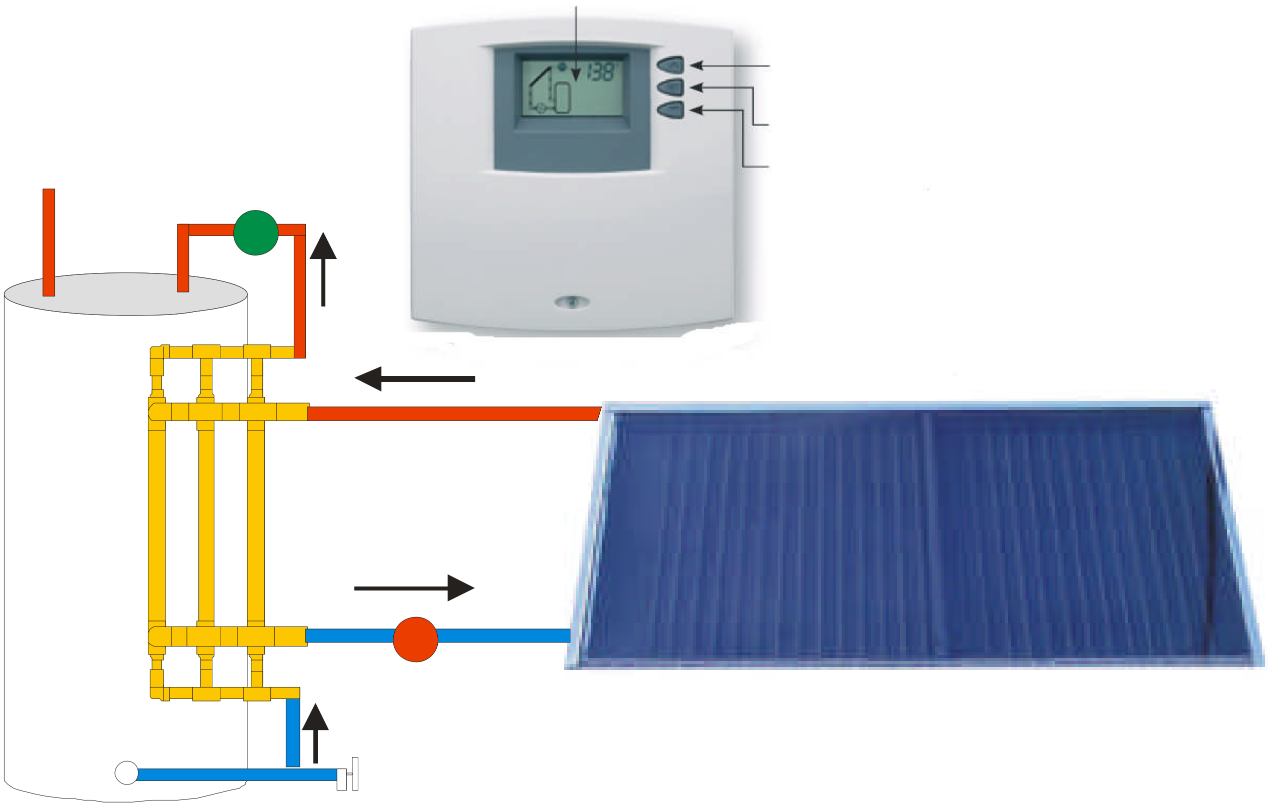
Hot Water Solar Collector Design Manual

The First Step to

Lessen Your Dependence on the Grid



Ronald B. Little, DC

Preface

There appears to be a lot of general information about solar collector systems available today, but when you start to investigate building a DIY system, you quickly discover that there are serious gaps in available information. I purchased plans which showed how to build a solar collector and while they were helpful, I still had to make several changes and improvements to improve the efficiency and the longevity of the panel. I was disappointed that the plans did not explain necessary information concerning how to reconfigure an existing water heater to support a solar collector or how to build a heat exchanger.

I have worked diligently to assure that your will not be disappointed in these plans or in my system. You worked hard for your money and I will not just pull information off the web, throw it together and call it a set of plans in order to cheat someone out of a few bucks.

My goal is to provide a quality set of plans at a low enough cost that any one who is interest in building a system will be willing to invest a few dollars to see how much effort is involved. These plans will provide you valuable information concerning the building of a hot water solar collector and will show you where you can save money using better industrial pumps than the overpriced pumps available from the on-line Solar Stores. In return, I hope you will recommend my plans when the opportunity arises and that you will appreciate the laborious effort that went into these plans and will insist that others purchase their own plans.

I also decided on the use of a heat exchanger where the system would be used without worry of freezing temperature. I live in the Deep South and have seen it in single digit temperatures and the last thing that I want to do is to have to watch the weather to see if I need to drain the collector. This system should function in any climate which has enough sun to support solar operations.

I just wanted to share my thought process in the design of this system. Please study these plans and make sure that it makes sense to you and that you understand the process before you dive in.

Introduction

Before we get started to the actual building of the system, let me share the what and why's of this project and how it fits into my long term approach of saving money and lessen my dependence of foreign oil and the GRID.

As the oil prices increase our nation has to make choices and one of which is whether we continue as normal and use the same amount of electricity as we have done in the past or do we conserve and invest in self renewing forms of energy, such as solar collectors for heating our water.

The main users of electricity are the electric water heater, Heating and Air Conditioning (HVAC), the clothes dryer, and the electric oven.

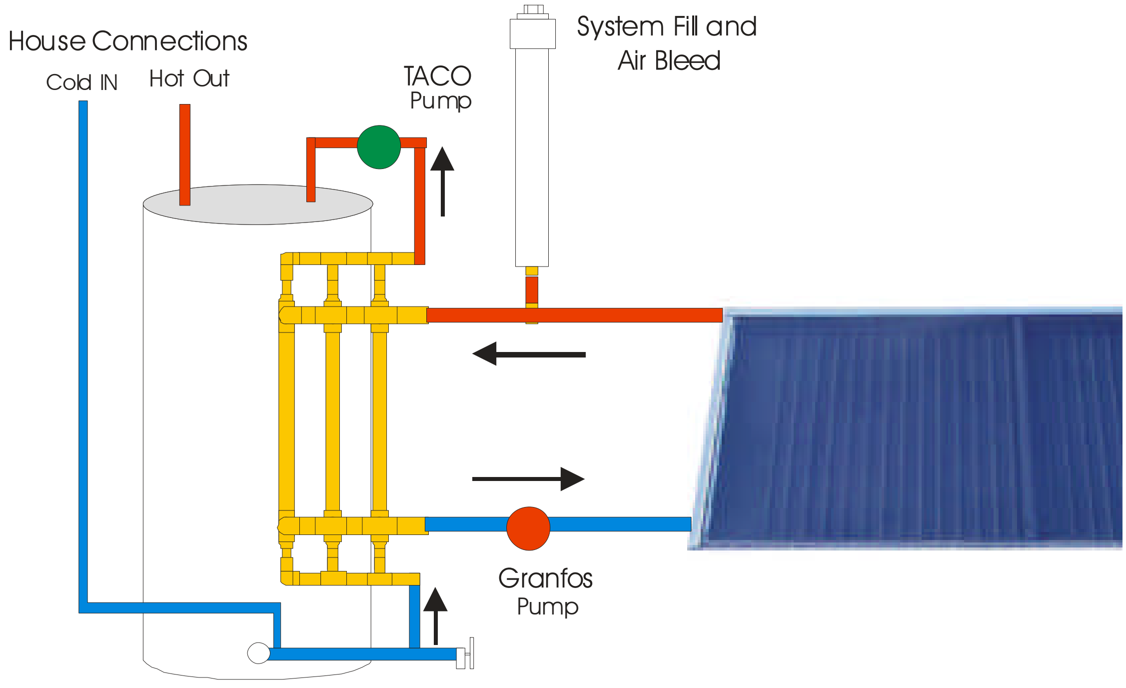
Currently, it cost on the average, about $50 a month for having the convenience of hot water, using electricity. I have been notified that my power bill will soon be increased by 28%, so I should expect that next month my hot water will cost $64 for the month. That is $768 a year for hot water. Don't get me wrong, electricity is a tremendous value and has made our lives very comfortable, but if we go back 2 generations our homes consumed very little electricity. Do we do without our connivances or do we plan ahead utilizing the available technology, reduce our commercial energy consumption while maintaining our current comfortable life style? At the end of this manual I included some easy steps that I have taken to reduce my electric bill.

Chapter 1 - Getting started – System Design Concepts

These plans will provide a clear path for you to meet the objective of the use of free energy to heat your water. There are five main components necessary for heating your hot water and they are:

1. The solar collector
2. The storage tank
3. The heat exchanger
4. The system controller
5. The circulation system

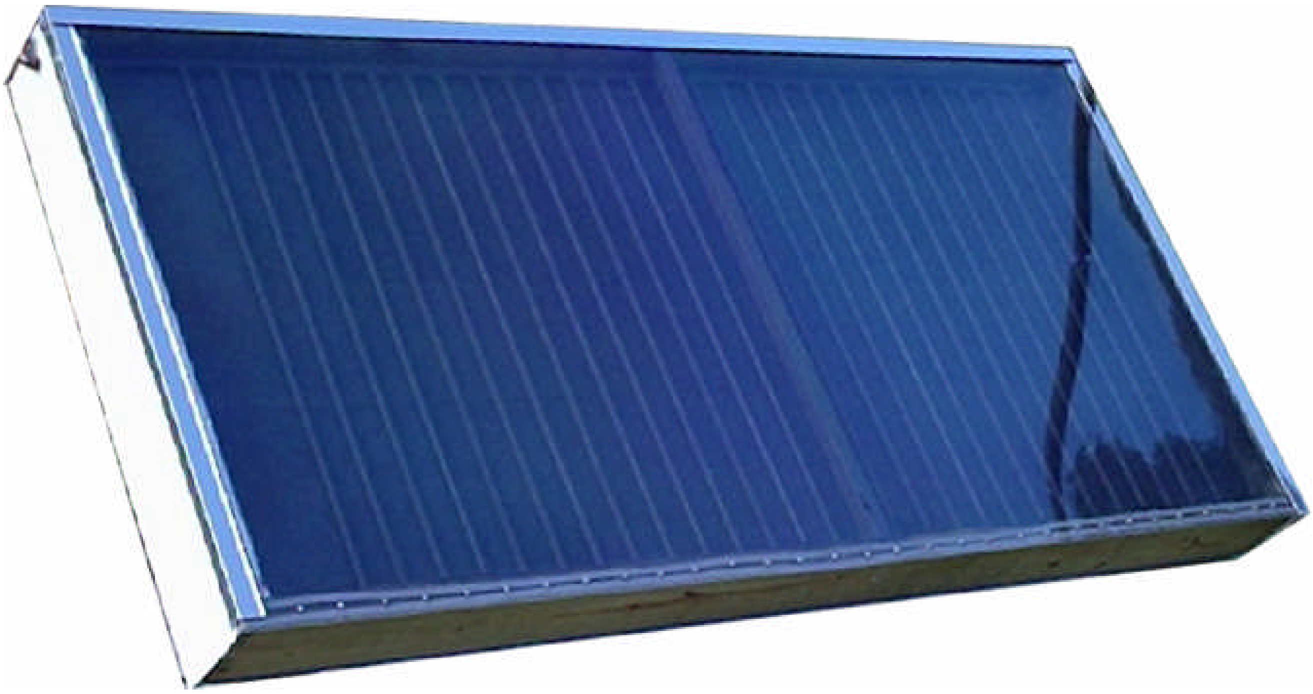
The plans will explain everything that I had to learn in order to build my system and to get it up and running. I will try pass on every thing necessary for you to be successful. I would like to see thousands of these systems conserving energy and saving families money on their hot water expenses. Please read the manual over a few times and hopefully it will answer most of your questions before you begin.



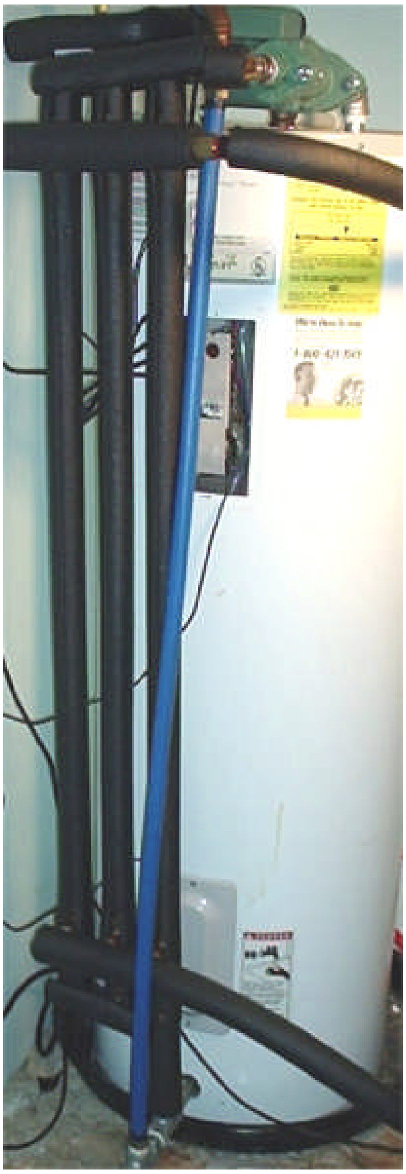
Plumbing System Diagram

These plans will show you how to build this solar collector using supplies that you can buy locally and some which can be ordered quickly.

The Solar Collector



The Solar Collector shown assembled



The storage tank shown with the heat exchanger

If you have an existing electric hot water heater it can easily be adapted for use in a solar collection system. For the next couple of pictures, I have removed the insulation to order to help you visualize the head exchanger and how your heat exchanger is connected to the water heater.

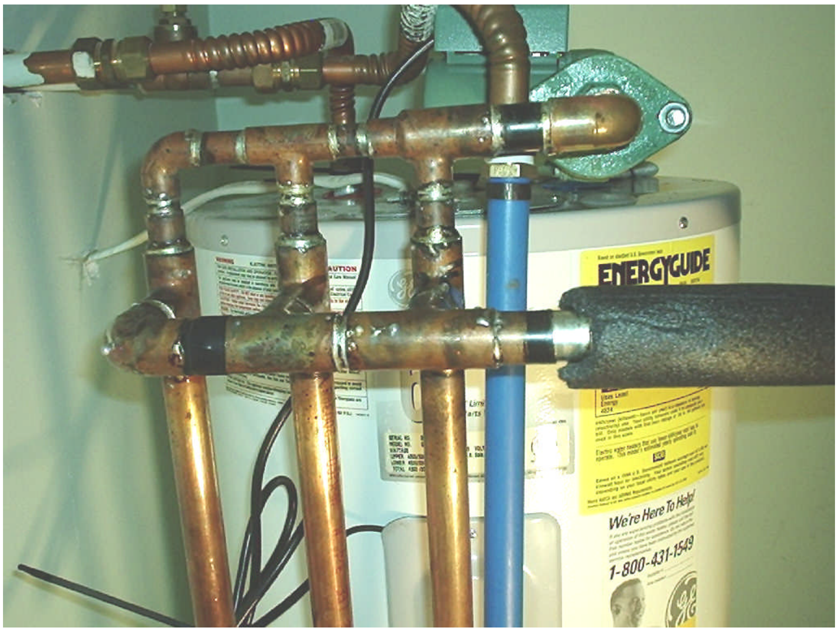
So, when you finish with your system, be sure to wrap the heat exchanger with the black pipe foam insulation and then use additional fiberglass insulation the wrap it again.

After, I completely finished with the pictures in these plans; I will re-insulate the heat exchanger and the water heater.

Also, when I built my house I placed the water heater on an insulated pedestal to prevent loss of heat through the floor.

The Heat Exchanger

You will then build a heat exchanger, which will transfer the solar generated heat from the collector to the potable water which is inside the water heater.



The Heat Exchanger (Top Manifold) -
The system controller is responsible for making the decisions of when to start and stop the transfer of heat from the collector into the tank. The controller will turn on the pumps which will circulate 1) the collector's heated fluid through the primary side of the heat exchanger and 2) the water in the water heater through the secondary side of the heat exchanger in order to gain heat. The two fluids remain isolated from each other. This is required in order to use an anti-freeze for use during cold weather operations.

I spent several weeks researching, designing and building a system that performs comparable to the commercially available systems costing several thousand dollars. I am very pleased with the results. If you follow these plans fairly closely, your system will provide you with many years of good and faithful service.

