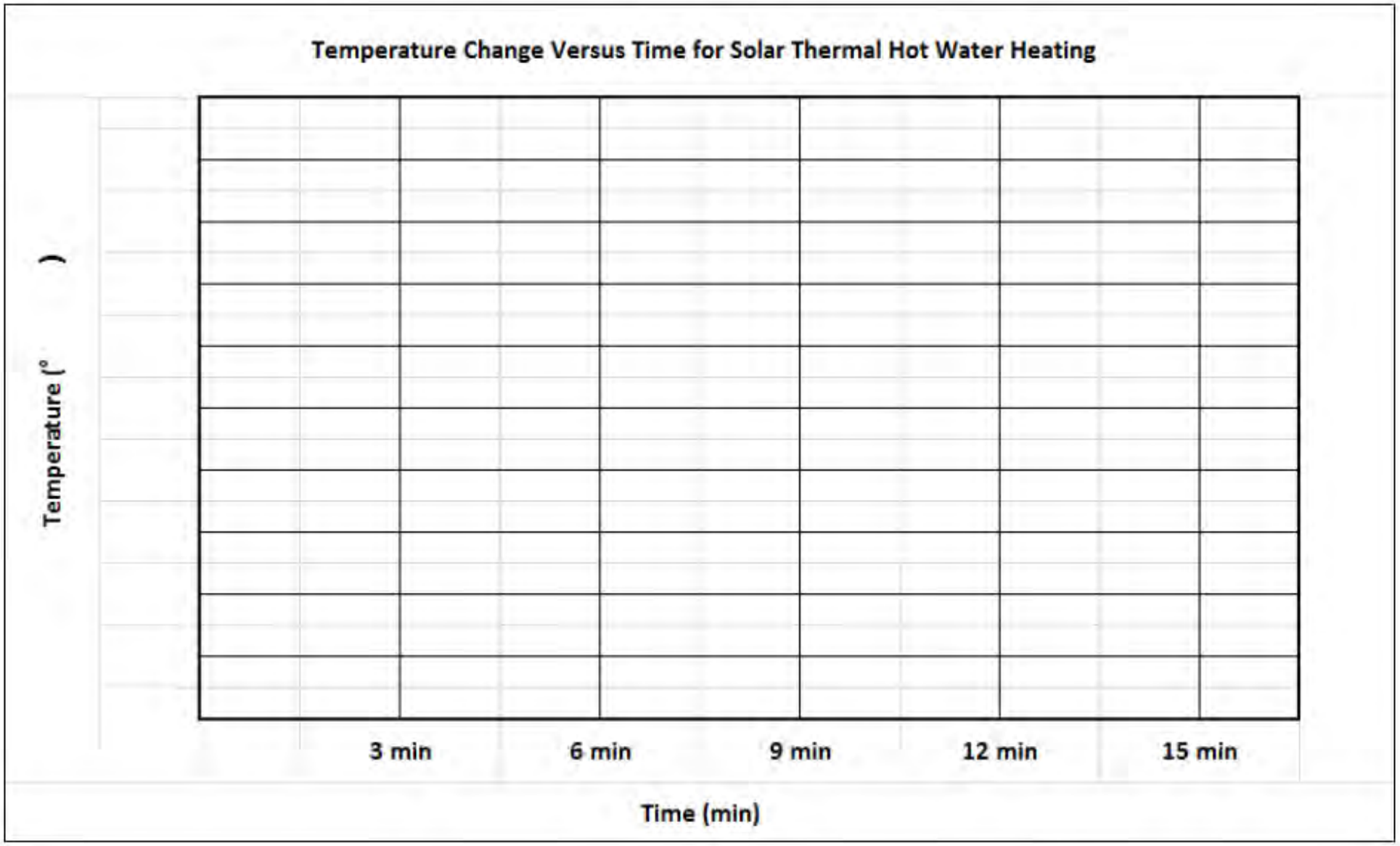
    What can be concluded from the graph?

Volumetric Container

Covert to L/s (Insert calculated time in the parenthesis): $\frac{1\ Liter}{(\quad)s} =$ _____ L/s

Convert to m^3/s (Insert value above): $(\quad)L/s * \frac{0.001\frac{m^3}{s}}{1\frac{L}{s}} =$ _____ m^3/s

Convert to gal/min (insert L/s value above): $(\quad)L/s * \frac{15.9\frac{gal}{min}}{1\frac{L}{s}} =$ _____ gal/min


Temperature Change Versus Time for Solar Thermal Hot Water Heating
Temperature (°)
3 min
6 min
9 min
12 min
15 min
Time (min)

Disassembling the System

1) Unclamp the Thermocouples from the system, and disconnect each clamp from the Dual Temperature Meter.
2) Flip the switch on the Switched Electrical Circuit to the OFF (down) position. The water will cease to flow.
3) Disconnect the wires connecting the Pump to the Switched Electrical Circuit.
4) Disconnect the wires connecting the Solar Panel to the Switched Electrical Circuit.
5) Using the Hose Removal Tool (U-shaped), disconnect the hose from the outlet of the Solar Collector. The outlet is located on the top side of the Solar Collector. The Hose Removal Tool is used by pressing the open side against the hose connector with some force, while pulling the hose out of the connection assembly. Once the hose is free from the outlet, remove this hose from the top of the bucket. Taking caution to avoid allowing debris to enter either end of the hose, drain any water from the hose and set it aside.
6) Using the Tube Hose Removal Tool, disconnect the hose from the inlet of the Solar Collector. The inlet is located on the bottom side of the Solar Collector.
7) Holding the hose and the Pump wire away from the ground, empty the bucket.
8) Once the bucket is empty, use the Hose Removal Tool to remove the hose from the pump, and the pump from the tube assembly connected to the bucket. Again, take care to avoid allowing debris to enter either the hose or the pump.