The Electrical Pumps

I want to address why I chose the use of a system controller and pumps to circulate the fluids in the system and why I decided to use AC pumps instead of DC pumps powered by a solar PV panel. PV cells and DC pumps seems like the way to go from the first glance.   Just hook up a solar panel and when the sun comes out the pump starts and starts pumping the water through the collector.

In truth, the pump will be pumping out heat from your tank at the beginning of the day, at the end of your day and any time during the day that it is cloudy and overcast long enough for your solar collector to cool down.

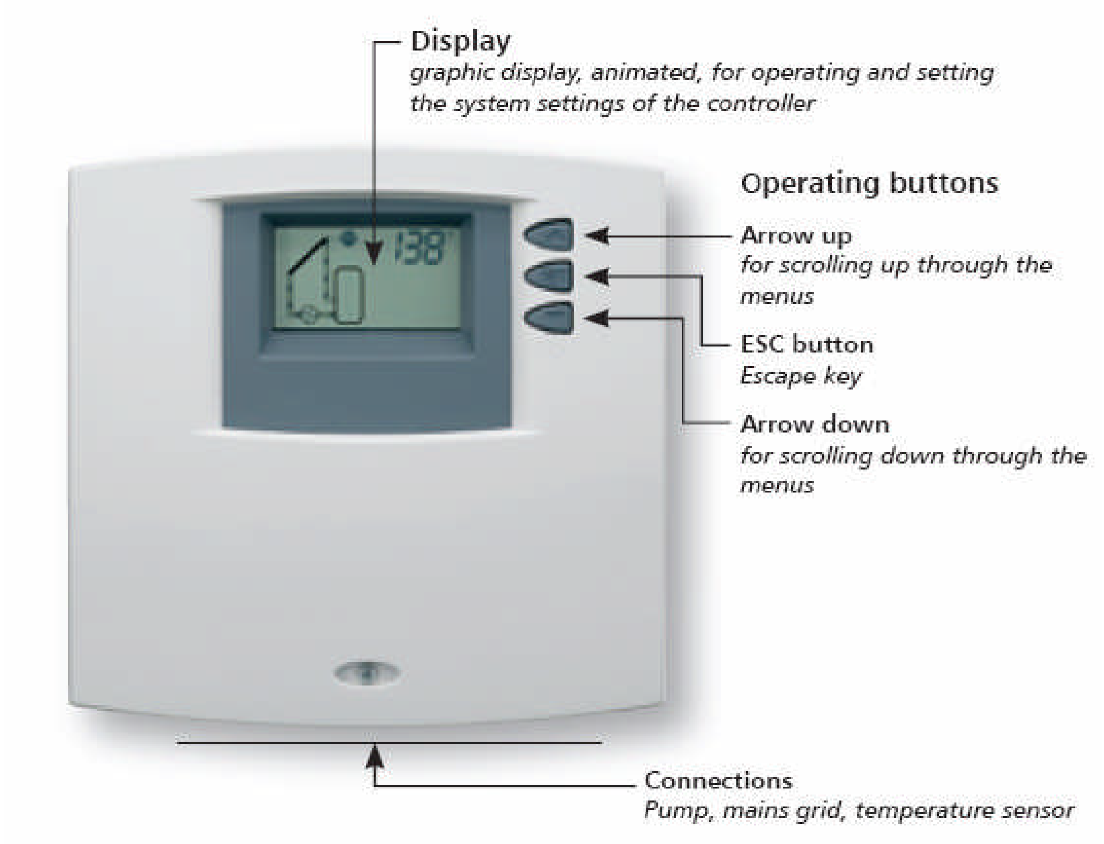
An efficient system requires a controller for it to work correctly and with out a controller, the system could waste lots of energy and perform poorly.

I chose to go with commercial quality AC pumps because:

1) AC pumps have a long life and
2) AC pumps are very affordable if you know which models to choose ($60-$75 ea.)
3) AC pumps consume very little power.
   The two AC pumps together use about 1 amp @ 115 VAC total which equates to about $2.00 a month (A pair of DC pumps are about $450 and then you need 12 VDC power (whether it's a supply or PV Cell)

The System Controller

The controller monitors and displays the temperature of the collector, the top tank TEMP and the bottom tank TEMP. For safety, the controller will shut down the pumps if the water heater exceeds the maximum temperature to protect the tank which could also prevent associated damages due to a ruptured tank or plumbing line or component. Besides how will you know if the system is working correctly without having access to these TEMPs? Using a system controller is the smart way to proceed if you wish to build a first rate system.



The System Controller – Figure 4

Chapter 3 - The Solar Collector Plans

In these plans, I will tell you about the mistakes that I made which will prevent you from doing so, and will also save you time and money.

Building the collector

Two mistakes that I made: (Don't make my mistakes)
1) The 2 x 8 treated lumber was in fact 96.75" and 96.50" long and not an even 96", so my panel was not square. Measure you lumber and cut to the desired length.

2) The Lexan sheet was longer and wider than the specified size of 8'x4'.
So, my Lexan overhangs my panel. (Not a problem, but something else to deal with).

The solar collector is comprised of a box made of pressure treated 2 x 8's. Construct the box approximately 8' x 4'. This dimension may change due to the size of the glazing that you use. I recommend that you use Lexan (Plexiglas will melt!!) and that you buy it first and measure it's dimensions prior to constructing your box. What I discovered was that the sheet of Lexan that I bought was about 1 inch longer and 1 inch wider that the 8' x 4' specification. **So, buy the Lexan sheet first, and measure it prior to building the frame of your collector!!**

STEPS for building the Box:

1. Measure your Lexan – This will be you solar collector dimension

2. Cut your 2 x 8 to build your box
Also, when you buy a 8' 2 x 8, it generally is not exactly 8', so measure it and cut it to length. For example, if your Lexan were 8'1", you would want to measure your lumber to try to get two of your 2 x 8's at least that length, or you would buy 2 x 10's and cut them down.

If you needed the width of your box to be 48", you would cut a 2 x 8 into 2 45" lengths, but again this width should be determined by the width of the Lexan sheet.

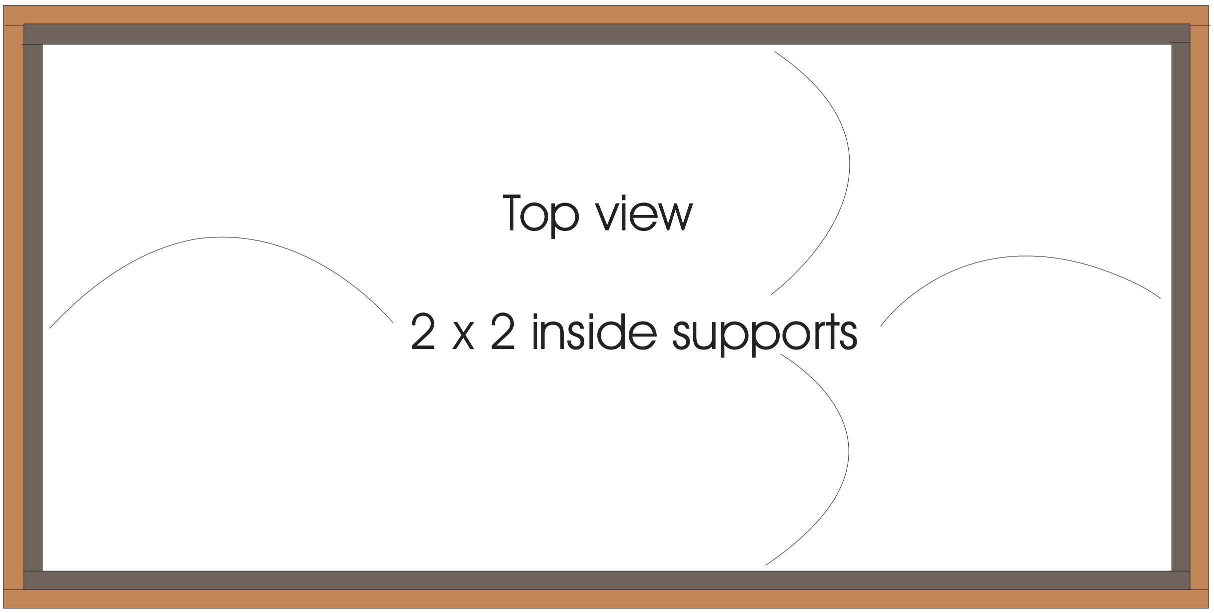
3. Use a total of 8 lag bolts (2 bolts at each corner) and pre-drill your holes which will prevent splitting the treated lumber and make bolting it together easier. Put the bolts 1 inch from the top and 1 inch from the bottom. We will be later drilling 1inch holes for the ports going into and out of the collector box, so you do not want to have the bolts in the way.
4. Seal the inside joints with a good quality caulk. This is for weather proofing and to keep insects out.

Take your time and do it right the first time.

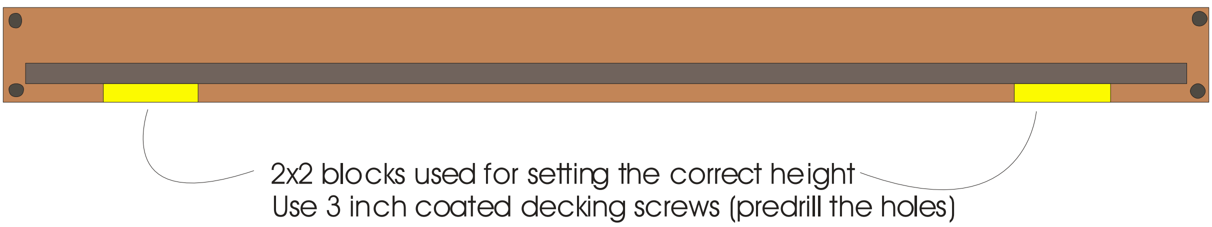
Step 1 - build a box - I will use the dimensions of 8' x 4'
but make the dimensions to fit your sheet of Lexan.

Use ¼ inch lag bolts, pre drill the holes and countersink the heads using a 1inch wiz bit.
Center the hole with the 2 x8 that you are drilling into and go 1inch down from the top and 1 inch above the bottom.

5. Place a 2 x 2 perimeter inside the box. Measure and cut the 2x2's to fit the inside perimeter. Use scrap pieces of 2x2 blocks under the 2 x 2s which will place the upper surface of the 2x2 perimeter at approximately 3 inches up from the bottom of the 2x8. Pre-drill holes through the 2x8 and use 3 inch coated deck screws to secure the 2x2's. This 2x2 ledge will serve to mount the 1 thick piece of foam board and your sheet metal.

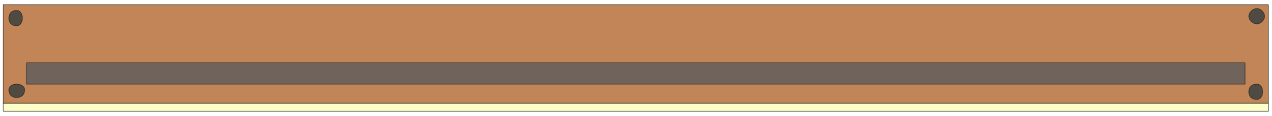


Step 5 build a support made of a 2X2 and attach to the inside perimeter of the 4X8 box, use two 2x2 blocks on the bottom for the correct height of the support



Side view

6. Nail the sheet of 4’x8’ OSB to the bottom of the box. OSB is commonly use as roof decking and is generally 15/16 thick and also is very weather resistant. Use the OSB to square up the box. (Assuming the sheet of OSB is square) Remove the temporary blocks.

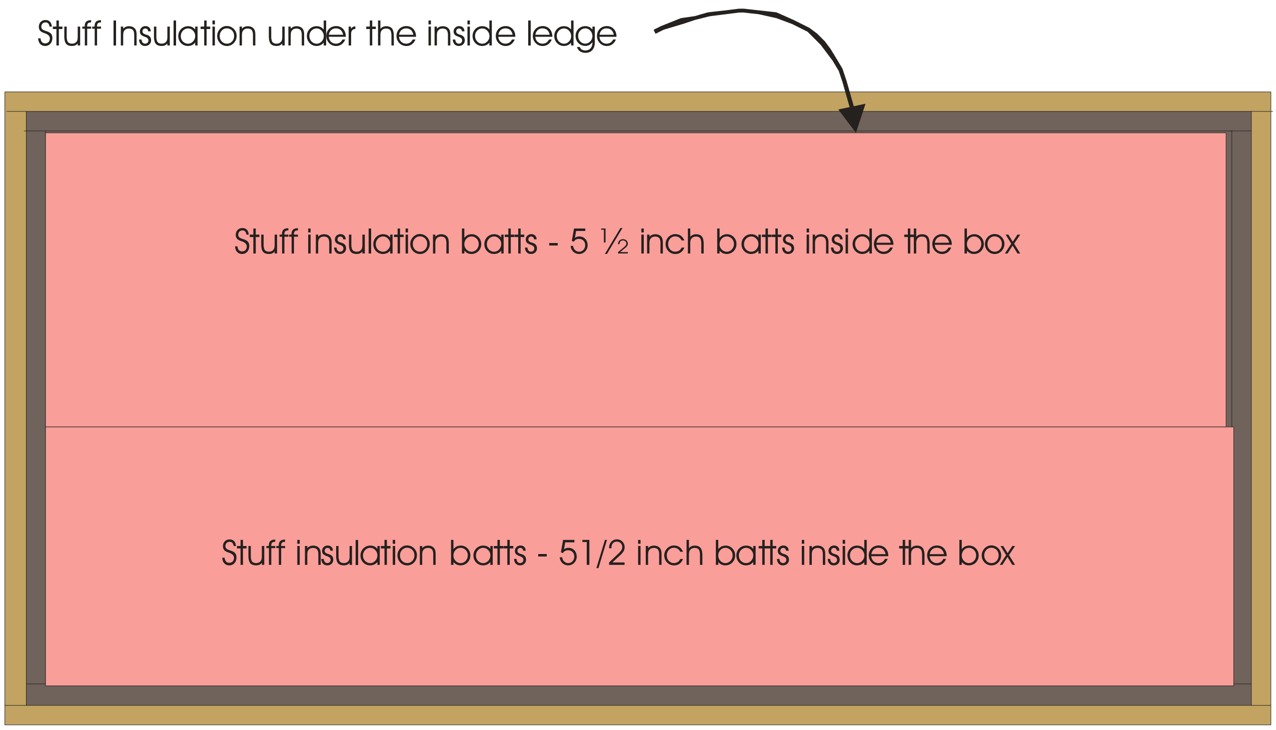


Attach the 4x8 sheet of OSB (roofing decking) to the bottom of the box

Side view

Just a word about OSB roofing decking. This material is will be on the bottom of your collector and the collector (if you build it like me) is comprised of treated lumber and is resistant to weather, but I also like to give it a little extra protection. I wrapped mine with a vinyl 8 inch soffet material which is tucked under galvanized 2" drip edge. As a licensed builder, I have seen the OSB directly exposed to the sun and rain (without roofing felt) for 4 to 5 weeks during Katrina when all commercial work halted. So, after all the storms and some 4 to 5 weeks later, this OSB still looked fresh. I prefer it over plywood after seeing this. So, you do not need to coat it, it will be ok. It is also on the bottom and protected by the 8 inch vinyl soffet which functions as a drip edge.

6. Place the $5^{1/2}$ thick inch fiberglass insulation in the bottom of the box (paper side up)

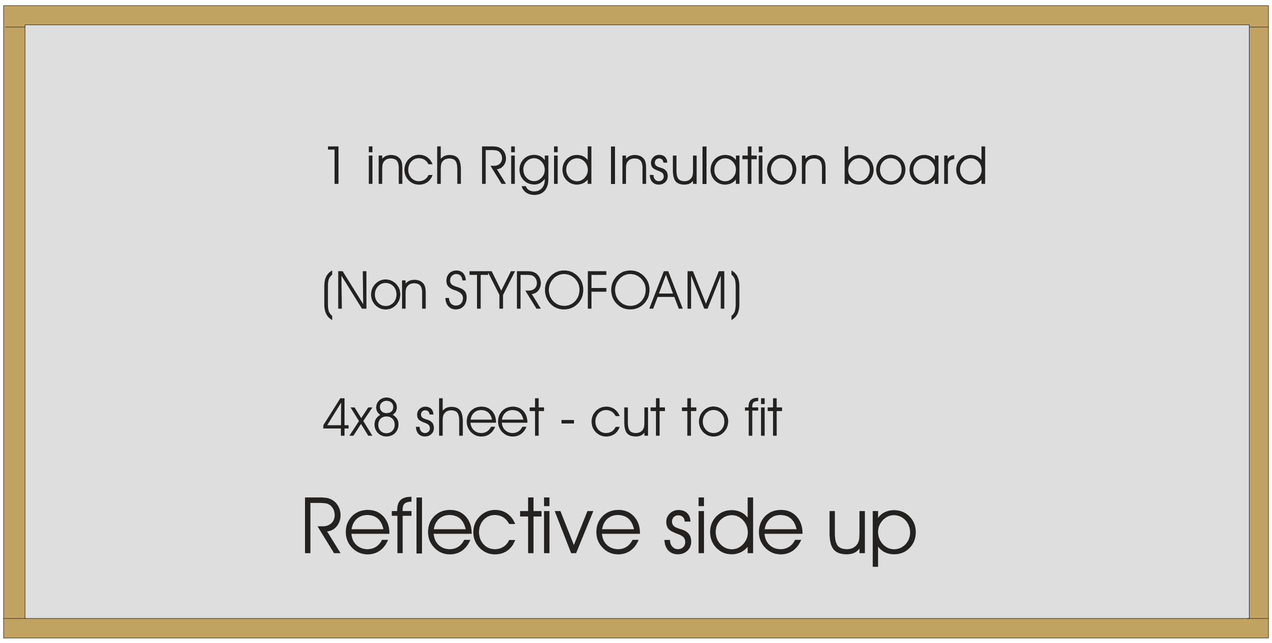


Insert roll insulation

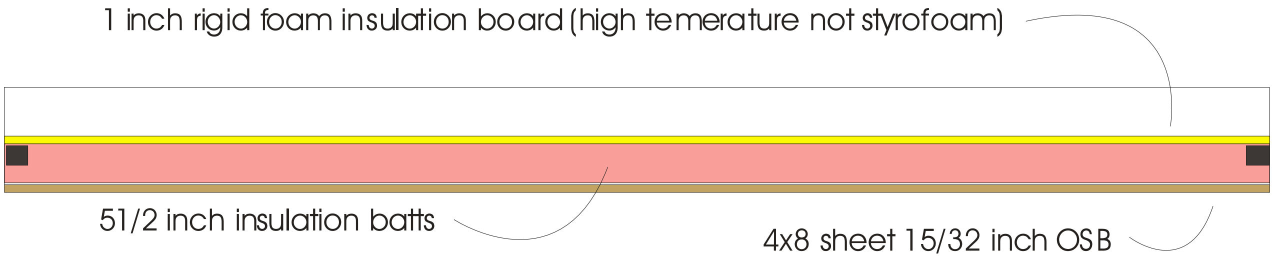
Desired is for the insulation batting to stick out (or pouch out), so when the rigid insulation board is placed on top and fastened to the ledge, it will also be bowed out, so when the metal is placed on top of the rigid insulation board, the copper heat collector will press against the sheet metal and make good contact with the metal sheeting which is required for good thermal conduction. It is through the direct contact of the copper collector and the flat black painted metal that heat transfer will occur. So, we are using the insulation as a spring mechanism to provide tension to enhance the direct contact of the metal sheeting to the copper collector.

7. Place the 1” ridges foam insulation board in the box on the ledge above the fiberglass insulation and use the plastic capped nails (button capped nails) to fasten the rigid foam insulation in place.

<u>Don’t use Styrofoam rigid foam, use the higher temperature rigid foam insulation which is available at your building supply store.</u>



Use button cap nails to attact the ridig foam board to the inside 2x2 supports



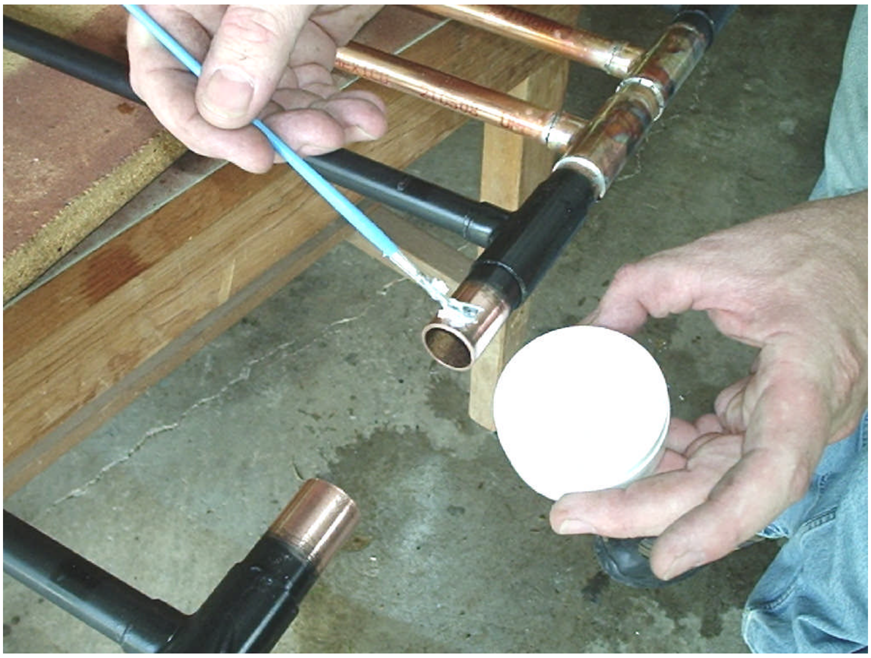
Side - cut away View

Chapter 4 - Building the Copper Collector

The copper collector is comprised of a bottom and top horizontal headers with vertical copper pipes connecting them. Cold water enters the bottom header and is heated as it goes through the vertical pipes and then exits the collector through the top header pipe. The headers pipes are ¾ inch and the vertical pipes are ½ inch copper. The water will enter and exit on the opposite side of the collector which assures for maximum heat transfer. ¾ x ½ x ¾ copper Tees will be used to combine the headers and the vertical pipes. If you decide to use 28 vertical pipes then you will use 28 Tees on the top and 28 tees on the bottom and you will cut 27 short pieces of ¾ inch copper pipe (2 3/8 inches) for the top header and 27 short pieces for the bottom. The best was to cut copper pipe is to use a tubing cutter which will taper the cut and allow the end to slide into the Tee.

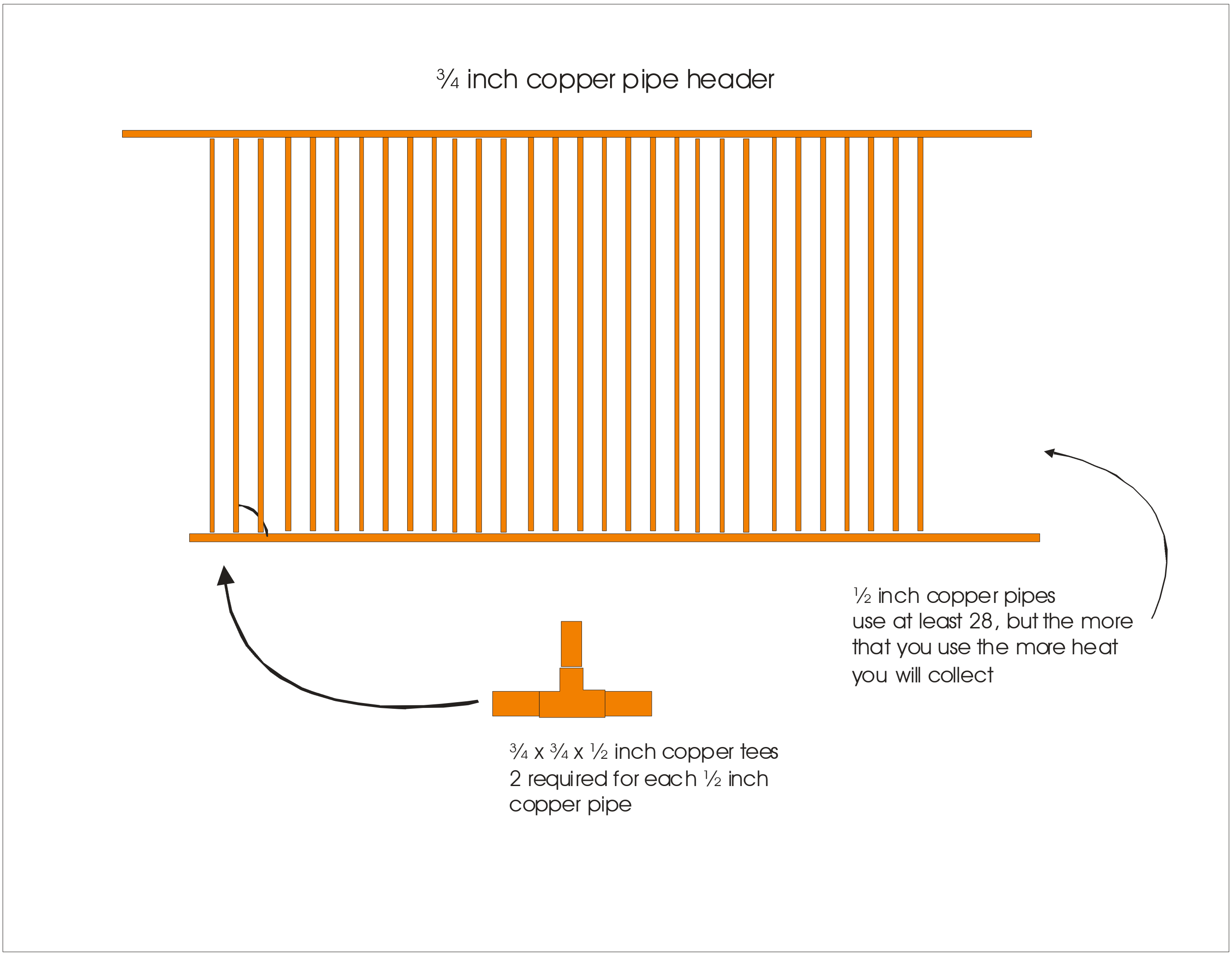
Cut the length of your vertical pipe to fit inside of your box with a tee on top and on the bottom. I hesitate to specify a length (mine was 42 ½ inches) because the overall dimension of the box is dependant on the size of your Lexan. Use silver Solder when sweating your pipes together and use a good cleaning flux to insure good joints. **The bottom left end of the header pipe will be capped off. After fabricating the copper, block off two of the open lines and pressure test for leaks using a water hose. Find any leaks before proceeding!!**

Do not use lead solder, it is toxic and may not stand the potential higher temperatures and pressures.



Proper cleaning and generous use of solder paste will assure leak proof joints. I place the paste on both surfaces prior to mating the copper pieces to assure a good joint. I just tried the Lennox brand paste and was really impress when it immediately remover the tarnish from oxidized copper. I usually use the wire brush on all fitting, but I did not when using the Lennox solder paste.

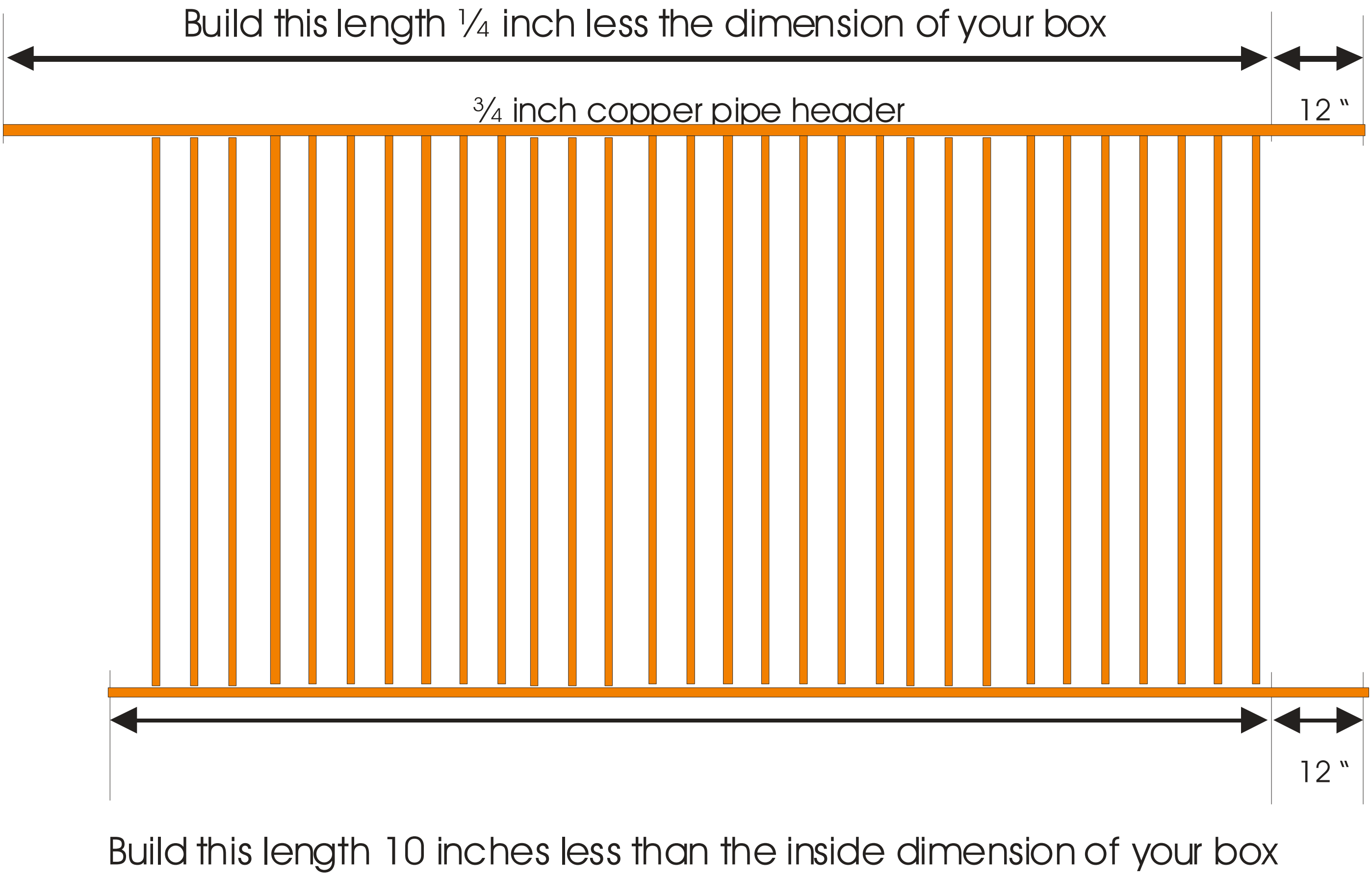
Make sure you pressure test your collector with a water hose.



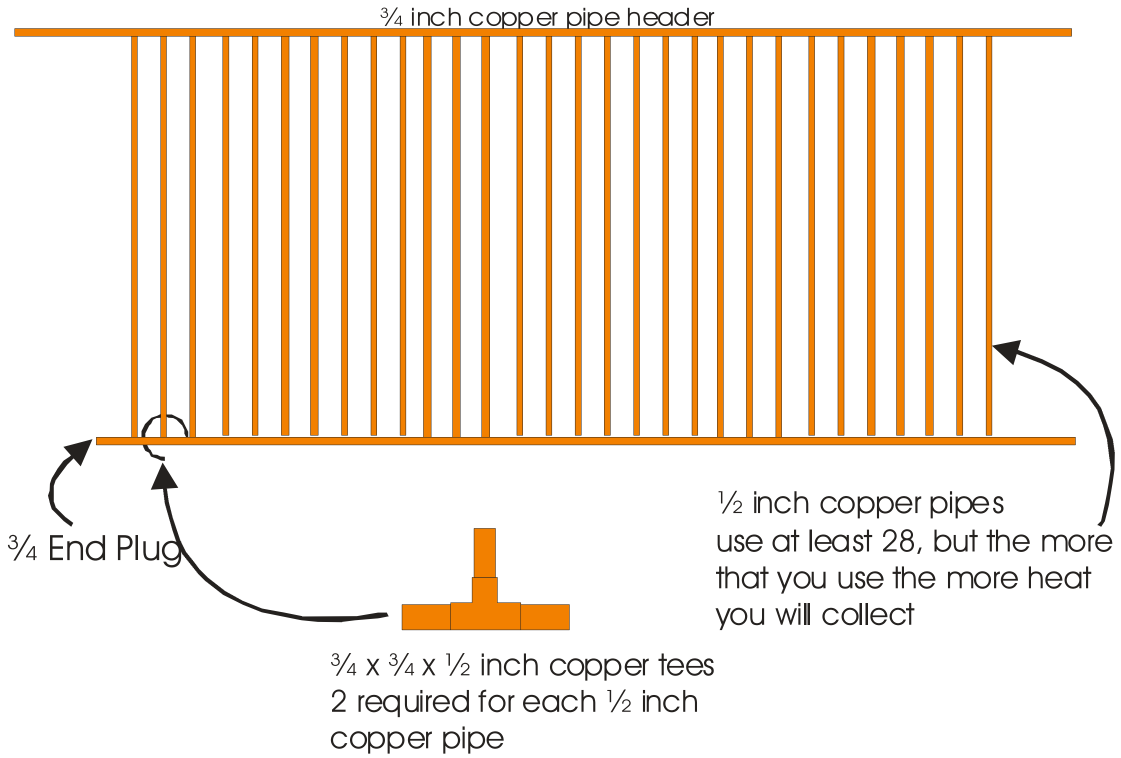
Copper Collector

I use a small wooden stool the right and set the propane torch on it and right under the joint to sweat. It takes a little longer to sweat using silver solder that it did using the lead bases solder. So by using the stool, you will be less fatigued. It you notice the already painted black copper, this was due to adding additional branches to the copper collector. I had originally built the collector with 10 branches and was not happy with the performance, so I added and additional 18 branches for a total of 28.

This is a good picture showing where the heat should applied to the fitting to draw the solder into the joint. I once went through a hole role of solder trying to weld a joint by placing the heat on the joint instead of placing the heat as shown here and drawing the solder into the joint. With the propane flame shown here, it takes at least 1 to 1 ½ minutes to heat the ¾ inch joint to where it will accept the solder and sweat the joint.



You want to build you copper collector to length where you can insert the right side through two holes (which you drill into your box) and extend through the holes far enough where you can drop in the left end down (with about ¼ inch clearance between the end of the left upper pipe and the inside edge of the box) and align with the hole and then the collector assemble can slide to the left and extend through hole until the assemble is centered in your box.



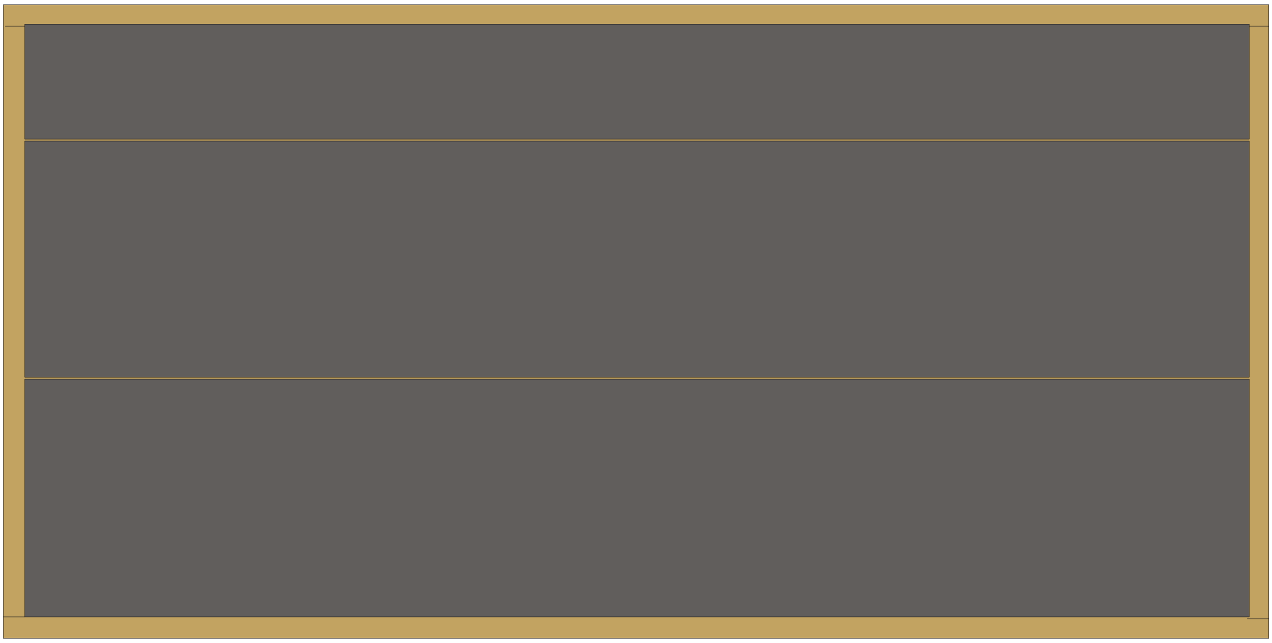
Parts List for a 28 riser tube Collector

¾ x ½ x ¾ Tee -	56 ea.
¾ end cap (plug)	1 ea
Copper Tubes (approx. 43 IN) -	56 ea
Copper Tube ¾ Inch -	20 ft

Note: The length of the ½ pipes need to be cut to fit the inside of you box when the two Tees are on each end of the pipe. I would recommend leaving ½ inch space between the top and bottom.

Parts List For the Copper Collector for a 12 ½ inch Pipe System

Chapter 5 - Preparing the box



Attach metal coil stock (width are available in 12, 16, 20 & 24 inch - cut to fot
Use either roofing nails or button cap nails to attach

Predrill holes in the metal to prevent bending then paint the metal flat black high temperature paint

Placing the sheet metal in your box

There are a couple of options. One would be to find copper sheeting and actually solder it to the copper collector that you just built. This is the most efficient design that is available and if you have, or can afford it, it is a good option. The other is to use some thin sheet metal or coil stock and cut and place it in the box. Fasten one of the ends to the ledge by pre-drilling the holes to prevent bending the metal. Then I placed 3 ½ inch thick by 15 inch wide fiberglass insulation under the 3 sheets of 14 inch wide metal coil stock.   This pushes the sheet metal against the copper collector. The metal will be painted with High Temperature flat black paint prior to the copper being inserted into the box. Give it a couple of good coats.

Use a high temperature Flat Black paint. Flat Black has the highest absorption properties for absorbing heat.

Paint both the copper collector and the sheet metal with two or three good coats. The paint will prevent corrosion which occurs when dissimilar metal are touching, so make sure that both are coated well.

Chapter 6 - Installing the Copper Collector

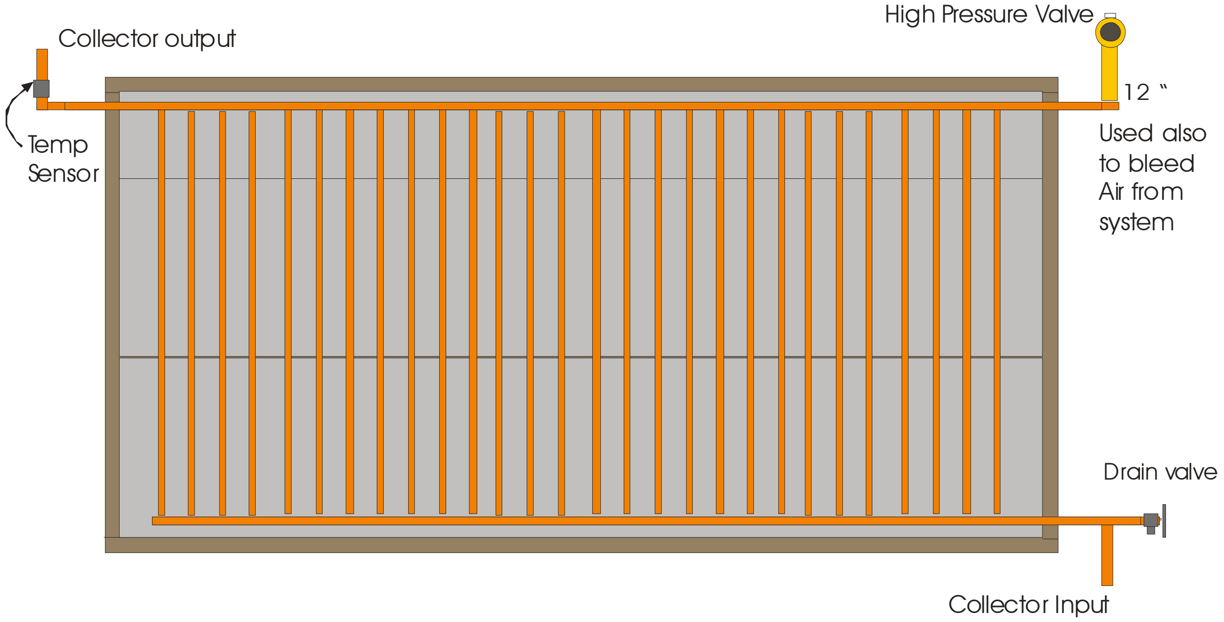
At this point the copper collector and the sheet metal are painted black and the metal is in the box. Drill three holes in the box with a 1&1/8 paddle bit to allow the 3 ends of the copper collector to extend from the box.

These 3 holes should be positioned where the copper collector is pressed tightly against the sheet metal which will result in good physical contact to achieve the highest heat transfer from the sheet metal to the copper collector.

To drill these three holes, use the copper collector as a pattern to assure that the holes are where they need to be.

Measure and mark the holes and then verify it as least 3 times!! Don't forget you want the copper pressed firmly against the black painted sheet metal.

Chapter 7 – Collector Connections



Drill 3 holes (1 1/8 inch) to insert the collector plumbing

Connect a water heater pop-off valve as shown in the above figure and the below picture. It will protect the system from over pressurization and will allow a point to bleed out air.

An elbow is soldered to the pipe extending through the collector and a female ¾ inch fitting is soldered onto the elbow. Do all of your soldering prior to installing the vinyl 8 inch soffit. Also shown is the drain plug out of the water heater. I used this here just to keep dirt dobbers from messing up the pop off valve. The drain valve is open to allow pressure release.

On the lower inlet pipe connect a ¾ inch tee and a female ¾ fitting and a hose bib. At this point I used PEX plastic ¾ pipe for plumbing into my house. PEX pipes use crimp type barb connectors and a special crimping tool. PEX lines are very inexpensive when compared to copper and easy to work with.
On the upper outlet of the collector, I sweated on an elbow and a short section of ¾ pipe and another ¾ elbow. This will be unique to the individual installation. But also seen is the collector temperature sensor which uses a water hose clamp to hold it to the out put of the solar collector.(which will be covered in more detail when we address the system controller).

Chapter 8 – Lexan Installation

Note the 2x2 installed midway in the collector to support the 4x8 Lexan sheet

I installed a 2X2 midway across the collector to support the lexan in the middle and predrilled for the coated decking screws to attach it to the 2x8s. The Lexan is not attached to the mid support. With some ones help and preferable on a work surface drill holes every four inches around the perimeter of the Lexan. I would recommend drilling an oversized hole and using a for an example a ½ inch washer with a #8 hole with a 1 inch #8 stainless steel screw. If you look at the below picture you will see stress cracks when too close a fitting hole/screw combination resulted in the cracks when the screw was not screwed in exactly perpendicular to the lexan. I may have to replace the lexan in the future ($100 mistake).

If possible, install the lexan after the panel is mounted. If not, take care not to torque the panel while mounting it to avoid stressing the lexan.

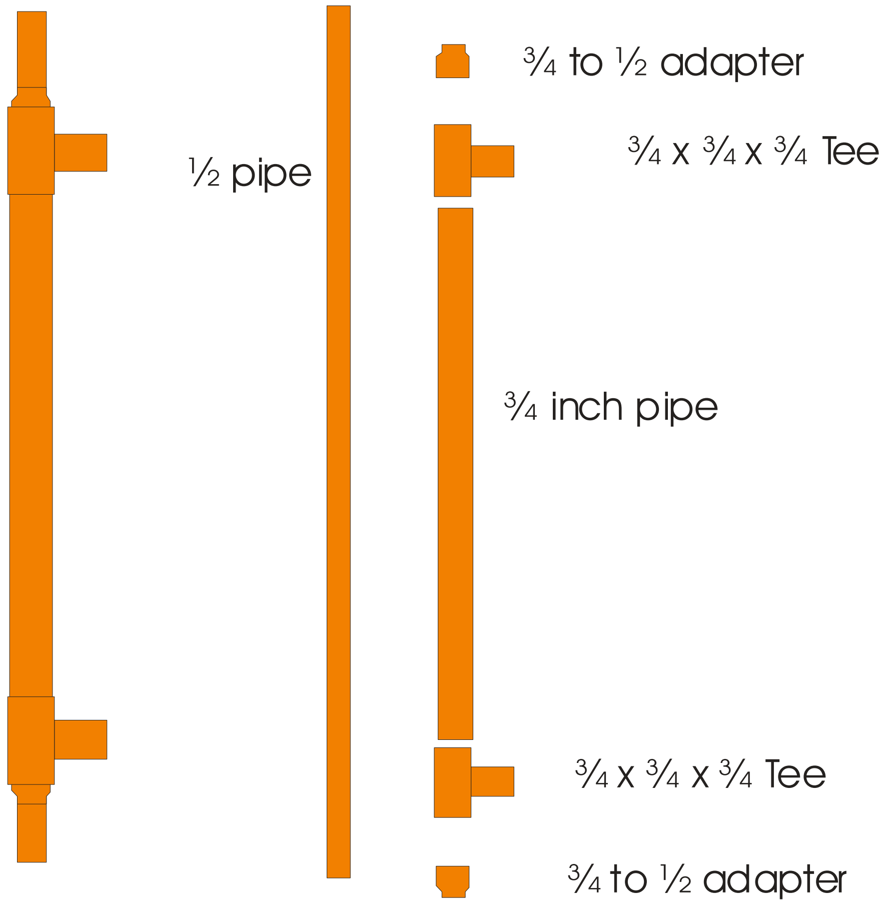
So, after you marked and drilled the perimeter holes, use ½ adhesive weather strip on each side of the holes, as shown. I chose to stick the weather stripping to the Lexan. Then pick a center hole on the top and using a sharp punch center punch the hole. You can use a cordless drill to start the screw into the hole, but snug it up with a screw driver. Just work your way around the box.

If you look carefully, you can see the washers under the screws. I would use a larger washer than I used, and hand tighten the screws after they are all started. **You can also see the overhang because the box was not built to the size of the lexan. Learn from my mistakes.**

Chapter 9 - Building the Heat Exchanger

I found one site which detailed building a pipe in a pipe heat exchanger.

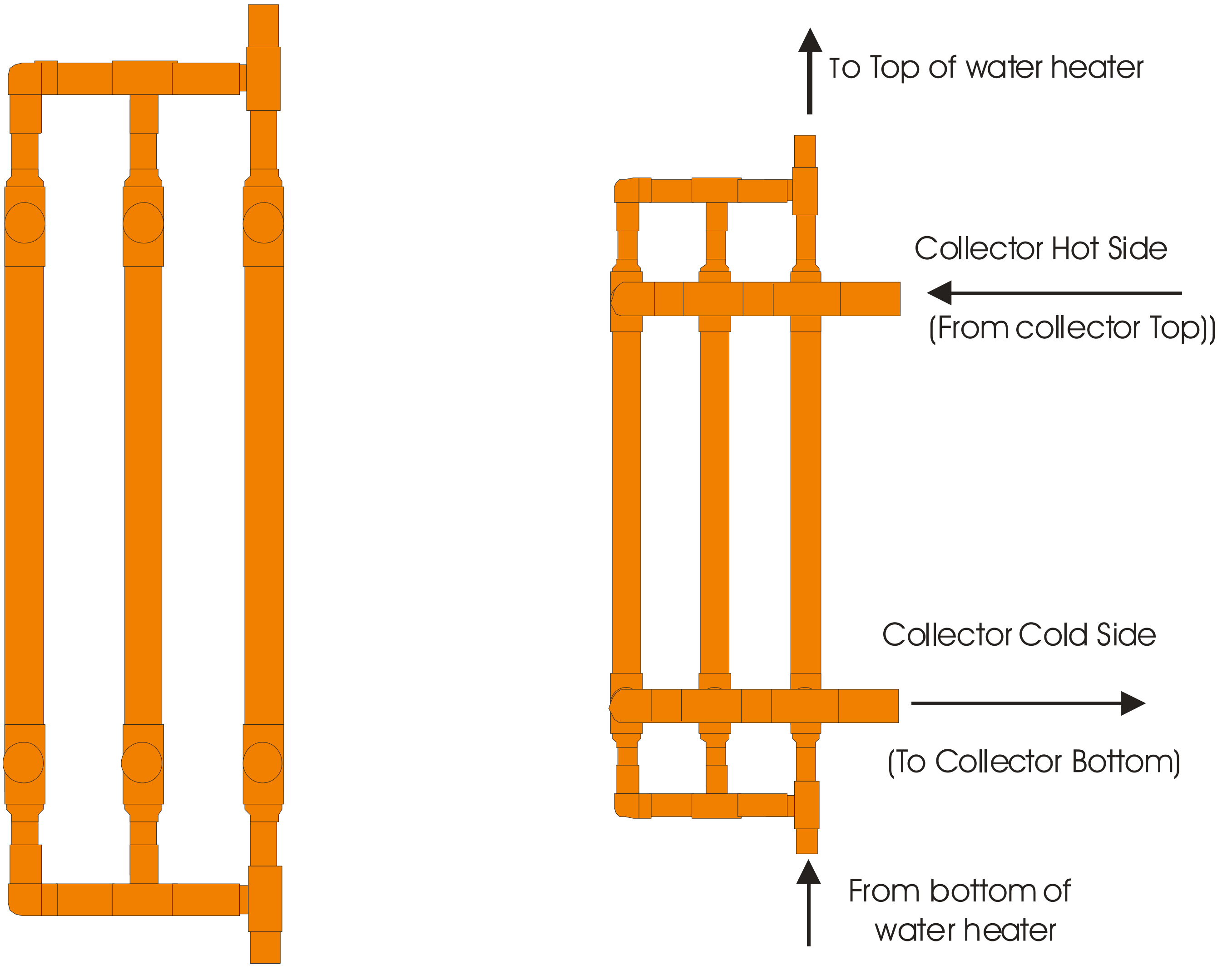
So, basically a ½ inch pipe is placed in a ¾ inch pipe and this creates a water jacket in which hot water heats the water in the ½ pipe. In the space between the ¾ and ½ inch pipe hot water from the solar collector is circulated and the water from the water heater is circulated through the ½ inch pipe, thereby the heat is transferred from the collector and into the tank without the two fluids coming in contact. This allows the use of **propylene glycol** as antifreeze. **Never use ethylene glycol as it is very toxic.**



This shows how one heat exchanger pipe is assembled. The heat exchanger that I am using is made of three of these units.

Important Note: Inside the ¾" to ½ adaptors there is a small dimple which is there to allow a ½ inch pipe to only go in approximately ¾ of a inch. We need the ½ pipe to go all the way through the adaptor so, take a ½ inch bit and drill the small dimple out. It is recommended to use a drill press and hold the adapter firmly, but be careful not to bend it.

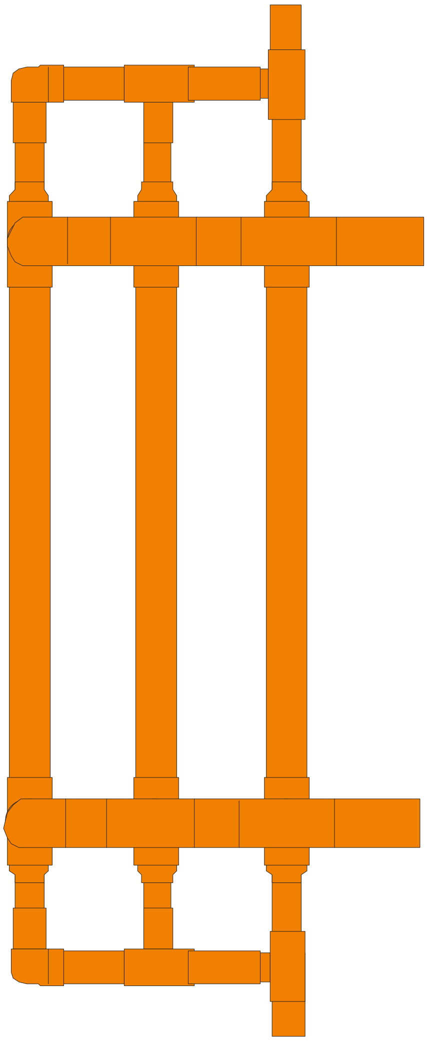
The following diagrams further explain the design and how to assemble the heat exchanger, for my exchanger I used three tubes and cut the ½ inch pipe 40 inches (this gave me 3 pieces out of a 10 foot length (120 inches) and this was the right length for my 50 Gallon tank), but you will have to measure the height of your tank and determine the appropriate length for your heat exchanger.



Heat Exchanger

This diagram (left) shows the three pipe heat exchanger and the (right) other diagram shows how it is connected into the system.

Heat Exchanger Parts Lists



Tees ¾ x ½ x ¾	4ea
Elbow ¾ x ½	2ea
adapter ¾ x ½	6ea
Tees ¾ x ¾ x ¾	4 ea
Elbow ¾ x ¾	2 ea

Copper ¾ pipe 40 " 3 ea

Copper ½ length 3ea

Determined by height of tank

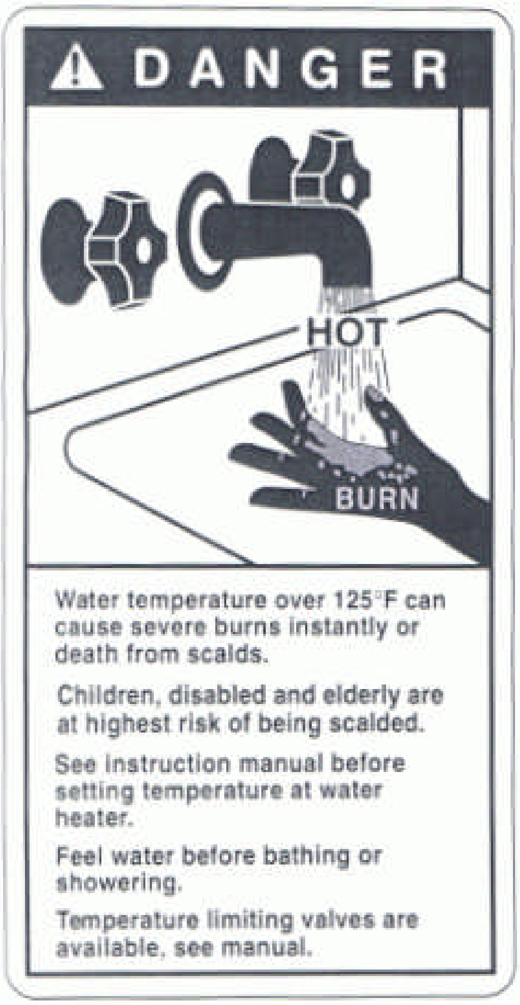
Note: the plumbing into and out of the tank will be different according to the brand and make of the tank.

The lengths of the ¾ and ½ inch pipe will also change according the length and size of the water heater, so measure your tank and plan where you will make connections, then size you pipes accordingly.

After fabricating the copper, block off the open line for both paths through the heat exchanger and pressure test for leaks using a water hose. Find any leaks before proceeding!!

Do not use lead solder, it is toxic and may not stand the potential higher temperatures and pressures.

Chapter 10 - Electric water heater safety



Time/Temperature Relationship in Scalds

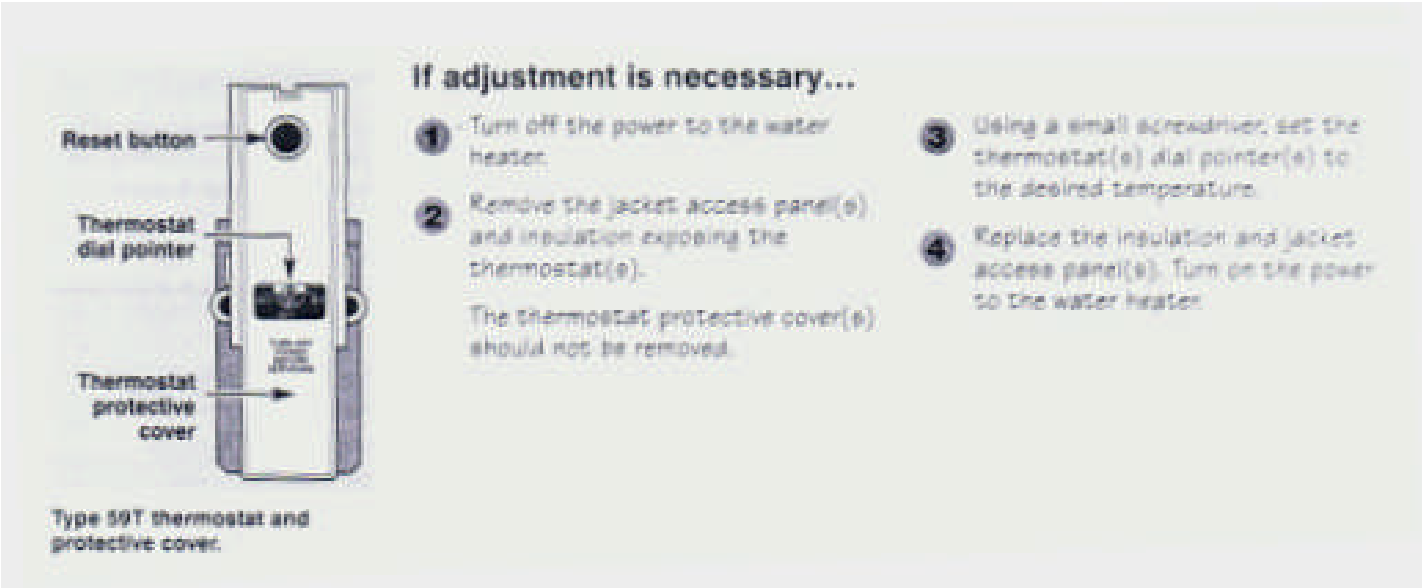
Temperature	Time To Produce a Serious Burn
120°F	More than 5 minutes
125°F	1½ to 2 minutes
130°F	About 30 seconds
135°F	About 10 seconds
140°F	Less than 5 seconds
145°F	Less than 3 seconds
150°F	About 1½ seconds
155°F	About 1 second

Table courtesy of Shriners Burn Institute

The chart shown above may be used as a guide in determining the proper water temperature for your home.

NOTE: Households with small children, disabled, or elderly persons may require a 120°F. or lower thermostat setting to prevent contact with "HOT" water.

When setting up your temperature requirement take into account the potential dangers of hot water. Instead of trying to super heat water above the safe limits, you may wish to heat a larger quantity of water.

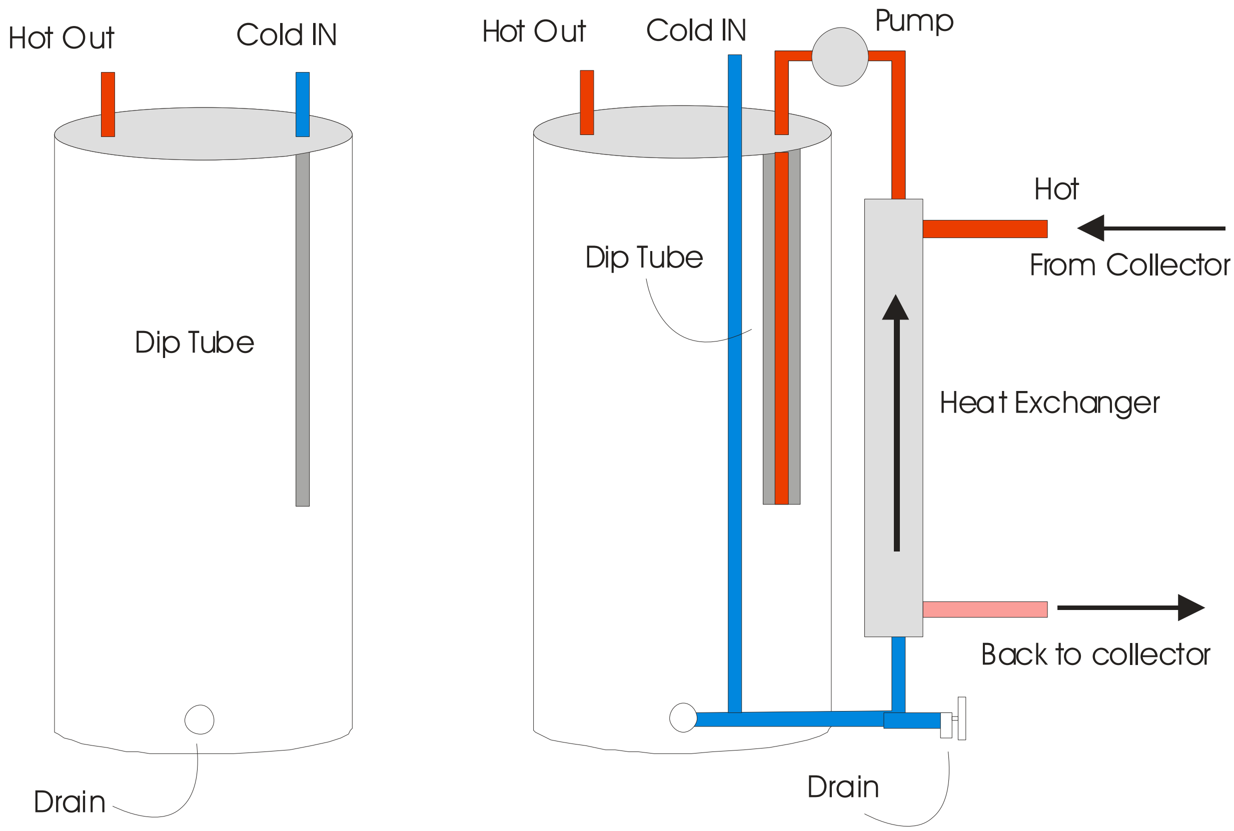


Caution:

Any time you are adjusting the thermostat or have the access covers off the water heater, turn the breaker off to the water heater, because 220 VAC can be lethal!

Chapter 11 - Anatomy of Electric water heater with Heat Exchanger

Let's take a look at the water heater and how it will be connected to support the solar collector system. The ultimate goal is to heat the water in this tank.



The water heater on the left is your typical electric water heater. Water enters through the "cold in" and goes through a DIP tube which directs the cold water to the bottom of the heater. This assures that the cold water does not mix with the hot water and that the hottest water is supplied throughout the house.

The diagram on the right is our configuration and we will supply the cold water directly into the bottom of the water heater. A pump on the top of the water heater will pump water from the bottom of the tank (which is the coldest water in the tank) and will pump it through the heat exchanger and into the tank through the DIP tube.

The above picture shows the top of the heat exchanger, which is pretty much identical to bottom of the heat exchanger. The line coming from the right is the “Hot” output of the Solar Collector. The top of the heat exchanger is plumbed into pump which circulates water from the bottom of the water heater through the heat exchanger (where it picks up heat) through the pump and into the top of the water heater tank.

Another picture of the top of the heat exchanger and the pump

The pump is plumbed into the “Normal Water In” inlet of the water heater. Notice the blue “cold water line”, it now is connected to the bottom of the water heater.

Here is the bottom of the heat exchanger. First, the red line goes through the red pump which pumps the collector water back to the lower input of the solar collector.

The blue line is the cold water input which is going into the bottom of the water heater.

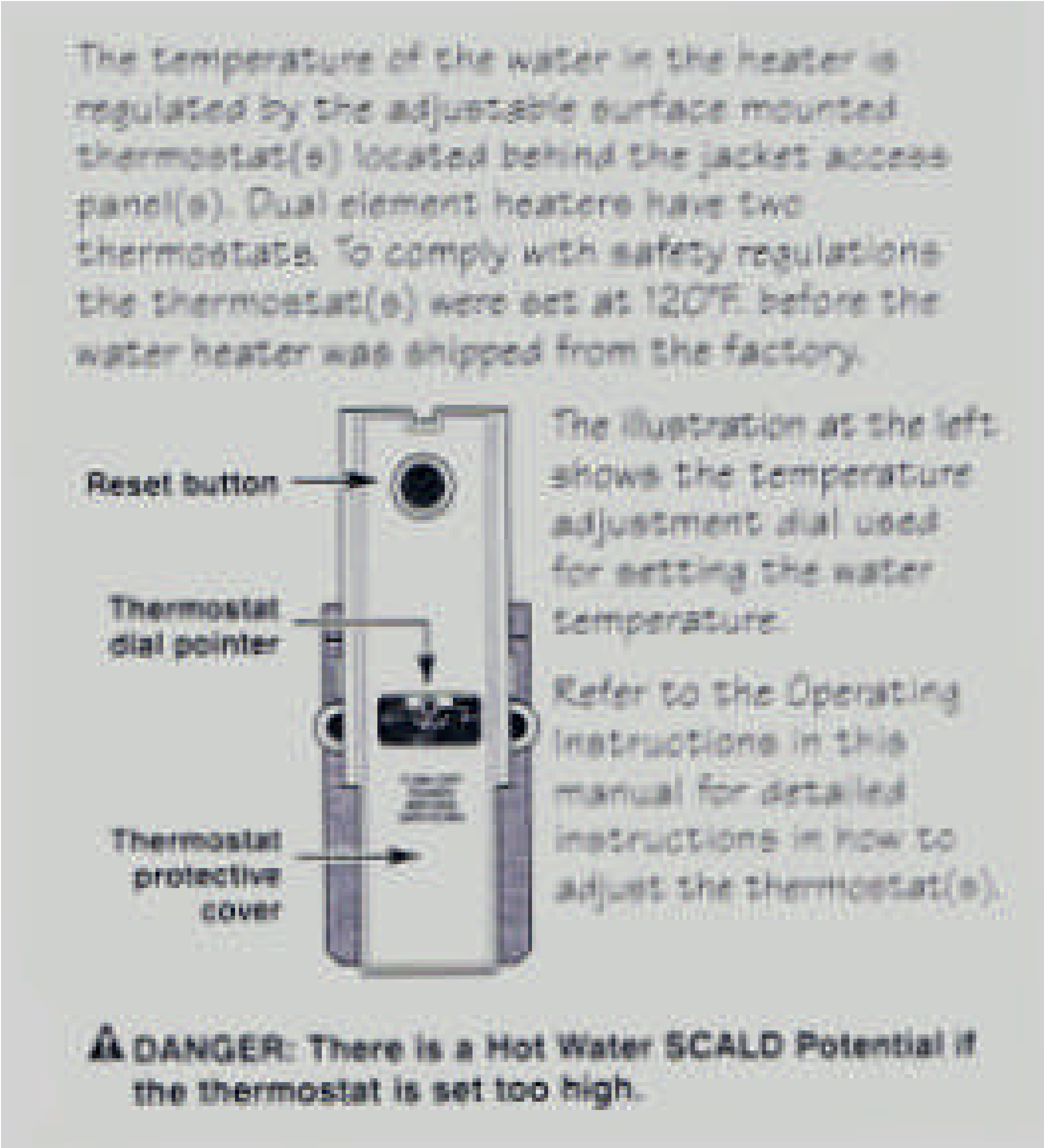
You will unscrew the drain valve (most likely white plastic) out of the bottom of the water heater. It is a ¾ inch pipe threat and it will be replaced with a galvanized 3 inch length of threaded pipe which then connects into a galvanized tee, a short 2 inch treaded pipe, then another tee and finally a quality drain valve. (Use the plastic drain valve to keep dirt dobbers out of the pop off valve of the collector).

Here is another view of the lower connection, so as the “Green Pump” on the top of the tank turns on it will pump water from the bottom of the water tank through tee closes to the tank, through the copper heat exchanger and through the pump into the top of the water heater.

Note that the heat exchanger and all of the lines will be recovered with insulation after this installation guide is completed. This heat exchanger has reached 160 deg F and I’ve been burned a few times by accidentally touching it, so do be careful.

The **Taco and Grundfos** pumps Use the same flange kits. I like this system and removing pumps is a breeze. For example, I needed to tighten the flange because of a leak, so just remove the bolts and tighten the fange another revolution and the leak was fixed and insert the 2 bolts and the job was done. So order the pumps with the flanges.

Chapter 12 - Setting the Thermostat for Solar Operations



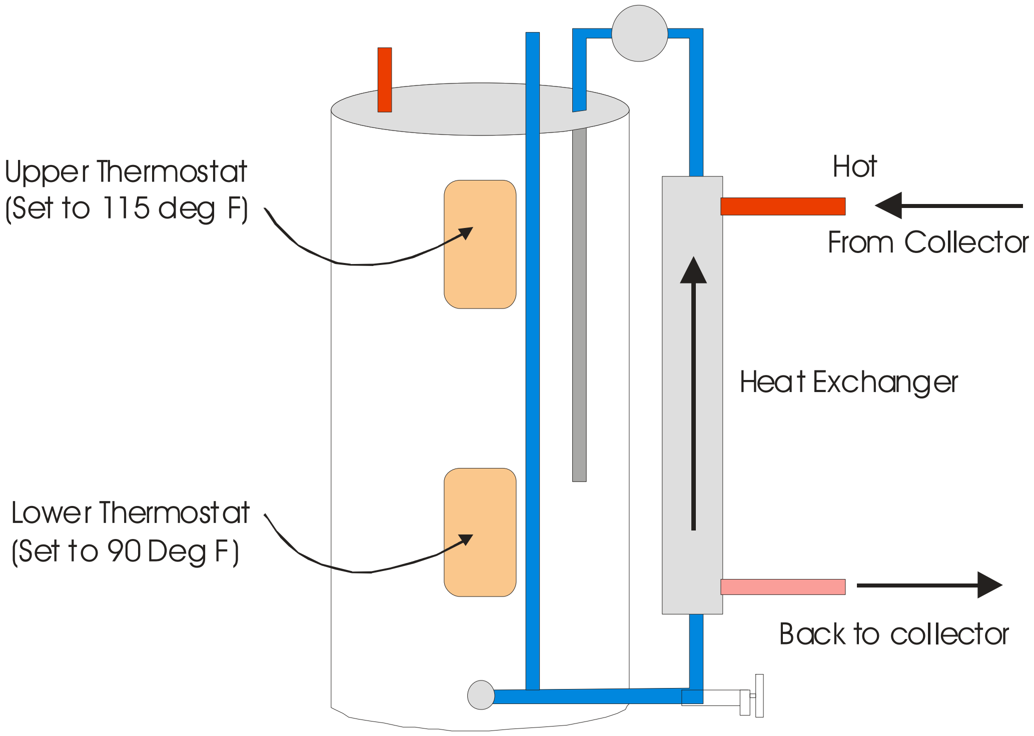
The temperature of the water in the heater is regulated by the adjustable surface mounted thermostat(s) located behind the jacket access panel(s). Dual element heaters have two thermostats. To comply with safety regulations the thermostat(s) were set at 120°F before the water heater was shipped from the factory.

The illustration at the left shows the temperature adjustment dial used for setting the water temperature.

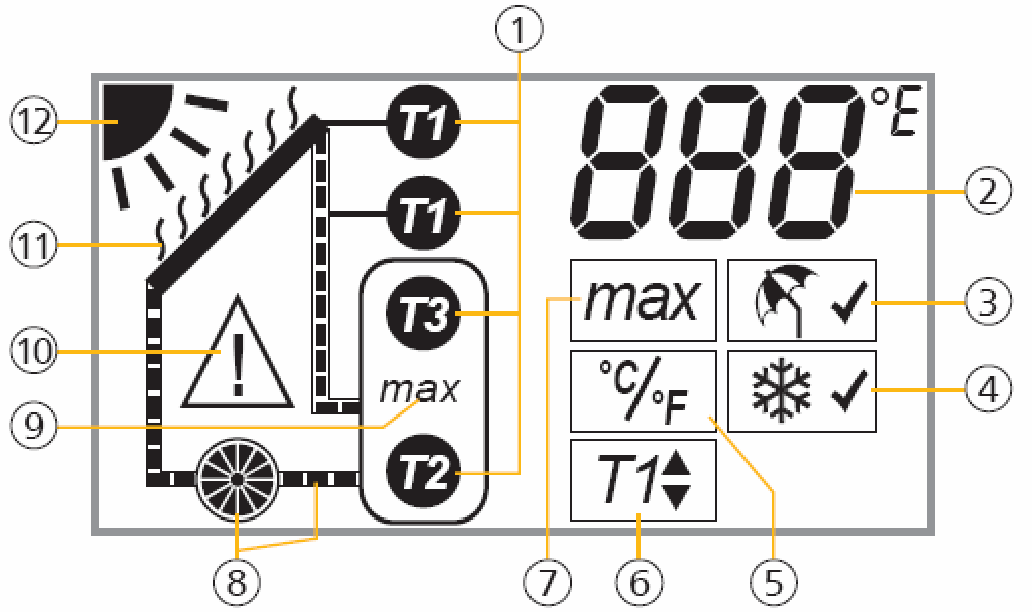
Refer to the Operating Instructions in this manual for detailed instructions in how to adjust the thermostat(s).

⚠ DANGER: There is a Hot Water SCALD Potential if the thermostat is set too high.

Your typical electric hot water heater has two thermostats, one on the top 1/3 of the tank and the other around the bottom third of the tank. Set the top thermostat to 115 Deg F and the bottom thermostat to the lowest setting (this should be around 90 Deg F). What this is doing is insuring that you will have 115 degree F water even on non solar friendly days. So what you really have is a solar/electric hybrid system.



By setting your thermostats this way, there will be a temperature gradient in the bottom of the tank when the collector and tank pumps are turned on and the did tube assures that the bottom water (the coldest) will continue to be the water that is heated.

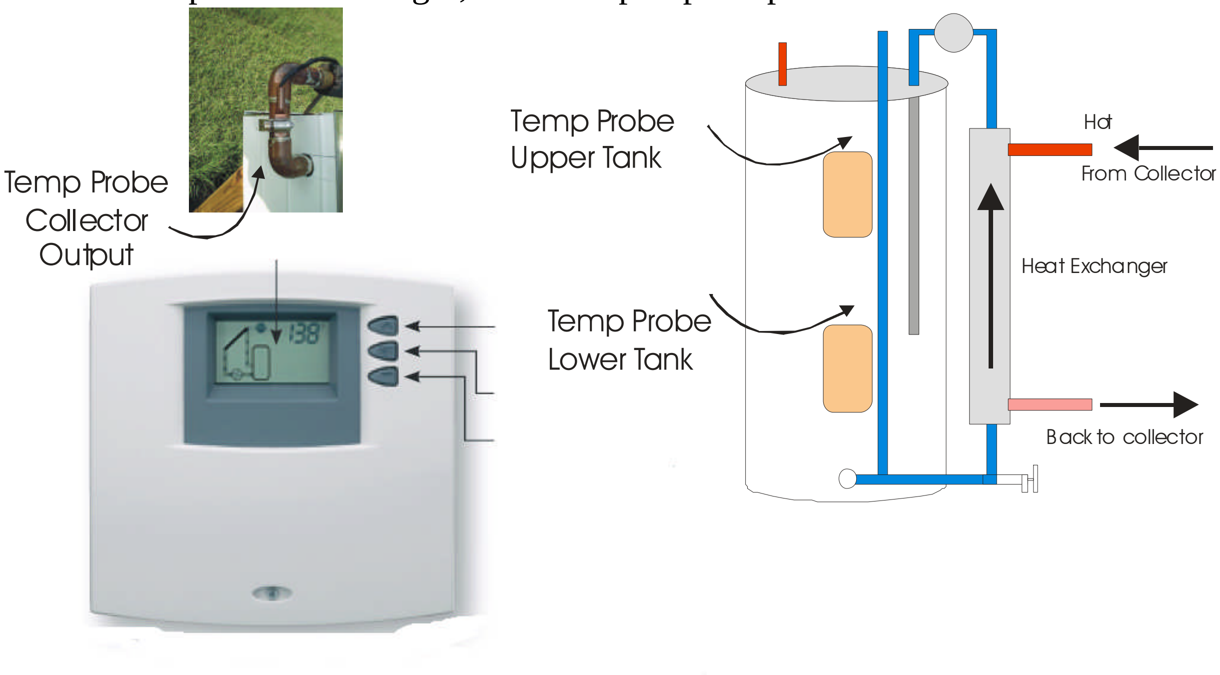


1. Temperature sensor symbols
2. Displays the temperature values and faults, e. g. short circuit, interruption (see p. 27) or SYS = system error (see p. 28)
3. Holiday function (see p. 21)
4. Anti-freeze function (see p. 21)
5. Selecting the temperature unit °C / °F
6. Tube collector function (see p. 20)
7. Setting the maximum storage tank temperature
8. Solar circuit symbols
9. Displays message "Maximum storage tank temperature has been reached"
10. Warning display if faults occur, e. g. short circuit, interruption (see p. 27) or SYS = system error (see p. 28)
11. Displays message for evaporation of the collector fluid
12. Displays message for sufficient heat supply

This is the Controller's Front Panel Display

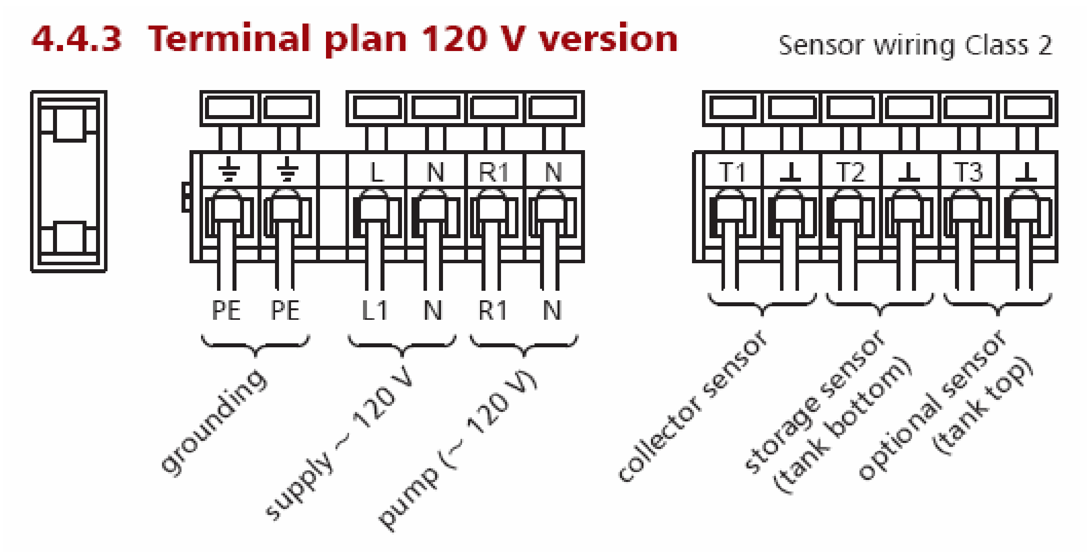
Controller

I chose a digital Sun Earth Steca TR0301U digital controller from Sun Earth ($115) (800) 515-1671 and order the 3rd Temp Probe ($15). The controller is configured from the factory to monitor and compare the temperature of the output of the collector to the temperature at the bottom of the tank and when there is a difference of 16 deg F, the pumps start and continue until the differential temperature is 8 deg F, when the pumps stop.



The upper tank temperature probe is used only to display the tank temperature optional equipment and is ordered separately. The controller comes with the other two sensors.

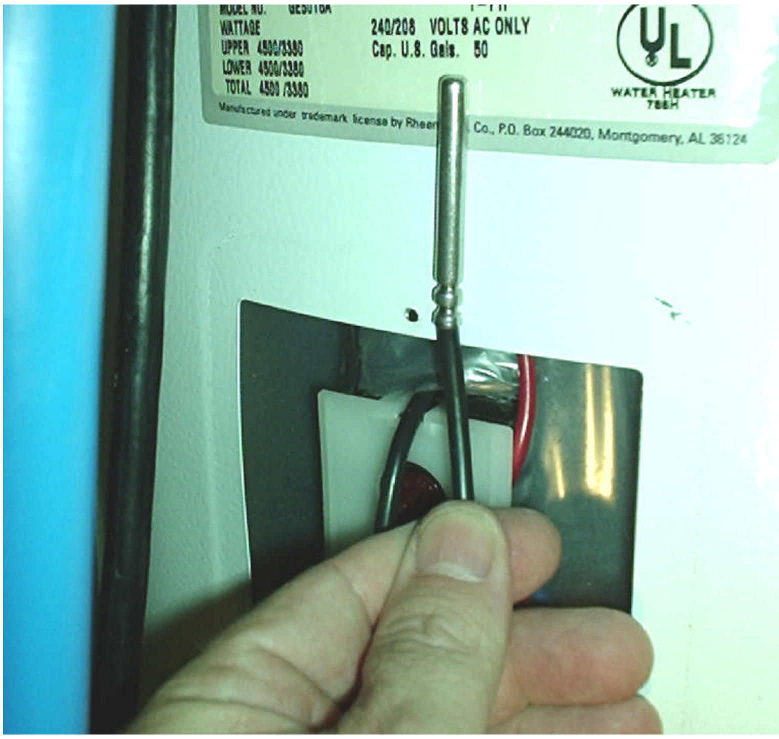
Cords – Pump PWR, AC PWR IN, Col. TEMP, Bot Tank TEMP, Top Tank TEMP



There is a line cord attached to the controller, so you just plug it into a wall socket and the output power to the pump is actually an outlet socket so you just plug right into it.

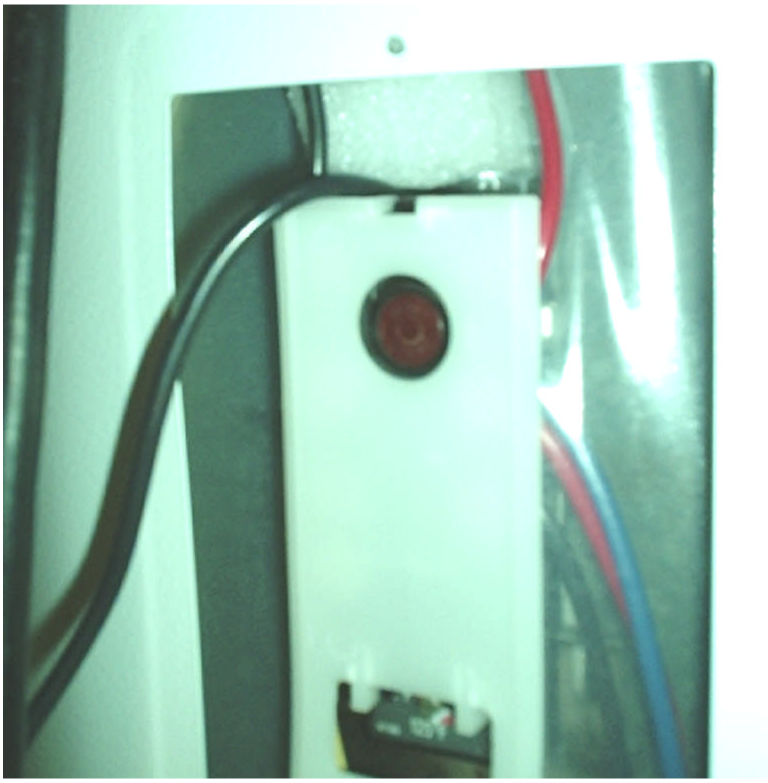
The tan cord is a power strip (the PWR to Pumps) and plugs the pumps into it. So the controller supplies the power for the pumps through my power strip.

Chapter 14 - The temperature probes



The probes are mounted above the upper and lower thermostats directly against the tanks, using a couple foam blocks which hold them in place. Make sure the power is off. **I got bit once by the 220 VAC, and won’t make that mistake twice (learn from my mistake)!!**

Probe mounting

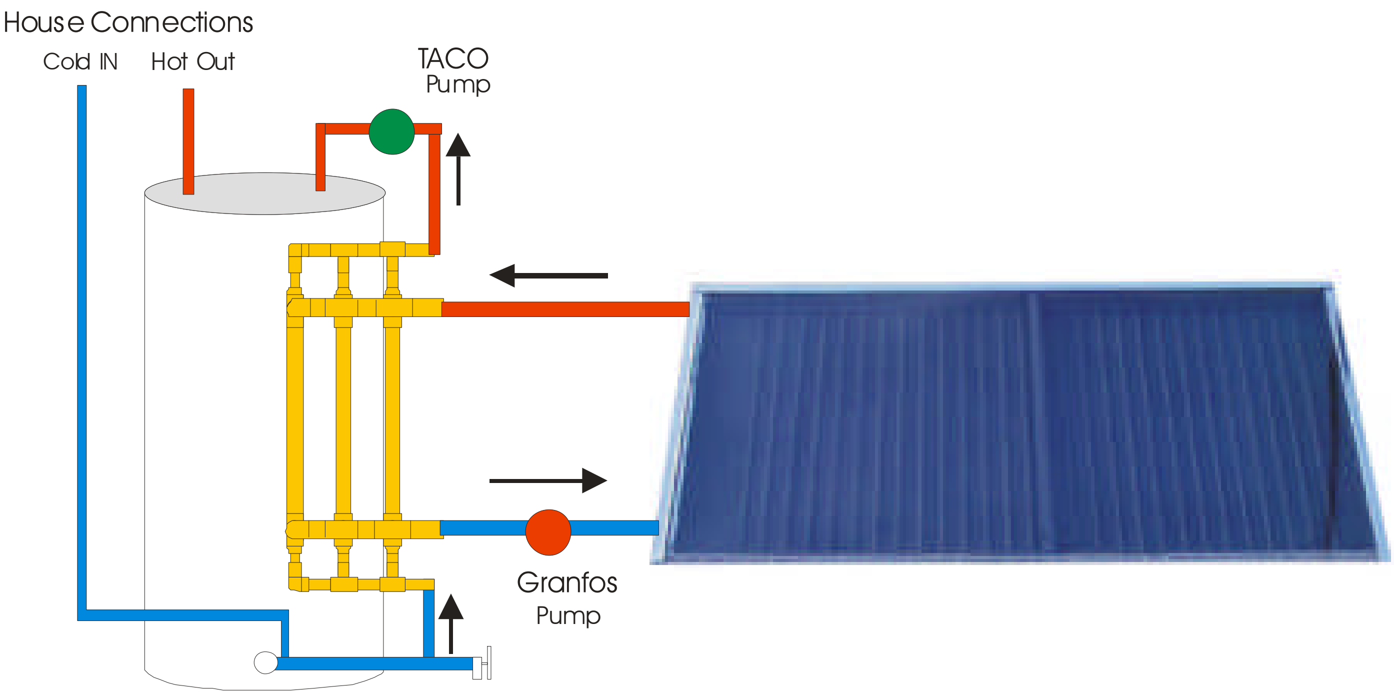


Look carefully and you can see the foam cube which is pressing and holding the temperature probe against the tank. Turn off the breaker to the water heater. The same method is used on the top and bottom tank sensors. This foam was used in the packaging of some electronic appliance and was handy.   The insulation was reinstalled.

Then the cover's upper left corner was flattened out as to not damage the probe cord and reattached to the tank. The same was done for the lower probe.

As mentioned earlier, the probe for the top tank temp was purchased separately and cost about $15, but it is nice to be able to monitor this temp. This is a nice controller and I am impressed with it. I will include a PDF manual on the CD with these plans and also a file which shows how to change the factory settings. Be aware there are cautions concerning changing the factory settings, so wait until you are very familiar with your system and the controller.

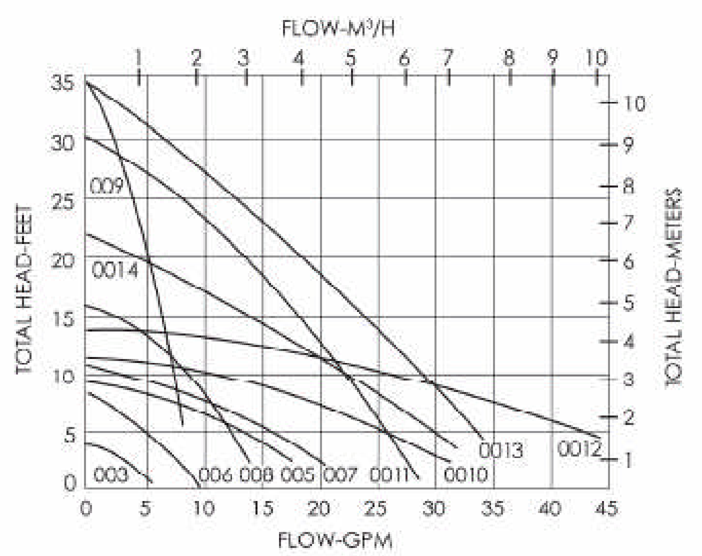
Chapter 15 – Plumbing system diagram



Plumbing System Diagram

Taco Model 005 cartage Circulator

I bought the Taco Model 005 cartage Circulator to circulate the water in the tank through the heat exchanger. It is a 120 VAC pump and pulls about .53 AMPS. It was purchased from PEX supply ((pexsupply.com) (888) 757-4774) for $62.45. It is an industrial pump with a three year warranty.



TACO 005 Pump Specifications

This is the flow diagram for the TACO 005 pump, it may look a little confusing because this diagram is for 11 different Taco pumps. Just look for the line that goes to “005”. So, basically this pump can handle 9 feet of head and it has about 5 foot of pressurized lift.

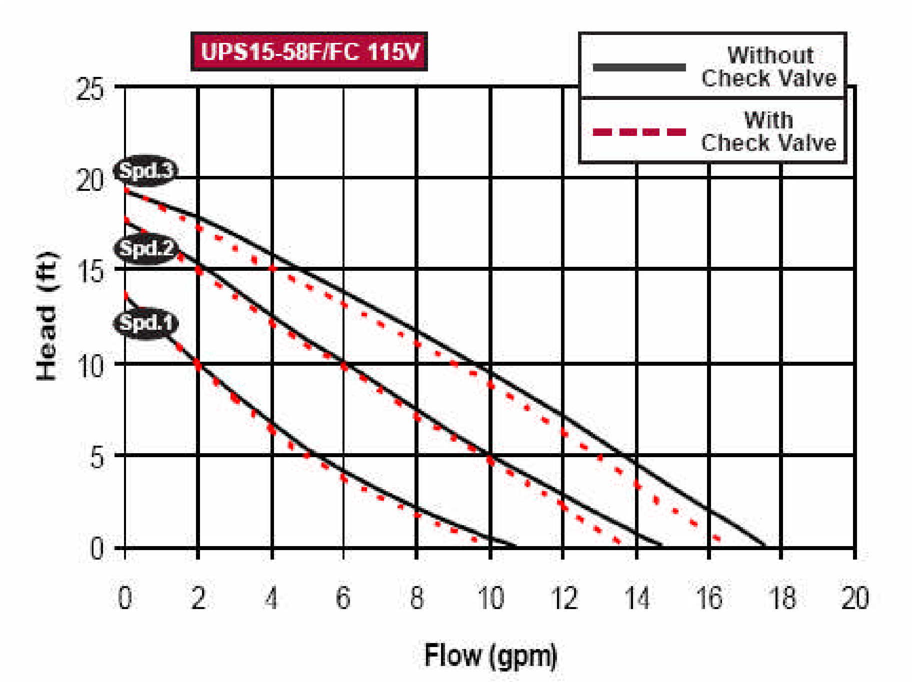
Electrical Data

Model	Volts	Hz	Ph	Amps	RPM	HP
005-F2	115	60	1	.53	3250	1/35
005-BF2	115	60	1	.54	3250	1/35
Motor Type	Permanent Split Capacitor Impedance Protected					
Motor Options	220/50/1, 220/60/1, 230/60/1, 100/110/50/60/1					

This pump uses very little electricity. 0.53 Amps which equates to 61 Watts. When I went to connect the power cord to the pump, I found only 2 wires, a white one and a yellow. Connect the white to the white (neutral) on the line cord and connect the yellow to the Black (hot) on the line cord. The instruction sheet said the wires would be white and yellow or blue.

Grundfos UPS15-58FC 3 Speed SuperBrute Circulator Pump

The Grundfos UPS15-58FC 3 Speed SuperBrute Circulator Pump was chosen to pump the water through the outside collector and through the primary side of the heat exchanger. This pump is actually a 3 speed pump and is capable of replacing several different industrial pumps. I also bought it from PEXsupply and it cost $79.95. It does have a check valve (which is removable) which will eliminate thermal pumping, so it is quite a bargain and will be able to meet the demands if your are not sure of how much head pressure your system may have.



Here is the characteristic flow diagram of the Grandos UPS15-58 pump for each of its 3 speeds. So this pump can handle up to about 18 feet of head pressure which makes this pump a safe buy because it can handle a large range of pumping requirements.

Product Data:

MODEL		AMPS	WATTS	CAPACITOR
UPS15-58F	Spd. 3	.75	89	10mF/180V
(115V)	Spd. 2	.66	80	---
1/25 HP	Spd. 1	.55	60	---

Grandos UPS15-58 Electrical Specifications

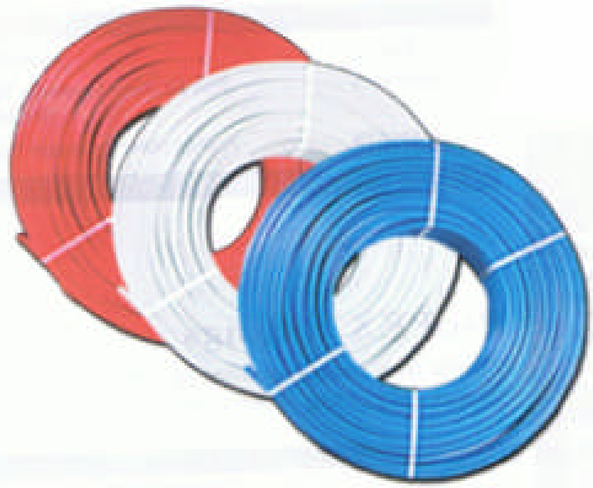
This pump is very efficient and when your system is up and running, just a flip of a switch will change speeds. Use the lowest speed that circulates the hot water.

Chapter 16 - Using PEX Plastic Plumbing Products

With the expense of copper, you may want to use PEX for the long runs of water plumbing to and from the solar collector. I have seen PEX used over years and I think it's a good alternative to expensive copper. So, I wanted to put a small section in the manual about it.

Here's a good picture of the PEX tubing, the blue line has a barbed fitting that is a male threaded ¾ fitting to thread into the galvanized ¾ inch Tee. The red line has a barbed sweat on fitting that is sweated on ¾ inch copper line. You can see the black ring clamps that has been crimped into position.

Sku	Item Description	Unit Price
F1040250	1/4" AQUAPEX - (100 ft. coil)	$29.99
F1090375	3/8" AQUAPEX - (400 ft. coil)	$123.20
F1120375	3/8" AQUAPEX - (1000 ft. coil)	$308.00
F1040500	1/2" AQUAPEX - (100 ft. coil)	$32.45
F2040500	1/2" AQUAPEX Red - (100 ft. coil)	$32.45
F3040500	1/2" AQUAPEX Blue - (100 ft. coil)	$32.45
F1060500	1/2" AQUAPEX - (300 ft. coil)	$97.55
F2060500	1/2" AQUAPEX Red - (300 ft. coil)	$97.55
F3060500	1/2" AQUAPEX Blue - (300 ft. coil)	$97.55
F1120500	1/2" AQUAPEX - (1000 ft. coil)	$327.95
F2120500	1/2" AQUAPEX Red - (1000 ft. coil)	$364.00
F3120500	1/2" AQUAPEX Blue - (1000 ft. coil)	$364.00
F1040750	3/4" AQUAPEX - (100 ft. coil)	$59.65
F2040750	3/4" AQUAPEX Red - (100 ft. coil)	$59.65
F3040750	3/4" AQUAPEX Blue - (100 ft. coil)	$59.65
F1060750	3/4" AQUAPEX - (300 ft. coil)	$167.35
F2060750	3/4" AQUAPEX Red - (300 ft. coil)	$167.35
F3060750	3/4" AQUAPEX Blue - (300 ft. coil)	$167.35
F1041000	1" AQUAPEX - (100 ft. coil)	$104.95
F2041000	1" AQUAPEX - (100 ft. coil)	$104.95
F3041000	1" AQUAPEX - (100 ft. coil)	$104.95



Also Available:
Zurn PEX, Watts PEX, Viega PEX

The ¾ inch size is what I used to go to and from the collector.

PEX Tubing - Cutters

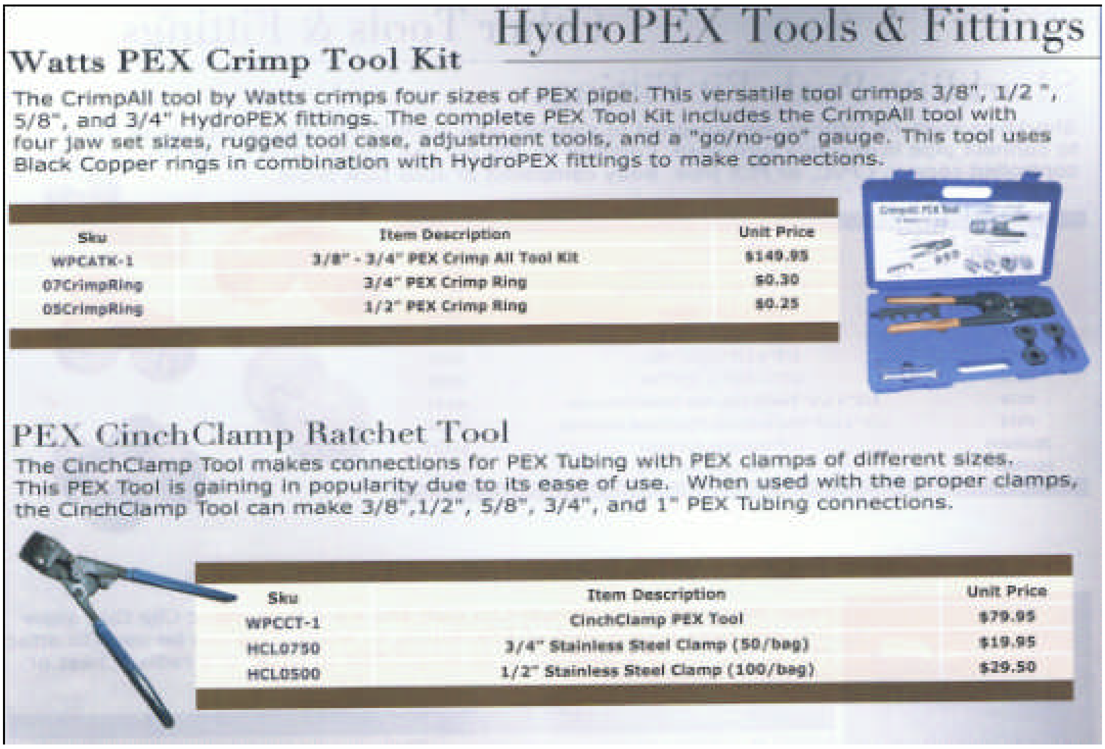
Tube Cutters are used for cutting PEX Tubing. We sell three types of cutters: the plastic cutter, the ratchet style cutter, and a metal pex cutter.

Sku	Item Description	Unit Price
E6081128	Tube Cutter, (plastic) up to 1" PEX	$16.45
E6081500	Ratchet-style Tube Cutter, up to 1" PEX	$20.75

The tubing is cut with the above cutters, spend a few dollars and get one if you are going to use PEX pipe

Sku	Item Description	Unit Price	Box Price
H000500	1/2" PEX x 1/2" PEX Brass Elbow	$0.98	$23.25 (25*$0.93)
H000750	3/4" PEX x 3/4" PEX Brass Elbow	$1.32	$28.88 (25*$1.16)
H010500	1/2" PEX x 1/2" PEX Brass Coupling	$0.57	$13.50 (25*$0.54)
H010750	3/4" PEX x 3/4" PEX Brass Coupling	$0.69	$16.50 (25*$0.66)
H020500	1/2" PEX x 1/2" Copper Pipe Brass Adapter	$0.85	$20.25 (25*$0.81)
H020750	3/4" PEX x 3/4" Copper Pipe Brass Adapter	$1.26	$30.00 (25*$1.20)
H030500	1/2" PEX x 1/2" NPT Brass Male Adapter	$1.48	$34.08 (25*$1.36)
H030750	3/4" PEX x 3/4" NPT Brass Male Adapter	$1.89	$43.50 (25*$1.74)
H040500	1/2" PEX x 1/2" NPT Brass Female Adapter	$1.67	$39.75 (25*$1.59)
H040750	3/4" PEX x 3/4" NPT Brass Female Adapter	$2.30	$54.75 (25*$2.19)
H050500	1/2" PEX x 1/2" PEX x 1/2" PEX Brass Tee	$1.10	$26.25 (25*$1.05)
H050750	3/4" PEX x 3/4" PEX x 3/4" PEX Brass Tee	$1.80	$42.75 (25*$1.71)

Once the PEX tubing is cut, then these fitting which have a barbed fitting on one end is placed into the Pex tubing with a metal clamp ring over the tubing. Then a ring clamp crimper tool, as shown below, crimps the fitting on. It's a simple process.



HydroPEX Tools & Fittings

Watts PEX Crimp Tool Kit

The CrimpAll tool by Watts crimps four sizes of PEX pipe. This versatile tool crimps 3/8", 1/2 ", 5/8", and 3/4" HydroPEX fittings. The complete PEX Tool Kit includes the CrimpAll tool with four jaw set sizes, rugged tool case, adjustment tools, and a "go/no-go" gauge. This tool uses Black Copper rings in combination with HydroPEX fittings to make connections.

Sku	Item Description	Unit Price
WPCATK-1	3/8" - 3/4" PEX Crimp All Tool Kit	$149.95
07CrimpRing	3/4" PEX Crimp Ring	$0.30
05CrimpRing	1/2" PEX Crimp Ring	$0.25

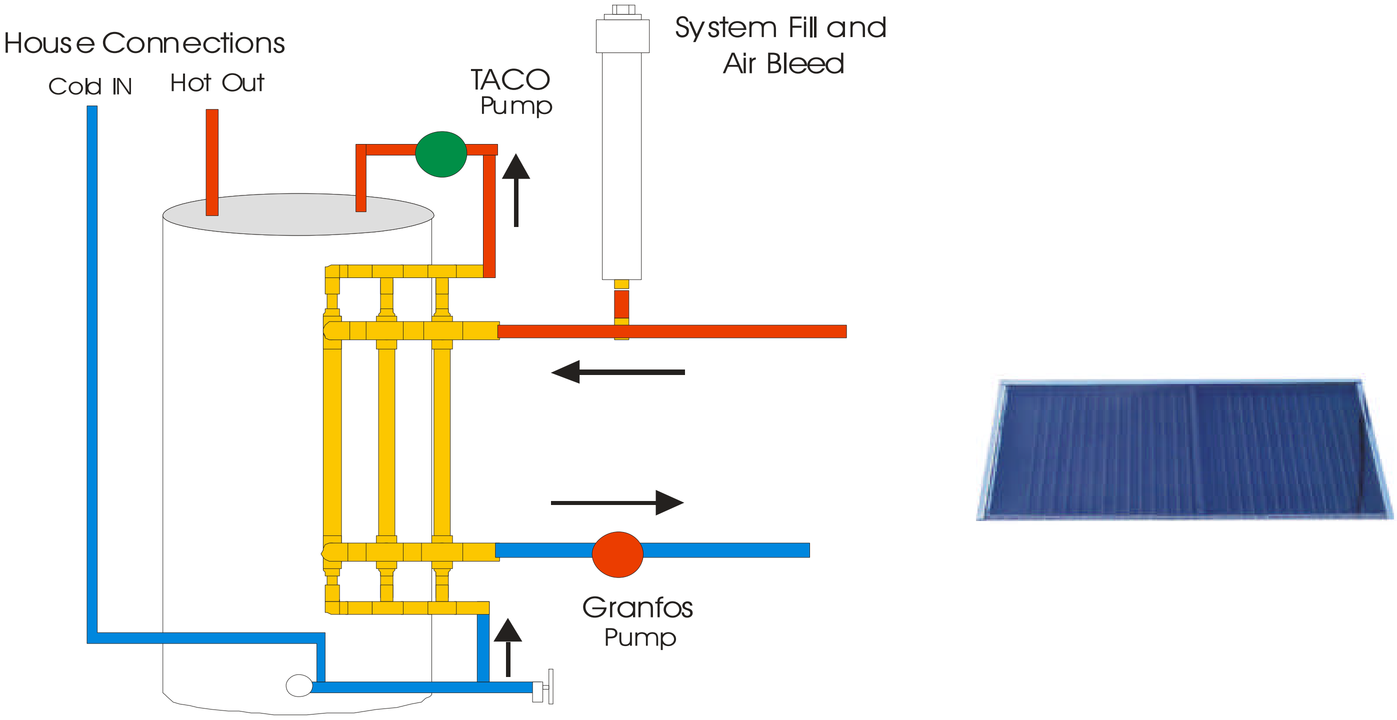
PEX CinchClamp Ratchet Tool

The CinchClamp Tool makes connections for PEX Tubing with PEX clamps of different sizes. This PEX Tool is gaining in popularity due to its ease of use. When used with the proper clamps, the CinchClamp Tool can make 3/8",1/2", 5/8", 3/4", and 1" PEX Tubing connections.

Sku	Item Description	Unit Price
WPCCT-1	CinchClamp PEX Tool	$79.95
HCL0750	3/4" Stainless Steel Clamp (50/bag)	$19.95
HCL0500	1/2" Stainless Steel Clamp (100/bag)	$29.50

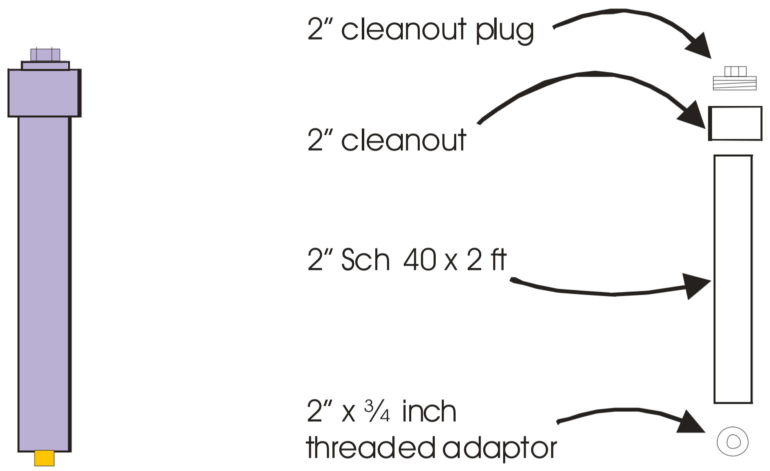
Here are a couple of examples. I bought my PEX supplies at Lowes.

Chapter 17 – System Fill and Bleed



The Filling and Bleed Port

The last component for your system is the filling port. I used a 2 foot long piece of 2 Inch Schedule 40 PVC pipe and placed it in the highest point of the hot line before it enters into my house and mounted onto a treated 4x4 post which is set in concrete. This allows for easy filling of the system and also a reservoir to hold fluid as it expands. I wanted to place this outside of my home.



System Fill and Air Bleed Canaster

You will need to paint the fill and bleed canister, PVC does not hold up very long exposed to the suns UV light and will tend to become chalky in a year or so. I have used Krylon Fusion paint with great success, so I recommend picking a light color and painting it.

I found a very easy way to fill and bleed air from the system. Only do this procedure if the system fill canister is located outside.

1. Connect a garden hose to the drain valve (hose bib) on the lower input port of the collector.

2. Remove the top (clean out plug) of the filling port.

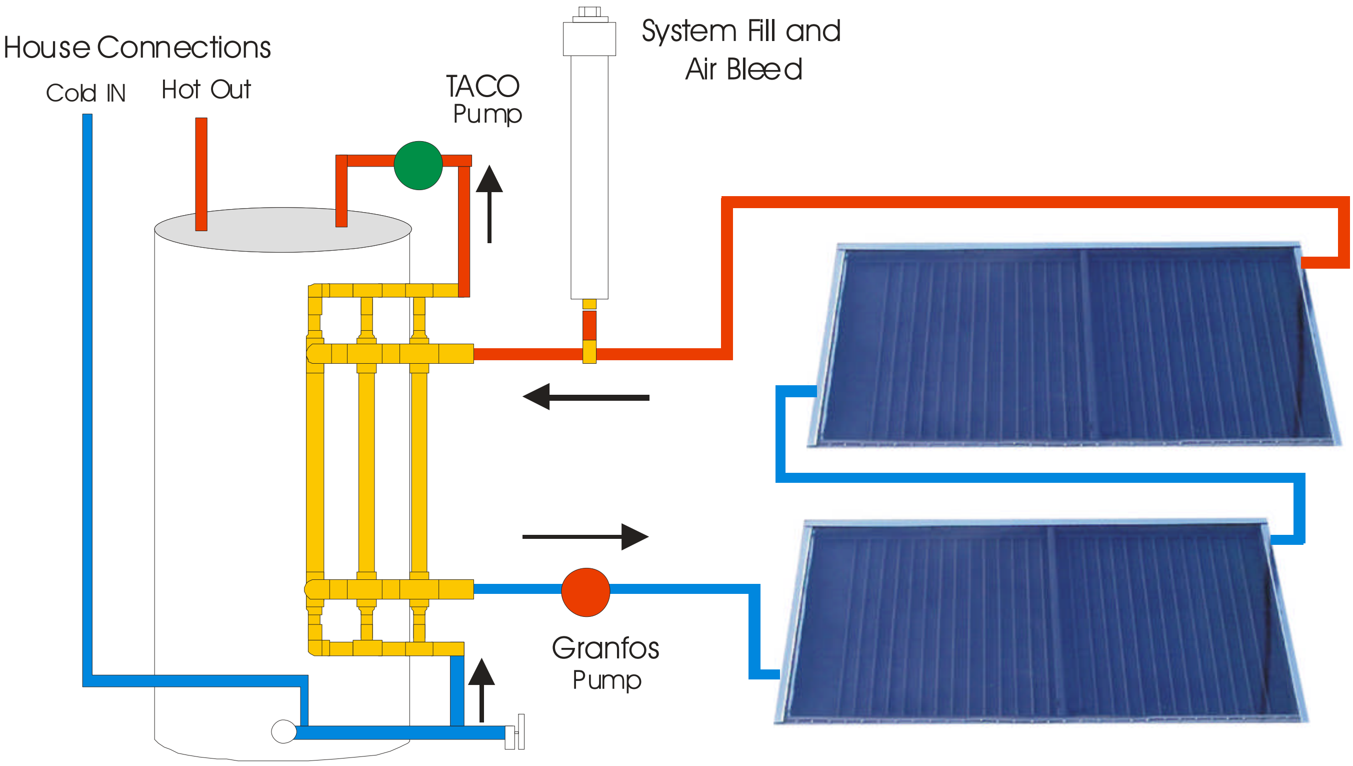
3. Turn the hose on to a medium flow and open the collector hose bib and allow the water to purge the system of air.

4. Allow the water to run a couple of minutes and run out of the system fill canister.

5. Close the hose bib on the bottom of the collector while the garden hose is still turned on.

6. Test the system and repeat if necessary.

Note: Use a washing machine hose to couple the garden hose to the collector bib.



Typical System Diagram

Typically, a solar collector hot water system will require the use of 2 solar collectors or about 64 square feet of surface area. The output of one collector feeds the input of the next. You can start with one unit and will most like need to add a second. This is dependant on your hot water needs. Only one pressure release valve is necessary on the solar panels, but, you have one on each panel which would protect the panel in case one fails. Make sure that the input and the output of the solar panels are diagonally from each other (if the input is on the lower left, then the output is on the upper right.

Check Valve

The check valve will prevent reverse flow through the system which would cause heat to be lost by being pumped out to the solar collector at night and could in fact start pumping the heat out of your water storage tank. The Granfos pump has a build in check valve, so you need not buy a check valve. This just saved you $20 and well paid for your plans.

Winter Time – Filling with Propylene Glycol

1. Take a bucket of water and place the washing machine hose or a small hose in the bucket of water and get the air out of the hose.

2. With the hose submerged in the bucket of water, place and position the bucket where the solar collector hose bib is actually in the water and screw the hose on the bib.

3. Remove the cap from the filling station and crack open the hose bib and let the system water drain out until it is barely still in the bottom of the filling station.

4. Close the valve and fill the filing station to the top.

5. Repeat the process until you have added the proper amount of anti freeze.

Note: The hose in the water will prevent air from entering into the system. Air in the system seems to always find the pump and will stop circulation.

Helpful Hints to Start Saving Energy Costs Now

As for me, my current research and planning is to lessen my dependence on the grid (Commercial Electrical Power) without sacrificing any comfort. So far I have replaced the incandescent light bulbs in my house with the energy efficient bulbs. This not only saves about 78% electricity that is used for lighting, it also reduces the heat that the older bulbs generate and is also directly reflected in my cooling bill. How much does this save me? In my household, three people are home pretty much all day long so, I figure in my house 20 bulbs burn 8 hours a day which equates to (20 x 8 x 60 watts (.060 kwatts) x 30 days/month) = 288 Kwatts @ 0.10/Kwatt= $28.80 a month (Current cost of lighting in my house). Now I burn mainly the 13 watt replacement bulbs, which replace the 60 watt incandescent bulbs which is a ratio of 13/60 = .216%, so my current cost associated with lighting is $28.80 x .216% = $6.22, which is a savings of $22.58/month or $271/year. It all adds up.

I recently bought a small countertop electric oven which can be used for cooking or heating foods such as frozen pizzas, TV dinners, biscuits, brownies, and chicken pot pies that would normally be places in the full sized oven (which would draw 30 AMPS of 220 and really spin your power meter).

Thank you for your purchase, I hope these plans start you in the right direction, and I sincerely hope that you find value in my plans and recommend them to your friends.